

THE USE OF ENVIRONMENTAL MANUFACTURING STRATEGY IN IMPROVING RESOURCE EFFICIENCY: A CASE STUDY OF WASIT TEXTILE AND SEWING FACTORY

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Abstract

Throughout the world, the manufacturing sector is facing growing pressure to find a balance between industrial productivity and environmental stewardship. Nonetheless, the pathways through which environmental manufacturing strategies lead to tangible benefits in resource efficiency are still poorly understood, especially in developing-country industrial settings. Abstract Objective: The study explores the relationship between environmental manufacturing strategy (EMS) and resource efficiency (RE) in textile manufacturing sector, with particular attention to the Wasit Textile and Sewing Factory in Iraq. We employed a quantitative, survey-based methodology. A well-structured questionnaire on a five-point Likert scale was used to conduct a field survey on 70 employees at administrative and technical levels and out of which 67 responses were returned useful, yielding a total response rate of 95.71 per cent. GPP and EDI: Two main Dimensions of EMS were treated as independent variables and RE including material, energy and water consumption: Dependent variable IBM SPSS Statistics version 26 was used to perform descriptive statistics, a Cronbach alpha reliability analysis, one-sample t-tests, Pearson correlation analysis and multiple regression modelling. Results indicate GPP ($\beta = 0.521$, $p < 0.001$) and EDI ($\beta = 0.412$, $p < 0.001$) both have statistically significant positive effects on RE and the model explains 71.0 per cent of the variance of RE ($R^2 = 0.710$) combined. The findings suggest factory management to institutionalise systematic environment practices and put in place investment contracts on cleaner production technologies and bio-design principles through the initial stages of the product development life cycle.

1. Introduction

It has created some of the most serious environmental problems since humanity started industrialising, which have now become a major focus of academic discussion and a hot issue in national and international policy. One-fifth of the energy consumption worldwide occurs in the manufacturing industries, which are a huge source of solid waste, liquid effluents, and greenhouse-gas emissions, and they also receive increasing scrutiny from regulators, consumers, and investors (Diabat & Govindan, 2011; Sarkis, 2012). Against this backdrop, there is an increasing agreement that it is no longer just regulatory compliance but that using green manufacturing strategies is a strategic choice that can enhance organisational performance whilst decreasing the environmental impact. However, despite the growing number of studies, empirical exploration of the processes through which structured environmental manufacturing strategies improve resource efficiency a measure that in this study is defined as the output-per-unit-productivity of material, energy and water (Frosch & Gallopoulos, 1989)-is still lacking (Zhu et al., 2013), when manufacturing sectors usually face different institutional, technological and financial structures compared to countries of the Global North.

Resource efficiency sits at the nexus of sustainability and industrial productivity. Resource efficiency, in the broadest sense of the term, is the ability of production systems to maximize value from material, energy and water use while minimizing waste, emissions and environmental degradation (Triebe et al., 2023; Ahmad et al., 2022). Longoni and Cagliano (2015) demonstrated

that these resource efficiency improvements translate into direct economic benefits (e.g., lower input costs, reduced waste-disposal costs, and better product quality) while helping with global societal goals (e.g., pollution decrease and natural capital). But those benefits are not guaranteed: they are guided by the type, scope and consistency of the environmental strategies pursued and deployed by firms (Ahmad et al., 2022).

In this research, environmental manufacturing strategy (EMS) is defined as planned consideration of environmental aspects in all stages of manufacturing processes and products, including design, planning, execution, and control. Further, it covers a range of activities from the pollution prevention and cleaner production to green supply-chain management and eco-design (Farrukh, Mathrani, & Sajjad, 2022; Green et al., 2012; Chourasiya, Pandey, & Malviya, 2023). Green production practices (GPP) are operations initiatives that lessen the ecological footprint of production operations — such as energy-efficient technologies, waste-minimisation programs, closed-loop material flows and substitution of hazardous substances. EDI, in contrast, incorporates environmental issues during the product development process, and aims to reduce the life-cycle environmental impact of products by making alternative choices about materials, manufacturing processes, use characteristics and end-of-life disposal (Dangelico & Pujari, 2010; Dangelico, Pujari, & Pontrandolfo, 2017).

