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The Impact of Establishing a Biomass Energy-Based Reverse Logistics (Recycling and Distribution) Facility in the TRB2 Region on Sustainable Local Development[1]

Sevda YAPRAKLI *(https://orcid.org/0000-0002-1902-899X), Atatürk University, Türkiye; sevda1@atauni.edu.tr*

İbrahim Halil POLAT *(https://orcid.org/0000-0001-9785-160X), Hakkari University, Türkiye; ibrahimhalilpolat@hakkari.edu.tr*

TRB2 Bölgesi İllerinde Biyokütleye Dayalı Tersine Lojistik (Geri Dönüşüm ve Dağıtım) Tesisi Kurulmasının Sürdürülebilir Yerel Kalkınmaya Etkisi[2]

Abstract

Reverse logistics facilities using local renewable energy sources can promote sustainable regional development in the TRB2 Region (Van, Muş, Bitlis, Hakkâri), which has high biomass potential. This study examined the economic, social, and environmental impacts of a recycling and distribution facility through SWOT analysis. Field research and regression analyses identified opportunities as the most critical factor. Muş was recognised as the most suitable location for the facility. Establishing such a facility could support sustainable development by utilising regional resources, reducing income disparities among provinces, creating added value for the local economy, and enhancing overall regional equity.

Keywords : Reverse Logistics, Sustainable Local Development, Multiple Regression Analysis, TRB2 Region.

JEL Classification Codes : Q42, R11, C30, L91.

Öz

Yerel yenilenebilir enerji kaynaklarına dayalı tersine lojistik tesisleri, TRB2 Bölgesi'nde (Van, Muş, Bitlis, Hakkâri) sürdürülebilir yerel kalkınmaya katkı sunabilir. Bölgede özellikle biyokütle (bitki ve hayvan atıkları) potansiyeli yüksek olup, çalışmada geri dönüşüm ve dağıtım tesisinin ekonomik, sosyal ve çevresel etkileri ile güçlü ve zayıf yönleri, fırsatlar ve tehditler (GZFT) analizi yapılmıştır. Anket tabanlı saha çalışması ve regresyon analizleri sonucunda, en etkili değişkenin fırsatlar olduğu ve tersine lojistik tesisi için en uygun ilin Muş olduğu tespit edilmiştir. Böyle bir tesis, bölgeler arası gelir farklılıklarını azaltacak şekilde katma değer sağlayabilir.

Anahtar Sözcükler : Biyokütle, Tersine Lojistik, Sürdürülebilir Yerel Kalkınma, Çoklu Regresyon Analizi, TRB2 Bölgesi.

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[1] *This study is derived from the doctoral dissertation entitled "Proper Renewable Energy Sources for Sustainable Local Development: A Field Research on the TRB2 Region", completed by İbrahim Halil Polat in 2023 under the supervision of Prof.Dr. Sevda Yapraklı at Atatürk University Social Sciences Institute.*

[2] *Bu çalışma, Atatürk Üniversitesi Sosyal Bilimler Enstitüsü'nde Prof.Dr. Sevda Yapraklı'nın danışmanlığında İbrahim Halil Polat tarafından 2023 yılında tamamlanan "Sürdürülebilir Yerel Kalkınma İçin Tersine Lojistiğe Uygun Yenilenebilir Enerji Kaynakları: TRB2 Bölgesi Üzerine Bir Alan Araştırması" başlıklı doktora tezinden üretilmiştir.*

1. Introduction

Local Renewable Energy Sources (LRES) and reverse logistics facilities based on these resources are vital for Sustainable Local Development (SLD) in a world confronting threats such as environmental degradation, climate change, and resource depletion or scarcity.

LRES are resources that occur naturally due to various natural phenomena and ecological cycles on Earth. They are inexhaustible and reusable. Policies that support mobilising local potential and turning LRES into economic value emphasise the importance of natural capital and enable the efficient use of limited natural resources. This shift away from the fossil-fuel-based development model in the global economy offers opportunities to access new markets and achieve sustainable prosperity, according to the International Energy Agency (2011). Due to the adverse effects of fossil fuel-based energy production and consumption, such as coal and oil, on the environment and natural resources at local, regional, and global levels, as well as the environmental awareness emerging in the 1990s, LRES began to be recognised as clean, inexhaustible, cost-effective, and environmentally friendly energy sources (Li et al., 2020: 991-992).

One of the primary LRES, widely available in nearly every country and potentially causing environmental issues, is biomass. Biomass comprises organic materials produced by living organisms such as plants and animals. Used as a raw material for energy production, biomass includes animal and plant waste, agricultural and industrial residues, urban-rural waste, and solid organic waste from households and municipalities (Khan, 2009: 39; Polat, 2023: 83). The main component of biomass is carbohydrate compounds, which can be converted into commercial-grade solid, liquid, and gaseous forms of biomass energy through various physical, chemical, and biological processes. Biomass energy can be utilised as liquid fuels like butanol, biodiesel, methanol, and ethanol; as gases such as methane and hydrogen; as solid fuels like wood and dung for combustion; and for electricity generation in turbine boilers and microbial fuel cells (Polat, 2023: 83). Biomass resources are inexhaustible, universally available, help manage waste through biofuels, promote regional and local development, and can be adjusted according to demand (Jenkins, 1998: 41-42). Activating the investment and production potential of local biomass resources increases both the quantity and quality of production in regional economies, thereby strengthening national competitiveness and facilitating structural transformations (Polat, 2023: 69).

One of the core activities that allows biomass resources to benefit local economies is reverse logistics. Reverse logistics involves processes such as collecting, disassembling, recycling, and reintroducing waste or unusable products generated from production and consumption back into the market to prevent environmental harm (Polat, 2023: 2). Covering stages like collection/recovery, separation, screening, classification, recycling/recovery, disposal, transportation, and redistribution, reverse logistics activities can support the growth of firms and countries aiming for both environmental and economic benefits, while also helping to reduce local-national income disparities (Polat, 2023: 60; Fettahlıoğlu & Birin, 2016: 91). Since reverse logistics activities demand technological investments in areas such as sustainable production, recycling, energy efficiency, new materials development, and environmental services rather than pollution control they contribute to environmental protection while creating new jobs and employment opportunities (Demirer, 2001: 212-213; Pearce et al., 1989: 1).

Reverse logistics activities, which involve converting biomass resources and waste that cause environmental pollution at the local level into economic value, represent a significant focus for implementing sustainable development principles locally, that is, for SLD (Jacobs & Stott, 1992: 263). By effectively and efficiently utilising local natural resources, such as biomass through reverse logistics, SLD contributes to increased economic and social welfare, fostering a cleaner and more liveable world for future generations. The global discourse on environmental issues, drought, reckless resource consumption, waste, and interregional or intercountry disparities in development, especially during the 1980s, brought sustainable development to the forefront. From the late 1990s onwards, the concepts of sustainable development and localisation have been integrated, recognising the reciprocal interactions between global and local actors, making SLD a primary objective (Kadirbeyoğlu et al., 2014: 290). Various regional and local development approaches and theories, such as export centres, cumulative causation, new industrial hubs, endogenous regional growth, and new economic geography, have influenced one another and addressed each other's shortcomings, thereby advancing SLD, which emphasises the role of local and regional authorities, resources, and dynamics (Polat, 2023: 42-43).

The SLD approach aims to reduce local development disparities by addressing global economic, social, and environmental issues at the local level, integrating local development with sustainability (Garcia et al., 2019: 1; Liu et al., 2024: 107339-107340). Instead of focusing on regions, it highlights local geographical areas that can operate and sustain themselves based on their existing internal resources, accumulation, and potential (Coffey & Polese, 1984: 1). SLD promotes a development perspective that fosters local growth while tackling economic, social, and environmental concerns, making efficient use of resources and involving all local actors in the process (Kocaoğlu, 2015: 107). The economic dimension of SLD includes activities aimed at increasing economic welfare; the social dimension encompasses justice, equity, education, health, participation, and partnership; and the environmental dimension involves protecting ecological systems, waste management, pollution control, recycling, and natural resources such as biomass and waste (Newby, 1999: 67; Christy, 2008: 17). Through SLD, living conditions within a local community such as a province, metropolitan area, or subnational region improve, while local production, competitiveness, employment opportunities, and economic benefits grow, and environmental degradation decreases (Gwen et al., 2006: 1-3).

