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Analysis of Relation Between Indicators in the Sustainable Development Goals in Indonesia Using Higher-Order PLS-PM

Fatimah Ihza Aulia[1a], Subchan Subchan[2b*]

Abstract: The world has been placing greater emphasis on the Sustainable Development Goals (SDGs) over the last decade, including in Indonesia. The SDGs represent a global commitment to enhancing community welfare and are structured around four dimensions: social, economic, environmental, and law and governance. The SDGs include 17 goals and some indicators for their measurement. Indonesia has achieved 62% of the 138 indicators targeted in 2022. The purpose of this research is to model the relationships among the dimensions, goals, and indicators of the SDGs, enabling an analysis of the main factors influencing sustainable development in Indonesia. Higher-Order Partial Least Square Path Modelling (PLS-PM) was used in this research to map the relationship between each dimension, goal, and indicator. The indicators were derived from the annual SDG report as the data from 34 provinces in 2023. The results of the 298 indicators are reduced to 75 indicators that exist its data on provincial level. Goal 3 "Good Health and Well-Being" is giving the most influence in social dimension of SDGs, while for the economic dimension and environment dimension are Goal 8 "Decent Work and Economic Growth" and Goal 13 "Climate Action". The validation of the model shows that its predictive power is 64.55%, indicating that the constructed model closely fits the data. The findings of this study may be the consideration for policymakers in planning sustainable development in Indonesia to achieve the SDGs by 2030.

Keywords: SDGs, Higher-Order PLS-PM, indicator analysis, disaggregated data

1. Introduction

The Sustainable Development Goals (SDGs), or the 2030 Agenda, were declared by the United Nations in 2015 and agreed upon by 193 countries as a global commitment to improving community welfare, replacing the Millennium Development Goals (MDGs) (Rajani & Boluk, 2022). SDGs comprise 17 goals that focus on issues within social, economic, environmental, and law and governance dimensions such as poverty, gender equality, clean energy, justice and others. Indonesia has consistently supported the achievement of the SDGs goals, shown its implementation aligned with national development planning at both the national and sub-national levels. According to the 2023 report on the implementation of SDGs, Indonesia has achieved 62% of the 138 indicators targeted in 2022 (Bappenas, 2023). Several indicators suggest that the achievement status of the SDGs in Indonesia is trending toward reaching targets. However, the majority remain in progress and require substantial efforts to meet the target in 2030. Notably, 55 indicators are at risk of not being achieved, demanding attention since it has been in progress for 10 years.

However, despite these efforts, one of the major challenges in achieving the SDGs lies in their broad and ambitious scope, which spans across 4 dimensions and involves 17 goals, 169 targets, and 241 indicators for measurement. The evaluation of the implementation of the MDGs revealed, among other things, a lack of synergy in efforts to achieve each of the goals (Alisjahbana & Murniningtyas, 2020). Therefore, it is important to understand the interconnections between goals and indicators in the implementation of the SDGs.

To solve this problem, we need a method to discover the relationship between goals and dimensions in SDGs. One of the methods is Partial Least Square Path Modeling (PLS-PM). This model has been done in several research field, such as education (Zafeer et al., 2024), social and management (Maia et al., 2024; Yang et al., 2024), science and technology (de Morais Fernandes et al., 2023; Sun et al., 2024), and other sectors. Likewise, for sustainable development, there have been many studies using PLS-PM to measure the SDGs all over the world. Some of them only discuss one Goal or one sector in a paper, for instance, Bihun et al. (2022) analyze sustainable tourism in Ukraine using PLS PM. This study discusses the most influencing factor in sustainable tourism from the perspective of social, economic, and environmental areas. In Pu & Cheng (2024), PLS-PM was used to see the water quality status in rivers and reservoirs, which is included in Goal 6, in terms of the spatial-temporal dynamics and influence of natural and socioeconomic factors. This paper used a case study in southwest China with annual and seasonal data. The development of studies in PLS-PM, Higher-Order PLS-PM, is also being done, in which the relationship between unobserved variables is carried out in tiers and consisting of lack of observed variables or indicators. Cataldo et al. analyze and address gender

Authors information:
[a]Department of Mathematics, Faculty of Science and Data Analytics, Institut Teknologi Sepuluh Nopember, Surabaya, INDONESIA. E-mail: fatimahihza1@gmail.com[1], subchan@its.ac.id[2]

*Corresponding Author: subchan@its.ac.id.

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equality in EU countries using Higher-Order PLS-PM to achieve SDG Goal 5 (Cataldo et al., 2024). In Cataldo et al. (2019), second-order model in Higher-Order PLS-PM were used to see the quality of life in the historic center of Naples in order to measure the well-being of the citizens (SDGs Goal 3). Meanwhile, there are only few of the studies discussing some of goals and the whole SDGs. Crocetta et al. proposed the model to see the relationship between all of the Goals in social area (Goal 1 to Goal 6) in third order model of Higher Order PLS-PM. Then, this research compares four approaches in higher-order system (Crocetta et al., 2021). The model of the whole SDGs, including all of the indicators related to Goals, Dimensions, and SDGs itself has been done in Cataldo et al. (2021). This paper using the case study of European countries.

Among the studies mentioned, PLS-PM has been widely used in various research, including those on SDGs. However, none of these studies specifically focus on the de tailed mathematical modeling of the entire SDG framework using the most recent data, particularly in the context of Indonesia. Therefore in this work, we propose mathematical modeling of sustainable development involves its dimensions, goals, and indicators. We show the mathematical model and analyze the relationship between each dimension, dimensions and correlated goals, each goal and goals and correlated indicators. The indicators were used as data derived from the annual SDG report by the Ministry of National Development Planning as data from 2019 to 2023. The propose of this research can be used as an evaluation and reference for policymakers in planning development in Indonesia to achieve the SDGs targets by 2030.

