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Supply Chain Sustainability Measurement in Telecommunications Industry in Indonesia

Abdullah Nabil[1], Muhammad Asrol[2*]

[1,2] Industrial Engineering Department, BINUS Graduate Program – Master of Industrial Engineering,
Bina Nusantara University,
Jakarta, Indonesia 11480
abdullah.nabil@binus.ac.id; muhammad.asrol@binus.edu

*Correspondence: muhammad.asrol@binus.edu

Abstract *– In the fiercely competitive telecommunications industry of Indonesia, the significance of innovation and perpetual improvement cannot be underestimated. It is imperative for businesses to explore the potential of sustainable supply chain management, as it allows for the integration of environmental, economic, and social dimensions. By implementing a comprehensive and thorough approach, this study offers a theoretical framework for measuring sustainable supply chain performance. Through qualitative and quantitative methods, you'll be able to identify the attributes that greatly impact the success of your sustainable supply chain management. On this research Analytic Hierarchy Process (AHP) utilize to define Consistency Ratio (CR) and weight between dimension using SuperDecisions software. Then, Multidimensional Scaling (MDS) is utilized to measure performance of supply chain sustainability. At the same time, a stress value also measured to indicate the sustainability measurement of one specific dimension is sufficient in accordance with existing condition or not. Next, to better indicate which attributes are most influential on improving dimensional sustainability performance, it is essential to conduct a sensitivity analysis and Montecarlo analysis for each attribute. In the end, this research successfully determined which attributes that influence sustainable supply chain management and measure the value of supply chain sustainability in the telecommunications industry in Indonesia.*

Keywords: *Sustainability; Telecommunication Industry; Supply Chain; Indonesia*

I. INTRODUCTION

Indonesia's telecommunications industry is one of the most dynamic with fierce competition in Indonesia. Many cellular operators cannot survive in the cellular telecommunications industry market because of the competitive market. Many telecommunications companies choose to merge with other cellular operators to stay in the market (Widiastuti & Sylviana, 2020). Telecommunication industry regulation has been regulated through Law No. 36 of 1999 which has provided opportunities for competition and antitrust (Palinggi & Allolinggi, 2020). With the health of this competition space, it increasingly makes a profitable market for the community and government. Another thing that we can analyze is the development of the telecommunications industry from the end user side. This can also be seen from the level of household consumption in Indonesia from 2016 increased by around 40% in 2022. This synergy between technological developments and consumption levels shows that telecommunications are increasingly becoming a basic need for the Indonesian people.

Currently there are four telecommunication service providers in Indonesia, namely: PT Telekomunikasi Selular, PT Indosat Tbk, PT XL Axiata Tbk and PT. Smartfren Telecom Tbk. Currently PT Telekomunikasi Selular with Telkomsel products holds the largest market share in Indonesia, followed by PT Indosat Tbk (IOH).

All these telecommunication service providers have vendors who are experienced in supplying various telecommunications devices such as Huawei, Nokia, and Ericsson. Furthermore, this vendor recruited several more local telecommunications companies as construction

service providers.

As mentioned earlier, the telecommunications industry in Indonesia is a complex and growing sector. It is essential to understand supply chain mechanisms and schemes to ensure that the industry remains competitive and efficient.

The application of supply chains in the telecommunications industry starts from telecommunications operators as network owners who hand over network development to several telecommunications vendors.

Broadly speaking, telecommunications vendors will design network coverage, obtain permission from the government and the community, carry out pre-designed telecommunications equipment installation work and ensure network reliability after the handover process is rarely from vendor to operator completed. Furthermore, the vendor will distribute the work to subcontractors according to their respective capabilities.

The implementation of sustainable supply chain management in the telecommunications industry in Indonesia can bring several benefits to the industry. First, it can help reduce costs associated with supply chains, as sustainable practices often involve reducing waste and increasing efficiency.