This study, emphasising the critical role of SLD, aims to identify the strengths, weaknesses, opportunities, and threats (SWOT) of establishing a biomass-based recycling and distribution facility suitable for reverse logistics among LRES in the TRB2 Region. It also seeks to determine which province within the TRB2 Region is most ideal for establishing the reverse logistics facility. To achieve this, a conceptual and theoretical framework was initially discussed, followed by a literature review on the subject. Finally, the research methodology was outlined, the analysis results and their interpretations were presented, and the conclusion section offered policy recommendations.

2. Literature Review

Despite its vital role in addressing local development disparities and Sustainable Local Development (SLD), no applied research has examined the relationship among Local Renewable Energy Sources (LRES), reverse logistics, and SLD. In scholarly works, reverse logistics is regarded as a strategic, value-recovery function that complements forward supply-chain activities. Through returns, repair, reuse, remanufacturing, and recycling, it manages demand uncertainty, warranty costs, and environmental responsibilities, thereby enhancing overall cost efficiency, service performance, and sustainability. The supply chain, by contrast, is an end-to-end system coordinating material, information, and cash flows across planning, procurement, manufacturing, inventory management, distribution, and customer service. A closed-loop perspective clarifies how forward and reverse flows are integrated, how information systems boost transparency, and how standard metrics (such as cycle time, recovery rate, and carbon intensity) are utilised. Studies on this subject, which have increased since the late 2000s, generally focus on the relationship between reverse logistics and/or Renewable Energy Sources (RES), or between RES and reverse logistics using a single indicator of SLD. The literature review shows that most research focuses on the impact of energy sources on economic growth and development at the national or international level, whereas local-level studies remain limited. The key studies reviewed can be summarised as follows, based on their findings.

In panel data analyses conducted by prominent researchers such as Sadorsky (2009), Menyah and Wolde-Rufael (2010), Menegaki (2011), Marques and Fuinhas (2012), Salim and Rafiq (2012), Leitao (2014), Çınar and Yılmazer (2015), Bayraç and Çıldır (2017), Dees and Auktor (2018), Bello et al. (2018), Obsatar et al. (2019), Naseem and Ji (2020), Mehmood (2021), Azam et al. (2021), Chang et al. (2022), Dagar et al. (2022), Hieu and Mai (2023), Polat et al. (2023), Raihan et al. (2024), and Abdi et al. (2025), it was established that there is a relationship between RES and economic growth. However, the direction and strength of this relationship vary with factors such as countries' levels of development, dependence on non-renewable energy sources, production technologies, the type, potential, and level of RES use, investment costs, environmental impacts, public support, sampling, and the analytical methods employed.

Similarly, key studies conducted locally on RES investments, production facilities, and their impacts such as those by Ivanova (2005), Bergman et al. (2006), Chandrasekar and Kandpal (2007), Swofford and Slattery (2010), Zhu et al. (2011), Liu et al. (2013), Liu (2016), Shoaib and Ariaratnam (2016), Hess and Gentry (2019), Surya et al. (2021), and Almulhim (2022) revealed that RES investments and facilities have economic and environmental effects, but the direction and magnitude of these effects differ between urban and local areas. A limited number of studies investigating the relationship between RES and reverse logistics, including Damiano (2013), Kinobe et al. (2015), Dupal et al. (2016), Çınar and Yıldırım (2017), Agrawal and Singh (2019), Guarnieri et al. (2020), and Kostha et al. (2022), found similar results. According to these studies, the environmental and economic impacts of RES in general, and biomass resources specifically, vary depending on factors such as the location of use (e.g., households, workplaces, industries), forms of use (e.g., combustion, recycling, storage), cost-benefit levels, public attitudes towards natural resource use, and the completion of infrastructural, managerial, socio-cultural, and economic improvements, as well as the extent of public support.

For Türkiye, a limited number of local-level studies by Önaç et al. (2017), Deniz et al. (2019), Tunacan et al. (2020), and Taşkın et al. (2020) found that reverse logistics facilities based on RES and/or biomass resources are insufficient, high installation costs hinder investment growth, public collaboration regarding waste management is low, and the effects of these facilities on growth and development are either adverse or negligible.

A summary of the studies applied to the subject is presented in Table 1.

Table: 1
Key Studies on the Subject

	Researcher(s)/Year(s)	Periods/Samples	Methods	Findings
Single and Multi-Country Studies	Sadorsky-2009	1980-2005/G7 Countries	FMOLS/DOLS	RES positively affects Economic Growth.
	Menyah/Wolde-Rufael-2010	1960-2017/USA	Time Series Analysis	RES affects Economic Growth and carbon emissions.
	Menegaki-2011	1997-2007/27 EU Countries	Panel Causality	There is no causal relationship between RES and economic growth. RES reduces carbon emissions.
	Marques/Fuihas-2012	1990-2007/24 EU Countries	Panel OLS	The adverse effects of RES use on economic growth exceed its positive impact.
	Salim/Rafiq-2012	1980-2006/6 GÜ	ARDL	RES affects economic growth in the short term and carbon emissions in the long term.
	Leitao-2014	1970-2010/Portugal	Causality, Cointegration.	RES consumption positively affects Economic Growth.
	Çınar/Yılmazer-2015	1990-2013/ 8 Developing and Emerging Countries	Panel ARDL	RES consumption positively affects Economic Growth.
	Bayraç/Çildir-2017	2006-2015/ EU Countries	Panel Regression	RES consumption increases Economic Growth.
	Dees/Auktor-2018	1996-2012/ MENA Countries	Panel OLS	RES positively affects economic growth in member countries, except in Türkiye.
	Bello et al.-2018	1971-2016/ Malaysia	Causality, Cointegration.	RES positively affects Economic Growth and carbon emissions.
	Obsatar et al.-2019	1980-2017/ Indonesia	ARDL	Biomass energy supports sustainable growth and environmental protection.
	Naseem/Ji-2020	2000-2017/ SAARC Countries	Panel Causality	RES consumption negatively affects carbon emissions and Economic Growth.
	Azam et al.-2021	1990-2017/25 Developing Countries	Panel ARDL	There is a reciprocal relationship between RES production and consumption and Economic Growth.
	Mehmood-2021	1990-2017/G11 Countries	ARDL	RES usage reduces carbon emissions.
	Chang et al.-2022	1990-2019/10 Developing Countries	Cointegration	RES usage positively impacts the environment.
	Dagar vd-2022	1990-2019/38 OECD Countries	Panel GMM	RES usage reduces environmental degradation.
	Hieu/ Mai -2023	1990-2020/80 Developing Countries	Panel MMQR	RES consumption positively affects Economic Growth.
	Polat et al.-2023	1980-2020/12 OECD	CS-ARDL	RES usage reduces carbon emissions.
	Raihan et al.-2024	1965-2022/India	ARDL	RES usage reduces carbon emissions.
	Abdi et al -2025	1994-2021/ sub-Saharan Africa (SSA)	(FGLS), and Driscoll-Kraay	RES usage reduces carbon emissions and ecological footprint.

