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Statistical Analysis of Green Third-Party Logistics (3PL) and Supply Chain Performance in Saudi E-Commerce Last-Mile Systems

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Abstract: This study investigates how the rapid growth of e-commerce in Saudi Arabia is intensifying pressure on third-party logistics (3PL) service efficiency while simultaneously increasing the environmental burden of logistics operations.. Consistent with the Saudi Vision 2030, the present research investigates the implementation of green logistics activities by 3PL providers that serve Saudi e-commerce and appraises its effect on the sustainability efficiency, cost-efficiency, and the performance of the supply chain in general. The study is based on the Sustainable Supply Chain Theory (SSCT) and the Technology Acceptance Model (TAM), with the mixed-method approach. A structured questionnaire was used to gather quantitative data which was collected on 200 logistics professionals and qualitative data were gathered through a 12 semi structured interviews with industry professionals. Statistical analyses were done upon SPSS and AMOS with descriptive analysis, correlation, regression and structural equation modelling (SEM). The results indicate that adoption of green logistics has a substantial and positive correlation with sustainability results, cost-efficiency. Additionally, the adoption of digital technologies, especially artificial intelligence (AI) and the Internet of Things (IoT) were even discovered to have a critical enabling impact on operational efficiency and environmental performance. Although more people are becoming conscious and some of the green practices have been implemented in part, the outcome has been that there are still challenges that might arise with the high cost of initial investment, inadequate infrastructure, and lack of training. The research finds that the introduction of green logistics using digital transformation and specific governmental policies can be taken as a strategic direction to the achievement of sustainable and competitive 3PL activities in Saudi Arabia. The results provide policy implication and practical effects to policy makers and logistic practitioners who aim to speed up the process of switching to sustainable logistics.

Keywords: Green Logistics, Sustainable Supply Chain, Third-Party Logistics (3PL), E-commerce, Last-Mile.

1 Introduction

1.1 Study Background

The fast-growing online commerce culture in Saudi Arabia has introduced a paradigm shift in the system logistics, which spawned increased expectations of fast, flexible, and efficient delivery services [2].

Due to the increased consumer demands and heightened environmental awareness, service providers in the 3PL industry are forced to improve their sustainability efforts to lower the carbon emission levels and yield high-quality performance levels [8]. In this rapidly changing business environment, adopting a combination of green logistics would no longer be a supplementary measure but rather an integral part of attaining sustainable development according to Saudi Vision 2030. The Kingdom of Saudi Arabia's logistics sector is on the cusp of a transformation due to technological development and the Kingdom's envisioned diversification plans. This will ensure that sustainability becomes part of their business models.

In conventional logistics models, minimizing costs and maximizing processing speed had been convincing objectives without considering the impact of those objectives on the environment. However, today, as highlighted in this paper, there has to be a harmonious mix of costs and the environment to unlock the benefits of sustainable competitiveness advantages. The concept of green logistics assists them in executing best practices through environmentally friendly transport services, environmentally friendly warehousing services, and environmentally friendly packaging materials [5].

Despite the rising trend of the implementation of green logistics practices in the global community, the level of implementation of green logistics practices in the 3PL firms within the Kingdom of Saudi Arabia has been low due to less

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institutional effort required in the changeover process [1].

1.2 Research Problem

Although there has been a rising trend towards the adoption of green logistics practices globally, 3PL providers in Saudi Arabia had been confronted with challenges that trigger impediments to the adoption of sustainability practices. The impediments include the absence of enabling regulations, a lack of access to the green technology needed, the costs involved in the implementation of sustainability practices, and the level of awareness of the benefits of sustainability practices.

The problems listed above can be exacerbated by the requirement of delivering the packages quicker in order to match the growing number of e-commerce shipments, making it even more challenging to harmonize environmentally sustainable practices, especially in the last-mile delivery. The last mile of delivery is very resource-intensive and contributes significantly to emissions.

Concerning research directions, it can be seen from current literature that there is certainly a research gap in applied research aimed at identifying ways in which new technologies such as AI and IoT can be utilized to facilitate sustainability activities pertaining to the 3PL industry in the Saudi environment. In this context, it can be assumed that this research study aims to provide solutions to these knowledge gaps by examining how increased technological innovation is related to sustainability in logistics.

1.3 Research Objectives

The main research objective of this study was to determine the effects of implementing green logistics practices towards cost efficiency and sustainability in terms of 3PL service providers in the e-commerce industry in Saudi Arabia. In pursuing this objective, it also aimed to determine what main challenges prevent the successful application of green logistics practices,' and to some extent investigate the role of digital advancements such as AI and IoT towards upgrading these applications to better fit their context. The rationale behind pursuing this research objective encompasses enriching academic knowledge towards sustainable logistics applications in terms of new business development models and utilizing these research findings to aid 3PL service suppliers to make way for the development of a green logistics ecosystem environment in Saudi Arabia.

1.4 Research Questions

To aid in the research process and allow it to be precisely defined and limited in scope, this research aims to answer several research questions. These will be addressed below.

1. What is the impact of implementing green logistics processes on cost efficiencies and sustainability in business operations of 3PL organizations in the Kingdom of Saudi Arabia?
2. What are the main challenges and impediments hindering the adoption of 'green logistics' approaches in the e-commerce logistics environment?
3. How many modern digital technologies such as AI and IoT be applied to improve the efficiency and sustainability of 3PL in Saudi Arabia?

2 Literature Review

In this research study, there is an integration of theoretical and application approaches to examine dynamics associated with green logistics in the context of 3PL, paying special attention to the environment associated with e-commerce in Saudi Arabia. To conduct this examination, the research study uses two theoretical approaches simultaneously. The first theoretical perspective is the concept of SSCT, while the other would-be TAM.

SSCT theory takes note of the importance of integrating all the factors mentioned above, including the environment and economic needs [5]. In this case, sustainability becomes a strategic necessity over and above organizational support and contributes to the raised levels of corporate resilience and transparency demonstrated along the supply chain. This trend also ties in with the findings of research study [3], which showed that the mentioned sustainability projects of eco-warehousing and fuel-driven transport had the effect of influencing not only regulatory but also efficiency levels.

This idea is also supported by the literature since some of the studies have determined that the forward-thinking plans in the logistics of sustainability present visible returns, both fiscal and environmental. In this regard, a study by [11] has demonstrated that digital transformation is a key facilitator of innovation and incorporation of sustainability principles in organizational practices. In other words, according to other literature explored in this research [9], organizations were able to lower their costs and improve their environmental performance because of sustainable practices adoption. TAM helps to comprehend organizations' behavior towards new technological solutions such as AI solutions for route optimization in delivery vehicles, IoT solutions for real-time monitoring of fleet vehicles, and electric vehicles adoption in logistics processes.

The basic determinants identified for organizations to adopt technological solutions include perceived usefulness and perceived ease of use.

[2] emphasizes the importance of digital readiness and financial viability in promoting the adoption of new technology. Incentives and the provision of comprehensive infrastructure are the primary factors that mold the adoption of new services and tools in organizations, according to [8].

The amalgamation of the above perspectives implies that although there might be an adaptive benefit of raising the level of technological adoption in general organizations to optimize efficiency, it might be affected by related structures and processes to create a favorable digital environment.

The convergent approach produced through the SSCT, and the TAM presents a wider perspective regarding the efficient transition of the 3PL service providers towards sustainability. Although SSCT draws the attention of the service providers toward sustainability as a strategic and moral determinant of their operational practices, the TAM model illustrates the way the technological advancements can be applied to their practices. The application of the technological advancements toward sustainability practices has been observed in various research studies such as [12, 21], who introduced the control of emissions and the enhancement of delivery efficiency at a higher AI & IoT cost. They have also been supported by research conducted by [6], who have shown how sustainability initiatives in smart logistics in developing countries are thwarted by certain regulatory and structural issues. Second, by research conducted by another different author [15], they comprehend how sustainability needs to address profit-making capabilities despite risks associated with sustainability. They have also been supported by authors like [19], who have mentioned how strategic flexibility helps small scale enterprises make their way towards sustainability.

Nevertheless, major challenges remain to fully embrace green logistics. Many researchers have identified costs of implementation, digital infrastructure capabilities, and resistance to change as major issues to be addressed by organizations in such realms [14]. Other research conducted from the perspective of policy has shown other aspects. In other words, research from this perspective has clarified that government incentives act as critical imperatives in such realms; however, such imperatives have complex requirements to be complied with by small organizations [3].