This can lead to lower operating costs, which can be passed on to customers in the form of lower prices. Second, implementing this sustainable supply chain management can help boost the industry's reputation, as customers increasingly seek out companies committed to sustainability.

This can lead to increased customer loyalty and higher sales. Finally, it can help reduce the environmental impact associated with such telecommunications industries.

II. METHODS

Sustainable supply chain management is the strategic, transparent integration and achievement of an organization' social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains (Carter & Rogers, 2008). The performance of SSCM is based on the triple bottom line approach encompassing people-planet-profit, hence being defined not in only in social and environmental terms, but also the economic (Baliga et al., 2020)

Definition of sustainable supply chains is not restricted to so-called "green" supply chains, but recognizes that to be truly sustainable, supply chains must operate within a realistic financial structure, as well as contribute value to our society (Grant et al., 2023).

Collecting data is an integral part of a business's success; it can enable you to ensure the data's accuracy, completeness, and relevance to your organization and the issue at hand (Catherine, 2021) Broadly speaking, the stages in this research start from problem formulation, literature study, data collection, data processing then analysis and testing of the results of data processing and equipped with conclusions. Illustratively, the stages of research can be seen in Figure 1 while the explanation is explained as follows.

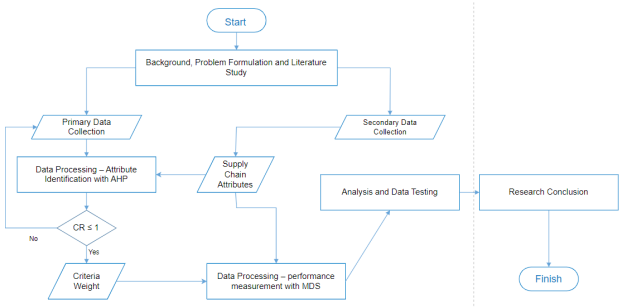

Figure 1. Stages of research

This research starts with problem formulation and literature study about telecommunication industry and its condition relate to supply chain sustainability. While primary research involves active participation from the researcher themselves, secondary research involves the summary or synthesis of data and literature that has been organized and published by others (Bouchrika, 2024). Then, data collection for both secondary and primary data. Secondary data collection developed dimensions and attributes of sustainable supply chain collected from relevant textbooks and journal mostly focusing on sustainable supply chain management. Primary data collection using expert responded questionnaire. Then, result of this questionnaire was processed or calculated using AHP methods using SuperDecisions software and MDS methods. Afterwards, result of data calculation were analyzed and tested. Finally, the conclusion of this research is presented.

As mentioned before, there are three dimensions used in measuring sustainability impacts, economic, social, and environmental (Cetinkaya et al., 2011). Furthermore, it is essential to define sub-dimensions to describe more detail on dimensions, shown in Table I:

Table I. Sustainability Dimensions & Attributes

No.	Dimension	Attribute
1	Economy	Quality
		Ability to respond change
		Efficiency
		Technology
2	Environment Impact	Emission
		Waste and recycle
		Environmentally friendly operations management
		Use of natural resources
3	Social Development	Occupational safety and health
		Corporate Social Responsibility
		Stakeholder development

The decision of the sub-dimensions of sustainable supply chains refers to the explanation of Wojciech Piotrowicz from Oxford University, England in his book 'Sustainable Supply Chain Management: Practical Ideas for Moving Towards Best Practice'. In addition, the author

also extracts from Robert P. Sroufe and Steven A. Melnyk in the book 'Developing Sustainable Supply Chains to Drive Value'.

The economic dimension of sustainability relates to the economic benefits derived by supply chain members, including the communities, regions, and countries in which operations are carried out (Sánchez-Flores et al., 2020).

The economic dimension is connected to the possibility on the one hand of reducing business costs, administrative costs and invested capital and, on the other hand, increasing returns and market appreciation (Belvedere & Grando, 2017).

Then, supply chain sustainability with an environmental dimension in mind is about how the interaction between environmental sustainability and supply chain management emphasizes expansion beyond internal operations and core supply chain practices (Pragmawiguno et al., 2023).