Studies on the Impacts of RES Investments and Facilities	Ivanova-2005	Australia, Queensland	Survey-Correlation	Biomass investment is suitable for clean energy and affordable electricity.
	Bergmann et al. (2006)	Scotland	Survey-ANOVA	RES investments yield economic and environmental benefits.
	Chandrasekar/Kandpal-2007	India	Survey-Correlation	Biomass energy production facilities have positive socio-cultural impacts.
	Swofford/Slattery-2010	USA, Texas	Survey-Average	Wind energy helps in combating climate change.
	Zhu et al. (2011)	China	Survey-ANOVA	Biomass is most widely used locally, and public support is required to facilitate investment.
	Liu et al. (2013)	Çin	Logit Probit	RES investments have economic, social, and environmental impacts.
	Lui-2016	1990-2010 / 31 Cities in China	Panel Regression	RES usage positively affects local per capita income but negatively impacts economic growth.
	Shoaib/Ariaratnam-2016	Afganistan	Survey-Average	RES investments have economic and social impacts.
	Hess/Gentry-2019	3 Cities in the USA	Survey-Regression	Transitioning to a RES production system is essential for local development.
	Surya et al.-2021	Indonesia	Input-Output Analysis	RES production facilities positively impact SLD.
	Almulhim-2022	Saudi Arabia	Survey-ANOVA	High investment costs hinder RES investments.
Studies on RES-Reverse Logistics	Damiano-2013	Italy	Survey-Logit	Recycling household waste has both positive and negative impacts.
	Kinobe et al.-2015	Kampala, Africa	Interviews-Case Analysis	Reverse logistics facilities reduce the negative economic and environmental impacts of solid waste.
	Dupal et al. (2016)	Slovakia	Survey-Regression	Recycling industrial waste positively affects sustainable development.
	Çınar/Yıldırım-2017	General	Optimization Model	Recycling and recovery of wind turbine waste have positive environmental and economic impacts.
	Agrawal/Singh 2019	India	Survey-Structural Equation Modelling	The disposal of electronic waste has economic and environmental impacts.
	Guarnieri et al. (2020)	Brazil	Survey-Frequency Forecast	Waste recycling affects the economy and the environment.
	Kostha et al. (2022)	India	Survey-Partial Least Squares	Applying reverse logistics to e-waste has positive social, environmental, and economic impacts.
Studies on Türkiye and Local Areas	Önaç et al. (2017)	Alaçatı	Survey-Frequency-Average	Wind power plants do not harm the environment.
	Deniz et al. (2019)	1965-2017 / Türkiye	Cointegration, Causality	Biomass energy will reduce energy dependency.
	Tunacan et al.-2020	Karabük, Türkiye	Survey-ANOVA, Frequency	Solid waste recycling has positive economic and environmental impacts.
	Taşkın et al. (2020)	Mucur, Türkiye	Survey-Frequency	Wind power plants have limited economic impacts.

Overall, the studies in the table indicate a relationship between Renewable Energy Sources (RES) and development, as measured by economic growth. However, the direction and magnitude of this relationship vary. While no study has been identified that simultaneously examines RES (biomass), reverse logistics, and SLD, existing research on the subject addresses different indicators of these areas, suggesting a complementary relationship among them. No such study has been found in the national literature. This study is expected to contribute to the literature by distinguishing itself through the identification of the impacts of a biomass-based reverse logistics facility's SWOT analysis on SLD's economic, social, and environmental indicators, and by serving as a guide for future local-level research.

3. Field Research on the TRB2 Region

This study used primary data collected from field research on agricultural and livestock enterprises to assess the impacts of establishing a biomass-based recycling and distribution facility in the TRB2 Region. Specifically, the study aimed to conduct a SWOT analysis of the facility with respect to the economic, social, and environmental indicators of

SLD. Additionally, the research sought to determine which province within the TRB2 Region would be most suitable for establishing a reverse logistics facility.

3.1. Population and Sample

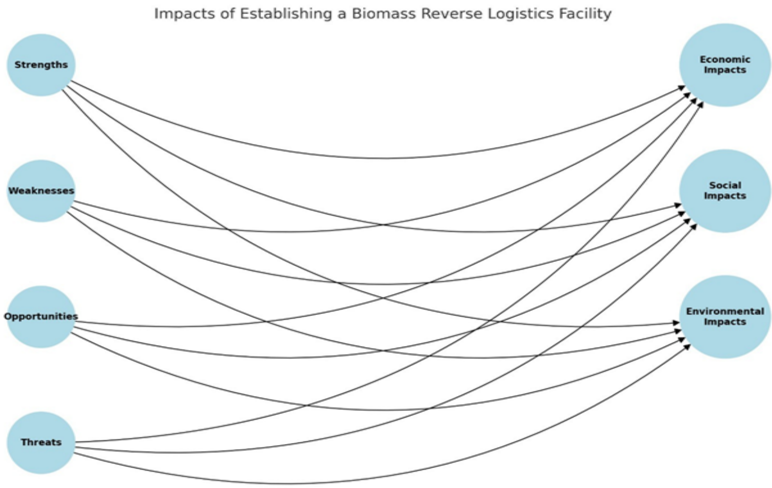
The TRB2 Region, one of Türkiye's underdeveloped sub-regions, has significant potential in biomass resources derived from plant and animal waste. Biomass, identified as the renewable energy source most suitable for reverse logistics in the TRB2 Region (Polat, 2023: 309), is the focus of this study. Therefore, the research covers agricultural and livestock enterprises in provinces, districts, and villages with abundant biomass resources within the region. The study population comprises enterprises registered with the provincial agriculture and forestry directorates (TUIK, 2022). In the TRB2 Region, there are 89,498 domestic and foreign agricultural and livestock enterprises, distributed as follows: 39,396 in Van, 23,266 in Muş, 17,660 in Bitlis, and 9,176 in Hakkâri. Consequently, the study's population size is 89,498 enterprises.

A simple random sampling method was used, ensuring that each individual in the population had an equal chance of selection. The sample size was calculated using the formula $n = \pi(1-\pi) / (e / z)^2$ (Polat, 2023: 242). With a 95% confidence level and a 5% margin of error, the minimum sample sizes were 380 for Van, 378 for Muş, 376 for Bitlis, and 369 for Hakkâri, totalling 1,503 enterprises. To account for potential response errors and incomplete evaluations, 1,600 survey forms were prepared. Before administering the survey to the sample, a pilot study was conducted with 30 enterprises to verify the clarity of the questionnaire. Due to constraints such as time, financial limitations, and participant reluctance, surveys were completed by 1,549 enterprise owners. The surveys were conducted by 12 surveyors selected from students of Hakkâri and Van Yüzüncüyıl University. These surveyors received training on the questions, the types of renewable energy sources considered, reverse logistics, sustainable local development (SLD), and interview techniques before being sent to the relevant areas. Data were collected through structured face-to-face interviews with enterprise owners.

3.2. Research Methodology

To assess the effects of the SWOT analysis for establishing a biomass-based recycling and distribution reverse-logistics facility on the indicators of Sustainable Local Development (SLD) in the TRB2 Region, the following fundamental model was formulated, drawing on studies by Mehta et al. (2022) and Kamran et al. (2020).

Figure: 1
The Model of the Study



Based on the basic model, regression analyses were conducted to examine the effects of SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis on SLD's economic, social, and environmental indicators for a biomass recycling and distribution facility. The equation used in the estimations is as follows.

$$Y_i = a_0 + a_1X_{i1} + a_2X_{i2} + \ldots + a_kX_{ik} + e_i \quad (1)$$

where the "XXX$_i$" variables represent the independent variables, Y_i denotes the dependent variable, "aaa" represents the coefficients, and "eee" signifies the error term. Based on Equation (1), the estimation equations provided below have been constructed within the framework of this study.

$$SLD_{EI} = a_{01} + a_{11}SS + a_{21}WS + a_{31}O + a_{41}T + e_{i1} \quad (2)$$

$$SLD_{SI} = a_{02} + a_{12}SS + a_{22}WS + a_{32}O + a_{42}T + e_{i2} \quad (3)$$

$$SLD_{E1I} = a_{03} + a_{13}SS + a_{23}WS + a_{33}O + a_{43}T + e_{i3} \quad (4)$$

Equations (2), (3), and (4) define SLD_{EI}, SLD_{SI}, and SLD_{E1I} as the economic, social, and environmental indicators of SLD, respectively; SS represents the strengths side of the proposed biomass recycling and distribution facility, WS its weaknesses, O the opportunities it offers, and T the threats it may face. These equations were tested through multiple regression analysis, with separate estimates conducted for the TRB2 Region and its provinces, namely Van, Muş, Bitlis, and Hakkâri. The research utilised primary data collected from field studies on agricultural and livestock enterprises, following ethical approval granted by the Scientific Research and Publication Ethics Committee of Hakkâri University (decision number 2022/101, dated 25 November 2022). For the variables in Equations (2), (3), and (4), participant perceptions were considered, with mean perception scores derived from survey responses used in the analysis.

