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Role of Ethiopian Industrial Parks in Safeguarding the Environment

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Abstract
This study explores the role of Ethiopia's industrial parks in enhancing environmental stewardship, with a focus on the adoption of sustainable practices in line with United Nations Industrial Development Organizations performance framework. Using cross-sectional study design, primary data was collected from randomly selected 395 managerial and technical employees in both private and public industrial parks (IPs). The research utilized binary logistic regression model to assess the role of IPs in environmental safeguarding. It emphasizes the importance of environmentally suitable site selection, developing green infrastructure, segregated recycling reception bins and containers for recyclable and non-recyclable byproducts in industrial parks. Moreover, efficient and clean production methods, effective emission, and waste management strategies in IPs significantly enhance environmental safeguarding. The study also reflects on off-site landfills for managing solid waste in industrial parks, as well as not installing solar street lighting throughout the IPs, problem related to collecting, storing, and treating, toxic and hazardous waste, conducting annual environmental audit on each company, making sure operators have International Sustainability and Carbon Certification, and availing efficient solid waste collection service are the major problems to protection and safeguarding environment. Therefore, the study recommends continuous monitoring and evaluation of the implementation of environmental rules and regulations on sustainable basis to ensure their effectiveness and relevance in the ever-evolving industrial landscape. More importantly, the study suggests the need for implementing mitigation measures concerning the generation of industrial hazardous wastes and the reduction of health hazards through waste minimization, waste recovery and reuse, and waste treatment and disposal.

Keywords: *Industrial parks, environment stewardship, green infrastructure, green systems, sustainable*

1. Introduction

The United Nations Sustainable Development Goal (SDG) emphasizes the construction of robust infrastructure, promoting inclusive and sustainable industrial development (ISID), and fostering innovation (Cheng & Cantore, 2020). ISID strives to stimulate economic growth and diversification in a socially equitable and environmentally conscious manner while advocating for solid infrastructure development and sustainable industrial growth (Moyo, 2020). The ISID framework calls for reducing environmental damage and social inequality in promoting industrialization (Lim et al, 2022).

ISID encapsulates the economic, social, and environmental dimensions of sustainable development in industrialization (Ali et al, 2023). Currently, the global urban population has surged from approximately 30% in 1950 to 55% in 2018, with projections indicating a rise to about

68% by 2050 (UNDESA (2018), most of this increase is expected to occur in Asia and Africa, underscoring the critical role of environmental protection for every nation. ISID is achieved when a country's manufacturing industry expands without exacerbating social and environmental impacts (Cheng & Cantore, 2020). This is accomplished by simultaneously promoting industrialization, green industry, and social improvements directly associated with manufacturing (Altenburg & Rodrik, 2017).

The global policy agenda is now centered on reducing pollution and mitigating carbon emissions to foster economic growth while preserving the environment (Sadiq et al, 2023). Sustainable Development Goal 12, established by the United Nations, aims to decouple economic progress from environmental degradation, particularly about pollutants and carbon emissions (Bebbington & Unerman, 2018). Developed countries face challenges in the business and industrial sectors, including air pollution, waste management, resource depletion, aging infrastructure, and limited land availability (Mihai, 2020). In response to these challenges, the advent of sustainable development and industrial ecology has led to Eco-Industrial Parks. These parks facilitate resource exchange and have been recognized as a promising approach to address these challenges (Le Tellier et al., 2019).

The World Bank and the United Nations Industrial Development Organization (UNIDO) are championing the establishment of Eco-Industrial Parks as a strategic approach to managing industrial parks. The goal is to enhance economic, social, and environmental outcomes by implementing standardized principles and promoting knowledge exchange (Varnavskii, 2019). Industrial parks, designated regions with specific rules and management strategies, are pivotal in attracting investments, fostering manufacturing resources and infrastructure concentration, and stimulating economic growth (Azmach, 2019). These parks significantly impact the environment and serve as a strategic approach to managing environmental pollutants and transitioning toward sustainability (Liu & Renjie, 2015).

Performance issues in industrial parks, such as the absence of environmental safeguards, are frequently associated with the parks' planning, construction, and operation and the roles assigned to stakeholders (Massard et al, 2018). Establishing an industrial park includes identifying the park's location, potential demand, and dimensions, acquiring land, designing, and planning the park layout, securing financing, constructing infrastructure, maintaining operations, and monitoring and evaluating progress (Saleman & Jordan, 2014). Ethiopia has made significant strides in expanding IPs across its regions to enhance economic competitiveness (Jote, 2020). With combined public and private efforts, twenty-four IPs have been established in Ethiopia (IPDC, 2022). While the economic benefits of IPs are well-recognized, their social and environmental performance is equally important. However, comprehensive studies on the environmental impact of IPs using accepted and renowned indicators suggested by UNIDO (2019) still need to be included in the literature. Consequently, this study endeavors to bridge these gaps by scrutinizing Ethiopia's environmental stewardship through industrial parks. This examination is conducted through a quantitative analysis derived from survey data and is further enriched by synthesizing these findings with literature-based reviews.

2. Literature Review

2.1 Theoretical literature

The United Nations Industrial Development Organization (UNIDO) is renowned for its influential worldwide leadership in promoting industrial ecology (IE) and facilitating environmentally sustainable industrial development while also improving the management of solid and hazardous wastes in both developed and developing countries (Wang et al., 2021). The theory of sustainable development has developed through experience, and the examination of sustainability must be linked to implementing relevant policies (Stagl, 2007). The theory of sustainable development has undergone significant changes, shifting its focus from solely solving environmental issues to including a broader global strategic challenge and it has been used as a framework for recent academic exertions (Olawumi & Chan, 2018).