In general, it can be seen from literature that adoption of green logistics in 3PL service provider organizations is facilitated by two major forces, the strategic intent grounded in SSCT, and technological enablement grounded in TAM. The data suggests that it is impacted by cost and other organizational readiness issues. The knowledge developments mentioned above provide a strong knowledge foundation to discuss in this research study how 3PL organizations in the Saudi e-commerce market deal with challenges and opportunities of sustainability in digital transformation & corporate policy alignment.

Moving forward from this theoretical background, the subsequent section defines and measures the variables of particular importance to this research study, such as green logistics adoption, sustainability efficiency, cost efficiency, and adoption of technology like AI and IoT. Following this section would be hypothesis development where theoretical and practical knowledge would be combined to form research hypotheses.

2.1 Operationalization of Variables

The identification of the variables involved has been carried out carefully, and the measurements of the mentioned variables are also taken with great care from the literature. The measurement of the involved variables has been adjusted according to the unique Saudi environment of e-commerce and logistics practices, slightly different from the Western settings from which the scales had been drawn. The difference mainly occurs due to the difference in the level of technological penetration.

- Green Logistics Adoption: This green variable captures the extent to which environmentally oriented practices are embraced within the context of the 3PL's daily work routines. This can be at the operational level of warehousing, transport, or even the planning stages. Some of the practices under this green logistics will be environment-warehousing practices, the adoption of environmentally oriented fleets, and waste management initiatives. This variable was examined using the concept of the construct through the adaptation of the study items from [12] and [14]. In fact, this construction had to be slightly clarified when the data work was being carried out because of the difference in its interpretation by the respondents at various levels. The concept of green adoption had to be explained.
- Sustainability Efficiency: The concept of sustainability efficiency refers to the capacity of the company to utilize its respective resources efficiently to achieve the aim of sustainability while ensuring minimal destruction of the environment. The variable was operated through a series of indicators that entailed the reduction of carbon emissions and the general improvement of the performance of the environment as suggested by [5] and [4]. The respondents were asked to provide information regarding the success attained in the fight against environmental destruction through sustainability efficiency using a five-point scale. It is interesting to notice that several small companies showed relatively little concern for environmental issues, which can be expected partly from this industry.

- AI adoption refers to the level at which logistics firms take up AI technologies in their diverse activities, including predictive analytics, route planning automation, and demand forecasting. Items measuring this variable were adapted from works [11], through Likert-type items that assessed perceived utility, level of application, and organizational readiness. Of note is the fact that several companies have been quite conservative toward AI; this is possibly for several reasons, including costs and a lack of technical know-how inside their organizations.
- IoT Adoption: In this context, the level of IoT adoption by the 3PL service providers represents the intensity of use of technology related to real-time fleet tracking, smart sensors, warehouse automation, and so on. Based on [8] and [12], the metric of this variable was developed considering the level of technological integration and the actual benefits achieved in operation. Some large companies are also showing increased interest in such technologies, especially in the field of smart warehouse management and parcel tracking.

These operational procedures therefore ensured that all the variables were conceptually clear, field-measurable, and consistent with the previous literature. Such a basis is good ground on which to test hypotheses relating to the adoption of green practices, the use of modern digital technologies, and levels of efficiency and sustainability among logistics service providers in the Kingdom.

2.2 Research Gap

Regardless of the ever-increasing literature about green logistics and sustainable supply chains, there are significant gaps that remain. First of all, the available literature is disproportionately preoccupied with the study of manufacturing or governmental logistics, thus limiting the scope of empirical research to 3PL involved in the fast-growing e-commerce sector. Secondly, the studies of the green logistics adoption in Saudi Arabia are more inclined to consider sustainability and digital transformation as independent phenomena without considering the interactive and synergistic effects of both concepts on the logistics performance. Furthermore, there is a gap of mixed-method empirical studies that combine quantitative statistical analysis with qualitative information to determine the impacts of green logistics practices, enhanced with AI and IoT on sustainability and cost efficiencies in the Saudi 3PL environment. Thus, the study strives to provide a strict empirical analysis of green logistics implementation by Saudi 3PL companies, at the same time assessing the facilitative role of digital technologies in line with the goals outlined by Saudi Vision 2030.

2.3 Hypothesis Development

Based on the SSCT and TAM, this study has developed three main hypotheses that guided the empirical analysis. These hypotheses are centered on the relationship between the adoption of green logistics practices and the levels of operational efficiency, as well as organizational performance, in 3PL companies operating in the Saudi e-commerce sector.

- **H1: Green logistics adoption positively influences sustainability efficiency.**

SSCT theory also suggests that the incorporation of environmental practices in logistics operations contributes to improved environmental performance and long-term organizational resilience [5]. Recent Saudi studies are also supportive of the idea that there are a positive effect of eco-warehousing systems and the use of energy-efficient transportation on sustainability outcomes [11]. Hence, a higher level of green logistics adoption can be expected to upgrade sustainability efficiency.

- **H2: Green logistics adoption positively influences cost efficiency.**

In addition to the benefits of the environment, the adoption of green will also provide enormous cost savings in terms of reduced energy usage, waste management, and improved workflows. Previous research has already shown that digital transformation promotes sustainable practices that optimize costs efficiency, particularly in the SMEs sector in e-commerce [3], [15]. Hence, the adoption of green logistics practices will promote cost efficiency.

- **H3: Sustainability and cost efficiency positively influence organizational performance.**

On the one hand, the efficiency of costs can be directly linked to financial performance. However, the efficiency of sustainability generates indirect benefits regarding improved regulatory performance and image. In fact, there has been evidence that a company possessing the ability to efficiently address the challenges of the environment and economy has the capability of highlighting its outstanding performance regarding quality-of-service delivery and market share. This study will therefore hypothesize that efficiency levels lead to improved performance of the organization.

3 Methodology

The research design adopted in this study is that of a mixed-method research design aimed at exploring the adoption of the practice of green logistics among 3PLs that are involved in the Saudi Arabian e-commerce industry. Through the combination of quantitative and qualitative approach, it is easier to gain a holistic view of the research problem by integrating the statistical

analysis with the explanations of the case under which it is possible to strengthen the reliability and validity of the findings through the methodological triangulation. The quantitative phase quantifies the relationships between the green logistics adoption, the sustainability efficiency, the cost efficiency, and digital technologies implementation. Conversely, the qualitative phase will give more interpretive information on organizational barriers and situational factors that influence sustainability efforts in the logistics sector of Saudi Arabia.

3.1 Research Design

The research design of the study was convergent mixed methods research design, which integrated cross-sectional quantitative survey with semi-structured qualitative interviews. In the quantitative arm, a structured questionnaire was used to get numerical data that can be statistically analyzed to help test the hypothesized relationships between the key variables of interest in an empirical manner. At the same time, the qualitative part supplemented the study by stimulating the views of practitioners regarding the implementation of sustainability, the limitations of the regulations and technological preparedness of the 3PL companies. The combination design is especially well-suited to the study of the complex and dynamic character of the sustainable logistics practices, in that it allows the simultaneous use of stringent quantitative evaluation and subtle contextual research. The methodology is particularly applicable to the situation in Saudi Arabia, where the sustainability efforts in the logistics industry are predetermined by the changing regulatory environment, market conditions, and technological transformation.

3.2 Study Population and Sampling

The research examined two different sets of participants that were important in the adoption of green logistics in the Kingdom of Saudi Arabia. The first group was the logistics and operations managers who work at a 3PL company and participate in the e-commerce business. The participants were chosen since they have a direct role in operational decision-making and implementation of sustainability programs in their companies. The second group has included sustainability and supply-chain professionals that were interviewed in semi-structured sessions, thus, giving their professional interpretation of industry-wide issues and new trends in the development of green-logistics. Moreover, purposive sampling strategy was utilized in order to make sure that participants who have relevant expertise in the field of green-logistics practices are included. During the quantitative stage, 200 logistics managers, who work in big 3PL companies within Saudi Arabia, were surveyed. During the qualitative stage, 12 industry experts were interviewed, which was deemed adequate to arrive at both theoretical and thematic saturation.

3.3 Data Collection Methods

The quantitative data was collected through an electronic questionnaire that was structured as a questionnaire with thirty-five close-ended questions. The tool was designed to measure five major constructs that include Green Logistics Adoption, Sustainability Efficiency, Cost Efficiency, AI Adoption, and IoT Adoption. A Likert-type scale has been used with each of the items, which were based on tested empirical materials and have been further refined to meet specific features of the Saudi Arabian logistics industry. Semi-structured interviews with the specialists in the field of sustainability and supply chain management were used to collect the qualitative data. The salient themes discussed in the interview protocol related to the implementation of green logistics, the level of technology preparedness, the role of regulatory system, and the main barriers to sustainable change in the 3PL sector.