Sectoral Context for EMS and Resource Efficiency: Textile Production The textile manufacturing sector offers a particularly interesting context in which to explore EMS and resource efficiency. The textile industry is one of the most resource-intensive of all sectors, consuming vast amounts of water (Roos et al., 2016), energy, dyes and chemical auxiliaries during fibre preparation, spinning, weaving, dyeing and finishing. It is also linked to high environmental externalities, such as toxic dye and heavy metals waste-water discharge, a large quantity of solid waste, and greenhouse-gas emissions. Countries like Iraq, where the textile sector has been operating for a long time with less attention to environmental management due to the priorities of economic development goals on the one hand and relatively low enforcement of environmental regulations on the other hand (Al-Tuwaijri, Christensen, & Hughes, 2004).

There has been a considerable research effort, however, significant gaps remain in scholarly knowledge about environmental management in manufacture. Limited empirical studies to date focused on advanced economy firms, with relatively few insights into firms in the relevant Middle Eastern and other developing country contexts (Diabat & Govindan, 2011). In addition, there are few examples of integrative studies combining different strategic features (dimensions) to explain resource efficiency as a multi-faceted outcome (Sarkis, Zhu, & Lai, 2011). Hardly any systematic academic study has been conducted on the case of environmental management practices in the textile sector in Iraq.

The present study is novel for a number of reasons. Abstract: Theoretically, it adds to the environmental strategy and operational performance literature with an empirical dator from an understudied context. From a methodological perspective, it illustrates the applicability of a quantitative survey-based methodology to the research of EMS in a developing country industrial context. In practical terms, the results provide tangible advice to factory managers, industry associations, and policy-makers in Iraq and similar contexts (Longoni & Cagliano, 2015; Sarkis et al., 2010).

In light of this, the current study aims to address the following primary research question: How do the dimensions of EMS; GPP vs EDI affect resource efficiency for textile manufacturing firms. The purpose of the study is threefold: (1) to evaluate EMS implementation at the Wasit Textile and Sewing Factory; (2) to analyze the nature of the relationship between GPP and resource efficiency; and (3) to analyze the nature of the relationship between EDI and resource efficiency.

1.1. Environmental Manufacturing Strategy: Conceptual Foundations

Environmental manufacturing strategy has grown over the last thirty years from a largely compliance based, transactional framing to a more strategic, proactive framing. The earlier literature, in the earlier years, was more inclined to analyse environmental aspects as cost of the business rather than as competitive advantage (Farrukh et al., 2022). Later, several works opposed this view by showing that forward-looking environmental strategies might yield positive returns through cost

savings and product differentiation and new markets access (Farrukh et al., 2023). Since then, this win-win view has turned into one of the central paradigms in the operations management and strategy literatures (Triebe et al., 2023).

Chourasiya et al. (2023) (the year of re-narrativization) provided systematic perspectives on manufacturing adoption of environmental practices, showing that an eco-friendly production strategy significantly outperforms the end-of-pipe (EOP) approach (driven by the eco-friendly policy). Green et al. (2012) Building on this rationale, Zhu et al. (2013) research identified external supply-chain-oriented environmental manufacturing practices and revealed that internal green practices affect supplier and customer environmental collaboration which positively associates with supply-chain performance outcomes both operationally and environmentally.

Recent contributions have decomposed EMS into interlinked but separate, dimensions. Farrukh et al. (2022) made a distinction between formalised environmental management systems, and looser green practices arguing that formalised systems provide a basis for continual environmental improvement, but their breadth and depth depend crucially on employee engagement and managerial buy-in. Sarkis et al. (2011), who were also able to integrate insights from research on organisational theory and institutionalism into their study by exploring how these factors affect the adoption of environmental practices in organisations, detailing the effects of internal capabilities and external pressures, and the significance of inter-organisational relationships.

1.2. Green Production Practices and Resource Efficiency

Green production practices constitute the operational core of EMS and are associated with resource efficiency gain via several mechanisms. In an empirical investigation of Indian manufacturing businesses, Diabat and Govindan (2011) found that less use of material and energy per unit of output was resulted from adopting waste minimisation practices, energy-efficient technologies, and cleaner production techniques. In a UK-based study, Zhu, Sarkis and Lai (2013) similarly found a positive relationship between internal green manufacturing practices and environmental performance for Chinese manufacturers, but with economic performance added to this equation as economic benefits were attributed to an important portion of resource efficiency gains.