In the face of the global economy's resource constraints and the imperative to reduce pollution from human activities, worldwide and localized coordinated approaches are being proposed to address this global issue (Fan & Fang, 2020). Industrial symbiosis, which involves the interchange, sharing, or transaction of excess resources between various entities in a structured manner to minimize the use of new materials, energy, waste, and emissions, has garnered more research interest (Vahidzadeh & Bertanza,2022). This collaborative concept is based on the industrial ecology outlined by Allenby and Richards (1994) and later explained by other scholars as industrial symbiosis (IS.), which eco-industrial parks (EIPs) expand upon; EIPs are a practical demonstration of industrial ecology (Behera et al., 2012).

The introduction of industrial ecology and its recognition have also garnered worldwide interest in advancing and establishing eco-industrial parks (EIPs) (Belaud et al., 2019). EIP is an advanced industrial system developed from a conventional industrial park (Yuan et al., 2024). It focuses on preserving natural and economic resources, minimizing materials, enhancing operational efficiency, and facilitating knowledge exchange among companies at the inter-firm level (Korhonen, 2004). Industrial ecology is the most widely used method in related research, including input-output models, life cycle assessment, and material flow analysis. For instance, the environmental responsibility of corporations in IPs was measured based on an input-output model (Han & Cao, 2021).

The study by Sueyoshi and Goto (2017) focuses on an extensive literature review on energy and the environment. They acknowledged that industrialization is crucial for enhancing a nation's economy, even though it results in pollution and health problems. In this regard, Yoro and Daramola (2020) also noted that industry contributes to approximately 28% of worldwide greenhouse gas emissions and 61% of environmental pollutants. With a focus on lowering pollutants and carbon emissions, Sustainable Development Goal 12 of the United Nations seeks to reduce the harm economic growth causes to the environment (Bebbington & Unerman, 2018). These objectives can only be accomplished by diminishing the carbon dioxide emitted from industrial operations (Yuan et al, 2020).

EIPs have been identified as a significant contributor to low-carbon development, Nie et al. (2022) have empirically established that implementing EIPs can substantially augment the low-carbon development trajectory of nations and regions. The Kalundborg eco-industrial system, as highlighted by Branson (2016), is often cited as the epitome of EIPs. This system has evolved organically over half a century, embodying an industrial symbiosis paradigm where waste exchange and infrastructure sharing are integral components. Liu et al (2018) further underscore that such a system not only confers environmental benefits but also enhances economic competitiveness.

While IPs can stimulate economic growth and social progress, they can also lead to adverse environmental and social consequences such as climate change, pollution, resource depletion, labor issues, and community disturbance (Gebremariam & Feyisa, 2019). According to UNIDO (2017), the economic benefits of establishing IPs may result in a decline in environmental quality in and around industrial areas. The case of Vietnam demonstrates that IPs can affect not just local populations but the entire surrounding region (Cu & Nguyen, 2021). Global instances illustrate that the effective enforcement of environmental protections in IPs hinges on their ability to compete and offer economical and non-intrusive solutions to the companies within them (UNIDO, World Bank Group, & GIZ, 2017). Various metrics used to evaluate industrial zones' environmental and economic performance can be categorized into five primary groups: land area and population, resource consumption, energy use and emissions, environmental contamination, and governance and oversight (Mengistu & Panizzolo, 2023).

African nations progressively establish diverse IPs as a primary driver or significant catalyst for sustained economic advancement (Mebratu, 2019). In this regard, Khisa et al. (2018) also noted that some African countries aim to enhance industrial productivity and achieve efficient industrial output by implementing Environmental Improvement Programs (EIPs) to address environmental challenges caused by swift industrial growth. African nations, including Egypt, Ethiopia, and South Africa, are exploring the potential of industrial symbiosis, and partnering with the United Nations Industrial Development Organization (UNIDO) to conduct Eco-Industrial Park (EIP) projects (Negesa et al, 2022). This is due to the need for established techniques and standards for EIPs. The international EIP framework evaluation tool offers crucial indicators and performance assessment criteria to create sustainable EIPs, serving as a benchmark for individuals or entities in Ethiopia seeking more national or firm-level standards (Nessim et al, 2024). Implementing these criteria can help Ethiopia improve its indicators to be more regionally suitable (UNIDO, 2017; Khisa et al., 2018).

2.2. Empirical literature

Zeng et al. (2017) also conducted a study that defines an eco-industrial park as implementing sustainable supply chain management at the industrial park level. Integrating the circular economy concept into supply chain management is crucial for achieving a desirable balance of economic, social, and environmental benefits, especially as external sustainability becomes increasingly challenging. The researchers developed a conceptual model based on institutional theory, following the "institution-conduct-performance" paradigm. They analyzed data from 363 questionnaires distributed to eco-industrial park enterprises in China to assess the relationship between institutional pressure, supply chain relationship management, sustainable supply chain design, and circular economy competency. The study demonstrates that institutional pressure positively impacts supply chain relationship management and the design of sustainable supply chains. Sustainable supply chain management strategies enhance companies' circular economy competence.

The study conducted by Lyu et al. (2022) analyzed the green development of Chinese IPs by extracting and reviewing five leading research focuses through keyword clustering. Based on the literature, they concluded diversified practices of green development and discussed four challenges and prospects arising from the review and practice. The researchers describe the green development model for Chinese IPs and identify inadequate dissemination of concept and knowledge, heterogeneity of interest, untargeted assessment and guidance, and a backward management system as the five main challenges in the field.