To collect data, a questionnaire comprising 128 items, divided into four sections, was developed based on a review of the relevant literature. The survey employed closed-ended questions and a 5-point Likert scale [Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), Strongly Disagree (1)]. The first section of the questionnaire included items on the demographic characteristics of business owners, such as gender, age, education level, marital status, and monthly income. The second section addressed the characteristics of the businesses, biomass potential, methods for waste utilisation, information about reverse logistics, expected costs, and workforce requirements for establishing an appropriate recycling and distribution facility for reverse logistics, among other topics. Due to space constraints, the findings from the first and second sections are not included here. The third section comprised 40 questions assessing the strengths, weaknesses, opportunities, and threats (SWOT) associated with the proposed biomass recycling and distribution facility. The fourth section comprised 30 questions concerning the economic, social, and environmental indicators of SLD. The data were analysed using SPSS.

3.3. Analysis Results

Before estimating Equations (2), (3), and (4), analyses of the survey questions were conducted to identify the dependent and independent variables. These analyses included reliability and validity tests to determine whether the questions administered to participants were appropriate for identifying the variables to be used in the equations. For this purpose, the reliability of the measurement results was assessed using the internal consistency method and evaluated against the Cronbach's Alpha reliability criterion (Polat, 2023: 243).

To evaluate the accuracy of the variables used in the equations, the survey data were subjected to exploratory factor analysis. Before conducting the factor analysis, the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity were performed. A KMO test value above 0.50, which reflects the proportion of common variance among variables, suggests that the data are appropriate for factor analysis. Likewise, a significant Bartlett's test of sphericity ($p < 0.05$) confirms that the data are suitable for factor analysis (Şencan & Fidan, 2020: 642). As part of the exploratory factor analysis, the factor loadings and the total variance explained by the factors for each survey question were analysed. Factor loadings above 0.50 for each item and a total explained variance exceeding 50% indicate that the survey data are valid and appropriate for use as dependent or independent variables in the equations (Şencan & Fidan, 2020: 668, 646).

The results of the reliability and validity analyses conducted on the survey data to identify the variables for the equations to be estimated are presented in Tables 2 and 3.

Table: 2
Results of Reliability and Validity Analysis for Dependent Variables

Economic Sub-Indicators	Factor Loadings
1) Facilitates the increase in infrastructure investments	0.720
2) Supports small and medium-sized energy production companies	0.696
3) Contributes to the increase in investments targeting local resources	0.687
4) Promotes entrepreneurship activities and increases employment opportunities	0.658
5) Enables local firms to gain cost advantages	0.651
6) Contributes to enhancing competitiveness in biogas production	0.632
7) Provides opportunities for biogas sales at local, regional, national, and international levels	0.612
8) Supports the development of bioenergy activities locally	0.611
9) Facilitates the increase in local logistics activities	0.562
10) Contributes to local economic growth	0.503
Cronbach Alpha = 0.834; **Kaiser-Meyer-Olkin (KMO)** = 0.848 **Bartlett's Test of Sphericity** = 4393.891; **Sig.** = 0.000; **Total Variance Explained** = 52.1%	
Note: All questionnaire items in the relevant section have factor loadings above 0.50.	
Social Sub-Indicators	**Factor Loadings**
2) Contributes to the strengthening of human development and social solidarity	0.802
3) Reduces social pressures on farmers stemming from waste and environmental issues	0.795
4) Enhances intra-family relationships and stakeholder organisations	0.774
5) Facilitates the strengthening of social dialogue and participation	0.768
7) Helps reduce migration outside the province/region	0.761
8) Increases the number of skilled labourers in agricultural and livestock production	0.722
9) Contributes to the improvement of healthy and high-quality living	0.649
10) Leads to better opportunities for education	0.524
Cronbach Alpha = 0.873; **Kaiser-Meyer-Olkin (KMO)** = 0.875 **Bartlett's Test of Sphericity** = 5215.957; **Sig.** = 0.000; **Total Variance Explained** = 53.2%	
Note: Only standardised loadings ≥ 0.50 are reported; sub-threshold loadings and Items 1 and 6, which were removed from the questionnaire, are not displayed.	
Environmental Sub-Indicators	**Factor Loadings**
1) Facilitates the acquisition of clean energy that contributes to the environment	0.693
2) Contributes to the development of environmental enterprises	0.682
3) Supports leaving a clean environment for future generations	0.632
4) Ensures the economic utilisation of waste that is harmful to the environment and human health	0.632
5) Helps mitigate climate change	0.629
6) Assists in achieving energy and water savings	0.625
7) Contributes to the improvement of air, soil, and water quality	0.598
8) Supports the conservation of natural resources	0.578
9) Plays a role in reducing environmental pollution	0.574
10) Helps reduce the use of fossil fuels	0.596
Cronbach Alpha = 0.811; **Kaiser-Meyer-Olkin (KMO)** = 0.849 **Bartlett's Test of Sphericity** = 3726.988; **Sig.** = 0.000; **Total Variance Explained** = 50.2%	
Note: All questionnaire items in the relevant section have factor loadings above 0.50.	

As shown in the table, the Cronbach's Alpha coefficients for the items within the scales are 0.83, 0.85, and 0.81 for the economic, social, and environmental sub-indicators, respectively. Since these values exceed the threshold of 0.70, it can be concluded that the scales related to the dependent variables in the estimation equations are reliable. Additionally, the results of the KMO and Bartlett's sphericity tests indicate that the data are suitable for factor analysis.

The results of the exploratory factor analysis for the economic and environmental indicator scales of SLD indicate that the factor loadings for each item exceed 0.50. However, the social indicator scale analysis revealed that two items (Items 1 and 6) had factor loadings below 0.50. These items were removed, and the factor analysis was repeated with the remaining items. Based on the analysis results in the table, decisions were made regarding which items to retain in the survey form. As shown in the table, the total explained variance for the economic, social, and environmental indicators is 52.1%, 53.2%, and 50.2%, respectively. The factor loadings and total explained variance values confirm that the survey data are valid and appropriate for use as dependent variables in the equations.