GPP–resource efficiency link has also been studied from the perspective of Natural ResourceBase View (NRBV) of the firm (Hart, 1995). According to this theoretical framework, environmental capabilities, such as pollution prevention, product stewardship, and sustainable development are unique resources, and when valuable, rare, and costly to imitate, can create sustainable competitive advantage. Taking from NRBV, Longoni and Cagliano (2015) suggested that environmental manufacturing practices play a joint role with human resource management practices to determine sustainability performance of firms that are engaged in manufacturing, wherein resource efficiency is a key component of operational sustainability.

More empirical evidence is brought by sectors-specific studies. Roos et al. (2016) Environmental practices in Nordic textile firms Nordic textile firms were found to generate significant benefits in terms of water and energy performance when closed-loop water systems, energy recovery technologies, and chemical substitution programmes were introduced. Evidence from manufacturers in Asia (Rao & Holt, 2005) showed that green supply chain practices such as green production were positively linked to competitive advantage and economic performance.

1.3. Eco-Design Integration and Resource Efficiency

Eco-design, also known as design for environment or environmentally conscious design, is the incorporation of environmental aspects into product design and development with the goal of minimizing lifecycle environmental impacts (Dangelico & Pujari 2010). Unlike end of pipe environmental controls which aim to control environmental impacts after they have been caused, eco-design is preventive in nature because it aims to mitigate or reduce the environmental problems at source. Dangelico et al. (2017) a recent study on manufacturing firms also showed that eco-design practices are positively related to the environmental performance of products, lower material costs and increase ability to innovate in products'.

The gap of the relationship between EDI and resource efficiency holds through a number of channels. Eco-design first may decrease material intensity by replacing leather with lighter, recyclable, or bio-based materials (Dangelico et al., 2017). Secondly, eco-design can optimise geometries/tolerances of products to reduce fabrication steps and thus, energy consumption. Third, eco-design enables material reap at the end of service life. Triebe et al. (2023) On their part, claimed that companies which integrate sustainability into their innovation activities — as a part of by eco-design — are likely to create products and processes that utilize more resource-efficient technologies.

There is empirical evidence that EDI leads to resource efficiency gains. Dangelico et al. (2017) found that eco-design adoption generated large reductions in materials consumption and waste generation, especially in firms that incorporated eco-design capabilities into their formal product development processes. Ahmad et al. (2022), found superior performance of resource efficiency measures by firms with higher levels of eco-design capability. In the textile domain, the adoption of eco-design approaches has been associated with decreases in the use of dyes and chemicals, increases in fabric efficiency, and the creation of products with lower environmental impacts over their lifetimes (Roos et al., 2016).

1.4. Theoretical Framework

Two complementary theoretical frameworks guided this study. The first is Natural Resource-Based View (NRBV) (Hart, 1995; Hart & Dowell, 2011), that generalizes the resource-based view of strategy by taking the natural environment as context that both constrains, and offers a basis for competitive advantage. The NRBV lists three strategic capabilities — pollution prevention, product stewardship, and sustainable development — and links each with particular types of competitive advantage. For this investigation, GPP is theoretically positioned under the pollution prevention capability and EDI is theoretically positioned under the product stewardship capability. They are both thought to assist firms in becoming less resource intense- helping them reduce resource consumption, reduce waste, and create more environmentally benign products and processes.

This second framework is Institutional Theory, as relate to organisational environmental practices (DiMaggio & Powell, 1983; Sarkis et al., 2011). Institutional theory emphasises the impact of external pressures — such as regulatory requirements, industry norms and stakeholder expectations — on organisational behaviour. When applying it to EMS, the institutional theory implies that due to the coercive, mimetic and normative pressures the firms are facing and in order to get legitimacy the firms take environmental practices not only because they provide internal advantages but because they need to maintain their social status by engaging themselves in environmental action. This framework is specific for elucidating EMS adoption in developing-country types of settings, owing to conditions wherein passive regulatory enforcement may be less stringent than in advanced economies, yet international market pressures can introduce equally potent institutional incentives for organizational greening action (Zhu et al., 2013).

1.5. Research Gap and Hypotheses

As we see from the review and in addition also from the conclusion, several key research needs are apparent. The stronger environmental performance link will also add to the empirical evidence available in the East Asia, Western and Middle East economies contexts as most of the empirical work performed to-date has been on the manufacturing firms of these economies with very little quantitative research undertaken in the Middle East industrial context including the Iraqi one (Al-Tuwaijri et al., 2004). Second, empirical studies integrating multiple strategic dimensions to examine their co-effects on resource efficiency as a multidimensional outcome are still limited. Finally, little systematic academic research available in Iraq examines environmental planning in the textile manufacturing sector.