This paper is structured as follows. Section 2 describes the theory of the PLS-PM framework, while Section 3 describes Higher-Order PLS-PM. Then, the mathematical model is proposed in Section 4 along with the data of this paper. The interpretation and analysis results are discussed in Section 5. Finally, Section 6 concludes the paper.

2. Partial Least Square Path Modeling (PLS-PM)

Partial Least Square (PLS) is not a new concept in data analysis. PLS Structural Equation Models (SEM), which are more commonly known, are used as a tool for investigating complex models involving models that cannot be measured directly. PLS-PM tends to think of the cause-and-effect relationship of unobservable variables with their measurable indicators, putting PLS-PM in the PLS-SEM family (Cataldo et al., 2024).

PLS-PM is a statistical technique used for analyzing groups of observed variables, where each group is represented by a latent variable, and linear relationships are assumed to exist between these latent variables (Sanchez, 2013). Latent variable (LV) is an unobservable variable, on the other hand, an observed variable named as indicator or manifest variable (MV). We can indirectly measure LV by its consequences or effects indicators (MV). The primary distinction between formative and reflective approaches lies in their causal-effect relationships between the indicators and latent variables (LV). A model may contain a combination of both formative and reflective indicators, depending on the context of the problem.

PLS-PM comprised by two types of models, inner model and outer model. The inner model (or structural model) describes the relationship between each latent variable. Meanwhile, the outer model (or measurement model) has to do with the relationship between the latent variable and its block of indicators. Both an inner and an outer model are treated as linear relationships. Given a j number of LV and k number of MV, the mathematical equation for inner model, the relationship between LVs, expressed as:

$$LV_j = \sum_{i \to j} \beta_{ji} LV_i + error_j \quad (1)$$

Since the outer model describes the relationship between latent variable and its indicator, which can be interpreted in two types, formative and reflective, there are also two types of outer model, depends on its interconnection.

$$LV_j = \lambda_{jk} X_{jk} + error_j \ (Formative) \quad (2)$$

$$X_{jk} = \lambda_{jk} LV_j + error_{jk} \text{ (Reflective)} \quad (3)$$

Index k indicates the number of indicators in its LV. Parameter λ_{jk} are called loadings, as the relationship between LV and its MVs. The purpose of using PLS-PM is to get the estimates value of LVs and parameters, path coefficients and loadings.

3. Higher-Order PLS-PM

PLS-PM is a tool to measure an index of abstract concept named latent variable with respect to its relationship of other latent variables and its measurable indicators. But in fact, not all of the LV has indicator to be measured. Some of the LVs constructed as higher level of abstraction, which means, involve more than one dimension. To handle this case, researchers formed a new method for measure the LV without requiring all the LVs to have its associated MVs, later we call it as High-Order PLS-PM. Some approaches have been developed and proposed by researches to work with Higher Order PLS-PM: the Repeated Indicators Approach; the Hybrid Approach; and the Two Step Approach (Sanchez, 2013).

The approach used in this paper is the Mixed Two Step Approach. Based on Crocetta et al. (2021), it was found that the mixed two step approach showed the best results because it provided precise accuracy. The mixed two step approach started with the implementation of PLS-PM with re peated indicators. First, the indicators of lower-order LV are repeated for the higher-order LV. Then the algorithm of PLS-PM is run and we can obtain the scores of LV. After that, the scores of LVs are used to become the indicators for its higher-order LV. The algorithm of PLS-PM is run once again and we can obtain the finalize path coefficients and loadings for each LV and MV. This method use the components that represent best of each block and at the same time include the best prediction power for its higher-order LV, compared to repeated indicators approach. (Cataldo et al., 2021).

4. The Data and the Model

The concept of sustainable development goals, announced by the United Nations, is highly suitable with PLS-PM analysis that worked for complex and abstract concept. The SDGs aims to achieve all the 17 goals contained in four dimensions—social, economy, environment, and law and governance dimension. The

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relationship between these three variables, SDGs, its dimensions and correlated Goals, can be represented in a form of path diagram. The variables are difficult to measure because of their complexity; thus, they require indicators for their measurement. For this reason, SDGs, the four dimensions, and the 17 goals are the latent variables (LV), whereas indicators in each goal are the manifest variables (MV).

not have indicators, it is addressed using the Higher-Order PLS-PM framework.

The first-order LVs, representing the Goals in the SDGs, are measured formatively. Similarly, the relationships between each order of latent variables are treated as formative modes, where the lower-order LVs form the higher-order LVs. The path diagram of the proposed SDGs model is presented in Figure. 1.