Table: 3
Results of Reliability and Validity Analysis for Independent Variables

Strengths of the Facility	**Factor Loadings**
1) Utilisation of applicable and straightforward technology	0.683
2) Profitability enhancement through biomass energy facility and recycling practices	0.679
3) Government purchase guarantee for electricity produced from renewable energy sources	0.623
6) High potential of the region for bioenergy production	0.606
7) Minimisation of environmental pollution by the biomass energy facility	0.605
8) Being an investment-incentivised region	0.600
9) Obligation of waste disposal, ensuring system sustainability	0.587
10) Possessing vast pasture and forage crop potential	0.553
Cronbach Alpha = 0.767; **Kaiser-Meyer-Olkin (KMO)** = 0.740 **Bartlett's Test of Sphericity** = 2993.893; **Sig.** = 0.000; **Total Variance Explained** = 54.6%	
Note: Only standardised loadings ≥ 0.50 are reported; sub-threshold loadings and Items 4 and 5, which were removed from the questionnaire, are not displayed.	
Weaknesses of the Facility	**Factor Loadings**
1) Difficulties encountered during the transportation of animal waste	0.742
2) Lack of knowledge during the production and collection of waste	0.735
3) Absence of free market conditions and its impact on price competition	0.714
4) High water demand	0.695
5) Logistical problems due to the mountainous terrain of the region	0.687
6) Disruptions in production caused by migration from the region	0.642
8) Shortage of skilled technical personnel	0.634
9) Homogeneity issues in biomass quality	0.603
10) System problems caused by variable calorific values of animal waste used as fuel	0.504
Cronbach Alpha = 0.841; **Kaiser-Meyer-Olkin (KMO)** = 0.862 **Bartlett's Test of Sphericity** = 4292.858; **Sig.** = 0.000; **Total Variance Explained** = 55.8%	
Note: Only standardised loadings ≥ 0.50 are reported; sub-threshold loadings and Item 7, which was removed from the questionnaire, are not displayed.	
Opportunities Provided by the Facility	**Factor Loadings**
3) Increase in local energy resources	0.684
4) Support for electricity production in rural areas	0.677
5) Reusability of waste generated after energy production	0.668
6) Development of the livestock and agriculture sectors	0.657
7) Increased opportunities and incentives for establishing facilities in different regions	0.655
8) Strengthened collaboration with the public or stakeholders due to support for renewable energy	0.630
9) Creation of new businesses based on electricity and heat production	0.576
10) Opportunity to utilise the unused biomass potential	0.521
Cronbach Alpha = 0.781; **Kaiser-Meyer-Olkin (KMO)** = 0.795 **Bartlett's Test of Sphericity** = 2855.356; **Sig.** = 0.000; **Total Variance Explained** = 53.7%	
Note: Only standardised loadings ≥ 0.50 are reported; sub-threshold loadings and Items 1 and 2, which were removed from the questionnaire, are not displayed.	
Threats Faced by the Facility	**Factor Loadings**
1) Risk of increased installation costs due to exchange rate fluctuations	0.719
2) Activities aimed at preventing the facility from continuing production	0.695
3) Insufficient demand for the energy produced	0.675
5) Use of outdated production technologies	0.674
6) Increased production costs due to price instability in the country	0.663
7) Emergence of infectious diseases during waste logistics	0.627
8) Inability to meet the facility's waste demand due to animal deaths caused by infectious diseases	0.607
9) Environmental degradation caused by agricultural and livestock production activities	0.579
10) Risk of energy production reaching a halt due to an increase in the proportion of inefficient waste	0.555
Cronbach Alpha = 0.824; **Kaiser-Meyer-Olkin (KMO)** = 0.802 **Bartlett's Test of Sphericity** 4379.246; **Sig.** = 0.000; **Total Variance Explained** = 55.7%	
Note: Only standardised loadings ≥ 0.50 are reported; sub-threshold loadings and Items 4 and 5, which were removed from the questionnaire, are not displayed.	

As shown in Table 3, the Cronbach's Alpha coefficients for the items within the scales for strengths, weaknesses, opportunities, and threats are 0.77, 0.84, 0.78, and 0.82, respectively. Since these values exceed the 0.70 threshold, it can be concluded that the scales related to the independent variables in the estimation equations are reliable. Furthermore, the results of the KMO and Bartlett's sphericity tests indicate that the data are appropriate for performing factor analysis.

The exploratory factor analysis results for the strengths variable indicated that two items (Items 4 and 5) had factor loadings below 0.50. These items were removed, and the factor analysis was repeated using the remaining items, which confirmed that all factor loadings exceeded 0.50. Similarly, for the weaknesses variable, one item (Item 7) was excluded because its factor loading was below 0.50; for the opportunities variable, two items (Items 1 and 2) were removed. For the threats variable, one item (Item 4) was excluded, and the factor analysis was repeated. Based on the results presented in the table, decisions were made regarding which items should remain in the survey form. As shown in the table, the total explained variance for the strengths, weaknesses, opportunities, and threats variables is 54.6%, 55.8%, 53.7%, and 55.7%, respectively. The factor loadings and total explained variance values confirm that the survey data are valid and suitable for use as independent variables in the equations.

3.3.1. Findings Related to Regression Analyses

Equations (2), (3), and (4) were estimated for the TRB2 Region and its provinces; the estimation results are presented below.

3.3.1.1. Estimation Results Related to Equation (2)

Equation (2) was estimated separately for the TRB2 Region and each of its provinces, with the results shown in Tables 4, 5, 6, 7, and 8.

Table: 4
Findings for the TRB2 Region

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Statistics	
	B	Beta	Beta			Tolerance	VIF
Constant	0.852	0.094		9.103	0.000		
Strengths side	0.240	0.023	0.260	10.491	0.000	0.583	1.716
Weaknesses side	0.007	0.022	0.010	0.339	0.734	0.435	2.299
Opportunities	0.421	0.024	0.398	17.305	0.000	0.677	1.476
Threats	0.154	0.022	0.191	6.963	0.000	0.473	2.114
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Standard Error**		**DW**	
0.703	0.494	0.492	345.174 (0.000)	0.357		1.870	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

Table 4 indicates that Equation (2) is significant at the 1% level (F (p) = 0.000), with an explanatory power of 49.2%. The Durbin-Watson (DW) statistic ((1 < 1.87 < 2.5)) suggests no autocorrelation, and the Variance Inflation Factor (VIF) values (< 3) confirm the absence of multicollinearity issues.

Based on the table's estimates, the strengths, opportunities, and threats associated with establishing a biomass recycling and distribution facility in the TRB2 Region have a positive and significant effect on SLD's economic indicator. Specifically, a one-unit increase in the strengths, opportunities, and threats variables leads to increases of 0.24, 0.42, and 0.15 units, respectively, in the economic indicator. Among these, opportunities are the most influential independent variable impacting SLD's economic indicator in the TRB2 Region. For the Weaknesses dimension (p = 0.734), which exceeds the 0.05 threshold, the result is not statistically significant.

Table: 5
Findings for Van Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	0.888	0.168		5.302	0.000		
Strengths side	0.363	0.042	0.426	8.634	0.000	0.505	1.981
Weaknesses side	-0.013	0.042	-0.017	-0.300	0.764	0.372	2.686
Opportunities	0.308	0.050	0.277	6.199	0.000	0.617	1.621
Threats	0.135	0.044	0.180	3.032	0.003	0.351	2.852
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. error**		**DW**	
0.746	0.556	0.552	112.92 (0.000)	0.345		1.942	

Note: Only findings with p < 0.05 (95% confidence) are interpreted.

In Table 5, it is observed that the estimated Equation (2) for Van Province is significant at the 1% level (F-statistic (p) = 0.000) and has an explanatory power of 55.2%. The Durbin-Watson (DW) value (1 < 1.94 < 2.5) indicates no autocorrelation, and the Variance Inflation Factor (VIF) values (< 3) confirm the absence of multicollinearity issues. According to the regression results, the strengths, opportunities, and threats of establishing a biomass recycling and distribution facility in Van Province have positive and statistically significant effects on the economic indicator of SLD. A one-unit increase in the variables strengths, opportunities, and threats yields positive effects of 0.36, 0.31, and 0.14 on the economic indicator, respectively. Among these, the variable with the most significant impact on the economic indicator in Van Province is strength. For the Weaknesses dimension (p = 0.764), which exceeds the 0.05 threshold, the result is not statistically significant.

Table: 6
Findings for Hakkari Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	1.525	0.233		6.534	0.000		
Strengths side	0.054	0.041	0.076	1.329	0.185	0.655	1.527
Weaknesses side	-0.036	0.038	-0.070	-0.963	0.336	0.405	2.467
Opportunities	0.547	0.061	0.510	8.999	0.000	0.669	1.495
Threats	0.087	0.038	0.160	2.285	0.023	0.437	2.286
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.583	0.430	0.422	39.559 (0.000)	0.330		1.825	

Note: Only findings with p < 0.05 (95% confidence) are interpreted.

In Table 6, it is observed that the estimated Equation (2) for Hakkari Province is significant at the 1% significance level (F-statistic (p) = 0.000) and has an explanatory power of 42.2%. The Durbin-Watson (DW) value (1 < 1.83 < 2.5) indicates no autocorrelation, and the Variance Inflation Factor (VIF) values (< 3) confirm the absence of multicollinearity issues. According to the estimation results, the opportunities created and the threats faced by establishing a biomass recycling and distribution facility in Hakkari Province have positive and statistically significant effects on the economic indicator SLD. A one-unit increase in the variables opportunities and threats results in positive impacts on the economic indicator of 0.55 and 0.09 units, respectively. Among these, the variable with the most significant impact on the economic indicator in Hakkari Province is opportunities. The variables for Strengths (p = 0.185) and Weaknesses (p = 0.336) are not statistically significant.