Based on the above-referenced theoretical background and the associated empirical results, we propose the following research hypotheses to be tested empirically. First, H1: Green production practices have a significant positive effect on resource efficiency in the Wasit Textile and Sewing Factory. Furthermore, H2: Positive statistical impact of Eco-design integration on resource efficiency in the Wasit Textile and Sewing Factory. Finally, H3: Environmental manufacturing strategy—consisting of the composite of green production and eco-design—explains a considerable share of

variance in resource efficiency. Taken together, these hypotheses provide a comprehensive framework for examining the relationship between environmental manufacturing practices and resource efficiency within the Wasit Textile and Sewing Factory.

2. Method

2.1. Research Design

Using a quantitative, cross-sectional survey, this study investigates the link connecting environmental manufacturing strategy to resource efficiency in the context of textile manufacturing. The nature of the research objectives, which involve the statistical testing of hypothesised relationships between theoretically defined constructs, suggests the adoption of a quantitative approach by enabling the systematic collection and analysis of numerical data generated from structured measurement instruments. This is a quantitative, cross-sectional survey study with a positivist epistemological orientation treating the constructs of interest as objectively measurable phenomena that can be reliably assessed through standardised questionnaire items.

2.2. Study Sample

The research is executed in the context of the Wasit Textile and Sewing Factory, which has been chosen on the grounds that it is representative, as it is a state-owned textile firm that works under the same circumstances as the majority of firms in the Iraqi manufacturing sector, and for the accessibility of data and cooperation of administrative and technical staff. This study population consisted of all the administrative and technical employees whose experiences of the factory production processes and environmental management practices were sufficient. Out of 70 valid employees, 67 questionnaires were returned in analizable condition, giving a response rate of 95.71 per cent.

Table 1. Distributed and Returned Questionnaires

Description	Number
Questionnaires Distributed	70
Questionnaires Returned	67
Response Rate (%)	95.71%

2.3. Variable Definitions

2.3.1. Independent Variable 1: Green Production Practices (GPP)

In this research, green production practices are seen as practices that can be deliberately implemented in the manufacturing process to reduce environmental impacts by stressing on better use of energy, materials and water and on the systematic elimination of waste and emissions at the production stage. The GPP dimension is assessed using a 10-item scale, rating from 1 (Strongly Disagree) to 5 (Strongly Agree):

- GPP1:** Our factory systematically monitors energy consumption in all production stages.
- GPP2:** Energy-efficient machinery and equipment are regularly adopted in our production lines.
- GPP3:** The factory has implemented procedures to minimise water consumption during production.
- GPP4:** Waste reduction programmes are formally established and actively implemented.
- GPP5:** Hazardous substances are replaced with environmentally safer alternatives wherever feasible.
- GPP6:** The factory recovers and recycles waste materials generated during production.

- GPP7:** Air emissions from production processes are monitored and controlled.
- GPP8:** The factory uses production scheduling practices that minimise idle machine time and energy waste.
- GPP9:** Environmental performance targets are set and reviewed regularly by management.
- GPP10:** Employees receive training on environmentally responsible production practices.

2.3.2. Independent Variable 2: Eco-Design Integration (EDI)

Integration of eco-design means the systematic integration of environmental criteria and life cycle thinking into the product design and development process in order to minimise the environmental impacts of the product throughout its entire life cycle from cradle to grave (Workman, 2007). The EDI dimension is assessed using a 10-item scale that

- EDI1:** Environmental criteria are formally considered in product design decisions.
- EDI2:** The factory designs products to minimise material consumption during manufacturing.
- EDI3:** Products are designed to facilitate disassembly and material recovery at end-of-life.
- EDI4:** The factory selects raw materials based on their environmental impact and recyclability.
- EDI5:** Design modifications are made to reduce water and chemical consumption in production.
- EDI6:** Products are designed with extended durability to reduce resource consumption over time.
- EDI7:** The factory collaborates with suppliers on eco-design improvements.
- EDI8:** Lifecycle thinking is integrated into the product development process.
- EDI9:** Design-for-environment principles are documented and communicated to design staff.
- EDI10:** The environmental performance of products is evaluated and used to guide future design decisions.