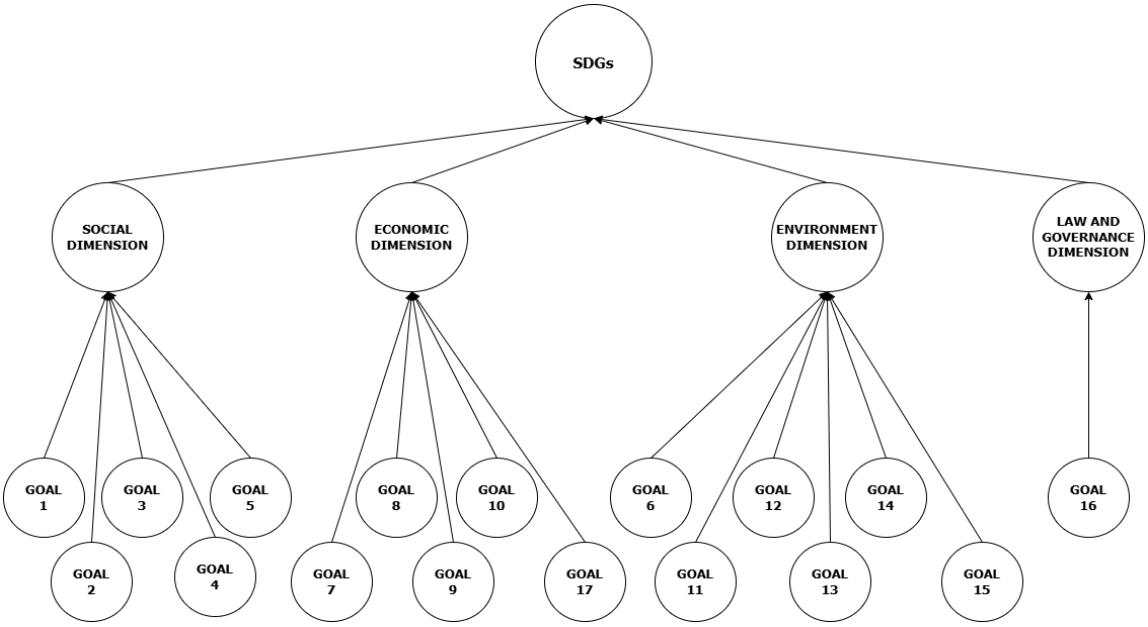


Figure 1. Path Diagram of SDGs.

UN provides indicators of every goal and able to be adapted depends on the country's condition. In 2023, Indonesia developed 298 indicators for measuring the achievement of 17 goals and the whole SDGs. These indicators are the data in this paper, derived from provincial-level data specifically addressing SDG achievements across 34 provinces in Indonesia. However, due to limited data on developing countries, there are no data for several indicators; thus, 298 indicators are being reduced to suit the data availability.

The construct comprises a third-order LV. The first-order LV represents the goals in SDGs, starting from Goal 1, Goal 2, Goal 3 to Goal 17. At this level, every LV has its own indicator or MVs for measurement. The data indicators were obtained from the annual SDGs report by the Ministry of National Development Planning (Bappenas, 2023).

The second-order LVs correspond to the four dimensions of the SDGs, which are formed by related goals. The social dimension encompasses Goals 1 to 5. The economic dimension is related to latent variables of clean energy, decent work, economic growth, industry, inequality, and partnership. The environmental dimension LV includes the most extensive range of latent variables. Meanwhile, only Goal 16 is associated with the dimension of law and governance.

These four second-order LVs are independent of MVs and collectively form a higher order LV, the SDGs. Due to the construct comprising high-order LVs and the presence of some LVs that do

As stated in the previous section, PLS-PM consists of two models: the internal model, which describes the relationship between latent variables, and the outer model, which describes the relationship between latent variables and their manifest variables. The internal model in this research is shown in Eq. (4).

$$
\begin{aligned}
&LV_{SDGs} = \beta_1 LV_{soc} + \beta_2 LV_{eco} + \beta_3 LV_{env} + \beta_4 LV_{gov} \\
&LV_{soc} = \beta_{11} LV_{Goal1} + \beta_{12} LV_{Goal2} + \beta_{13} LV_{Goal3} + \beta_{14} LV_{Goal4} + \\
&\beta_{15} LV_{Goal5} \\
&LV_{eco} = \beta_{21} LV_{Goal7} + \beta_{22} LV_{Goal8} + \beta_{23} LV_{Goal9} + \\
&\beta_{24} LV_{Goal10} + \beta_{25} LV_{Goal17} \\
&LV_{env} = \beta_{31} LV_{Goal6} + \beta_{32} LV_{Goal11} + \beta_{33} LV_{Goal12} + \\
&\beta_{34} LV_{Goal13} + \beta_{35} LV_{Goal14} + \beta_{36} LV_{Goal15} \\
&LV_{gov} = \beta_{41} LV_{Goal16}
\end{aligned}
\tag{4}
$$

The outer model describes the relationship between LVs and their associated MVs. In this SDGs model, each Goal is represented by an LV, and each LV has its own indicators or MVs. Therefore, it is essential to verify the availability of data (indicators) for the implementation of the SDGs in Indonesia. This paper utilizes provincial-level data from 2023, encompassing 34 provinces, as listed in the annual SDGs report by Statistics Indonesia (BPS, 2024). Out of 198 indicators published, only 75 indicators that available its data on provincial level. Based on the availability of data indicator, we propose the outer model showed in Eq. (5).

$$
\begin{aligned}
&LV_{Goal_1} = \lambda_{11} X_{1.2.1} + \lambda_{12} X_{1.4.1} + \lambda_{13} X_{1.4.2} + error_{Goal1} \\
&LV_{Goal2} = \lambda_{21} X_{2.1.1} + \lambda_{22} X_{2.1.2} + \lambda_{23} X_{2.2.1} + \lambda_{24} X_{2.2.2} +
\end{aligned}
$$

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$\lambda_{25}X_{2.3.1} + \lambda_{26}X_{2.3.1.(a)} + error_{Goal2}$