Giannecchini and Taylor (2018) conducted a study on Ethiopian special economic zones. The study examined the characteristics of clustering, connections to the global economy, and the importance of economic structural development. However, these studies do not address the environmental performance of industrial parks in Ethiopia. Similarly, Gebremariam and Feyisa (2019) conducted an exploratory study to assess the performance of IPs in Ethiopia, specifically focusing on the Eastern Industry Zone, Bole Lemi 1, and Hawassa Industrial Parks. The study examined only the parks' economic performance, including the occupancy rate, complex currency generation, and issues faced by the parks, but it did not consider environmental factors.

Another study by Negesa et al. (2022) investigated the process and outcome of the transition of Hawassa Industrial Park (HIP). This study demonstrates that the development of HIP is a distinct manifestation of the implementation of the sustainable development plan and the role of the industrial park development corporation. However, the analysis also revealed limitations, including the impracticality of specific criteria within the framework and the inapplicability of certain indicators.

Overall, there needs to be a significant gap in understanding the role of IPs in addressing sustainability concerns, especially regarding environmental performance. Several earlier studies on Ethiopian industrial parks, such as Gebremariam & Feyisa (2019), Giannecchini & Taylor (2018), and Negesa et al. (2022), do not adequately cover this particular subject. Thus, the primary focus of this research is to examine how IPs impact a country's sustainability in terms of environmental protection and to what degree the current parks help address environmental issues according to UNIDO's criteria, with a specific emphasis on the country's unique circumstances based on the conceptual framework below.

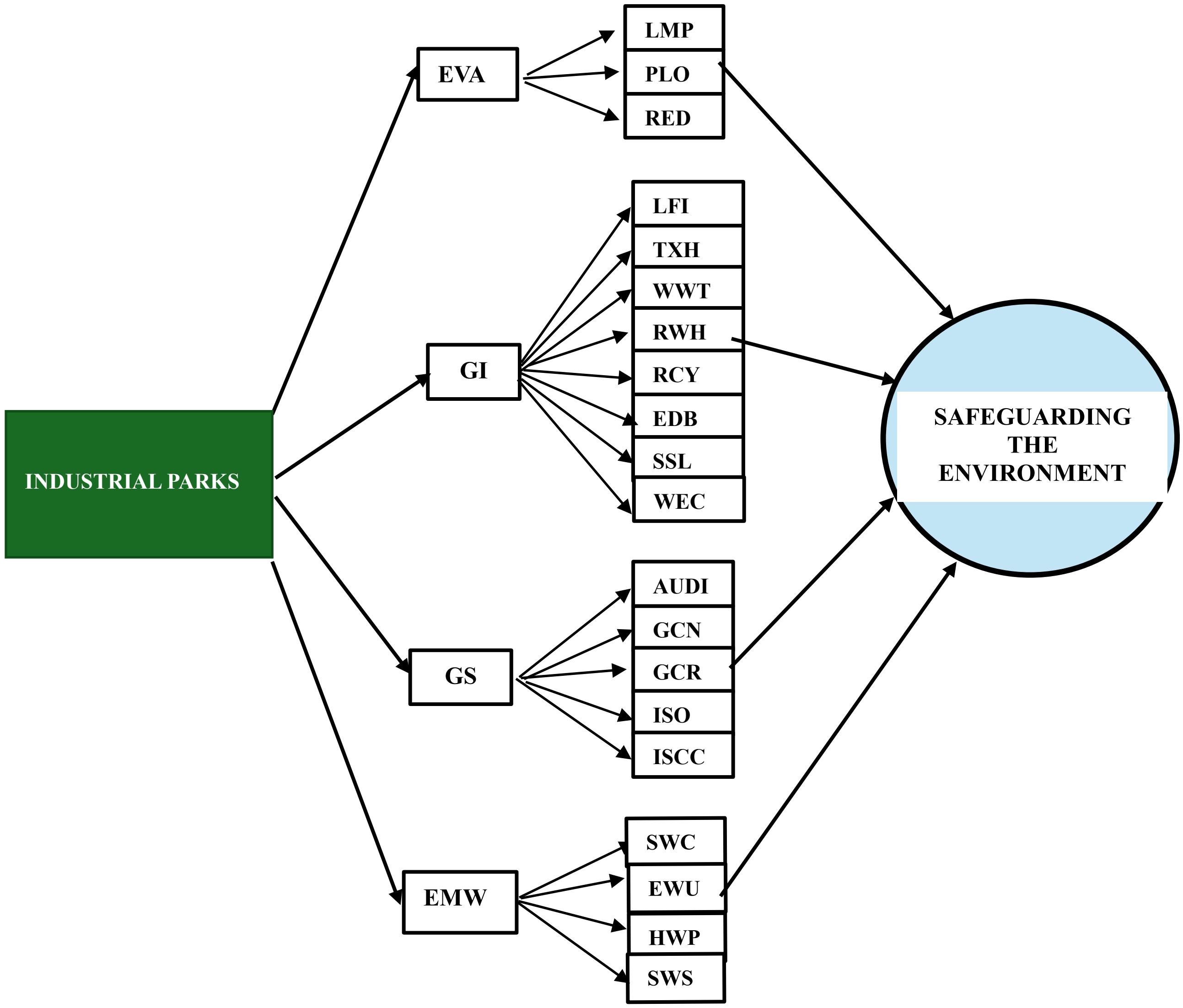

Figure 1. Conceptual framework of the study

Source: Own design based on UNIDO (2019) guideline. The variables are described in Table 3

3. Methodology of the Study

This study employs a cross-sectional research design, utilizing both descriptive and explanatory approaches. The required samples were selected using proportional stratified sampling technique. The study population was determined based on information from the Industrial park Development Cooperation (IPDC), indicating that there are 203 business enterprises in the 10 most functional IPs. Each company, whether operating in private or public IPs in Ethiopia, has management, administrative and technical staff ranging from 24 to 40. Given the variation in enterprise size, the minimum number of managerial staffs per company was used to determine the study population.