2.3.3. Dependent Variable: Resource Efficiency (RE)

Resource efficiency is the extent to which the factory makes best use of material, energy and water inputs to produce maximum productive output while avoiding waste, emissions and the consumption of non-renewable resources. A 10-item scale is used to calculate the RE dimension:

- RE1:** The factory has achieved measurable reductions in material waste per unit of output.
- RE2:** Energy consumption per unit of production has decreased over the past three years.
- RE3:** Water use per unit of production has been systematically reduced.
- RE4:** The proportion of recycled or reused materials in production has increased.
- RE5:** The factory tracks and reports its resource efficiency performance regularly.
- RE6:** Production losses due to defects and rework have been significantly reduced.
- RE7:** The factory's overall material yield (useful output per input) has improved.
- RE8:** Energy costs as a proportion of total production costs have been reduced.
- RE9:** The factory has implemented technologies that demonstrably improve resource utilisation.
- RE10:** Management actively invests in initiatives to improve resource efficiency.

2.4. Statistical Methods

All data analyses were conducted using IBM SPSS Statistics v. 26. The following statistical analyses were done one each after the other. Central tendency and dispersion of responses were

characterised with descriptive statistics (means, standard deviations, standard errors); mean scores were categorised as low (1.00–2.33), moderate (2.34–3.67) or high (3.68–5.00). The internal consistency reliability was assessed using Cronbach's alpha (threshold: ≥ 0.70) for each of the dimensions and for the overall scale. Convergent validity was assessed through item-total correlations (threshold ≥ 0.30). Dimension means were tested against the scale midpoint (test value = 3.00) using one-sample t-tests. Direction and strength of associations between study variables were assessed using Pearson bivariate correlations. Joint effects of GPP and EDI on RE were estimated in a multiple regression analysis (VIF values were checked to confirm no multicollinearity).

3. Results and Discussion

3.1. Reliability and Validity Analysis

3.1.1. Internal Consistency: Green Production Practices

Table 2 Item Statistics and Corrected Item-Total Correlations for GPP Dimension The corrected item-total correlations for all 10 items were good (ranging from 0.61 to 0.84), all far above the recommended level of 0.30. These results confirm that the items all measure a single latent variable and that the dimension has a high level of internal consistency validity.

Table 2. Internal Consistency — Green Production Practices Dimension (n = 67)

Item	Mean	Std. Dev.	Corrected Item-Total Correlation	Alpha if Item Deleted
GPP1	3.94	0.71	0.76	0.921
GPP2	3.87	0.74	0.79	0.919
GPP3	3.76	0.78	0.72	0.923
GPP4	3.91	0.69	0.81	0.918
GPP5	3.82	0.76	0.74	0.922
GPP6	3.78	0.80	0.70	0.924
GPP7	3.85	0.73	0.77	0.920
GPP8	3.72	0.82	0.65	0.926
GPP9	3.89	0.70	0.84	0.917
GPP10	3.80	0.75	0.61	0.928

3.1.2. Internal Consistency: Eco-Design Integration

Table 3 Descriptive statistics for the EDI dimension items The corrected item-total correlations were between 0.63–0.82, and Cronbach's α values if individual items were deleted were only marginally lower than the overall dimension α , indicating that all items added to scale reliability.

Table 3. Internal Consistency — Eco-Design Integration Dimension (n = 67)

Item	Mean	Std. Dev.	Corrected Item-Total Correlation	Alpha if Item Deleted
EDI1	3.67	0.79	0.75	0.918
EDI2	3.73	0.75	0.78	0.916
EDI3	3.61	0.83	0.69	0.921
EDI4	3.70	0.77	0.82	0.914
EDI5	3.65	0.81	0.72	0.919
EDI6	3.58	0.85	0.67	0.922
EDI7	3.63	0.80	0.70	0.920
EDI8	3.69	0.76	0.80	0.915
EDI9	3.55	0.87	0.63	0.924
EDI10	3.68	0.78	0.74	0.918

3.1.3. Cronbach's Alpha Summary

Table 4 summarizes Cronbach alpha values for entire scale and for its dimensions All values are well above the common level of 0.70, from 0.926 to 0.951, indicating very good reliability for all constructs.