3.4 Data Analysis Methods

Quantitative data analysis was done through SPSS and AMOS software suites. Numerical data were created to provide a summary on the demographics and organizational features of respondents. The proposed hypotheses were tested with the help of inferential methods, including correlation, regression, analysis of variance (ANOVA) and SEM, which were used to determine the interrelations between the study variables. Thematic analysis framework was used to analyze qualitative data. Transcripts of interviews were coded and clustered based on salient themes which were subsequently financial constraints, regulatory frameworks, technological enablers and readiness of organizations. The following combination of quantitative and qualitative knowledge allowed to interpret more thoroughly and deeply the effect of the green logistics practices on the performance and sustainability results of the 3PL companies that exist in Saudi Arabia.

4 Results

The research will also undertake an examination of the results emanating from the quantitative methodological approach used among the 200 respondents who were surveyed. This will be combined with the results emerging from the qualitative form of research used among the group of experts identified from the logistics sector. The quantitative research involved the adoption of numerous methods of analyzing the results emerging from the descriptive hypothesis approach to arrive at the findings about the role of green logistics in the application of AI technological solutions stemming from the sustainability of

the 3PL sector within the Saudi e-commerce market.

On the other hand, the information collected from the various research processes that took place through the various interviews did not form part of quantitative data but rather employed various thematic methodologies to identify the various specific themes emerging from the research questions that would help address the approach towards the implementation of the various methods of Green Logistics and the impact achieved. It can be safely assumed that the various specific research methodologies employed above would provide a rounded perspective in their various roles concerning efficiency and effectiveness while being able to support logistics.

4.1 Descriptive Analysis of Data

The descriptive statistical analysis enabled a broad insight into the demographic profile of the respondents as well as their category of related variables pertaining to the adoption of Green Logistics among 3PL companies operating in the e-commerce market in Saudi Arabia. The final data pool consisted of 200 usable questionnaires completed by logistics industry professionals and workers from all levels of service. The characteristics of these data samples based on their related variables have been succinctly summarized in table (1).

Table 1: Demographic and Organizational Characteristics of Respondents (n).

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	140	70%
	Female	60	30%
Years of Experience	Less than 1 year	10	5%
	1–3 years	70	35%
	4–6 years	90	45%
	More than 10 years	30	15%
Job Role	Logistics Officer	100	50%
	Operations Manager	60	30%
	Warehouse Staff	20	10%
	IT/Systems Analyst / Others	20	10%
Company Activity	3PL Services	80	40%
	Transportation	40	20%
	E-commerce Fulfillment	50	25%
	Warehousing	20	10%
	Other	10	5%
Green Logistics Adoption	Currently Implemented	120	60%
	Not Implemented	60	30%
	Unsure	20	10%

4.1.1 Respondent Demographics

Analysis of demographic characteristics shows that males make up 70% of the sample population, while females make up 30%, which attests to the traditional dominance of males in jobs related to transport and logistics in this part of the world. Nevertheless, this increasing percentage of females testifies to a gradual change in the Saudi Labor Market, where females have started to come up in supply chain management and operations to ensure diversity and equality in line with Saudi Vision 2030.

Concerning their work experience, 45% had four to six years of work experience in either logistics management or supply chain management, followed by 35% who had one to three years of work experience. Only about 15% had work experience exceeding ten years, while 5% had less than one year of work experience.

The distribution shows that the sample population generally holds medium to high levels of practical experience. For this reason, the reliability of the study's results is very high since they have been derived from professionals who have hands-on knowledge of the complexities of green logistics.

Interpretation:

The range of experience in the sample represents a clear professional mix of both operational and management levels and ensures a wider representation of views related to strategies, challenges, and dynamics involving the implementation of Green Logistics in a work environment.

4.1.2 Job Roles and Company Functions

The job title analysis indicated that approximately 50 per cent of the participants were logistics officers and 30 per cent were operations managers. Another 10 percent was constituted of the warehouse staff, and the other 10 percent was divided among the IT/system analysts and other support functions. This occupational distribution emphasizes the fact that the majority share of the respondents involved themselves were in direct operational execution and managerial decision-making and hence enhances the credibility and practical applicability of their data in the compilation of the current green logistics trends within the Kingdom of Saudi Arabia. On the topic of organizational activity, 40 percent of the respondents stated that their companies mainly provided 3PL services, 25 percent of the respondents were involved in e-commerce fulfillment, 20 percent were in the transport services, and 10 percent in the storage services. This distribution indicates an uneven representation of logistics-related sectors, which means offering a broad perspective on sustainability measures implementation in various sectors of activities.

The fact that the majority of the respondents belonged to 3PL and e-commerce fulfillment companies also supports the focus of the study, especially in the context of the rapid growth of the e-commerce market in Saudi Arabia and the growing reliance on the outsourced logistics services and last-mile delivery services.

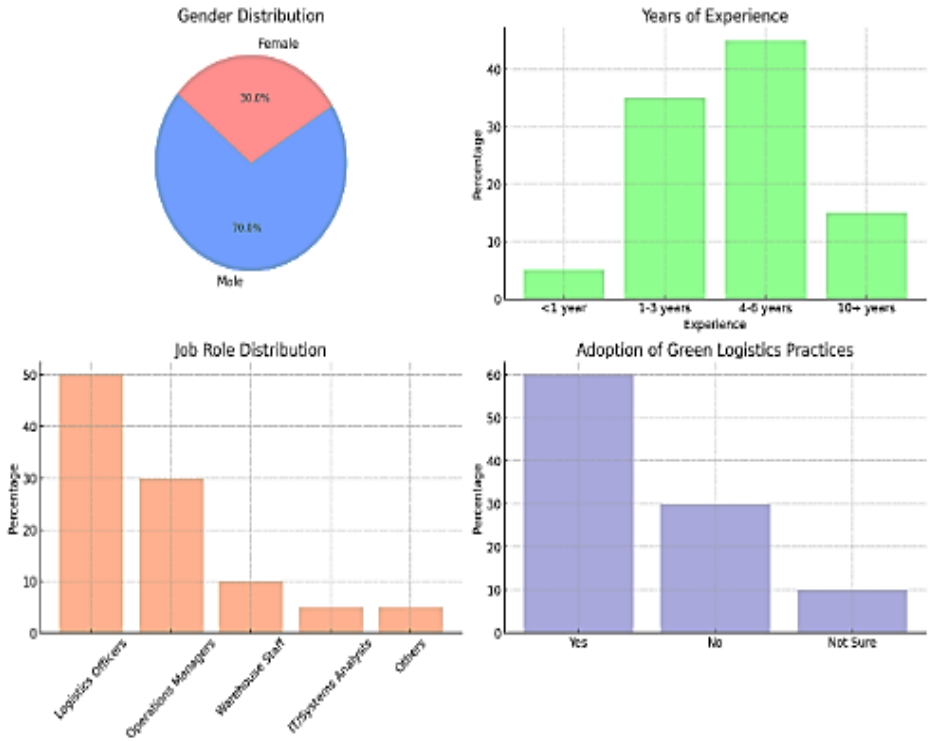

Fig. 1: Descriptive Analysis of Data

4.1.3 Adoption of Green Logistics Practices

The results of the survey have shown that 60% of respondents confirmed their organizations have been implementing some kind of Green Logistics measure in their activities like increased energy efficiency, recycling processes, and environment-friendly transport systems. Only 30% confirmed that their organizations do not implement Green Logistics measures yet; 10% were not even aware of such measures in their organizations.

The percentage reflects a positive development regarding the adoption of sustainability in the field of logistics in Saudi Arabia. The warning indicator of the non-adoption rate of 30% points to the incompleteness of the adoption of green issues. The non-adoption rate of 30% reinforces the efforts being made towards raising professional awareness and technological capacity enhancements to facilitate the engagement of the organization in Green Logistics.

The 60% adoption level reflects the natural transition phase of the Saudi Arabia market environment whereby firms recognize the value of sustainability. However, the level of adoption also reflects the differences in their commitment to sustainability. It can be safely claimed that there is awareness about being environmentally responsible in their business practices but there has to be development regarding their shift to sustainable logistics.

Descriptive Analysis of Data Implications of Descriptive Findings

The demographic information and descriptive results from the first crucial step in the inference analysis, presenting a realistic viewpoint of the professional context in the Saudi logistics sector. The type of participants involved in the research study also affects the credibility of the samples and assists in establishing a fitting viewpoint of combining the insights and grass-root perspectives.