This resulted in a total study population of 4,872. The sample size that is 375 was determined using the sample size determination formula developed by Yemane (1967). An additional 10% (i.e., 37) was added to the initial sample size to account for potential non-responses, bringing the total sample size to 412. This sample was proportionally distributed across 203 enterprises operating in ten private and public industrial parks. Respondents were selected from each enterprise using a simple random sampling method. A total of 395 questionnaires were returned, yielding a 96% response rate, which is sufficient to proceed with the data analysis. The data was analyzed using a binary logistic regression model to fulfill the study's objective.

The questionnaire consisted of open-ended categorical questions pertaining to the dependent variable and 20 quantifiable variables. The standard variables, derived from UNIDO (2019), were categorized into four primary factors that served as explanatory variables. Responses to questions about these explanatory variables, also referred to as environmental performance variables, were measured on a 5-point Likert scale, with 1 denoting strong disagreement and 5 denoting strong agreement. Prior to the commencement of full-scale data collection, a pilot study was conducted with 30 randomly selected participants to assess the reliability of the structured questionnaire using Cronbach's alpha. According to Kothari (2004), a data collection tool is considered reliable if it produces consistent results. Cronbach's alpha is commonly used to evaluate the internal consistency or reliability of a data collection instrument. Sekaran and Bougie (2013) further noted that a Cronbach's alpha value below 0.6 is considered poor, 0.7 is acceptable, 0.8 is very good and 0.9 or higher is excellent. As indicated in Table 1, the structured questionnaire exhibited reliability as Cronbach's alpha values for all five major social inclusiveness factors exceeded 0.7.

Table 1: Reliability Test results for individual items

Major environmental categories	No of items	Cronbach's alpha
Environmentally appropriate site	3	0.7343
Green Infrastructure	8	0.8101
Green Systems	5	0.7761
Efficient and Clean Production, Emissions and Waste Management	4	0.8012

Source: Authors' computation from pilot survey data (2024)

After checking the reliability and internal consistency, the questionnaire was administered to sample respondents in person. As mentioned earlier, 5-point Likert-scale questions used as explanatory variables, which are ordinal because the items have clear rank order but do not have an even distribution. Regarding the dependent variable, however, sample respondents were asked to rate their agreement levels to the binary question "Do IPs in Ethiopia have contributed to environmental safeguarding?" Consequently, a binary Logistic regression is the most appropriate model for this study.

Letting Z_{ij} be the i^{th} respondents agreement level to the question of whether IPs in Ethiopia have contributed to environmental stewardship or not (a binary outcome, 1= if the response is yes, 0=otherwise) operating in the j^{th} public or private IPs as the dependent variable and X_i observable environmental indicators expected to flourish following the establishment of IPs as explanatory variables. Thus, the role of IPs for environmental stewardship in Ethiopia was assessed based on the dependent variable indicated below.

$$Z_{ij} \sim Bernoulli\ (P_j) \text{ -- (1)}$$

This leads to the response or outcome variable:

$$Z_{ij} = \begin{cases} 1\ if\ a\ respondent\ agrees\ that\ IPs\ contribute\ to\ environmental\ safguarding \\ 0, otherwise \end{cases}$$

Then, supposing $Z_{ij} = 1$ in a case whereby IPs in Ethiopia have contributed to environmental stewardship, the linear functional relationship between the probabilities of achieving this objective in Ethiopia and key input-level sub-indicators used as explanatory variables is specified as:

$$P_i = E(Z = 1/X) = \alpha + \beta_1 X_1 + \beta_2 X_2 + - - - + \beta_i X_i \text{-------------- (2)}$$

For simplicity, equation (2) can be written as:

$$P_i = E(Z = 1/X) = \frac{1}{1+e^{-(\alpha+\beta_1 X_1+\beta_2 X_2+---+\beta_i X_i)}} \text{------------------------- (3)}$$

Thus, following Gujarati's (2004) work, the cumulative logistic distribution model is specified as follows:

$$P_i = E(Z = 1/X) = \frac{1}{1+e^{-Z_i}} = \frac{e^Z}{1+e^Z} \text{-------------------------------------- (4)}$$

Where, $Z_i = \alpha + \beta_1 X_1 + \beta_2 X_1 + - - - + \beta_i X_i$

If P_i is the probability that IPs contribute to environmental stewardship in Ethiopia, given by equation (2), then $(1 - P_i)$, the probability of not achieving the environmental stewardship objective is written as:

$$1 - P_i = \frac{1}{1+e^{Z_i}} \text{--------------------------------- (5)}$$

Therefore, by dividing equation (4) by equation (5), we get an expression as

$$Odds\ P(Z) = \frac{P_i}{1-P_i} = \frac{e^{Z_i}}{1+e^{-Z_i}} = e^{Z_i} \text{---------------- (6)}$$

Furthermore, Cramer (2003) indicates that for logistic probabilities, the above odds are

$$Odds\ (Z_i) = \exp(Z) = \exp(\alpha + \beta_i X_i)$$

The above equation estimates odds ratios (Pi/1-Pi) for each independent variable in the model. Thus, taking take the natural log on both sides of equation (6), we obtain the log odds or logit regression model employed in this study to evaluate the role of IPs in contributing to environmental stewardship in Ethiopia as:

$$logit[P/(Z_i)] = log \frac{P/(Z_i)}{1-P/(Z_i)} = Z_i \text{ , which is also}$$

$$logit{=}log\left(\frac{P_i}{1-P_i}\right) = \frac{e^{Z_i}}{1+e^{-Z_i}} = Z_i. \text{ Finally,}$$

$$Z_i = \alpha + \beta_1 X_1 + \beta_2 X_1 + - - - + \beta_i X_i \text{ -------- (7)}$$