Table: 7
Findings for Muş Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	1.525	0.211		7.239	0.000		
Strengths side	0.188	0.047	0.219	3.993	0.000	0.551	1.814
Weaknesses side	-0.079	0.047	-0.089	-1.674	0.195	0.590	1.694
Opportunities	0.509	0.044	0.517	11.498	0.000	0.823	1.215
Threats	0.049	0.042	0.060	1.171	0.242	0.643	1.555
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. error**		**DW**	
0.624	0.389	0.382	58.538 (0.000)	0.285		2.134	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

In Table 7, it is observed that the estimated Equation (2) for Muş Province is significant at the 1% significance level (F-statistic (p) = 0.000) and has an explanatory power of 38.2%. The Durbin-Watson (DW) value (1 < 2.13 < 2.5) indicates no autocorrelation, and the Variance Inflation Factor (VIF) values (< 3) confirm the absence of multicollinearity issues. According to the estimation results, establishing a biomass recycling and distribution facility in Muş Province has positive and statistically significant effects on the economic indicator SLD. A one-unit increase in the variables' strengths and opportunities yields positive effects of 0.18 and 0.51 on the economic indicator, respectively. Among these, the variable with the most significant impact on the economic indicator in Muş Province is opportunities. For the Weaknesses dimension (p = 0.195), which exceeds the 0.05 threshold, the result is not statistically significant.

Table: 8
Findings for Bitlis Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	0.418	0.199		2.103	0.036		
Strengths side	0.213	0.057	0.187	3.698	0.000	0.524	1.910
Weaknesses side	0.112	0.055	0.103	2.012	0.045	0.510	1.960
Opportunities	0.294	0.050	0.282	5.920	0.000	0.589	1.699
Threats	0.320	0.052	0.295	6.166	0.000	0.583	1.714
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. error**		**DW**	
0.714	0.509	0.504	95.151 (0.000)	0.392		1.862	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

In Table 8, it is observed that the estimated Equation (2) for Bitlis Province is significant at the 1% significance level (F-statistic (p) = 0.000) and has an explanatory power of 50.4%. The Durbin-Watson (DW) value (1 < 1.86 < 2.5) indicates no autocorrelation, and the Variance Inflation Factor (VIF) values (< 3) confirm the absence of multicollinearity issues. According to the estimation results, the SWOT (Strengths, Weaknesses, Opportunities, and Threats) of establishing a biomass recycling and distribution facility in Bitlis Province has positive and statistically significant effects on the economic indicator of SLD. A one-unit increase in the SWOT variables yields positive effects of 0.21, 0.11, 0.29, and 0.32 on the economic indicators, respectively. Among these, the variable with the most significant impact on the economic indicator in Bitlis Province is threats.

Overall, the regression results indicate that establishing a biomass recycling and distribution facility in the TRB2 Region and its provinces would significantly affect SLD's economic indicators, primarily through the opportunities it creates. The findings regarding SLD's economic indicator agree with those of prominent researchers such as Bergmann et al. (2006), Zhu et al. (2011), Liu et al. (2013), Kinobe et al. (2015), Shoaib and Ariaratnam (2016), Çınar and Yıldırım (2017), Hess and Gentry (2019), Agrawal and Singh (2019), Guarnieri et al. (2020), Tunacan et al. (2020), Surya et al. (2021), Azam et al. (2021), and Kostha et al. (2022). These studies underline the positive economic impacts of RES, production facilities, and reverse logistics systems.

3.3.1.2. Estimation Results Regarding Equation (3)

Equation (3) was estimated separately for the TRB2 Region and its provinces, and the findings are shown in Tables 9, 10, 11, 12, and 13.

Table: 9
Findings Related to the TRB2 Region

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	-0.105	0.134		-0.781	0.435		
Strengths side	0.249	0.032	0.197	7.791	0.000	0.607	1.648
Weaknesses side	0.248	0.031	0.241	8.110	0.000	0.440	2.273
Opportunities	0.391	0.034	0.270	11.438	0.000	0.696	1.438
Threats	0.155	0.031	0.143	4.998	0.000	0.475	2.106
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.677	0.458	0.456	294.315 (0.000)	0.495		1.547	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

Table 9 shows that the estimated Equation (3) for the TRB2 Region is significant at the 1% level (F-stat. (p) = 0.000), with an explanatory power of 45.6%. The DW value (1 < 1.55 < 2.5) indicates no autocorrelation, and the VIF values (< 3) suggest no multicollinearity. According to the estimation results, the SWOT analysis of a biomass recycling and distribution facility to be established in the TRB2 Region has a positive and statistically significant effect on the social indicator SLD. A one-unit increase in the strengths, weaknesses, opportunities, and threats variables positively influences the social indicator by 0.25, 0.25, 0.32, and 0.16 units, respectively. Among these, opportunities are identified as the most influential variable affecting the SLD social indicator in the TRB2 Region.

Table: 10
Findings Related to the Van Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	-0.135	0.268		-0.506	0.613		
Strengths side	0.193	0.065	0.152	2.954	0.003	0.509	1.966
Weaknesses side	0.382	0.066	0.354	5.815	0.000	0.362	2.765
Opportunities	0.117	0.078	0.068	1.495	0.136	0.641	1.561
Threats	0.302	0.070	0.268	4.321	0.000	0.349	2.869
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.739	0.546	0.541	102.016 (0.000)	0.522		2.064	

Note: Only findings with p < 0.05 (95% confidence) are interpreted.

Table 10 shows that the estimated Equation (3) for Van Province is significant at the 1% level (F-stat. (p) = 0.000) with an explanatory power of 54.1%. The DW value (1 < 2.064 < 2.5) indicates no autocorrelation, and the VIF values (< 3) suggest no multicollinearity. The estimation results indicate that the strengths, weaknesses, and threats associated with establishing a biomass recycling and distribution facility in Van Province have a positive and significant effect on the social indicator of SLD. A one-unit increase in the strengths, weaknesses, and threats variables raises the social indicator by 0.19, 0.38, and 0.30 units, respectively. Among these, the weakness variable has the most considerable impact on the social indicator of SLD in Van Province. For the Opportunities dimension (p = 0.136), which exceeds the 0.05 threshold, the result is not statistically significant.

Table: 11
Findings Related to the Hakkari Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	3.035	0.333		9.123	0.000		
Strengths side	0.018	0.048	0.023	0.369	0.712	0.801	1.248
Weaknesses side	0.072	0.042	0.145	1.742	0.183	0.434	2.306
Opportunities	0.213	0.077	0.168	2.762	0.006	0.816	1.225
Threats	0.022	0.043	0.042	0.517	0.606	0.448	2.232
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.883	0.680	0.668	60.620 (0.000)	0.372		1.934	

Note: Only findings with p < 0.05 (95% confidence) are interpreted.

Table 11 shows that the estimated Equation (3) for Hakkari Province is significant at the 1% level (F-stat. (p) = 0.000), with an explanatory power of 66.2%. The DW statistic (1 < 1.93 < 2.5) indicates no autocorrelation, while the VIF values (< 3) suggest no multicollinearity. According to the estimation results, establishing a biomass recycling and distribution facility in Hakkari Province has a positive and statistically significant effect on the social indicator SLD. A one-unit increase in the opportunities variable positively influences the social indicator by 0.21 units. In Hakkari Province, opportunities are the only variable affecting the social indicator of SLD. Regarding the weaknesses, (p = 0.183), which exceeds the 0.05 threshold, the result is not statistically significant.

Table: 12
Findings Related to the Muş Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	1.365	0.203		6.729	0.000		
Strengths side	0.126	0.047	0.141	2.676	0.008	0.544	1.839
Weaknesses side	-0.022	0.047	-0.024	-0.463	0.644	0.586	1.706
Opportunities	0.591	0.043	0.599	13.830	0.000	0.806	1.240
Threats	0.013	0.041	0.015	0.319	0.750	0.643	1.556
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.665	0.442	0.436	73.127 (0.000)	0.283		1.961	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

Table 12 shows that the estimated Equation (3) for Muş Province is significant at the 1% significance level (F-stat. (p) = 0.000), with an explanatory power of 43.6%. The DW statistic (1 < 1.96 < 2.5) indicates no autocorrelation, while the VIF values (< 3) suggest no multicollinearity. According to the estimation results, establishing a biomass recycling and distribution centre in Muş Province has positive and statistically significant effects on the social indicator SLD. A one-unit increase in the opportunities and threats variables positively impacts the social indicator by 0.13 and 0.59 units, respectively. Among these, opportunities have the most significant impact on the social indicator of SLD in Muş Province. For the Weaknesses and threats sides respectively (p = 0.644) and (p=0.750), which exceed the 0.05 threshold, the results are not statistically significant.