Lastly, to be socially sustainable, activities must be satisfactory to all stakeholders: shareholders, employees, customers, governments, and communities where the company operates. Social sustainability often relates to ethical concerns around human rights, labor conditions and minority development (Kreye, 2023).

2.1 Data Calculation

As shown on figure 1, this research uses two methods of calculation which are Analytic Hierarchy Process (AHP) and Multidimensional Scaling (MDS). Firstly, AHP methods was calculated.

2.2 Analytic Hierarchy Process (AHP)

The application of the analytic hierarchy method (AHP) that aims to calculate the priorities of each alternative against a set of criteria (Leal, 2020). On this research Analytic Hierarchy Process (AHP) use to define Consistency Ratio (CR) and weight between attributes using SuperDecisions software.

In this research, we have five respondents including one from academia and four from telecommunication professionals. Experience from professionals and academia is used to estimate the relative size of factors through pairwise comparisons. The questionnaire uses pairwise comparisons based on experience from experts. Respondents had to compare the relative importance between the two items that uses a scale of 1 to 9 to describe the expected data. Respondents compare the importance between dimensions of sustainability supply chain. Then, respondents compare the importance between attributes in same dimension. After getting the result, this data being processed to define the geomean of each respondent. This calculation will be an input to SuperDecision software for AHP methods calculations.

Consistency ratio (CR) is a measure of consistency used in the Analytic Hierarchy Process (AHP) used to measure the degree of inconsistency in paired comparison matrices. A CR of less than 0.1 can mean that there is a probability of less than 10% of questionnaire respondents giving random answers. The measurement of ratio consistency in this study was to evaluate whether respondents' answers had a random probability of less than 10%.

Weighted attributes describe the significance of influence between attributes. The higher random probability of one attribute means the more significance this attribute compares to others.

2.3 Multidimensional Scaling

Multidimensional Scaling (MDS) is a method used in this study to measure the performance of sustainable supply chain management in the telecommunications industry in Indonesia. Furthermore, MDS is a method used in performance measurement to analyse and visualize complex data. Multidimensional scaling (MDS) is one of the dimensionality reduction technique which has been used extensively in the recent past for wireless networks localization (Saeed, 2019). MDS helps to assess the performance of multiple factors or dimensions simultaneously. The advantage MDS-based data dimension reduction is its ability to visualize the level of similarity of a traffic flow data set (Zhao et al., 2018).

To start MDS calculation refer to different questionnaire from AHP calculation. There are four respondents (one academia and three telecommunication professionals). This questionnaire uses direct scoring for every attribute and define its modes.

On this research, Multidimensional Scaling (MDS) is used to measure performance of supply chain sustainability using RAPFISH. At the same time, a stress value also measured to show the sustainability measurement of one specific dimension is sufficient following existing condition or not. Also required to calculate Root Square Correlation (RSQ) of one specific dimension, which can be concluded that how many percentage (%) of attributes used on a specific dimension can be explained well or not.

Furthermore, to better show which attributes are most influential on improving dimensional sustainability performance, it is essential to conduct a leverage analysis for each attribute. The highest leverage value of one attribute means the most influential attribute to increase the performance of sustainability of supply chain.

Lastly, to verify that errors in scoring by respondents of each attribute are small or in other words the diversity of scoring due to differences in respondents' opinions is small, Monte Carlo analysis which illustrate on scatter plot is needed. The Monte Carlo methods for obtaining estimates of answers for well posed problems for which quantitative answers exist (Dunn and Shultis, 2021) The more scattered value of sustainability performance (resulted from MDS calculation), the more diverse of scoring from experts.

III. RESULTS AND DISCUSSIONS

This section describes the obtained findings gathered from this research and explain what the collected results mean and what is their importance and contribution to this research.

3.1 Questionnaire Result

As described above, that questionnaire developed with experts from academia, telecommunication professionals as respondents, shown in Table II and Table III.