Therefore, equation (7) is the binary logit model, where

Z_i = represents the dependent variable (for environmental safeguarding objective)
X_i = the vector of explanatory variables
β_i = is the vector of unknown coefficients/ the parameter estimates

Table 2. Variables definition and expected signs in Environmental stewardship study

Dependent variable	Description
ENVIRONMENTAL SAFEGUARDING	
Independent variables	
	Environmentally Appropriate Site (EVA)
SITE COMPATABILITY WITH LUMP (LMP)	Site compatibility with Land Use Master Plan as regards non-agricultural use
PERCENTAGE OF PLOTS ALLOCATED TO LMA (PLO)	The % of plots actually allocated to non-polluting or light manufacturing activities in IP is greater than % of GDP represented by non-polluting or light manufacturing activity nationally
IPs IN REDEVELOPED BROWNFIELD SITE (RED)	Industrial Park situated on redeveloped brownfield site, with the effective possibility of reusing, re-purposing, and converting existing infrastructure or buildings
	Green Infrastructure (GI)
OFF-SITE LANDFILL FOR IP SWM (LFI)	Presence of an off-site landfill for IP solid waste management
TOXIC & HAZ. MATERIALS CSTD MGT SYSTEM (TXH)	Presence of toxic and hazardous waste collection, storage and treatment or disposal management system
WSS AND WWTP (WWT)	Presence of Public Wastewater Sewerage System, STP and/or of Wastewater Treatment Plant
SUSTAINABLE RAINWATER COLL.& RE-USE SYSTEM (RWH)	Presence of sustainable rain and storm water collection / harvesting (i.e., culverts/drains, cisterns/tanks), management, treatment (e.g., filter, water hyacinth) and re-use systems
SEGREGATED RECY. RECEPTION BIN/CONT. (RCY)	Segregated recycling reception bins, bells and/or containers for: paper & card; recyclable plastic containers; recyclable metals and others.
BUILDINGS WITH ENV. DESIGN CERTFICATES (BED)	There are buildings with environmental design related certificates
SOLAR STREET LIGHTING (SSL)	There are Solar Street lighting
WASTE EXCH CLEANING HOUSE (WEC)	Presence of waste exchange clearinghouse, promoting industrial symbiosis andeconomic circularity
	Green Systems (GS)
ANNUAL ENV AUDIT PERFORMED (AUDI)	Annual environmental audits performed on each firm
FIRMS WITH “GREEN” CERT. AT NATIONAL LEVEL (GCN)	Presence of firms having obtained a “Green” certification at national level
OPERATOR POSSESSES UN COMPACT REGIS. (GCN)	Operator possesses UN Global Compact Registration[3]
OPERATOR POSSESSES ISO14001 (ISO)	Operator possesses ISO14001
OPERATOR POSSESSES ISCC (ISCC)	Operator possesses International Sustainability and Carbon Certification
	Efficient and Clean Production, Emissions and Waste Management (EMW)
SWC SERVICE (SWC)	Presence of solid waste collection service
EFFICIENT WATER USE IN m3 TO USD SALES (EWU)	The ratio of Efficient water use in m3/US$ Sales in Industrial Park is lowerthan water use in m3/US$ Sales nationally
HAZARDOUS WASTE PRODUCED /US$ SALES (HWP)	Hazardous waste produced/US$ in Sales nationally in Industrial Park is lowerthan Hazardous waste produced /US$ in Sales nationally

PERCENTAGE SOLIDE WASTE SENT TO LANDFILE (SWS)	Percentage (%) solid waste sent to landfills (store of garbage) in Industrial Parkis lower than solid waste sent to landfills nationally

Source: Description of the variable adopted from UNIDO (2019) guideline

The above 20 variables were selected among 59 sub-indicators categorized under the four key environmental performance indicators by UNIDO (2019). The criteria used for selection is their prevalence in industrial parks established in Developing countries in general and in Ethiopia in particular and strategically relevant for environmental performance in future based on information collected from 30 respondents for pilot test.

There are several rationales for employing the Logit model in this study. First, OLS estimation is infeasible if we collect data from ungrouped or individual respondents like this study (Gujarati, 2004: 597). Second, though many studies suggest that both Probit and Logit models are appropriate in instances where the dependent variable is binary or dichotomous (Maddala, 1999), the Logit model is a more realistic pattern of change in the probability compared to other qualitative dependent variable models like the Probit, for four main reasons. That is, the odds ratio, which measures the strength and direction of the relationship between two variables, has the unique property of not requiring variables to be normally distributed, and the mathematical transformation of the odds ratio is the Logit model. Moreover, this mathematical transformation removes the problem of asymmetry existing in the odds ratio, making this a superior method, as argued by Peng et al., (2005). The third reason is that the logistic regression model has mighty predictive power. Its close relationship to log-linear discriminate function analysis made the logistic model more popular than other related models, a feature that enables logistic regression to serve as a standard to which other models are compared. Fourth, compared to its competitor, the Probit model, the Logit model is less sensitive to outliers and easy to correct bias (Copas & Corbett, 2002). Finally, the basic assumptions that must be fulfilled for statistical tests in logistic regression are far less restrictive than those for ordinary least squares regression.

4. Results and Discussions

The socio-demographic characteristics of the respondents, as presented in Table 3, reveal that 84.3% of respondents were male and 15.7% were female. The majority (about 72%) was aged between 31 and 40 years, with 22.28% aged 18 to 30, and about 5.8% of the respondents were above 41 years of age. The mean age of the sample respondents was about 35 (SD=4.76). The majority (60.5%) held a master's degree, while others had a terminal degree (1.77%) or a bachelor's degree (37.72%). Over half (52.91%) had experience in the manufacturing sector, and 81.77% were employed in the private sector, which are capable of providing insights into the opportunities and challenges faced by enterprises operating within industrial parks.