$LV_{Goal3} = \lambda_{31}X_{3.1.2.(a)} + \lambda_{32}X_{3.3.3} + \lambda_{33}X_{3.3.3.(a)} + \lambda_{34}X_{3.3.5.(a)} + \lambda_{35}X_{3.3.5.(b)} + \lambda_{36}X_{3.4.1.(b)} + \lambda_{37}X_{3.4.1.(c)} + \lambda_{38}X_{3.5.1.(b)} + \lambda_{39}X_{3.8.1.(a)} + \lambda_{310}X_{3.a.1} + \lambda_{311}X_{3.b.1} + \lambda_{312}X_{3.b.3} + \lambda_{313}X_{3.c.1} + error_{Goal3}$

$LV_{Goal4} = \lambda_{41}X_{4.1.1.(a)} + \lambda_{42}X_{4.1.2} + \lambda_{43}X_{4.1.2.(a)} + \lambda_{44}X_{4.2.2} + \lambda_{45}X_{4.3.1} + \lambda_{46}X_{4.3.1.(a)} + \lambda_{47}X_{4.4.1.(a)} + \lambda_{48}X_{4.5.1} + \lambda_{49}X_{4.6.1.(a)} + \lambda_{410}X_{4.a.1} + \lambda_{411}X_{4.c.1} + error_{Goal4}$

$LV_{Goal5} = \lambda_{51}X_{5.3.1} + \lambda_{52}X_{5.5.2} + \lambda_{53}X_{5.a.1} + \lambda_{54}X_{5.b.1} + error_{Goal5}$

$LV_{Goal6} = \lambda_{61}X_{6.2.1} + \lambda_{62}X_{6.3.2.(a)} + \lambda_{63}X_{6.6.1} + error_{Goal6}$

$LV_{Goal7} = \lambda_{71}X_{7.1.1} + \lambda_{72}X_{7.1.2.(a)} + error_{Goal7}$

$LV_{Goal8} = \lambda_{81}X_{8.1.1} + \lambda_{82}X_{8.1.1.(a)} + \lambda_{83}X_{8.2.1} + \lambda_{84}X_{8.3.1} + \lambda_{85}X_{8.5.1} + \lambda_{86}X_{8.5.2} + \lambda_{87}X_{8.5.2.(a)} + \lambda_{88}X_{8.7.1} + \lambda_{89}X_{8.7.1.(a)} + \lambda_{810}X_{8.9.1.(b)} + error_{Goal8}$

$LV_{Goal9} = \lambda_{91}X_{9.1.2.(a)} + \lambda_{92}X_{9.2.1} + \lambda_{93}X_{9.2.1.(a)} + \lambda_{94}X_{9.2.2} + \lambda_{95}X_{9.b.1.(a)} + error_{Goal9}$ (5)

$LV_{Goal10} = \lambda_{101}X_{10.1.1} + \lambda_{102}X_{10.1.1.(a)} + \lambda_{103}X_{10.3.1.(a)} + error_{Goal10}$

$LV_{Goal11} = \lambda_{111}X_{11.1.1.(a)} + \lambda_{112}X_{11.6.2.(b)} + error_{Goal11}$

$LV_{Goal12} = \lambda_{121}X_{12.3.1.(a)} + \lambda_{122}X_{12.5.1.(a)} + error_{Goal12}$

$LV_{Goal13} = \lambda_{131}X_{13.1.1} + error_{Goal13}$

$LV_{Goal14} = \lambda_{141}X_{14.5.1} + error_{Goal14}$

$LV_{Goal15} = \lambda_{151}X_{15.1.2.(a)} + error_{Goal15}$

$LV_{Goal16} = \lambda_{161}X_{16.7.2.(a)} + \lambda_{162}X_{16.7.2.(b)} + \lambda_{163}X_{16.7.2.(c)} + \lambda_{164}X_{16.9.1} + \lambda_{165}X_{16.9.1.(a)} + \lambda_{166}X_{16.9.1.(b)} + error_{Goal16}$

$LV_{Goal17} = \lambda_{171}X_{17.1.1} + \lambda_{172}X_{17.1.1.(a)} + \lambda_{173}X_{17.8.1} + error_{Goal17}$

5. Result and Discussion

This section discusses the analysis and interpretation of results using PLS-PM for SDGs in Indonesia. The analysis of the results of Higher-Order PLS-PM model must be performed sequentially. The first step is to analyze the results from the outer model then the inner model, because before we look at the value of the latent variable in the inner model, we first need to look at the measuring tool, it is the indicators contained in the outer model. Subsequently, the results of the inner model provide the structural model, which illustrates the relationships between latent variables (LVs) and other relevant factors. Once the parameters for the outer and inner models are obtained, model validation is necessary by assessing the model's Goodness of Fit (GoF).

5.1 Analysis on the Result of Outer Model

The outer model in this SDGs model work in formative mode, where the indicators or MVs form the latent variables. There are two important aspects that can be obtained from the outer model analysis; correlations and loadings. However, before analyzing the result of the outer model, we must evaluate the outer model obtained.

In the outer model using formative mode, evaluation can be done by obtaining multicollinearity, which indicates that there are indicators that are similar to other indicators. There are indications of multicollinearity in the outer model of the SDGs in Indonesia, as shown by the VIF values that exceed 5. Table 1 presents the VIF values for each indicator. It can be seen that indicators 4.2.2, 4.4.1.a, 8.2.1, 8.7.1, 8.7.1.a, 16.9.1, 16.9.1.a, and 16.9.1.b have VIF values greater than 5, which are highlighted in red. This indicates that these indicators are highly similar to other indicators, suggesting that they can be removed. After the high-value VIF indicators were removed and the PLS-PM algorithm was rerun, no multicollinearity was detected; thus, the result of outer model is significant. Note that there are now only 66 indicators remaining due to evaluation of the outer model, which show that the eliminated indicators are similar to others.