Table II. Questionnaire Result for Dimension (AHP)

Dimension	Respondents					Dimension	Geo Mean
	Aa	Bb	Cc	Dd	Ee		
Economy	5	8	0.20	1	3	Environment Impact	1.89
Economy	3	7	0.33	4	3	Social Development	2.43
Environment Impact	6	0.17	7	0.17	0.33	Social Development	0.83

Table III. Questionnaire Result for Attributes (AHP)

Attributes	Respondents					Attributes	Geo Mean
	Aa	Bb	Cc	Dd	Ee		
Quality	6	0.14	7	3	3	Efficiency	2.22
Quality	7	6	7	0.25	3	Technology	2.94
Ability to respond change	1	0.14	1	3	1	Quality	0.84
Efficiency	5	8	5	3	1	Technology	3.59
Efficiency	5	8	1	1	0.33	Ability to respond change	1.68
Emission	4	0.14	3	0.25	3	Use of natural resources	1.05
Emission	4	0.14	1	0.25	0.33	Waste and recycle	0.54
Emission	4	0.14	3	0.25	0.33	Environmentally friendly operations management	0.68
Use of natural resources	5	0.14	0.33	1	0.20	Waste and recycle	0.54
Use of natural resources	0.25	0.13	5	1	0.33	Environmentally friendly operations management	0.55
Waste and recycle	0.25	0.13	1	1	1	Environmentally friendly operations management	0.50
Occupational safety and health	8	8	3	1	5	Corporate Social Responsibility	3.95
Occupational safety and health	8	8	7	3	7	Stakeholder development	6.23
Corporate Social Responsibility	7	0.14	7	3	3	Stakeholder development	2.29

Table II and III data will be submitted to SuperDecision software for AHP method calculations.

Table IV. Questionnaire Result for Attributes (MDS)

Dimension	Attribute	Mode
Economy	Quality	9
	Ability to respond change	9
	Efficiency	7
	Technology	7
Environment Impact	Emission	6
	Waste and recycle	6
	Environmentally friendly operations management	7
	Use of natural resources	7
Social Development	Occupational safety and health	9
	Corporate Social Responsibility	7
	Stakeholder development	9

Finally, Table IV. data will be submitted to start MDS calculation.

3.2 Attributes Identification

As mentioned before, this research uses Analytic Hierarchy Process (AHP) as an analytical tool to identify attributes and/or dimension which have high influence compares to others.

After questionnaire data from experts processed and uploaded to SuperDecision software, as illustrated on below Table V:

Tabel V. Critical Ratio and Attributes Weight

Supply Chain Dimension	Critical Ratio	Attributes Weight
Economic	0.065	0.51
Environmental Impact	0.033	0.24
Social Development	0.015	0.25

All dimensios have a consistency ratio below 0.1 or a random probability below 10%. The researcher concluded that the answers from respondents had a tolerable ratio consistency so that it could proceed to measuring the weighting attributes of sustainability supply chain.

Furthermore, researchers can also conclude that the most prominent dimension of the supply chain is the economic dimension. With an attributes weight of 0.51, the economic dimension is more important than the other two dimensions. Other two dimensions (environmental impact and social development) share similar weight, which means that these two dimension share almost similar importance.

To be able to survive in the long term, it is inevitable for the company to continue to be profitable. Stable and sustainable profits provide a strong foundation for business development and enable companies to face future challenges and risks. So in conclusion, good economic performance is the main foundation for the continuity of a company's operations. Moreover, it is entailed calculation to define which attributes which have high influence compares to other attributes.