Table 3. Socio-demographic characteristics of respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	333	84.30
	Female	62	15.70
Age group	1=18 - 30	88	22.28
	2=31 - 40	284	71.90
	3=41 - 60	23	5.82
Educational Qualification	1=BA degree	149	37.72
	2=Masters' degree	239	60.50
	3= PhD degree	7	1.77
Number of years in current Position	1	209	52.91
	2	186	47.09
Do you have experience working in the manufacturing sector?	Yes	229	57.97
	No	166	42.03
What is the business form of your company?	Public	70	17.72
	Private	323	81.77
	Joint venture	2	0.51
Total respondents		395	100%

Source: *Authors' computation from survey data (2024)*

Before the execution of logistic regression, a pairwise correlation test was conducted among the explanatory variables to ascertain if a high correlation (above 0.7) existed, which could indicate a multicollinearity problem. Multicollinearity arises when there is a correlation among multiple independent variables in a multiple regression model (Wooldridge, 2002). The Pearson correlation test results revealed a maximum correlation of 0.6122 between segregated recycling reception bins, bells, and containers for various materials and a waste exchange clearinghouse promoting industrial symbiosis and economic circularity. Therefore, given the relatively lower pairwise correlation coefficients among time-variant explanatory variables and the VIF and tolerance values within acceptable limits, it can be concluded that there is no multicollinearity problem among the study's independent variables.

As presented at the commencement of Table 4, the logistic regression results reveal that the analysis incorporated all 395 observations from the survey data, indicating an absence of missing values across all variables employed in our Logit model. The iteration log-likelihood value of -165.1867 indicates the model's convergence speed when comparing nested models. The Pearson chi-square value for the likelihood ratio Chi-Square, which stands at 41.72 (on 20 degrees of freedom), gauges the overall goodness of fit or adequacy of the logistic regression, with a Prob. > chi2 = 0.0030 is highly significant at the 1% significance level, suggesting that the explanatory variables collectively contribute significantly to environmental stewardship in Ethiopian IPs (the dependent variable). Conversely, the Pseudo R2 is 0.1121. Given that the majority of the explanatory variables in our logistic regression model are statistically significant, the coefficient of determination (R2) value, which lies between 0.10 and 0.50, is deemed acceptable as per the guidelines proposed by Maydeu-Olivares and Garcia-Forero (2010) for social science research.

Further, the estimated coefficients, their standard errors, the z-statistic, associated p-values, and the 95% confidence interval of the coefficients for the logit model used in this study are shown in Table 3. On the other hand, columns 7 and 8 report the odds ratio (OR) that shows the probability of Ethiopia's achievement of environmental stewardship in Ethiopia's objective through IPs development and the marginal effects of each explanatory variable, respectively. Overall, when all independent variables in the logit model increase by one unit, the probability of achieving the environment stewardship objective by Ethiopia through the expansion of IPs also changes or increases by 0.8626.

The binary Logit regression model identified several key indicators that foster environmental stewardship within IPs: the compatibility of IPs with the local land use plan emerged as significant factor (OR 1.7992, $p<0.05$). This suggests that when IPs are developed in harmony with local land use plans, they are more likely to contribute positively to environmental stewardship. Another positive contributor to environmental stewardship is the allocation of plots to Local Manufacturing Activities (LMA). The study found that a higher percentage of plots allocated to LMA (OR 1.7124, $p<0.05$) has positive impact on environmental safeguard. This could be due to the fact that local manufacturing activities are more likely to adhere to local environmental regulations and standards. However, not all factors were found to contribute positively. For instance, the redevelopment of brownfield sites into IPs did not show a significant effect on environmental stewardship (OR 0.6947, $p>0.10$). This could be due to potential environmental contamination associated with brownfield sites.

Among green infrastructure indicators, the presence of a Public Wastewater Sewerage System (WSS) and WastewaterTreatment Plant (WWTP), and segregated recycling reception bins and containers for recyclable and non-recyclable byproducts in IPs contributed significantly to the achievement of environmental protection (Safeguarding the Environment) objective of Ethiopia. More specifically, the Water Supply Systems (WSS) and Wastewater Treatment Plants (WWTP) were found to have strong positive effect on environmental stewardship (OR 2.4611, $p<0.01$). This underscores the importance of water management in IPs.

Contrarily, the presence of an off-site landfill for solid waste management in industrial parks, a system for the collection, storage, treatment, or disposal of toxic and hazardous waste, and solar street lighting were identified as green infrastructure indicators that significantly and adversely affect the attainment of environmental safeguarding objective in Ethiopia. The detrimental effects of these facilities could be attributed to their scarcity within IPs relative to the demand. This shortfall could hinder firms' compliance with environmental protection codes of practice. This deficiency is evident from the fact that less than 30% of respondents agreed or strongly agreed with the questions about the presence of these facilities. Ezeala et al. (2023) highlighted the adverse impacts of industrial toxic and hazardous waste, noting more than such wastes and their sources pose health hazards, contribute to climate change, and pollute the surrounding air. Therefore, these results suggest a focus on ensuring adequate off-site landfill availability for waste management, improving the toxic and hazardous waste collection, storage, and treatment system, and enhancing solar street lighting in industrial parks.