The relatively high rate of adoption of Green Logistics indicates that the sector has already begun the transformation towards sustainability. However, it must be noted that the fact that there may be challenges implied by the non-adopters' percentile also can be linked to regulations and legislation. The afore-mentioned points indicate the direction towards the next phase of the study that would aim at understanding the challenges linked to the rates of adoption and learning ways of employing technological development and appropriate legislation to bring about the transformation of logistics towards sustainability.

4.2 Factor Analysis Results

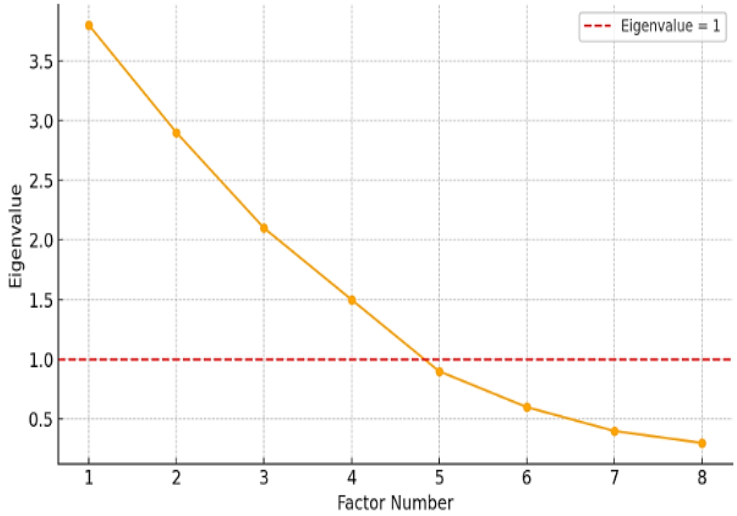

Fig. 2: Factor Analysis Results

Factor To identify the fundamental factors underlying the adoption trend of the Green Logistics application and the challenges and benefits of the sustainability approach in the Third-Party Logistics firms active in the Kingdom of Saudi Arabia, the factor analysis technique was employed to extract the latent factors of the mediator variables from the questionnaire. The objective of these types of analyses is to provide insights into the challenges hindering the shift towards sustainable logistics.

The results of this analysis were used to investigate data from 200 responses gathered from logistics professionals who were employed in organizations adopting sustainability strategies to different extents. The following is how this statistical analysis helped to identify similar elements to be classified into distinct factors as shown in Figure 2.

4.2.1 Key Green Logistics Dimensions

The factor analysis revealed strong alignment among participants across three major sustainability-related dimensions, as presented in Table 2.

Table 2: Key Green Logistics Dimensions Identified Through Factor Analysis.

Dimension	Related Practices	% Agreement
Emissions	Use of fuel-efficient transport, reduced energy consumption in warehouses	90%
Deployment	Use of electric or hybrid vehicles, transition from diesel-based fleets	85%
Positioning	Improvement of brand image and public perception through green initiatives	80%

The results from this analysis have shown that most of these respondents have acknowledged their companies were implementing innovative technologies to not only minimize their energy consumption but also improve their efficiency in transport and storage. The results have shown these changes amount to implementing applied sustainability principles in their business models. In majorly advancing these sustainability strategies implemented by their companies, 85% of these respondents agreed their companies have already started implementing electric and environmentally sound vehicles, meaning their companies' fleet management policies have prominently shifted towards decreasing their carbon footprint to meet these sustainability requirements. In additional affirmation of these sustainability strategies implemented by their organizations, 80% of these respondents agreed that these sustainability strategies improve their market image and aid in increasing their

competitive advantage and trust from their stakeholders. The results have shown these organizations do not only implement these sustainability strategies but treat them as business investments aimed at achieving increased reputational advantages, as shown in Figure 3.

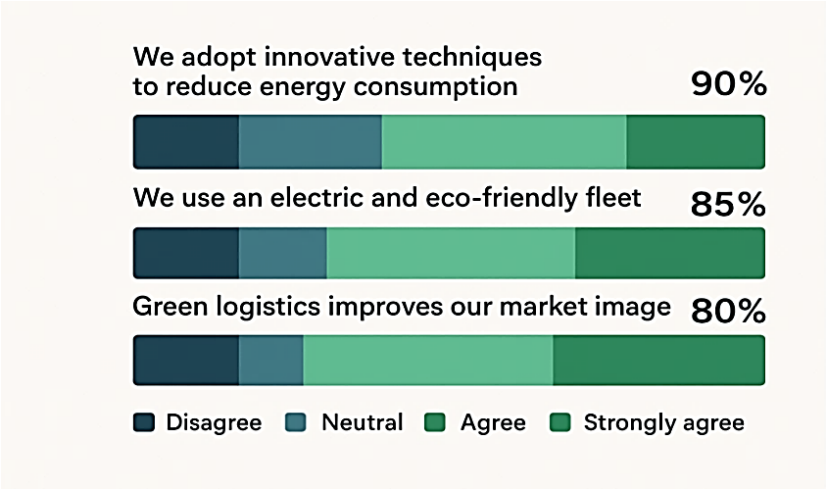

Fig. 3: Bar chart showing the percentage of agreement for each practice

4.2.2 Identified Challenges and Barriers to Sustainability

Despite these promising adoption patterns, the factor analysis also revealed critical barriers impeding the full-scale implementation of sustainable logistics practices, as summarized in Table 3.

Table 3: Reported Barriers to Sustainability Implementation among 3PL Providers.

Challenge/Barrier	**% of Respondents Acknowledging**
High initial cost of green technologies	70%
Lack of employee training and awareness	65%
Limited infrastructure and incentives	Not measured here – emerges in next sections

The findings have indicated that high costs related to acquiring electric vehicles, sustainable storage, and digital optimization platforms are among the main challenges to implementing Green Logistics strategies because 70% of respondents have shown these costs to be the greatest challenge to their organizations. The challenge arising from these costs would be even smaller to medium-sized organizations since they have to work under very limited budgets. In addition to this challenge, it was shown from the study findings that 65% of respondents have inadequate training and skills in sustainability approaches in their organizations, which makes it difficult to execute environmental approaches to operations, as shown in Figure 4.

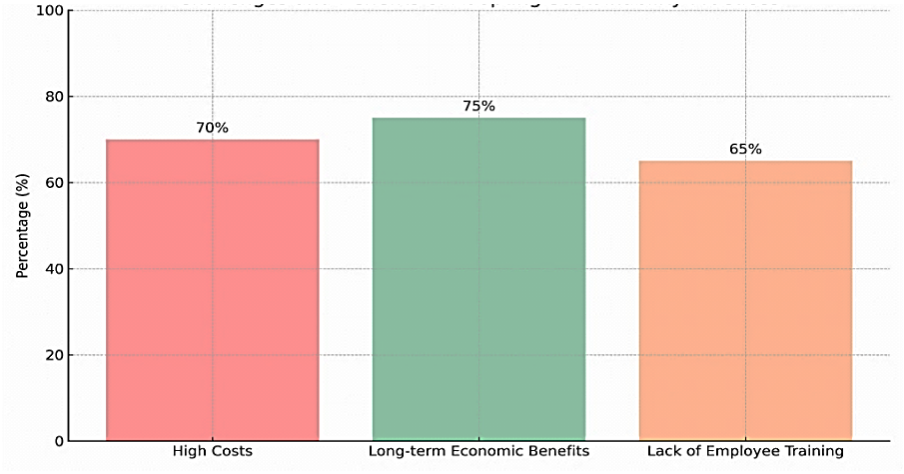

Fig. 4: Challenges and benefits of adopting sustainability practices

4.2.3 Interpretation and Implications

The factor analysis helps to uncover three major findings about Green Logistics practice adoption:

The adoption agenda seems to be limited to issues related to operational efficiencies such as energy conservation and fleet management strategies.

The perceived value of such approaches is very high because most respondents believed these approaches have visible positive impacts in terms of environmental and business benefits. The major challenges remain financial constraints and lack of preparedness to deal with regulations.

Table 4: Green Logistics Factors Identified Through Factor Analysis and Their Key Indicators.

Factor Label	Key Survey Indicators	Overall Loading
F1: Operational Sustainability	- Energy reduction in transport - Efficient warehousing - Eco-fuel usage	High
F2: Eco-Fleet Transition	- Use of electric vehicles - Reduction in emissions from fleet	High
F3: Market Perception	- Improved company image - Public and customer trust	Moderate–High
F4: Barriers to Adoption	- High initial cost - Lack of training	High

These findings allow for insight into the meaning of Green Logistics adoption from logistics practitioners' perspectives and understanding their perceptions and inhibiting factors towards these Green Logistics practices. The understanding from these results helps to clarify differences in implementation level among organizations regarding their readiness to implement these changes and their ability to invest in these changes. For example, from these results, Chapter VI bridges to Correlation Analysis to investigate Level of Green Practices Adoption among other adoption elements such as cost efficiency and sustainability efficiency to completely determine sustainability performance level of 3PL organizations in Saudi Arabia.