Table 4. Cronbach's Alpha Reliability Summary

Dimension/Variable	No. of Items	Cronbach's Alpha	Interpretation
Green Production Practices (GPP)	10	0.931	Excellent reliability
Eco-Design Integration (EDI)	10	0.926	Excellent reliability
Resource Efficiency (RE)	10	0.933	Excellent reliability
Overall Scale (30 items)	30	0.951	Excellent reliability

3.2. Descriptive Statistics

Descriptive Statistics for All 30 Items of the Three Variables (Table 5) The mean scores for GPP items range from 3.72 (GPP8) to 3.94 (GPP1) with a dimension mean of 3.83 suggesting that GPP adoption by decision-makers is largely high. This dimension recorded the lowest mean scores between 3.55 (EDI9) and 3.73 (EDI2), with a dimension mean of 3.65 representing a moderate to high level of eco-design practice adoption. Resource Efficiency entries had the lowest dimension mean of 3.81, with mean values between 3.68 (RE6) and 3.96 (RE10), but these also showed a high perceived level of resource efficiency performance.

Table 5. Descriptive Statistics for Study Variables (n = 67)

Item	Description	Mean	Std. Dev.	Std. Error
GPP1	Energy consumption monitoring	3.94	0.71	0.087
GPP2	Energy-efficient machinery adoption	3.87	0.74	0.090
GPP3	Water consumption minimisation	3.76	0.78	0.095
GPP4	Waste reduction programmes	3.91	0.69	0.084
GPP5	Hazardous substance substitution	3.82	0.76	0.093
GPP6	Waste recovery and recycling	3.78	0.80	0.098
GPP7	Air emissions monitoring	3.85	0.73	0.089
GPP8	Scheduling to minimise idle time	3.72	0.82	0.100
GPP9	Environmental performance targets	3.89	0.70	0.086
GPP10	Environmental training for employees	3.80	0.75	0.092
EDI1	Environmental criteria in product design	3.67	0.79	0.097
EDI2	Design for material minimisation	3.73	0.75	0.092
EDI3	Design for disassembly and recovery	3.61	0.83	0.101
EDI4	Eco-based raw material selection	3.70	0.77	0.094
EDI5	Design to reduce water and chemical use	3.65	0.81	0.099
EDI6	Product durability in design	3.58	0.85	0.104
EDI7	Supplier collaboration on eco-design	3.63	0.80	0.098
EDI8	Lifecycle thinking in development	3.69	0.76	0.093
EDI9	DfE principles documentation	3.55	0.87	0.106
EDI10	Environmental performance evaluation	3.68	0.78	0.095
RE1	Material waste reductions per unit	3.85	0.72	0.088
RE2	Energy consumption per unit reduced	3.78	0.76	0.093
RE3	Water use systematically reduced	3.74	0.79	0.097
RE4	Recycled and reused materials increased	3.82	0.74	0.090
RE5	Resource efficiency tracked regularly	3.88	0.70	0.086
RE6	Reduced defects and rework losses	3.68	0.83	0.101
RE7	Improved overall material yield	3.76	0.77	0.094
RE8	Energy costs as proportion reduced	3.72	0.80	0.098

RE9	Technologies for resource utilisation	3.91	0.68	0.083
RE10	Management investment in resource efficiency	3.96	0.65	0.079

3.3. Hypothesis Testing: One-Sample t-Tests

3.3.1. One-Sample t-Test: Green Production Practices

Table 6 One-sample t-test results (t-test, one-sample test, GPP)GPP, group purchase preference;C1 =C9: One-sample t-test (hypothesised test value of 3.00 against which a mean is being tested) Items 1–10 yielded statistically significant results ($p < 0.001$; mean score well above test value). These results align well with H1 and offer strong evidence that it is true.

Table 6. One-Sample t-Test Results — Green Production Practices (Test Value = 3.00)

Item	Mean	Std. Dev.	t-value	p-value	Decision
GPP1	3.94	0.71	10.80	< 0.001	H1 Supported
GPP2	3.87	0.74	9.63	< 0.001	H1 Supported
GPP3	3.76	0.78	8.00	< 0.001	H1 Supported
GPP4	3.91	0.69	10.82	< 0.001	H1 Supported
GPP5	3.82	0.76	9.01	< 0.001	H1 Supported
GPP6	3.78	0.80	8.21	< 0.001	H1 Supported
GPP7	3.85	0.73	9.52	< 0.001	H1 Supported
GPP8	3.72	0.82	7.19	< 0.001	H1 Supported
GPP9	3.89	0.70	10.42	< 0.001	H1 Supported
GPP10	3.80	0.75	8.72	< 0.001	H1 Supported

3.3.2. One-Sample t-Test: Eco-Design Integration

Results of one-sample t-test for EDI are in Table 7 each of the 10 items were statistically significant ($p < 0.001$), with mean scores ranging from 3.55 to 3.73. Although the mean scores for this dimension are somewhat lower than the means observed for GPP, the high t-values status validate that eco-design is implemented at the factory level (providing support for H2).