The following are the results the weight of supply chain sustainability attributes in the telecommunications industry in Indonesia using the Analytic Hierarchy Process (AHP) method, shown in Table VI:

Tabel VI. Sustainability Attributes Rank

Rank	Atribut	Normal
1	Quality	0.2007
2	Occupational safety and health	0.1724
3	Efficiency	0.1509
4	Ability to respond to change	0.1078
5	Environmentally friendly operations management	0.0869
6	Waste and recycling	0.0649
7	Technology	0.0578
8	Corporate Social Responsibility	0.0494
9	Emission	0.0442
10	Use of natural resources	0.0405
11	Stakeholder development	0.0245

Attribute 'quality' is the most important attribute of the sustainability of the supply chain of the telecommunication industry in Indonesia. Followed by 'occupational Safety and Health' and 'efficiency'. These three attributes indicate as the focus of this industry.

The three attributes with most least importance attributes are 'stakeholder development', 'use of natural resources' and 'emission'.

3.3 Performance Measurement

On this research, Multidimensional Scaling (MDS) is used to measure performance of supply chain sustainability. After questionnaire data from experts processed and uploaded to RAPFISH, as illustrated on below Table VII:

Tabel VII. Dimension Sustainability Performance

Dimension	Sustainability Performance	Stress	Squared Correlation (RSQ)
Economic	69.10	0.17	0.94
Environmental Impact	56.24	0.19	0.92
Social Development	72.56	0.18	0.92

Table VII will be explained per dimensions on following sub-section.

3.4 Supply Chain Performance Measurement – Dimension Economy

Dimension economic consists of four attributes which are quality, ability to respond to change, efficiency, and technology. As shown on table 7, sustainability performance value for dimension Economic is 69.10, this shows that the economic dimension is quite sustainable. Achieving an acceptable sustainable economic performance involves finding a balance between short-term financial goals and long-term value creation.

A stress value of 0.17 shows that the resulting analysis is sufficient following existing conditions. This is reinforced by the coefficient of determination (RSQ) in this economic dimension of 0.94, it can be concluded that 94% of the attributes used in the economic dimension can be explained very well.

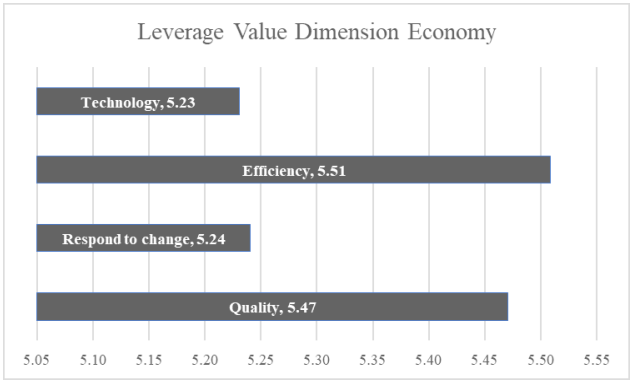

Figure 2. Leverage Value Dimension Economic

To better show which attributes are most influential in improving dimensional sustainability performance, it is compulsory to conduct a leverage analysis for each attribute.

Quality and efficiency attributes are the attributes that play the most role in increasing the sustainability value of supply chain management with score 5.47 and 5.51 respectively. All stakeholders may consider fully focus on these two attributes but at the same time do not forget the other two attributes.

Furthermore, to validate errors in scoring by expert respondents of each attribute are relatively small or in other words the diversity of scoring due to differences in respondents' opinions is relatively small, Monte Carlo analysis is needed.

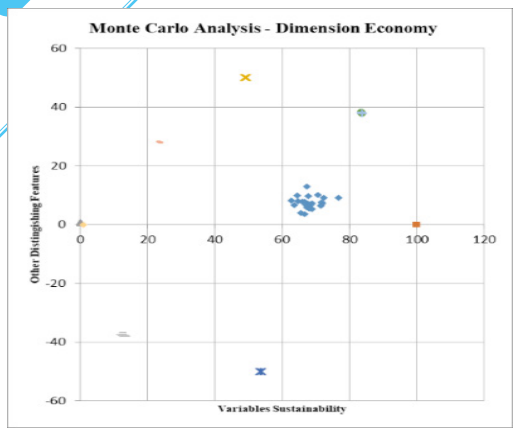

Figure 3. Monte Carlo Analysis – Dimension Economy

For the Economic dimension, it can be concluded that the scoring results from respondents are valid. Twenty-five iterations were carried out resulting in plots that did not scatter out.