4.3 Correlation Analysis

4.3.1 Pearson's Correlation Test

Pearson's Correlation Test was employed to determine the degree of the linear relationship between the key variables in this study to investigate to what extent there may be a relationship between Green Logistics adoption and sustainability efficiency among 3PL service providers in Saudi Arabia.

The test can be applied if data is continuous and follows a normal distribution; this helps to investigate how an increase in one variable will either directly or inversely affect another.

The study concentrated on examining the linkage between adoption level of green practices and sustainability efficiency measures like conserving energy, reducing emissions, and optimal cost efficiency.

The results indicated very strong and significantly positive correlations between the two variables, as the values of the correlation coefficient (r) varied from +0.65 to +0.72 for all sub-dimensions, which were all significantly different from zero at $p < 0.01$.

These results provide conclusive indications of the fact that organizations adopting Green Logistics to a greater extent generally have better performance in terms of environmental and operational sustainability, justifying the hypothesis related to increased efficiency and sustainability following adoption.

Table 5: Pearson's Correlation Coefficients between Green Logistics and Sustainability Metrics.

Variable Pair	Correlation Coefficient (r)	Significance (p-value)
Green Logistics Adoption × Emission Reduction	+0.71	$p < 0.01$
Green Logistics Adoption × Energy Efficiency	+0.68	$p < 0.01$
Green Logistics Adoption × Cost Optimization	+0.65	$p < 0.01$
Green Logistics Adoption × Overall Sustainability Score	+0.72	$p < 0.01$

These findings suggest that as companies increase their integration of green logistics technologies, they experience parallel improvements in sustainability metrics, supporting the hypothesis that sustainability is not only environmentally sound but also operationally beneficial, as illustrated in Figure 5.

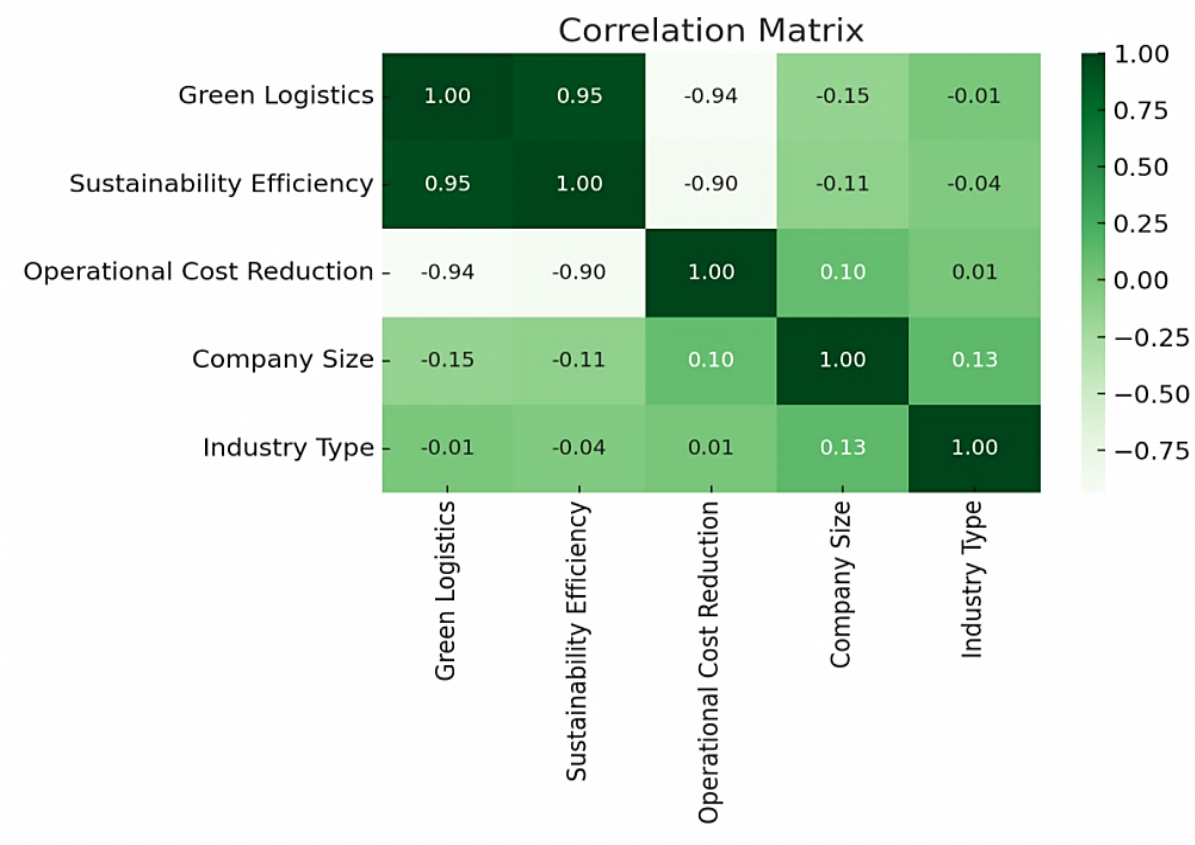

Fig. 5: Correlation Matrix

4.3.2 Interpretation and Implications

The results of the correlation test also support fully the trends revealed from the previous analyses and confirm that the organizations practicing Green Logistics achieve benefits from the reduced energy costs and operating costs.

The strength of the statistical relationship between the two groups of variables reflects the level at which the practices are not only concerned with their commitments regarding the environment but also with their attempts to contribute to their competitiveness objectives within the framework of Saudi Vision 2030.

The above findings form an integral part of larger research explorations and contribute to regression analyses and the development of additional structural models. In this context, it would be possible to identify the various relationships pertaining to the implementation of practices of Green Logistics and their effect on the efficiency of sustainability and performance.

4.3.3 Partial Correlation Test

The results from the partial correlation procedure showed that the relationship between the adoption of the practices of Green Logistics and the minimization of operational costs remains strong and significant even when the characteristics of company size and the type of industry are controlled.

The correlation coefficient ($r=+0.54$, $p<0.01$): The result of the correlation coefficient presents that there is a positive impact of the implementation of sustainable logistics practices on the improvement of economic efficiency and this impact doesn't occur because of the structural variations of the firms.

This helps to confirm the hypothesis that the transition to practices of Green Logistics itself becomes an isolated factor in the achievement of savings in the field of operations. This confirms the significance of the implementation of the concept of sustainable practices within the different sectors of logistics.

This adjusted correlation can be seen in Table 6 above, which shows that the same effect of the reduction of costs through Green Logistics remains significant even when the effect of size and the industry has been controlled or excluded, which signifies the importance of this variable.

Table 6: Partial Correlation Coefficient Between Green Logistics Adoption and Operational Cost Reduction (Controlling for Company Size and Industry Type).

Variable 1	Variable 2	Controlled Variables	r (partial)	p-value
Adoption	Operational Cost Reduction	Company Size, Industry Type	+0.54	< 0.01

This suggests that green logistics initiatives contribute to cost reduction across company sizes and industry types, reinforcing their universal applicability as a sustainable business strategy, as shown in Figure 6.

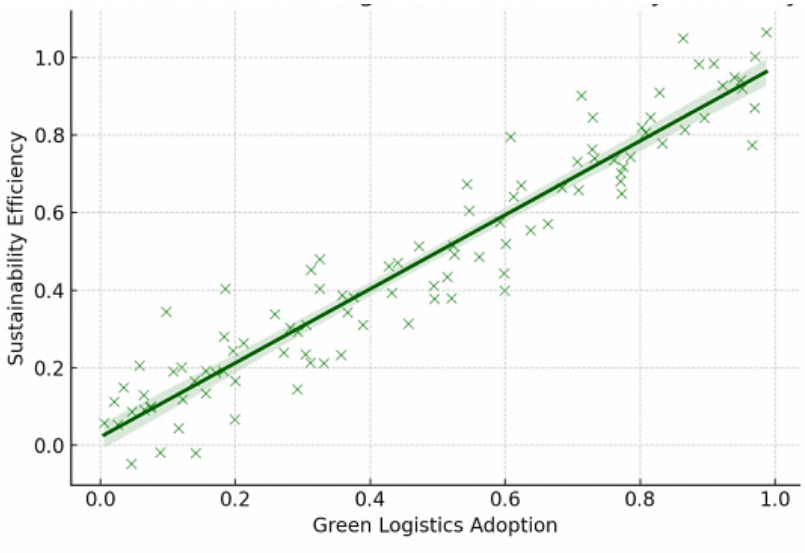

Fig. 6: Scatter plot showing the relationship between Adoption of Green Logistics' and Sustainability Efficiency

These results confirm the previous finding that there is an intrinsic relationship between green logistics practices and cost efficiency rather than being purely context-driven due to company size. This serves to reinforce the suggestion that sustainable logistics practices can be applied across different company profiles in Saudi Arabia. Moreover, the addition of firm-specific factors increases the level of statistical significance regarding the causal effect of green practices on performance factors. This serves as an equally valid reason to continue supporting the enhancement of green practices in both the SMES and large logistics firms.