About the green system indicators proposed by UNIDO (2019) and incorporated in this study, it was found that the requirement for operators of IPs to possess an ISO 14001 certificate significantly bolsters the environmental safeguarding objective of Ethiopia through IPs development. ISO 14001 is an international standard that delineates the prerequisites for an Environmental Management System (EMS), providing a framework that firms can adhere to for establishing and maintaining an EMS. This assists them in managing their environmental responsibilities systematically and effectively. Consequently, a one percent increase in firms with an ISO 14001 certificate operating in IPs not only enhances the environmental responsibilities of firms but also amplifies the environmental performance achievement of Ethiopia by log odds ratio of 3.05, holding all other factors constant. The magnitude of this odd ratio underscores the relevance of this requirement for achieving the country's environmental performance (Alba & Todorov, 2018).

The study also identified the crucial role of effective management systems for toxic and hazardous materials (OR 0.5058, $p<0.01$). However, its negative effect indicates room for improvement in this area. Sustainable rainwater collection and reuse systems also has positive but insignificant effect on environmental safeguarding (OR 1.4447, $p<0.10$), suggesting that these systems can help to conserve water and reduce the demand for freshwater resources. The presence of segregated recycling bins or containers in IPs was positively linked to environmental stewardship (OR 0.6190, <0.05). This suggests that effective waste segregation and recycling practices can contribute to environmental sustainability.

Solar street lighting has negative and significant association with environmental safeguarding (OR 0.5107, $p<0.01$), which may indicate issues with the implementation or maintenance of these systems. Finally, annual environmental audits conducted on each firm were negatively associated with environmental safeguarding (OR 0.4846, $p<0.05$). This suggests that firms that undergo audits may have more identified areas for improvement, highlighting the importance of continuous improvement and learning in environmental management.

The findings also highlight the need for a balanced approach in leveraging IPs for environmental safeguarding. It is crucial to build on the identified strengths while addressing the challenges. This could involve implementing policies and practices that promote site compatibility with local land use plans, allocate a higher percentage of plots to LMA, enhance WSS and WWTP, implement sustainable rainwater collection and reuse systems, provide segregated recycling bins or containers, and manage toxic and hazardous materials effectively. At the same time, efforts should be made to address the challenges associated with redeveloped brownfield sites, off-site landfills, solar lighting, and environmental audits. By addressing these issues, Ethiopia can enhance the role of its IPs in promoting environmental safeguarding.

Table 4. Binary Logit Model result

Logit Regression — Number of obs. = 395

LR chi^2 (20) = 41.72

Prob. > chi^2 = 0.0030

Log Likelihood = -165.1867 — Pseudo R^2 = 0.1121

Variables	Logit Regression						Logistic	Mfx
	Coeff.	**S.E.**	**Z**	**P>|Z|**	**[95%conf. Inter.]**		**Odds Ratio**	**dy/dx**
SITE COMPATIBILITY WITH LUMP	0.5873	0.2487	2.36	0.018**	0.0998	1.0718	1.7992	0.0696
% OF PLOTS ALLOCATED TO LMA	0.5379	0.2383	2.26	0.024**	0.0709	1.0049	1.7124	0.6375
IPs IN REDEVELOPED BROWNFIELD SITE	-0.3643	0.2397	-1.52	0.129	-0.8341	0.1056	0.6947	-0.0432
OFF-SITE LANDFILL FOR IP SWM	-0.8310	0.2170	-3.83	0.000***	-1.2562	-0.4057	0.4356	-0.0985
TOXIC & HAZARDOUS MATERIALS CSTD MGT SYS	-0.6763	0.2209	-3.06	0.002***	-1.1092	-0.2433	0.5085	-0.0801
WSS AND WWTP	0.9006	0.3753	3.27	0.001***	0.3609	1.4403	2.4611	0.1067
SUSTAINABLE RAINWATER COLLECTION & REUSE SYS.	0.3679	0.2140	1.72	0.086*	-0.0515	0.7872	1.4447	0.0436
SEGREGATED RECYCLING RECEPTION BINS/ CONT.	0.4818	0.2360	2.04	0.041**	0.0193	0.9443	1.6190	0.0571
BUILDINGS WITH ENV DESIGN CERTIFICATES	0.0038	0.2002	0.02	0.985	-0.3886	0.3961	1.0038	0.0004
SOLAR STREET LIGHTING	-0.6720	0.2412	-2.79	0.005***	-1.1447	-0.1993	0.5107	-0.0796
WASTE EXC CLEARING HOUSE	0.3519	0.2662	1.32	0.186	-0.1698	0.8737	1.4218	0.0417
ANNUAL ENV AUDIT COND. ON EACH FIRM	-0.6379	0.2537	-2.51	0.012**	-1.1351	-0.1407	0.5284	-0.0756
FIRMS WITH “GREEN” CERTIFICATION AT NATIONAL	-0.3653	0.2422	-1.51	0.131	-0.8400	0.1094	0.6940	-0.0433
OPERATOR POSSESSES UN COMPACT REGISTRATION	-0.6100	0.4729	-1.29	0.197	-1.5368	0.3169	0.5434	-0.0723
OPERATOR POSSESSES ISO14001	1.1138	0.4481	2.49	0.013**	0.2356	1.9920	3.0459	0.1320
OPERATOR POSSESSES ISCC	-0.7382	0.3570	-2.07	0.039**	-1.4379	-0.0385	0.4780	-0.0875
SEC SERVICE	-0.7243	0.2499	-2.90	0.004***	-1.2141	-0.2346	0.4846	-0.0858
EFFICIENT WATER USE IN m3 TO USD SALES	-0.3788	0.2872	-1.32	0.178	-0.9418	0.1842	0.6847	-0.0449
HAZARDOUS WASTE PRODUCED /US$ SALES	0.2061	0.2641	0.78	0.435	-0.3116	0.7237	1.2288	0.0244
% OF SOLIDE WASTE SENT TO LANDFILE.	0.7339	0.3278	2.24	0.025**	0.0915	1.3763	2.0832	0.0870
Cons	4.2491	1.0171	4.18	0.002***	2.2551	6.2431	70.0417	
Marginal effect after logit	**Y=pr (social inclusiveness) (predicted)**							**0.8626**