Table 1. The Value of VIF.

Indicators	VIF	Indicators	VIF	Indicators	VIF	Indicators	VIF
1.2.1	1.173	3.b.3	1.652	7.1.1	1.491	10.1.1.a	1.059
1.4.1	1.375	3.c.1	2.960	7.1.2.b	1.491	10.3.1.a	1.076
1.4.2	1.568	4.1.1.a	3.361	8.1.1	2.027	11.1.1.a	1.014
2.1.1	1.956	4.1.2	2.623	8.1.1.a	3.615	11.6.2.b	1.014
2.1.2	1.533	4.2.2	10.091	8.2.1	2.972	12.3.1.a	1.051
2.2.1	2.956	4.3.1	3.589	8.3.1	7.887	12.5.1.a	1.051
2.2.2	3.699	4.4.1.a	10.257	8.5.1	3.486	13.1.1	1.000
2.3.1	1.451	4.5.1	1.979	8.5.2	2.952	14.5.1	1.000
2.3.1.a	1.550	4.6.1.a	2.881	8.5.2.a	2.897	15.1.2.a	1.000
3.1.2.a	2.591	4.a.1	1.924	8.7.1	46.778	16.7.2.a	2.604
3.3.3	2.207	4.c.1	3.076	8.7.1.a	50.235	16.7.2.b	1.123
3.3.5.a	3.242	5.3.1	1.274	8.9.1.b	1.515	16.7.2.c	1.123
3.3.5.b	1.885	5.5.2	1.213	9.1.2.a	1.571	16.9.1	8.833
3.4.1.b	1.428	5.a.1	1.182	9.2.1	1.461	16.9.1.a	111.928
3.5.1.b	3.448	5.b.1	1.360	9.2.1.a	2.088	16.9.1.b	100.667
3.8.1.a	2.397	6.2.1	1.325	9.2.2	2.178	17.1.1	1.057
3.a.1	2.207	6.3.2.a	1.244	9.b.1.a	1.771	17.1.1.a	1.129
3.b.1	2.461	6.6.1	1.574	10.1.1	1.110	17.8.1	1.184

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The outer model also provides the loading values that represent the relationships between LVs and their MVs. Loadings indicate the direction and magnitude of the indicator's contribution of the latent variable. As we can see in Figure 2, most of the loading value is positive. This indicates that the relationship between MV and its correlated LV is positively related, increasing the value of the indicator will increase the value of the latent variable. In Goal 1, indicator 1.2.1* has the largest loadings compared to other indicators, which indicates that the percentage of people living below the national poverty line is the most influencing factor in the achievement of no poverty goal. Indicator 1.1.1* and 14.1.1* show the highest loading values. In other words, these indicators are the ones that most influence its corresponding LV. The next highest loading value is 2.1.1 which is the prevalence of undernourishment, making it the most influencing factor in Goal 2. Indicators in Goal 3 do not show loadings value indicator 3.c.1 or density and distribution of health workers is the most influencing indicator. Indicator 4.1.2 and indicator 5.3.1 namely level of completion of high school and proportion of women whose age at first marriage was before the age of 18 years old are the most influencing factor in Goal 4 and Goal 5, respectively.

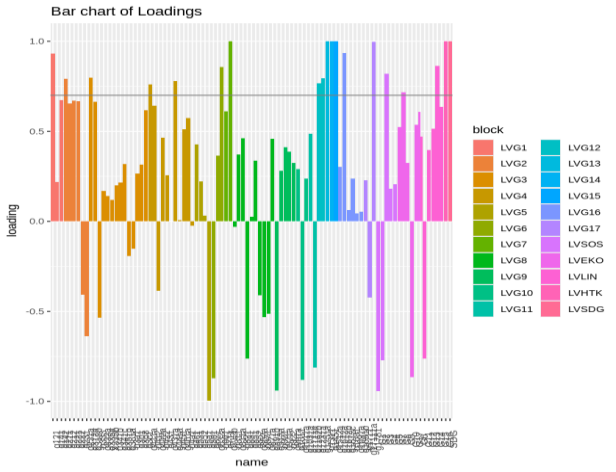


Figure 2. Loadings.

The percentage of households that have access to adequate sanitation become the most influencing factor in achieving Goal 6, indicated by the loadings value of indicator 6.2.1 being the highest among all the indicators. Subsequently, the higher the ratio of household gas usage, the higher the achievement of Goal 7. This is shown from indicator 7.1.2.b has a positive relationship with Goal 7 and is the indicator with the highest value of loadings. Indicators in Goal 8, Goal 9 and Goal 10 do not show a large loadings value. Indicator 8.2.1, 9.b.1.a, and 10.3.1.a is the most influencing factors of achievement in each correlated Goals, which are GDP growth rate per worker, proportion of exports of high-tech industrial products and freedom index. Indicator 11.1.a is the percentage of household that have access to affordable living giving the high value of loadings in Goal 11, in contrast to indicator 12.3.1.a is the percentage of food waste which shows a small loading value but is the most influencing factor in Goal 12. In addition, Goal 13, 14, and 15 each only have 1 indicator and its loading is all positive, which means that each indicator has a direct positive effect on the achievement of correlated Goal.