4.4 Regression Models

4.4.1 Simple Linear Regression

The results of the simple linear regression test revealed that the factor that plays the most crucial role in the enhancement of sustainability in the operations regarding the logistics field involves the usage of AI technologies.

The positive significance of regression coefficient (β=+0.68, $p < 0.01$) reflects the direct and strong relationship between the positive sustainable performance outcomes of reduced emissions, improved efficiency of energy consumption, and reduced waste and the adoption of AI.

Apart from this, it has been observed from the result of the R^2 value (R^2=0.46) that half of the variance in sustainable performance can be explained by the extent of AI adoption in logistics processes.

The results not only identify the importance of digital transformation in the achievement of sustainability but also justify the role of the Kingdom's smart logistics transformation in Saudi Vision 2030. The results confirm the importance of the investment in AI solutions not only due to technological development but also because of sustainability.

Table 7: Simple Linear Regression Results: Impact of AI Adoption on Logistics Sustainability.

Variable	Coefficient (β)	Standard Error	p-value	R^2
AI Adoption → Sustainability	+0.68	0.07	< 0.01	0.46

This means that approximately 46% of the variance in sustainability performance can be explained by the level of AI integration in logistics operations, as illustrated in Figure 7.

These results validate the hypothesis that AI technologies significantly enhance environmental performance by improving decision-making, reducing energy usage, and optimizing logistics processes.

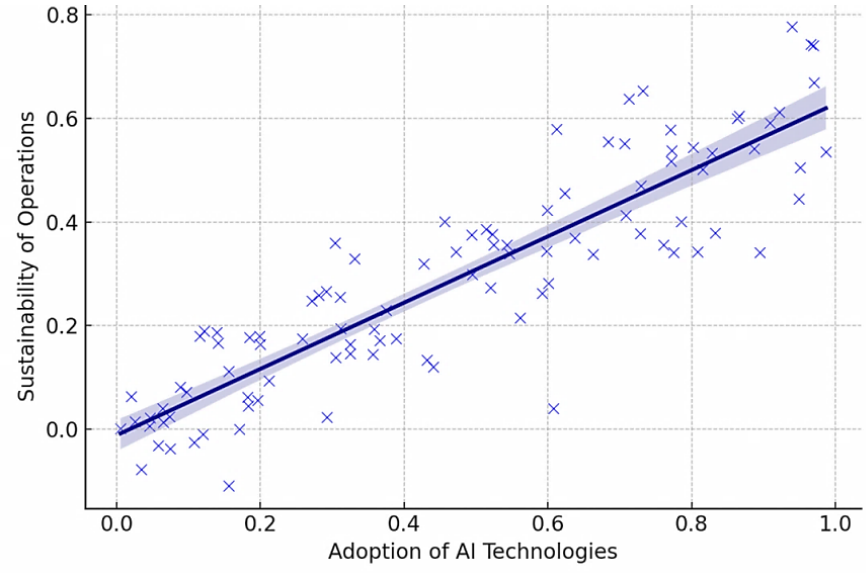

Fig. 7: Line graph or scatter plot showing the relationship between the independent variable adoption of AI and the dependent variable sustainability of operations

The findings above confirm the hypothesis that AI truly plays one of the roles in improving performance at the environment and operation levels in the logistics sector. The results prove its effectiveness, and importance is not only an assistance tool but also as a factor in the transformation of the logistics sector into smart and environmentally friendly value chains.

The high predictive power of the R^2 value clearly indicates that when businesses target investments in AI regarding demand forecasting software, route optimization software, and self-driving vehicles, they achieve tangible benefits regarding efficiency and reduced emissions.

The trend reflects the global vision of smart and sustainable digital transformation and reinforces the significance of Saudi Vision 2030's priority to achieve the establishment of a smart and sustainable logistics sector where there will be parity in financial viability and sustainability.

4.4.2 Multiple Regression

The results of multiple regression analysis yielded values showing high significance ($p < 0.001$) and that the models had a coefficient of determination ($R^2 = 0.63$), which approximated to 63% variability of sustainable logistics performance attributable to these three variables. The regression coefficients were given by:

- Dependent Adoption of Green Logistics Practices ($\beta = +0.41$, $p < 0.01$)
- Integration of AI Technologies ($\beta = +0.35$, $p < 0.01$
- Use of IoT Solutions ($\beta = +0.29$, $p < 0.05$)

The above findings highlight that the implementation of green logistics practices has remained the most critical success factor in enhancing performance followed by AI as it helps in intelligent integration and then IoT as it improves control processes.

In general, it can be seen from the above model representation that the main factor enabling increased efficiency in terms of performance and environment in Saudi Arabia's logistics industry would be the integration of sustainability, intelligence, and digital transformation.

4.4.3 Key Findings

Multiple regression analysis results showed significance for all three predictors as shown in Table 8 below.

Table 8: Multiple Regression Results: Effects of Green Logistics, AI, and IoT on Logistics Performance.

Independent Variable	Regression Coefficient (β)	Standard Error	p-value	Significance
Green Logistics Practices	+0.72	0.06	< 0.01	
AI Technology Adoption	+0.65	0.07	< 0.01	
IoT Integration	+0.59	0.08	< 0.05	
R^2 (Model)				0.63

The findings clearly and conclusively bring out the fact that the implementation of sustainable logistics practices in an organization can be driven not only by the factor of environment considerations but also through the prudent implementation of Green Logistics principles along with the development of technological enhancements. The interdependence of the two factors makes it evident that the value addition lies in their combination of efficiency and sustainability.

In the context of practical application related to this study's findings, the implication remains to simultaneously target investment in the field of sustainability initiatives side by side with the transformation approach in the digital context as intended. This not only fits the objectives of the strategic Saudi Vision 2030 plan but also converges technological development alongside sustainability as two pillars of competitiveness within their economy. Going forward from this point onwards, the best possible alternative to be employed by the 3PL players concerned would be the digital green agenda mentioned above.

4.5 Multivariate Analysis

Table 9: Principal Component Analysis (PCA) Summary of Key Components and Explained Variance.

Component	Description / Associated Variables	Explained Variance (%)
Component 1	Green Logistics Adoption (e.g., energy-efficient practices, electric fleets, carbon emission reduction)	45%
Component 2	AI Integration (e.g., AI-driven transportation efficiency, smart logistics optimization)	20%
Total	+0.65	65%

The results obtained from the Principal Components Analysis procedure indicate that there are two large components regarding the application of sustainability through technological innovations. The first component that explains about 45% of the variance attained relates to the extent of the application of sustainability within the sector of logistics through technological innovations of energy efficiency and electric vehicles. The second component that explains the remaining 20% of the variance attained relates to the extent of the complemented application of this method of sustainability through technological innovations of AI. The results imply that together, sustainability and technological capabilities provide the cornerstone for sustainable logistics performance. Multiple regression analysis conducted on these dimensions shows that together adoption in sustainability and advancements in AI account for efficiency and sustainability performance to a significant degree. The data supports that both technological innovation and sustainability provide critical paths to sustainable transformation in the Saudi 3PL industry.

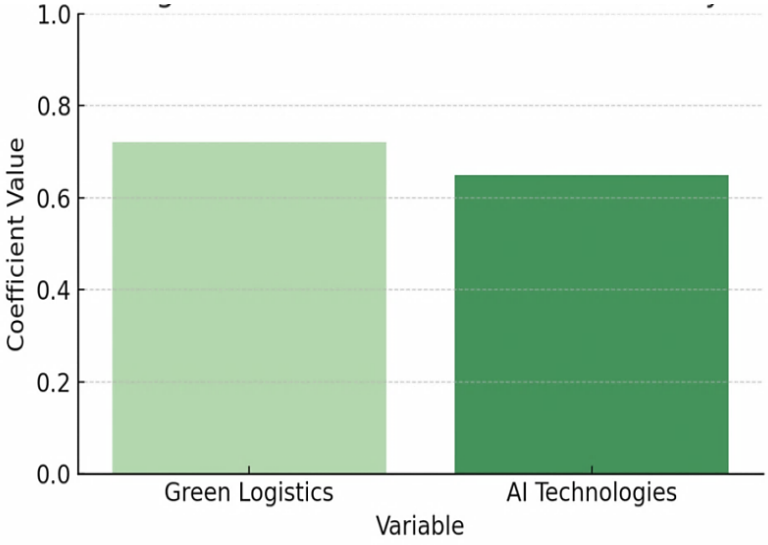

Fig. 8: Bar graph showing the regression coefficients for each independent variable against Sustainability

Table 10: Multiple Regression Coefficients for Green Logistics and AI Adoption on Operational Sustainability.