*Note: Values in this table are rounded to 4 decimal places. ***, **, & * indicate significance at 1%, 5% & 10% respectively.*

Source: Authors' computation from survey data (2024)

Moreover, among the four indicators of efficient and clean production, emissions, and waste management included in the binary response regression models, the lower percentage of solid waste sent to landfills (store of garbage) from IPs compared to the national average was the only indicator that contributes to the achievement of environmental performance significantly. The odd ratio value shows that keeping other thongs constant, a percentage reduction of solid waste sent to landfills from IPs compared to the national average will increase the probability of achieving the environmental performance objective of IPs by log odd of 2.1. This result implies that there is proper industrial solid waste management in IPs, and it is one of the effective proxies for good governance. Moreover, this finding is consistent with the argument of Firdissa and Soromessa (2016) that improper management of vast amounts of industrial waste is one of Ethiopia's most critical environmental problems, especially in Addis Ababa.

However, the variable that states the presence of solid waste collection services in IPs affected the achievement of environmental performance in Ethiopia through IPs development adversely and significantly. An increase in the current solid waste collection service in IPs by 1% reduces the odds of achieving the environmental protection objective in Ethiopia by a factor of 0.5, keeping other variables constant. Thus, the implications of this result related to solid waste collection service in industrial parks are that though the presence of the service is critical, greater attention should be paid to the effectiveness of the service, not to the mere existence of the service in IPs to achieve the environmental performance of Ethiopia through the expansion of industrial parks.

The diagnostic tests performed after the binary logistic regression and shown in Table 5, namely multicollinearity test based on correlation analysis with and without residual as well as the VIF value of 2.99 proved that there is no multicollinearity problem among the independent variables included in the three models. Further, the Hosmer-Lemeshow goodness of fit statistics for the Logistic model indicates that the goodness of fit Chi2, ($\ddot{\widehat{H}}\,\chi 2$ (8)) =4.03, with p-value 0.8542, suggesting that the binary logistic model fits quit well. The overall rate of correct classification for those respondents who perceive/believe that Ethiopia has achieved environment safeguarding objective through development of IPs (i.e., Z=1) was 82.53%. Last but not least, the receiver-operating characteristic (ROC) that measure the area under the curve provides a measure of discrimination, which is the likelihood that Ethiopia's achievement of the three objectives via IPs will be higher $Pr(Z = 1)$ than the country failed to achieving the objectives was 0.7233, which indicate that the model is acceptable for prediction.

Table 5. Summary of Postestimation Diagnostics tests result after Binary logit model regression

	Model: Environmental safeguarding
Multicollinearity tests	
Max. correlation coefficient -Without residual -With residual	 0.6122 0.0332
Mean, Variance inflation factor (VIF)	2.99
Hosmer-Lemeshow goodness of fit Chi2 ($\ddot{\widehat{H}}\,\chi 2$ (8)) Prob > chi2	4.03 [0.8542]
Correctly classified	82.53%
Area under ROC curve	0.7233

Source: Own computation from survey data (2024)

5. Conclusion and Recommendations

The study provides valuable insights into the role of Industrial Parks (IPs) in promoting environmental stewardship in Ethiopia. It is evident that IPs can significantly contribute to environmental sustainability when they are developed in harmony with local land use plans and allocating higher percentage of plots to Local Manufacturing Activities (LMA). Moreover, the Wastewater Sewerage System and Wastewater Treatment Plant; the presence of segregated recycling reception bins and containers for recyclable and non-recyclable byproducts; the requirement for IP operators to possess an ISO 14001 certificate; and the lower percentage of solid waste sent to landfills (store of garbage) from IPs compared to the national average contributed significantly to the achievement of environmental safeguarding objective of Ethiopia. However, the study also highlights several areas that need improvement, such as the management of toxic and hazardous materials, the reliance on off-site landfills for waste disposal, the installation of solar street lighting systems throughout the IPs, and ensuring the requirement for the IP operators to possess International Sustainability and Carbon Certification (ISCC) certificates.

Based on the study's findings, the following recommendations are proposed:

- ***Waste Management***: IPs should prioritize the development of effective on-site waste management strategies to reduce reliance on off-site landfills. This could include the implementation of waste segregation and recycling practices, as well as the establishment of a waste exchange clearinghouse.
- ***Management of Toxic and Hazardous Materials***: IPs need to improve their management systems for toxic and hazardous materials. This could involve regular training for staff and the implementation of stringent safety measures.
- ***Water Management***: IPs should continue to invest in Water Supply Systems (WSS) and Wastewater Treatment Plants (WWTP). Additionally, the implementation of sustainable rainwater collection and reuse systems should be encouraged.
- ***Solar Street Lighting***: IPs should address the issues related to the installation of solar street lighting systems throughout the IPs campus to ensure their effectiveness.
- ***Environmental Audits***: IPs should conduct regular environmental audits on each firm. The reason is that such an audit audits should not just identify areas for improvement, but also provide guidance and support to help firms implement necessary changes.
- ***Environmental Design Certificates***: While buildings with environmental design certificates did not show significant effect on environmental safeguarding, IPs should still strive to meet environmental design standards as part of their commitment to sustainability.

While IPs have made positive contributions in promoting environmental safeguarding, there is still room for improvement. By implementing the above recommendations, IPs can play vital role in enhancing environmental safeguarding and sustainability in Ethiopia.

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