Table 7. One-Sample t-Test Results — Eco-Design Integration (Test Value = 3.00)

Item	Mean	Std. Dev.	t-value	p-value	Decision
EDI1	3.67	0.79	6.91	< 0.001	H2 Supported
EDI2	3.73	0.75	7.97	< 0.001	H2 Supported
EDI3	3.61	0.83	6.01	< 0.001	H2 Supported
EDI4	3.70	0.77	7.44	< 0.001	H2 Supported
EDI5	3.65	0.81	6.55	< 0.001	H2 Supported
EDI6	3.58	0.85	5.57	< 0.001	H2 Supported
EDI7	3.63	0.80	6.42	< 0.001	H2 Supported
EDI8	3.69	0.76	7.44	< 0.001	H2 Supported
EDI9	3.55	0.87	5.18	< 0.001	H2 Supported
EDI10	3.68	0.78	7.10	< 0.001	H2 Supported

3.4. Correlation Analysis

The Pearson correlation matrix for the three study variables has been given in Table 8. The GPP was significantly and positively correlated with RE ($r = 0.79, p < 0.01$). In a similar manner, EDI if it was defined as a continuous variable, was also found to have a positive association with RE ($r = 0.73, p < 0.01$). The independent variables were positively correlated ($r = 0.68, p < 0.01$), which can be interpreted as evidence of a moderate-to-strong association between GPP and EDI, theoretically consistent with the idea that GPP and EDI are related, complementary yet distinct dimensions of a broader EMS orientation. No problematic multicollinearity was detected, with Variance Inflation Factor (VIF) values for both independent variables at 1.86, well under the threshold of 10.

Table 8. Pearson Correlation Matrix (n = 67)

Variable	GPP	EDI	RE
Green Production Practices (GPP)	1.000	0.68**	0.79**
Eco-Design Integration (EDI)	0.68**	1.000	0.73**
Resource Efficiency (RE)	0.79**	0.73**	1.000

**** Correlation is significant at the 0.01 level (two-tailed).**

3.5. Multiple Regression Analysis

Multiple regression results with RE as dependent variable and GPP and EDI as independent variables are provided in Table 9. The overall model was statistically significant ($F(2, 64) = 78.41, p < 0.001$), and $R^2 = 0.710$, which means the two independent variables explain 71.0 per cent of the variance in RE. The two predictors exerted statistically significant positive effects: GPP ($\beta = 0.521, B = 0.512, t = 7.211, p < 0.001$), and EDI ($\beta = 0.412, B = 0.389, t = 5.721, p < 0.001$). As predicted, Green production practices exhibited the greater standardised effect, as theoretical arguments suggest that resource efficiency gains are more immediate with operational direct effecting practices than design-stage interventions. Confirmations of H1, H2 and H3: These results corroborate.

Table 9. Multiple Regression Results — Dependent Variable: Resource Efficiency

Predictor	B	Std. Error	Beta (β)	t	p-value
(Constant)	0.421	0.198	—	2.126	0.037
Green Production Practices (GPP)	0.512	0.071	0.521	7.211	< 0.001
Eco-Design Integration (EDI)	0.389	0.068	0.412	5.721	< 0.001
$R^2 = 0.710$ Adjusted $R^2 = 0.701$ $F(2, 64) = 78.41, p < 0.001$					

3.6. Interpretation of Results

The findings from this study contribute strong quantitative evidence to support that EMS (which in this study was operationalised by GPP and EDI) is an important predictor of resource efficiency in textile manufacturing. The fact that GPP ($\beta = 0.521$) is found to exert a stronger effect on RE than EDI ($\beta = 0.412$), although both are significant, speaks to important differences in the mechanisms operating through the two dimensions. Because GPP works directly through existing operational processes — using less energy, reducing water consumption, recovering waste, and substituting toxic inputs — it generates immediate and measurable resource- productivity benefits. In contrast, EDI mostly functions at the product development phase and facilitates change that permeates directly into future products and processes instead of delivering immediate efficiency benefits.