3.5 Supply Chain Performance Measurement – Dimension Environmental Impact

There are four attributes of the environmental impact dimension, namely emissions, waste and recycling, environmentally friendly operations management and the use of natural resources.

Refer to table 7. shown that sustainability supply chain performance value is 56.24. this shows that the environmental impact dimension is quite sustainable. Dimension environmental impacts slightly lower on sustainability performance compared to dimension economic. This result denotes that telecommunication

company in Indonesia put high attention to dimension economic.

A stress value of 0.19 indicates that the sustainability measurement of this dimension of environmental impact is sufficient in accordance with existing conditions. The same conclusion is also obtained from the coefficient of determination (RSQ) in this economic dimension of 0.92, in other words 92% of the attributes used in the environmental impact dimension can be explained very well.

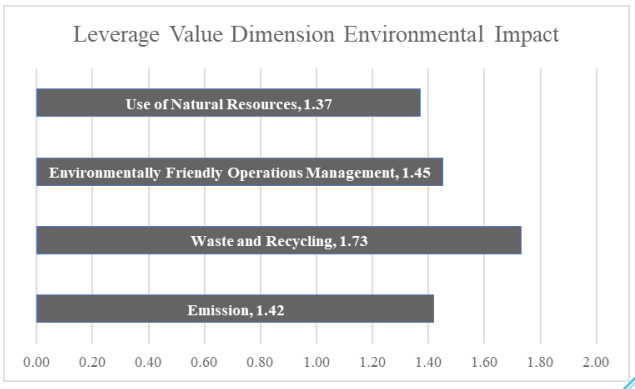

Figure 4. Leverage Value Dimension Environmental Impact

To maximize leverage value of environmental impact attributes, it is crucial to prioritize waste and recycling attributes. These attributes hold the highest leverage score and therefore require immediate attention to enhance the sustainability value of supply chain management.

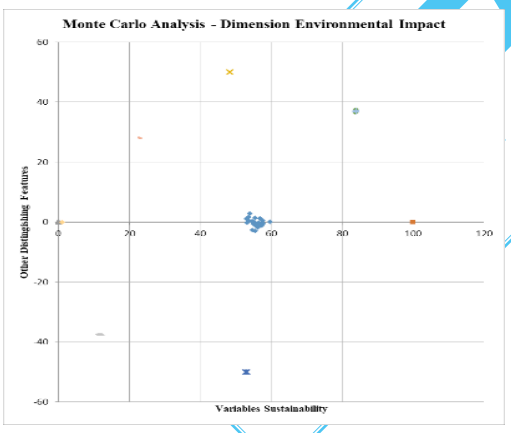

Figure 5. Monte Carlo Analysis – Dimension Environmental Impact

Furthermore, Monte Carlo analysis was conducted with twenty-five iterations presenting the validity of respondent data visually. For the environmental impact dimension, it can be concluded that the scoring results from respondents are valid and produce a gathering plot.

3.6 Supply Chain Performance Measurement – Dimension Social Development

Lastly, the last dimension is social development. Here are three attributes of the social development dimension, namely occupational safety and health, corporate social responsibility, and stakeholder development.

Refer to Table VII, the social development dimension of sustainable supply chain management in the telecommunications industry in Indonesia has a performance value of 72.56. So, it can be concluded that the dimension of social development is also quite sustainable. Achieving maturity in sustainable supply chain practices requires organizations to go beyond mere compliance with regulations. It involves actively engaging stakeholders, fostering transparency throughout the value chain, promoting fair trade practices, supporting local communities, and continuously improving environmental performance.

A stress value of 0.18 shows that the resulting analysis is sufficient following existing conditions. This is reinforced by the coefficient of determination (RSQ) in this dimension of social development valued at 0.92, or in other words 92% of the attributes used in the dimension of social development can be explained very well.