However, there are negative loadings in the outer model of SDGs in Indonesia. Negative loadings indicate that the indicator has an opposite relationship with the latent variable; that is, increasing the value of the indicator reduces the value of the latent variable. There are 2 indicators in Goal 2 that have negative loadings; 2.3.1 and 2.3.1. In addition, indicator 5.b.1 in Goal 5 also has negative loading. Goal 3 and 8 have the most indicators with negative loadings, namely indicator 3.3.3, 3.3.5.a, 3.8.1.a and 3.a.1 and indicators 8.1.1, 8.5.1, 8.5.2.a and 8.7.1. Similarly, indicators 9.1.2.a, 10.1.1.a, 12.5.1.a, and 17.1.1.1.a have an opposite relationship with the Goal. This indicates that the higher the value of indicators such as malaria incidence, unmet need of health service, the percentage of children aged 5-17 who work and etc. the lower the achievement of SDGS in Indonesia.

The results of the outer model were found to be significant, as shown by evaluating the model by checking for the multi-collinearity. Each indicator with VIF value is greater than 5 is indicated to have multi-collinearity, so it must be removed. After re moving the indicator, the PLS-PM algorithm using 66 indicators was run again so that significant correlations and loadings were obtained.

5.2 Analysis on the Result of Inner Model

After evaluating the quality of the outer model, the results of the inner model can be examined. In analyzing this model, correlations are calculated to determine the strength and direction of the relationship between two variables, as well as the path coefficient, which indicates the relationship between one LV and another. Similar to the outer model, it is essential to evaluate the inner model before analyzing its results. This evaluation involves examining the outcomes of each regression within the model. The quality of the inner model can be assessed based on two aspects: the R^2 coefficient of determination and the redundancy index.

The R^2 indicates the amount of variance in the endogenous latent variable, which is explained by its independent latent variables. The model is considered good if the R^2 is high ($R^2 > 0{,}50$). It is shown in Table. 2 that the inner model of SDGs in Indone sia is considered good, since the value of all the R^2 are greater than 0.6. Redundancy measures the ability of a set of independent latent variables to explain variation in the dependent latent variable. The redundancy of SDGs LV has a value of approximately 0.865, indicating that the four dimensions account for 86.5% of the variability in the SDGs. Based on the evaluation of the inner model, it is determined that the inner model is both good and significant, allowing for further analysis of the inner model of the SDGs in Indonesia.

Figure. 3 representing the obtained path coefficient by SDGs model using PLS-PM. Path coefficient represents the strength and direction of relationship between latent variable. As shown in the figure, some path coefficient values are negative, indicating that the relationship between these two LVs should be in the opposite direction. However, to identify the factors that most influence the intended LV, is seen from the absolute value. Therefore, although the path coefficient of Goal 3 on the social dimension is negative,

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Table 2. Inner Model Quality.

	Type	R^2	Communality	Redundancy
Social Dimension	Endogenous	0.999	0.879	0.878
Economic Dimension	Endogenous	0.996	0.805	0.805
Environment Dimension	Endogenous	0.986	0.479	0.476
Law and Governance Dimension	Endogenous	1.000	0.863	0.863
SDGs	Endogenous	1.000	0.865	0.865

which means that if Goal 3. "Good Health and Well-Being" increases, the social dimension decreases, Goal 3 is the most influential factor in achieving SDGs in the social dimension after Goal 5 "Gender Equality" and Goal 1 "No Poverty". In the economic dimension, Goal 7 "Affordable and Clean Energy" is the most influencing factor, followed by Goal 8 "Decent Work and Economic Growth" and Goal 9 "Industry, Innovation and Infrastructure". Goal 10 "Reduced Inequalities" and Goal 17 "Partner ships for the Goals" have a very small path coefficient values, which indicates that those Goals only make a small contribution to the achievement of the SDGs in the economic dimension, but that does not mean they are not important. Then, Goal 13 "Climate Action" is the most influential factor in the achievement of SDGs in the environment dimension, because it shows the largest path coefficient value. Although Goal 6 shows a negative path coefficient, its absolute value shows the second largest value among other Goals in the environment dimension, which means that Goal 6 "Clean Water and Sanitation" is the second most influencing factor in the achievement of SDGs in Indonesia, especially in the environment dimension. The law and governance dimension only have one correlated LV, Goal 16 "Peace, Justice and Strong Institution", and its path coefficient value is positive and significant.

In terms of the second-order and third-order LV, the path coefficient between the four dimensions and the SDGs itself. The four dimensions give the same portion of contribution to the achievement of SDGs in Indonesia, which means that the difference in the path coefficient values of the four dimensions is very small. Of the four dimensions, the social dimension is the most influential factor on achieving SDGs in Indonesia. The other three dimensions contribute the same, with only slightly different numbers. The achievement of SDGs in Indonesia in 2023 is evenly distributed across all dimensions, not only excelling in one or two other dimensions. This is a good thing because sustainability requires a balance of progress across all dimensions.

The Higher-Order PLS-PM approach also allows us to predict the SDGs score as well as its four dimensions for each of the 34 provinces in Indonesia. This process allows us to rank each province by assigning it score. The latent SDGs score shows the value of the achievement of SDGs in each province based on the data availability and data processing. A high value of SDGs indicates that the quality of SDGs in the specific province is good, while a low and negative values indicates that the quality of the SDGs is low. Figure 4 shows that the province of DKI Jakarta in on top of the list, showing that the quality of SDGs in the capital of Indonesia is the best out of all the province. Provinces in Java and