Table: 13
Findings Related to the Bitlis Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	0.416	0.219		1.899	0.058		
Strengths side	0.220	0.063	0.182	3.476	0.001	0.527	1.899
Weaknesses side	0.160	0.061	0.141	2.635	0.009	0.508	1.969
Opportunities	0.393	0.055	0.357	7.172	0.000	0.586	1.707
Threats	0.167	0.057	0.145	2.909	0.004	0.581	1.721
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.683	0.467	0.461	80.640 (0.000)	0.432		2.069	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

Table 13 shows that the estimated Equation (3) for Bitlis Province is significant at the 1% level (F-stat. (p) = 0.000), with an explanatory power of 46.1%. The DW value (1 < 2.07 < 2.5) indicates no autocorrelation, and the VIF values (< 3) suggest no multicollinearity. According to the results, the SWOT analysis of a planned biomass recycling and distribution facility in Bitlis Province has positive and statistically significant effects on the social indicator SLD. A one-unit increase in the strengths, weaknesses, opportunities, and threats variables yields positive effects of 0.22, 0.16, 0.39, and 0.17 on the social indicator, respectively. Among these, opportunities are the most influential variable affecting SLD's social indicator in Bitlis Province.

Overall, the regression results indicate that the opportunities provided by a biomass recycling and distribution facility to be established in the TRB2 Region and its provinces are the most influential factor on the social indicator SLD. These findings related to the social indicator of SLD are consistent with the fundamental studies conducted by Chandrasekar and Kandpal (2007), Liu et al. (2013), Shoaib and Ariaratnam (2016), Dupal et al. (2016), Surya et al. (2021), and Kostha et al. (2022).

3.3.1.3. Estimation Results Regarding Equation (4)

Equation (4) has been estimated separately for the TRB2 Region and its provinces, with the results shown in Tables 14, 15, 16, 17, and 18.

Table: 14
Findings Related to the TRB2 Region

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	1.309	0.099		13.211	0.000		
Strengths side	0.180	0.024	0.204	7.609	0.000	0.600	1.666
Weaknesses side	0.012	0.023	0.016	0.513	0.608	0.447	2.235
Opportunities	0.395	0.025	0.388	15.587	0.000	0.695	1.439
Threats	0.127	0.023	0.165	5.498	0.000	0.476	2.100
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.632	0.400	0.398	232.042 (0.000)	0.368		1.887	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

Table 14 indicates that the estimated Equation (4) for the TRB2 Region is significant at the 1% level (F-stat. (p) = 0.000) with an explanatory power of 39.8%. The DW value (1 < 1.89 < 2.5) indicates no autocorrelation, while the VIF values (< 3) indicate no multicollinearity. According to the estimation results, the strengths, opportunities, and threats associated with establishing a biomass recycling and distribution facility in the TRB2 Region have positive and statistically significant effects on the environmental indicator SLD. A one-unit increase in the strengths, opportunities, and threats variables, respectively, raises the environmental indicator by 0.18, 0.40, and 0.13 units. Among these, opportunities are the most influential factor on the environmental indicator of SLD in the TRB2 Region. For the 'Weaknesses' variable (p = 0.608), which exceeds the 0.05 threshold, the result is not statistically significant.

Table: 15
Findings Related to the Van Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	1.681	0.194		8.677	0.000		
Strengths side	0.240	0.048	0.300	4.969	0.000	0.497	2.012
Weaknesses side	0.049	0.049	0.070	0.997	0.320	0.371	2.692
Opportunities	0.224	0.058	0.210	3.888	0.000	0.617	1.620
Threats	0.103	0.051	0.143	2.001	0.046	0.354	2.824
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.612	0.374	0.367	51.723 (0.000)	0.392		1.791	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

Table 15 shows that the estimated Equation (4) for Van Province is significant at the 1% level (F-stat. (p) = 0.000), with an explanatory power of 36.7%. The DW value (1 < 1.79

< 2.5) indicates no autocorrelation, and the VIF values (< 3) suggest no multicollinearity. According to the estimation results, the strengths, opportunities, and threats associated with establishing a biomass recycling and distribution facility in Van Province have positive and statistically significant effects on the environmental indicator SLD. A one-unit increase in these variables positively impacts the environmental indicator by 0.24, 0.22, and 0.10 units, respectively. Among them, strengths are the most influential variable affecting the environmental indicator of SLD in Van Province. The Weaknesses side (p = 0.320) does not exceed the 0.05 threshold and is not statistically significant.

Table: 16
Findings Related to the Hakkari Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	3.642	0.302		12.045	0.000		
Strengths side	0.020	0.041	0.031	0.490	0.624	0.787	1.270
Weaknesses side	0.029	0.037	0.069	0.789	0.431	0.426	2.346
Opportunities	0.097	0.071	0.087	1.377	0.169	0.813	1.230
Threats	0.045	0.040	0.096	1.140	0.255	0.452	2.211
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.606	0.442	0.429	32.790 (0.000)	0.332		1.545	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

Table 16 shows that the estimated Equation (4) for Hakkari Province is significant at the 1% level (F-stat. (p) = 0.000), with an explanatory power of 42.9%. The DW value (1 < 1.55 < 2.5) indicates no autocorrelation, and the VIF values (< 3) suggest no multicollinearity. According to the estimation results, the SWOT analysis of a biomass recycling and distribution facility to be established in Hakkari Province has no statistically significant effect on the environmental indicator SLD. That is, in this model, none of the predictors have p < 0.05 (Strengths: p=0.624; Weaknesses: p=0.431; Opportunities: p=0.169; Threats: p=0.255). Thus, at the 95% significance level, their effects are not statistically significant.

Table: 17
Findings Related to the Muş Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerance	VIF
Constant	0.703	0.214		3.280	0.001		
Strengths side	0.241	0.050	0.240	4.863	0.000	0.544	1.837
Weaknesses side	-0.132	0.050	-0.127	-2.664	0.008	0.587	1.703
Opportunities	0.690	0.045	0.620	15.253	0.000	0.804	1.243
Threats	0.038	0.044	0.040	0.880	0.379	0.642	1.557
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.714	0.510	0.505	96.054 (0.000)	0.300		2.182	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

Table 17 shows that the estimated Equation (4) for Muş Province is significant at the 1% level (F-stat. (p) = 0.000), with an explanatory power of 50.5%. The DW value (1 < 2.18 < 2.5) indicates no autocorrelation, and the VIF values (< 3) suggest no multicollinearity. According to the results, the strengths and opportunities of establishing a biomass recycling and distribution facility in Muş Province have a positive and significant effect on the environmental indicator SLD. In contrast, weaknesses have a negative and statistically significant impact. A one-unit increase in the strengths, weaknesses, and opportunities variables affects the environmental indicator by 0.24, (-0.13), and 0.69 units, respectively. Among these, opportunities are the most influential variable on the environmental indicator of SLD in Muş Province. For the threat side (p = 0.379), which exceeds the 0.05 significance level, the result is not statistically significant.

Table: 18
Findings Related to the Bitlis Province

	Unstandardized Coefficients		Standardized Coefficients	t stat.	p	Multicollinearity Stat.	
	B	Beta	Beta			Tolerans	VIF
Constant	0.827	0.190		4.353	0.000		
Strengths side	0.203	0.055	0.191	3.696	0.000	0.527	1.897
Weaknesses side	0.064	0.053	0.064	1.208	0.228	0.508	1.969
Opportunities	0.325	0.047	0.336	6.843	0.000	0.585	1.711
Threats	0.251	0.050	0.249	5.046	0.000	0.580	1.723
R	**R^2**	**$\bar{R}^2$**	**F stat. (p)**	**Std. Error**		**DW**	
0.696	0.484	0.478	85.770 (0.000)	0.375		1.755	
Note: Only findings with p < 0.05 (95% confidence) are interpreted.							