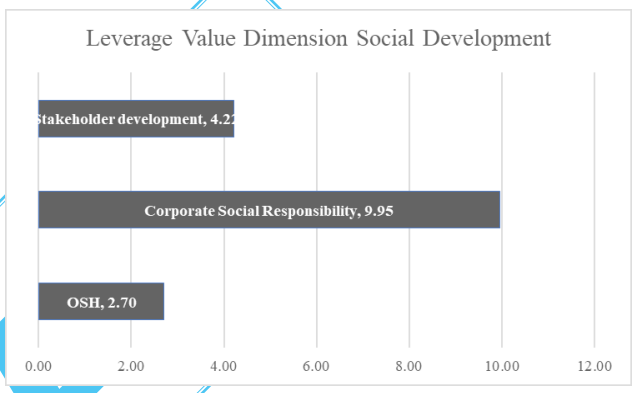

Figure 6. Leverage Value Dimension Social Development

The attribute of corporate social responsibility is the attribute with the highest critical leverage value with score 9.95. To increase the sustainability value of supply chain management in the social development dimension, this attribute must be given special attention at once.

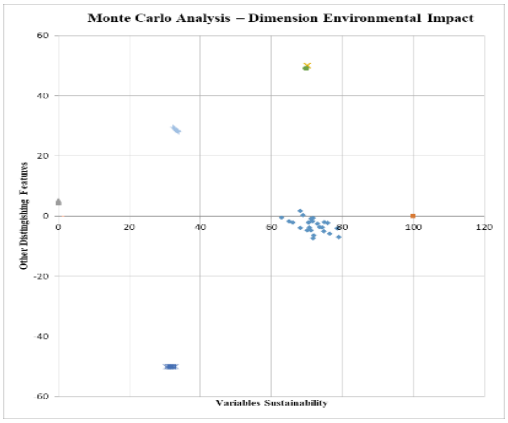

Figure 7. Monte Carlo Analysis – Dimension Social Development

Then, to confirm the uniformity of respondent data requires Monte Carlo analysis. For the social development dimension, it can be concluded that the scoring results from respondents are valid. This is visualized by Figure 7 plotting twenty-five non-scatter iteration values.

IV. CONCLUSION

This study successfully determined the attributes that influence sustainable supply chain management. The determination of attributes and dimensions of this supply chain uses a scientific and proven method, namely AHP. The economic dimension is the dimension with the highest level of importance compared to the other two dimensions.

This research also succeeded in measuring the value of supply chain sustainability in the telecommunications industry in Indonesia. This measurement also uses a method that is also scientific and tested, namely the MDS method using the RAPFISH tool. All dimensions in this study can be categorized as quite sustainable. The social development dimension has the highest sustainability value compared to the other two dimensions.

Environmental impact dimension is the least sustainable compared to other dimension in telecommunication industry in Indonesia. Therefore, to increase sustainability, need to increase awareness from society of waste management and recycling.

On the other hand, social development dimension has the highest score compared to other two dimensions. Yet, improvement still required, especially attribute corporate social responsibility needs to prioritize by every stakeholder including governments. Without this synergy, it will be very hard to increase the sustainability score.

Overall conclusion, performance score of sustainable supply chain in telecommunication industry in Indonesia is quite sustainable. It will require more effort from every stakeholders to achieve balance on life, nature and business.

This research focuses more on the telecommunications industry in Indonesia, further research can focus more on smaller entities of the telecommunications industry, such as IoT business, cloud technology, cellular business and so on. In addition, future research can focus more on narrower coverage areas, such as only in certain big cities in Indonesia.

Future research can also explore the use of other scientific methods in measuring the sustainability of supply chain management in the telecommunications industry in Indonesia, such as KPCA (Kernel Principal Component Analysis), SVD (Singular Value Decomposition) and so on.

Future research could also focus on developing a sustainability prediction model framework.

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