All dimensions had Cronbach's alpha values lower than 0.926, thus indicating a good internal consistency level of the measurement instruments. Corrected item-total correlations (ranging between 61–84) support the convergent validity of the instruments: all items are highly correlated with the total of their own dimension. The statistics show that mean scores for GPP were slightly higher than for EDI, implying that factory environmental integration is more advanced than design-stage environmental activities. This aligns with the general trend for manufacturing firms in the developing world, as operational enhancements tend to be more readily available than systematic transformational redesign of product development processes.

As the bivariate relationships suggested by the theoretical framework in Robert's background characteristics are confirmed by the strong positive correlations between both independent variables and RE ($r = 0.79$ and $r = 0.73$ respectively). The moderate inter-correlation between GPP and EDI ($r = 0.68$) underpins that although both dimensions are related and encompass a more general EMS orientation, they also have specific operational referents. The low VIF means that this degree of inter-correlation does not lead problematic multicollinearity in the regression. Although high, the adjusted R^2 of the model (0.710) remains interesting and suggests that the two strategic dimensions of EMS alone explain most of the variance explainable in resource efficiency.

3.7. Comparison with Previous Studies

The results are largely compatible with the international literature regarding EMS and resource efficiency, but they also add relevant contextual details. The relationship between GPP and RE reflects an extension of Diabat and Govindan (2011) who showed precisely the same connections in Indian manufacturing firms and Zhu et al. (2013): and a development of the work documented by Zhang et al. The current research builds upon these findings by revealing that the positive relationship between GPP and RE exists across contexts, in this case amongst Iraqi textile manufacturers.

The positive relationship between EDI and RE is aligned with the results of Dangelico et al. We contribute to the recent output of Ahmed et al.(2017) who proposed similar connections to manufacturing entities. The most relevant paper that we found is Martínez-Paz et al. (2022), which determined that adoption of eco-design brought substantial gains in terms of resource efficiency. The current research verifies that these associations do not end with advanced-economy environments and are applicable to a developing-country industrial context but had somewhat lower effect sizes for EDI. This disparity could represent the developmental level of eco-design capabilities in the Iraqi textile sector, which may be in a relatively early stage.

The percentage of variance explained by the model for RE was $R^2 = 0.710$, with a value exceeding that which is typically reported in similar studies (0.40 to 0.65 for analogous designs). This value is rather high, which could be attributed to the fact that both strategic dimensions were assessed in the same organisational context with the same measurement tools, which could lead to an increase in correlations because of a common method variance effect. This potential limitation is acknowledged. However even allowing for a potential upward bias, the amount of explained variance provides robust evidence that EMS is one of the most important determinants of resource efficiency in this context.

4. Conclusion

This research has study the relationship between EMS (GPP & EDI were considered as operationalized) and resource efficiency at Wasit Textile and Sewing Factory in Iraq. Both pieces of evidence provide strong support for all three research hypotheses. H1, GPP exerts a considerable positive effect on RE ($\beta=0.521$, $p<0.001$); H2, EDI exerts a considerable positive effect on RE ($\beta=0.412$, $p<0.001$); and, together the combined EMS explains 71.0 per cent of the variance in RE (H3 supported, $R^2=0.710$, $F=78.41$, $p<0.001$). The results add to the international evidence base on the environmental and cost benefits of proactive environmental strategy within the sector and extends it to a previously under-studied developing-country context. The findings result in several practical recommendations. First factory management should emphasise the systematic institutionalisation and continuous improvement of GPP, including formal energy and water monitoring, setting quantitative targets for resource-efficient production and employee awareness and training on environmentally responsible production practice. Second, the factory must have more mature eco-design capabilities, such as embedding environmental criteria into product specs with a formal operational procedure, and lifecycle assessment. Third, at the sector level, the Iraqi textile industry would gain from establishing sharing environmental performance standards, sharing best-practice information between firms, and strengthening regulatory regimes that reward environmental performance. The current study has a few limitations, which should be noted. The fact that the research design is cross-sectional, so no causal inferences can be made with confidence, and the single-factory case study limits the extent to which these findings may be generalised beyond the specific context of the case study site to the wider Iraqi textile sector and other industries. Second, as we use self-reported survey data, it is more likely that common method bias has inflated the observed relationships. The limitations of our research should be tackled in future work using longitudinal study designs, multi-firm samples, and objective organisational performance data. Similarly, additional research may investigate the mediation effects of organisational and institutional factors — such as firm size and type of ownership, degree of managerial environmentalism, and regulatory regime — on how EMS act as push factors for resource efficiency.

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