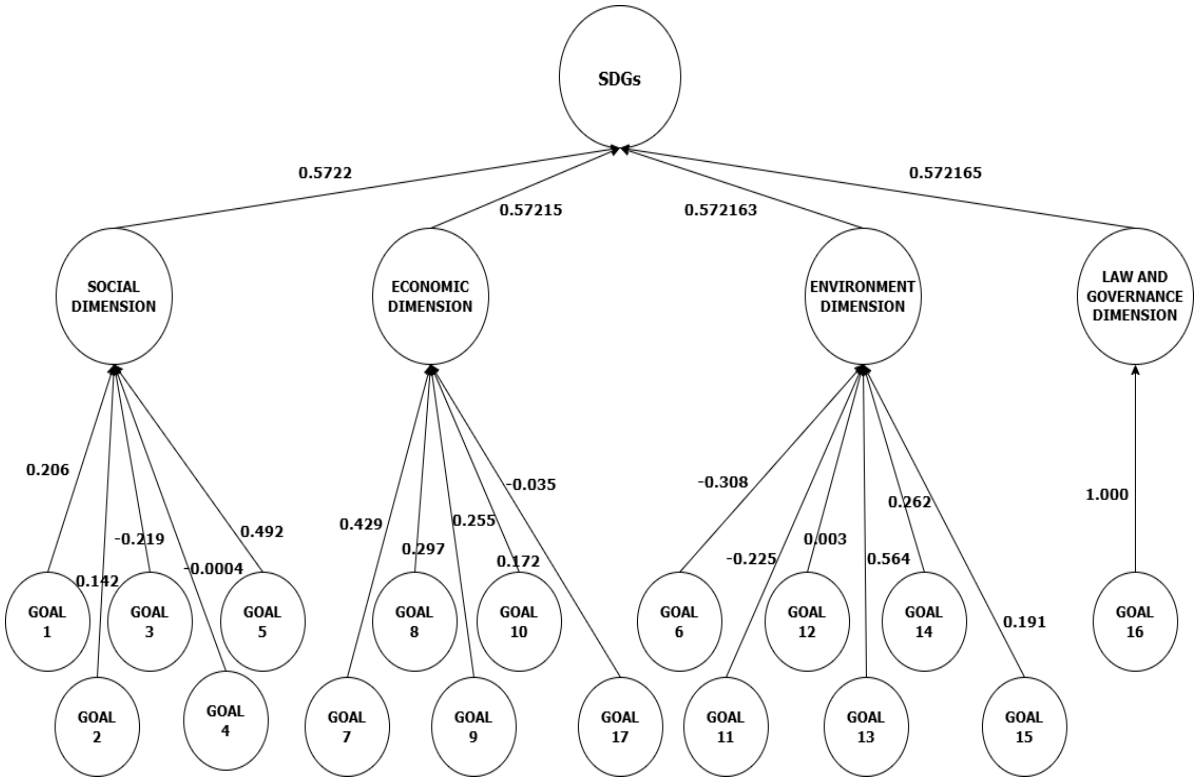


Figure 3. Path Coefficients in the Inner Model

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Kalimantan island are mostly on the top 10 ranking, while provinces in Sumatera and Sulawesi island are on the mid-rankings. It can be also seen that provinces in the east part of Indonesia are majorly on the bottom 10 ranking. This indicates that the sustainable development performance in Indonesia is uneven. It can be concluded that there needs to be equality in achieving SDGs in Indonesia, so that it is not only centered on one region that is superior compared to others.



Figure 4. Ranking of 34 Provinces in Indonesia according to the SDGs Achievements in 2023

5.3 Model Validation

The analysis of the outer and inner models led to the value of parameter, which are loadings and path coefficients for the SDGs mathematical model.

$$LV_{SDGs} = 0.5722 \cdot LV_{soc} + 0.57215 \cdot LV_{eco} + 0.572163 \cdot LV_{env} + 0.572165 \cdot LV_{gov}$$

$$LV_{soc} = 0.260 \cdot LV_{Goal1} + 0.142 \cdot LV_{Goal2} - 0.219 \cdot LV_{Goal3} - 0.0004 \cdot LV_{Goal4} + 0.492 \cdot LV_{Goal5}$$

$$LV_{eco} = 0.429 \cdot LV_{Goal7} + 0.297 \cdot LV_{Goal8} + 0.255 \cdot LV_{Goal9} + 0.172 \cdot LV_{Goal10} - 0.035 \cdot LV_{Goal17} \quad (6)$$

$$LV_{env} = -0.308 \cdot LV_{Goal6} - 0.225 \cdot LV_{Goal11} + 0.003 \cdot LV_{Goal12} + 0.564 \cdot LV_{Goal13} + 0.262 \cdot LV_{Goal14} + 0.191 \cdot LV_{Goal15}$$

$$LV_{gov} = 1.000 \cdot LV_{Goal16}$$

The validation of the model obtained in Eq. 6 can be validated by calculating its Goodness of Fit (GoF). GoF is measured as the geometric mean of the average communality and the average R^2 value. The Goodness of Fit (GoF) index represents the average predictive power of the entire model. The GoF index can be used to evaluate the performance of both the inner and outer models can be evaluated. There are differences of opinion among scientists regarding the number that could be considered a good GoF value. In Boubker & Douayri (2020), the GoF index is divided into 4 criteria: (1) no fit ($GoF < 0.1$); (2) small ($0.1 \leq GoF < 0.25$); (3) medium ($0.25 \leq GoF \leq 0.36$); (4) large ($GoF \geq 0.36$). In this model, the GoF value was 0.6455, which means that the prediction power of the model is of 64.55%. The obtained model is expected to be strongly valid for predicting the relationship between LV and MV.