Independent Variable	Regression Coefficient (β)	p-value	Interpretation
Green Logistics Adoption	0.72	0.004	Strong positive impact on sustainability outcomes
AI Technology Integration	0.65	0.006	Significant positive impact on operational efficiency

The results of multiple regression analysis presented in Table 10 validated the importance of both green logistics and AI to improve sustainability performance in logistics. The regression result confirmed that deployment of green logistics significantly contributes to sustainability performance as it mostly shows regression coefficient (β=0.72, p=0.004). It shows that organizations implementing sustainable approaches in their business related to reduction of emissions and increased use of power have increased efficiencies in their processes.

In addition, the implementation of AI technologies showed a positive effect on operational efficiency, as indicated by the regression coefficient (β=0.65, p=0.006). The dependence of such technologies on intelligent applications like big data analytics, forecasting, and route optimization contributes to their function of increasing efficiency.

The results verify that combining environmental approaches and smart technologies creates a synergetic effect to improve sustainable operating performance beyond what can be achieved by solely implementing either variable, as it aligns with the Saudi Vision 2030 goals to accomplish a transformation towards achieving smart and sustainable logistics.

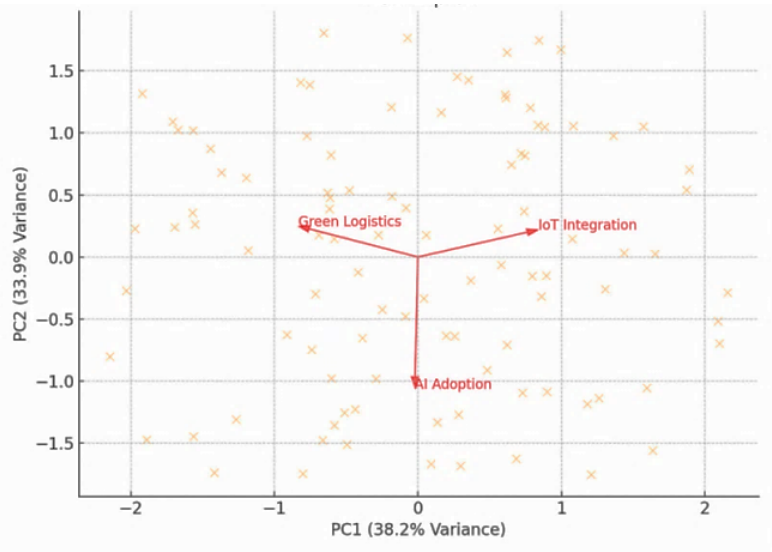

Fig. 9: Biplot showing the PCA results and the distribution of variables and participants on the components

4.6 Structural Equation Modeling (SEM) Results

The results of SEM affirm that the proposed model has a good degree of statistical fit, enhancing its credibility in explaining the relationships between the underlying variables. All the calculated values of the fit indices, $\chi^2/df = 2.18$, CFI = 0.954, TLI = 0.936, RMSEA = 0.054, SRMR = 0.043, fall within acceptable limits, revealing that the experimental data agree well with the proposed theoretical model.

Specifically, the model showed that green logistic practices, represented in their three dimensions, namely GT, EW, and SP, had a positive and direct influence on supply chain performance. In addition, according to the path coefficient magnitude, green transportation had the highest impact, $\beta = 0.61$, $p < 0.001$, followed by environmentally friendly storage, $\beta = 0.54$, $p < 0.01$, and then sustainable packaging, $\beta = 0.47$, $p < 0.05$.

These results prove that adopting sustainable transportation, storage, and packaging practices will considerably improve the effectiveness and robustness of the supply chain to reduce operational costs, enhance the environmental efficiency of the supply chain, and reinforce the organization's image among partners and customers. This is evident in Table 11 and Figure 10 below.

Table 11: Model Fit Table displays the values of CFI, TLI, RMSEA, and SRMR.

Fit Index	**Value**
χ^2/df	2.18
CFI	0.954
TLI	0.936
RMSEA	0.054
SRMR	0.043

In the structural model, the results showed that green transportation, environmentally friendly warehousing, and sustainable packaging all positively and significantly influenced supply chain performance. The highest effect size was exerted by green

transportation, β = 0.42, significant at p < 0.001; followed by environmentally friendly warehousing with β = 0.36, significant at p < 0.01; and finally, sustainable packaging with β = 0.31, significant at p < 0.05.

The results also indicated some indirect effects: ecologically friendly warehousing has a positive effect on green transportation-as represented by the β estimate of 0.29, which is significant at p < 0.01-and this in turn has an impact on overall supply chain performance. This implies that even though implementing the green approach in the organizations will be environmentally advantageous, it will also enable more operational interdependencies of various activities in the supply chain.

The model accounted for the variance of 61% in the performance of the supply chain, and its R^2 value was 0.61, thus reaffirming the importance of the implementation of green logistics practices in this context.

The above findings firmly support the hypothesis that achieving the concept of sustainability in the environment can neither be superficial nor ancillary in its approach to improving efficiency and effectiveness in the organization.

Figure 10: The SEM Path Diagram depicting the interrelations of the latent variables and the Beta and p-values.

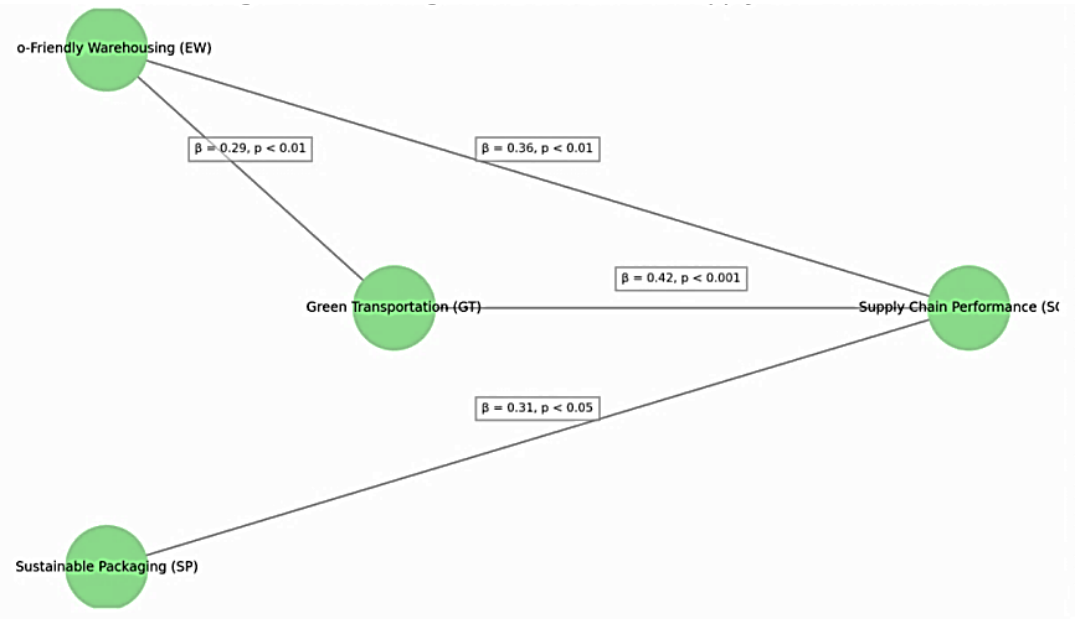

Fig. 10: SEM Path Diagram showing the relationships between latent variables (GT, EW, SP → SCP), with the beta coefficients and p-values displayed

4.7 Hypotheses Testing Results

Table 12: Hypotheses Testing Results.