Table 18 shows that the estimated Equation (4) for Bitlis Province is significant at the 1% level (F-stat. (p) = 0.000), with an explanatory power of 47.8%. The DW value (1 < 1.76 < 2.5) suggests no autocorrelation, and the VIF values (< 3) indicate no multicollinearity. According to the estimation results, the strengths, opportunities, and threats associated with establishing a biomass recycling and distribution facility in Bitlis Province have positive and statistically significant effects on the environmental indicator SLD. A one-unit increase in the strengths, opportunities, and threats variables, respectively, raises the environmental indicator by 0.20, 0.33, and 0.25 units. Among these, opportunities are the most impactful factor on the environmental indicator of SLD in Bitlis Province. For the Weaknesses side (p = 0.228), which exceeds the 0.05 threshold, the result is not statistically significant.

Overall, the regression results indicate that the opportunities offered by a planned biomass recycling and distribution facility in the TRB2 Region and its provinces significantly influence the environmental indicator of sustainable development. The results about the environmental indicator of sustainable development are in line with the findings of key studies by Ivanova (2005), Bergmann et al. (2006), Swofford and Slattery (2010), Liu et al. (2013), Kinobe et al. (2015), Dupal et al. (2016), Çınar and Yıldırım (2017), Agrawal and Singh (2019), Guarnieria et al. (2020), Tunacan et al. (2020), Surya et al. (2021), and Kostha et al. (2022), which emphasise the positive environmental impacts of renewable energy investments, production, and reverse logistics facilities.

3.3.1.4. Selection of the Province for Establishing the Biomass Recycling and Distribution Facility

Based on the results of the multiple regression analysis, an attempt was made to identify which province in the TRB2 Region would be most suitable for establishing a reverse logistics facility from the perspective of SLD. To achieve this, only statistically significant coefficient values were considered, and the combined scores for strengths and opportunities (SS + O) were compared with those for weaknesses and threats (WS + T). It was assumed that establishing a reverse logistics facility in the province with the highest coefficient value, based on the comparison (SS + O > WS + T), would provide the most significant benefit to SLD in the TRB2 Region.

Table 19 presents the results of a comparison of the effects of the SWOT factors of a proposed biomass recycling and distribution facility on SLD's economic, social, and environmental indicators across provinces.

Table: 19
Selection of the Province for Establishing the Reverse Logistics Facility

Economic	**Van**	**Hakkâri**	**Muş**	**Bitlis**
Strengths side	0.363	-	0.188	0.213
Weaknesses side	-	-	-0.079	0.112
Opportunities	0.308	0.547	0.509	0.294
Threats	0.135	0.087	-	0.320
Comparison	SS + O > T	O> T	SS + O > WS	SS + O > WS + T
	0.671 > 0.135	0.547 > 0.087	0.697 > (-0.079)*	0.507 > 0.432
Social	**Van**	**Hakkâri**	**Muş**	**Bitlis**
Strengths side	0.193	-	0.126	0.220
Weaknesses side	0.382	0.072	-	0.160
Opportunities	-	0.213	0.591	0.393
Threats	0.302	-	-	0.167
Comparison	SS < WS +T	O > WS	SS +O	SS + O > WS + T
	0.193 < 0.684	0.213 > 0.072	0.717*	0.613 > 0.327
Environmental	**Van**	**Hakkâri**	**Muş**	**Bitlis**
Strengths side	0.240	-	0.241	0.203
Weaknesses side	-	-	-0.132	-
Opportunities	0.224	-	0.690	0.325
Threats	0.103	-	-	0.251
Comparison	SS + O > + T	-	SS + O > WS	SS + O > T
	0.464 > 0.103		0.931 > (-0.132)*	0.528 > 0.251

** Indicates the province where the reverse logistics facility will be established.*

According to the table, with respect to the net effects of the SWOT factors on SLD's economic indicator, Muş has the highest performance, followed by Van, Hakkâri, and Bitlis. For the social indicator, Muş again leads, with Bitlis and Hakkâri trailing behind. In Van Province, however, the net effect is such that SS < WS + TSS < WS + T. Finally, with respect to SLD's environmental indicator, Muş once again ranks highest, followed by Bitlis and Van. Hakkâri is not statistically significant for the ecological indicator. As a result, the strengths and opportunities of a biomass recycling and distribution facility in Muş Province exert a greater net impact on SLD's economic, social, and environmental indicators [(SS+O)−(WS+T)] than those in other provinces.

Based on the comparative results of the regression coefficient analysis, it can be concluded that establishing a biomass recycling and distribution facility in Muş Province could contribute to the SLD of other provinces and the TRB2 Region as a whole. By generating added value, this initiative could help reduce income disparities between provinces and regions. To achieve this, it is essential to prioritise investments in the mobilisation of biomass resources and to emphasise collaboration among local stakeholders.

4. Conclusion

This study examined the impacts of SWOT factors associated with a planned biomass recycling and distribution facility in the TRB2 Region on economic, social, and environmental indicators of sustainable development. It also identified the most suitable province for establishing such a facility. To achieve this, a field survey employing a questionnaire targeting agricultural and livestock enterprises was conducted, and the primary data were analysed using multiple regression.

To identify the dependent and independent variables for the regression equations, preliminary tests such as Cronbach's Alpha, the Kaiser-Meyer-Olkin (KMO) measure, Bartlett's test of sphericity, and exploratory factor analyses were conducted. These tests verified the reliability and validity of the survey questions. Subsequently, the average perception scores from participants' responses were used as the data for both the dependent and independent variables.

The regression estimation results showed that the SWOT factors of a biomass recycling and distribution facility, at both regional and provincial levels within the TRB2 Region, significantly influence the economic, social, and environmental indicators of sustainable development. Among these, the most influential variable is the "opportunities" factor.

Based on the results of the multiple regression analysis, an effort was made to identify which province in the TRB2 Region would be most suitable for establishing a reverse logistics centre from a sustainable development standpoint. For this purpose, the statistically significant coefficient values were considered, and using the formula SS+O>WS+TSY + O > WS + TSS+O>WS+T, the province with the highest coefficient value was recognised as Muş.

Based on the analysis results, it can be concluded that establishing a biomass recycling and distribution facility in Muş Province has the potential to contribute to the SLD of both other provinces and the TRB2 Region as a whole. By generating added value, such an initiative could help reduce income disparities between provinces and regions. This would transform Muş into a reverse logistics hub, leveraging forward, reverse, and lateral linkages to advance SLD and help close regional development gaps. Additionally, establishing a facility in the province would increase local value added and employment; integrating SMEs into repair/remanufacturing and pre-processing would create new value chains and diversify incomes. Socially, strengthening cooperative-based supply relations with farm and livestock enterprises, alongside investments in skills, jobs, and capability building (such as occupational health and safety, quality/traceability, and training), would promote inclusive development and reinforce stakeholder collaboration and local governance capacity. Environmentally, source separation and pre-processing would reduce open burning and uncontrolled dumping, improve recovery rates, and, through shorter logistics loops and greater backhaul, lower carbon intensity and transport-related emissions; standardisation and traceability would limit leakage and pollution risks, and institutionalise circularity. Furthermore, by valorising agricultural and livestock residues as renewable energy feedstocks (biomass), the facility would reduce greenhouse gas emissions through fossil-fuel substitution and limit methane (CH_4) and black carbon emissions. Together, these channels suggest that a biomass recycling and distribution facility in Muş could simultaneously enhance SLD indicators.

To ensure the success of a reverse logistics facility in Muş Province and to attain SLD in the TRB2 Region, several measures are vital. These include incentivising biomass energy production and consumption suitable for reverse logistics through mechanisms such as tax reductions, targeted credits, project support, price purchase guarantees, and licence exemptions. Additionally, supporting the cultivation of energy crops, formalising the biomass sector, establishing forward and backward supply chains, prioritising public-private investments to mobilise biomass resources, fostering an environment that encourages collaboration among local stakeholders, conducting educational activities on the subject, and developing effective and practical policies tailored to the province and region are of utmost importance.

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