In Henseler & Sarstedt (2013), show that GoF cannot be the only standard of model validity. Although shows validity for both inner and outer models,or the formative mode, it is also impor tant to check the R^2, which describes how the endogenous latent variable is explained by exogenous latents and each indicator forms the latent. From Table 3, it can be seen that the value of R^2 is greater that 0.5, which means that it is considered good. This indicates that the proposed model is fit to the data.

6. Conclusions

The use of Partial Least Square Path Modeling (PLS-PM) proved to be efficient in forming the mathematical modeling for Sustainability Development Goals in Indonesia. The latent variables and manifest variables (indicators) form the path model for SDGs in third-order construct. The latent variables consist of 17 Goals and its corresponding four dimensions in SDGs where they form the latent variable for SDGs itself. The manifest variables consist of indicators in every Goal, based on the annual report of SDGs implementation from 34 provinces in 2023. From 298 indicators on the report, only 77 indicators are available for data at provincial level. It is evident that the lack of data is a crucial factor in this context, as the goal cannot be fully measured due to data loss.

The Higher Order PLS-PM framework facilitates the analysis of relationships between indicators, Goals, and their dimensions in measuring the implementation of the SDGs. In this study, we propose two types of models in PLS analysis: the outer model and the inner model. The outer model expresses the relationship between manifest variables with its latent variable, which means what it refers to in this concept is the relationship between

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indicators and its related Goal. By using this model, we obtain loading values that serve as parameters to assess the strength and direction of relationships. The inner model shows the relationship between latent variables. In this model, it is arranged in third order, where the first order is the 17 Goals, then the second order is dimensions in SDGs, namely, social, economic, environment, law and governance dimension and third order is the SDGs itself. This inner model work in formative-formative mode, where the lower order LV form the higher one. The inner model describes the relationship between each Goal with its corresponding dimension and dimensions with latent SDGs. The approach used in this study is Mixed Two Step Approach.

Although the loadings and path coefficients were obtained, the results cannot be directly analyzed. It is necessary to evaluate the model first, which sequentially starts from the outer model and then the inner model. Evaluation of the outer model of SDGs in Indonesia found that there is multicollinearity indicated by the VIF value of the MV which is more than 5, so the mV must be removed and re-run the algorithm with 66 MV. This means that 11 out of 77 SDGs indicators were eliminated to obtain accurate results in measuring SDGs in Indonesia. The inner model is evaluated to determine whether it is significant and appropriate, by considering the R^2 coefficient determination and redundancy index. The R^2 and redundancy of the model are good number, close to 1.00, meaning that the inner model is considered good. Thus, the next step is to analyze the results of the outer model and inner model.

Based on our model, the loading values in the outer model are either positive or negative. The positive loadings mean that increasing indicator it related Goal, while negative loadings apply the other way around. MV that has the largest loadings value compared to other loadings indicating that the indicator is the most influencing factor in the achievement of its Goal. Note that the MV with the smallest loadings does not mean that it is a factor that does not provide influence; the indicators make a small contribution to its related Goal.

The results of the inner model are presented in the form of path coefficients, which represent the strength and direction of relationships between latent variables. In this context, these coefficients allow us to identify the most influential Goal within each dimension and the dimension with the highest value in the implementation of the SDGs. The path coefficient of each dimension towards the SDGs is the same, but it differs slightly in small amount of number. This means that all dimensions make the same contribution to the achievement of the SDGs, there is no one dimension that is superior to the others and causes the quality of one another is too lag behind. This is a good thing because there is balance and sustainability in all dimensions.

Goal 5 “Gender Equality” excels all the Goals in social dimension, followed by Goal 1 “No Poverty” then Goal 3 “Good Health and Well-Being”. The quality of SDGs in Indonesia is largely influenced by the factors of equal rights for both men and women, poverty and the health of its citizens. For the economic dimension, Goal 7 “Affordable and Clean Energy” and Goal 8 “Decent Work and Economic Growth” have the highest value of path coefficients. In other words, Indonesia’s implementation on SDGs has showed a good performance in achieving these goals. Two Goals in environment dimension, Goal 13 “Climate Action” and Goal 6 “Clean Water and Sanitation” are the most influencing factor in the achievement of SDGs in Indonesia, as indicated by the largest path coefficient value. A small path coefficient value does not mean that it is not an influencing factor; however, they contribute little to the achievement of the SDGs. This means that Goal 4 “Quality Education”, Goal 17 “Partnerships for the Goals” and Goal 12 “Responsible Production and Consumption” need to get more attention by the government so that those Goals can also make a major contribution to the quality of SDGs in Indonesia.

From the score of each LV, the quality of SDGs in each province in Indonesia can be obtained based on the data. It is found that DKI Jakarta, DI Yogyakarta, and Kalimantan Timur occupy the top three in the rank of quality of SDGs in Indonesia. Meanwhile, the bottom ranks are occupied by the eastern part of Indonesia, such as Maluku, Papua, Maluku Utara and Papua Barat. The scores from these provinces also have a considerable difference, indicating that there is significantly different progress in achieving SDGs in each province.

Overall, based on the model obtained, the index of each LV shows the quality of the SDGs, dimension and Goals in Indonesia alongside 34 provinces in it. The prediction power of the model proposed by calculating the GoF is 64.55%, which indicates that the model fits the data. Thus, the results of this study may provide insights for policymakers in planning sustainable development in Indonesia to achieve the SDGs by 2030. Due to data unavailability, the analysis and interpretation of this model are applicable only to data with 66 SDGs indicators in Indonesia. There should be more complete data for other indicators mentioned or review of the indicators on the SDGs by the Indonesian government so that the measurement of SDGs progress is tangible and close to what is happening in reality.

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