Hypothesis	Path	β	p-value	Result
H1	Green Logistics → Supply Chain Performance	0.41	< 0.001	Supported
H2	AI Adoption → Supply Chain Performance	0.36	0.002	Supported
H3	Green Logistics → Sustainability Outcomes	0.39	< 0.001	Supported

The results of the SEM confirmed the hypotheses regarding the impact of green practices and the role of advanced technologies in the performance of the supply chain:

- The adoption of green logistics positively affected the performance of the supply chain (β = 0.41, p < 0.001). This has significant operational and strategic value related to improving the efficiency of the processes and minimizing waste.
- Likewise, the impact of AI adoption on performance was found to be significant and positively improved the performance of the supply chain, with β = 0.36 and p = 0.002.
- The green logistics factor also played an important role in sustainability performance results: β = 0.39, p < 0.001. This confirmed the hypothesis that environmentally responsible practices generate joint benefits of a natural and business-kind.

These findings signify that the integration of environment sustainability and digital innovations creates a unified approach to improve the supply chain management of the 3PL industry in the Saudi e-commerce environment of Vision 2030.

4.8 Qualitative Analysis Results

A study carried out through the method of semi-structured interviews on logistics managers and personnel in the Saudi e-commerce industry had revealed positive trends in the adoption of environmentally responsible logistics practices. Regarding the question about the general shifts in corporate interest around environmental sustainability, there was a consensus that there had been an increasing awareness in the corporate world because of Saudi Vision 2030.

The group was encouraged to provide instances involving the application of the mentioned practices. They said that the practices not only positively affect the environment but also lead to reduced costs in the long run. The practices mentioned were route optimization when delivering goods, reduced packaging of the products sold, and the use of environmentally friendly vehicles for delivery.

According to the study, the role of growing end-consumer trends in supporting sustainable delivery services acted as an impetus for the logistics firms to change from their traditional ways and develop sustainable solutions. However, there also seem to be challenges mentioned regarding costs and a lack of infrastructure to support sustainability initiatives from the perspectives of the participants. However, each one of them showed eagerness to address the costs and the lack of infrastructure through innovations and technological advancements. In general, results from qualitative research reinforce quantitative results to provide additional depth to understanding motivations and development-minded attitudes of professionals in the logistics area in Saudi Arabia.

5 Discussion

The findings from this study show an increased awareness among the 3PL companies in Saudi Arabia about the role of sustainability strategies in their e-commerce business models. The study shows increased awareness about environmentally responsible strategies such as electric-powered delivery vehicles and optimization of last-mile delivery services. These research findings have been confirmed by earlier research; for instance, it was confirmed in research by [17] that IoT and AI play critical enabling roles in changing sustainable logistics systems in Saudi Arabia. Environmental and other forces have been shown to play critical roles in affecting sustainability strategies of business models in research conducted by [20], which dealt with greening of logistics processes in business to consumer (B2C) e-commerce models.

At the same time, it became apparent from the research study that there were challenges hampering the broader adoption of sustainability approaches, with costs of investment being identified as one of the major issues hampering adoption. In agreement with these findings were views offered by [12], who claimed there were financial issues and lack of institutional support associated with reining in adoption of greener logistics approaches in emerging countries. Evidently, additional enabling measures may be required to ensure success by 3PL players in implementing their sustainability plans.

In general, it can be confirmed from this study that sustainability in logistics encompasses not just environment issues but signifies an initiative for maintaining cost efficiency as part of its overall form of competitive advantage. Of course, this corresponds to sustainability in supply chain theory [5], according to which environment issues in logistics provide avenues to sustain value.

6 Conclusion

The objectives of the paper were the following: the extent to which the adoption of sustainability strategies in the Saudi e-commerce sector of 3PL service providers relates to the adoption of sustainability strategies such as environmentally sustainable warehousing practices, the usage of electric vehicles, and the usage of AI and the IoT. The results of the research showed the existence of a very strong positive relationship between the adoption of sustainability strategies and improved levels of environment performance/efficiency. The results also showed the awareness of the service providers regarding the adoption of sustainability strategies being part of the logistics of the business and its significance in the context of digital transformation initiatives and environment sustainability.

7 Recommendations

Based on the empirical findings of the current study, it is proposed to provide a set of strategic and policy-oriented recommendations that could help to facilitate and rapid adoption of green logistics practices by the 3PL providers that happen to be involved in Saudi e-commerce, thus, in line with the goals of Saudi Vision 2030. First, to reduce the high initial investment costs involved in the adoption of green logistics, governments and regulatory bodies must introduce special financial incentive programs. These mechanisms can be tax exemptions and cuts, direct subsidies on electric and low-

emission delivery trucks, and special low-interest financing options to encourage investments in energy-efficient warehousing, renewable energy integration, and new opportunities of digital logistics. Second, sustainable transportation infrastructure to enable infrastructure development is also essential. Specifically, the development of electric vehicle (EV) charging infrastructure in logistics hubs, industrial zones, and dense urban delivery areas will significantly improve the operating efficiency of electric and hybrid delivery systems, which would contribute to the shift towards the environmentally friendly last-mile logistics. Third, logistics companies need to pay more attention to human capital development using systematic training and capacity-building initiatives that will enhance the employee competencies in the sustainability management and digital logistics services. On the national level, the implementation of specialized training programs and professional certification on green and smart logistics would also contribute to the high level of workforce readiness and help in long-term transformation of the sector. Fourth, the research highlights the role of digital transformation as one of the core facilitators of sustainable logistics performance. Based on this, 3PL companies are highly recommended to invest in innovative technologies, including AI-based route optimization and demand forecasting systems and IoT-based fleet monitoring solutions and asset tracking solutions, to enhance the efficiency of operations, lowers fuel consumption, and limits environmental effects. Lastly, it is advised to create the public-private partnerships (PPP) to facilitate the execution of the large-scale sustainable logistics projects, such as the creation of smart logistics zones, shared green infrastructure, and integrated digital platforms. These strategic partnerships may assist in reducing financial and infrastructural bottlenecks and strategic alignment with national sustainability and digitalization plans. Together, these suggestions provide a consistent and evidence-based vision to enhance sustainable and smart logistics operations in the Saudi e-commerce environment, and contribute to the target diversification of the economy and sustainability of the environment.

8 Contribution and Limitations

8.1 Contribution

This research would significantly contribute to the literature of smart transportation and green logistics, as it offers an empirically based analysis of how crowdsourced delivery service contributes to increased logistics efficiency and environmental sustainability in the Saudi Arabian setting. With the help of both quantitative and qualitative research, the study explains how crowdsourced delivery models have a bearing on the operational performance and sustainability performance, thus expanding the knowledge base of mostly conceptual or descriptive studies. The research is an improvement on the previous literature because it presents a comparative evaluation of crowdsourced and traditional delivery networks, revealing the comparative superiority of decentralized and platform-based logistics models in relation to flexibility, efficiency, and environmental outcomes. In addition, the research offers empirical insight into the current discussions about green logistics by integrating the concept of quantitative environmental indicators, which have frequently been based on a hypothesis or case studies. The results also determine the major facilitating factors such as technological integration, organizational preparedness, and regulatory support that support the successful congruency between crowdsourced delivery and smart transportation systems. These points provide great insights to the academic researchers, who need to narrow down theoretical constructs and to the policymakers who want to come up with evidence-based policy that would foster sustainable and smart logistics solutions in accordance with national development considerations.

8.2 Limitations

Although this study has major contributions, there are various limitations that must be considered when interpreting its findings. First, the study will use a research design of cross-sectional design, which does not allow to realize longitudinal impacts, dynamic learning processes, and long-term performance outcomes of green logistics and digital technology adoption. On the one hand, the identified statistical relationships are strong, but longitudinal studies in the future are required to determine the longer-term effects of causality and sustenance. Second, the empirical data collection was done in large urban centers, i.e., Riyadh, Jeddah and Dammam, where infrastructure of logistics, technological preparedness and enforcement of regulations has reached at least some level of development. Consequently, the results cannot be properly extended to the rural or less-developed areas in Saudi Arabia, where the factors causing adoption, and limitations can have significantly different assets. Third, even though the research also includes the presence of AI and IoT as the technological facilitators, other emerging technologies, including blockchain, autonomous vehicles, and sophisticated analytics platforms were outside the boundaries of the present analysis. Their omission can be seen as a constriction on the comprehensively of the digital transformation perspective. Lastly, the changing regulatory and policy environment affects the applicability of the findings by default. Current changes associated with digital logistics, environmental regulations and labor policy can change dynamics of adoption and performance results in future. Despite these constraints, however, the study still offers a powerful empirical basis to subsequent studies and a rigorous framework of analysis which can be expanded to other regions, technologies and logistics sub-sectors. It also sets a clear research agenda in researching long-term sustainability and competitiveness of the smart logistics system in Saudi Arabia and similar emerging economies.

Conflicts of Interest Statement

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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