PLS-SEM: Evaluation and Reporting

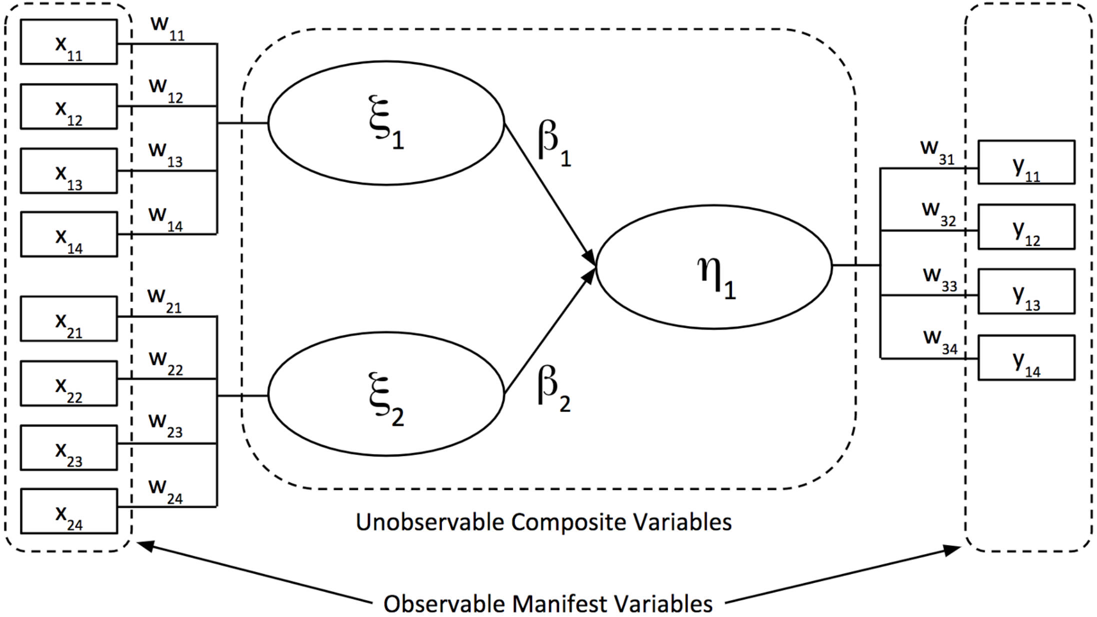
Optional Readings:
Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., # Sarstedt, M., Danks, N. P., & Ray, S. (2021). Partial least squares structural equation modeling (PLS-SEM) using R: A workbook (p. 197). Springer Nature.

PLS Path Modeling in Hospitality and Tourism Research: The Golden Age and Days of Future Past (Hengky Latan, 2018)

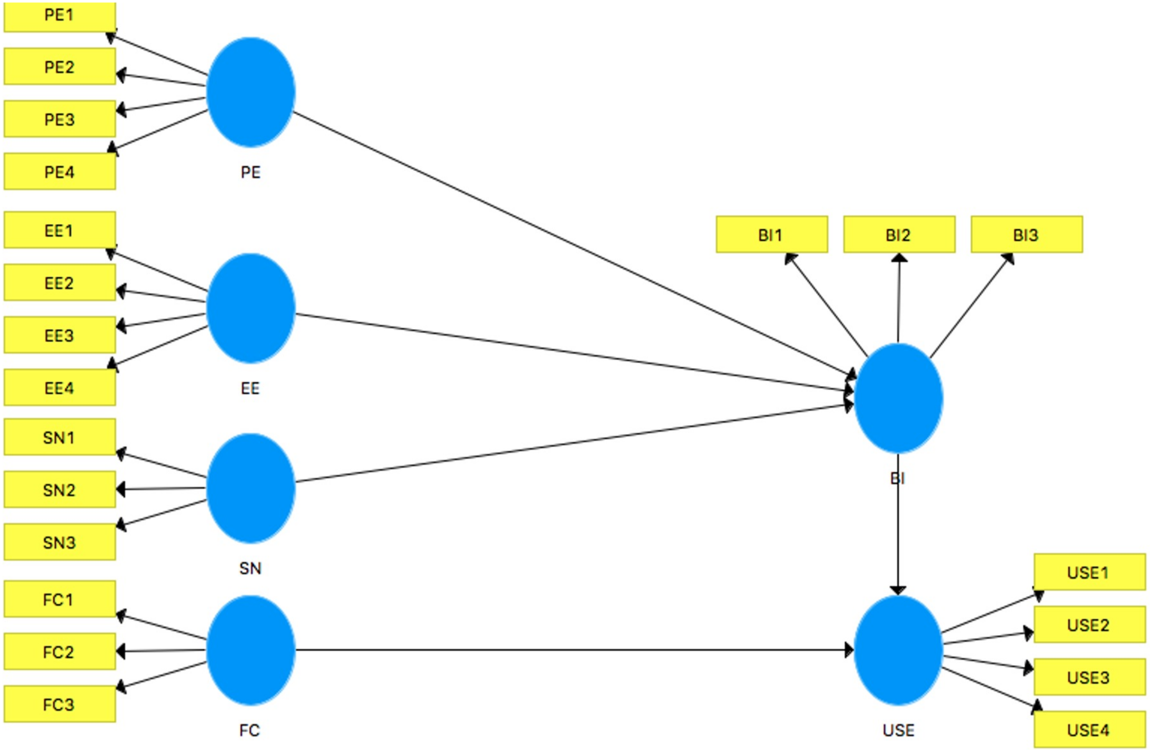
“ Haters Gonna Hate ”: PLS and Information Systems Research (Stacie Petter, 2018)

Using PLS path modeling in new technology research: updated guidelines (Henseler et al., 2016)

A Simple SEM Model



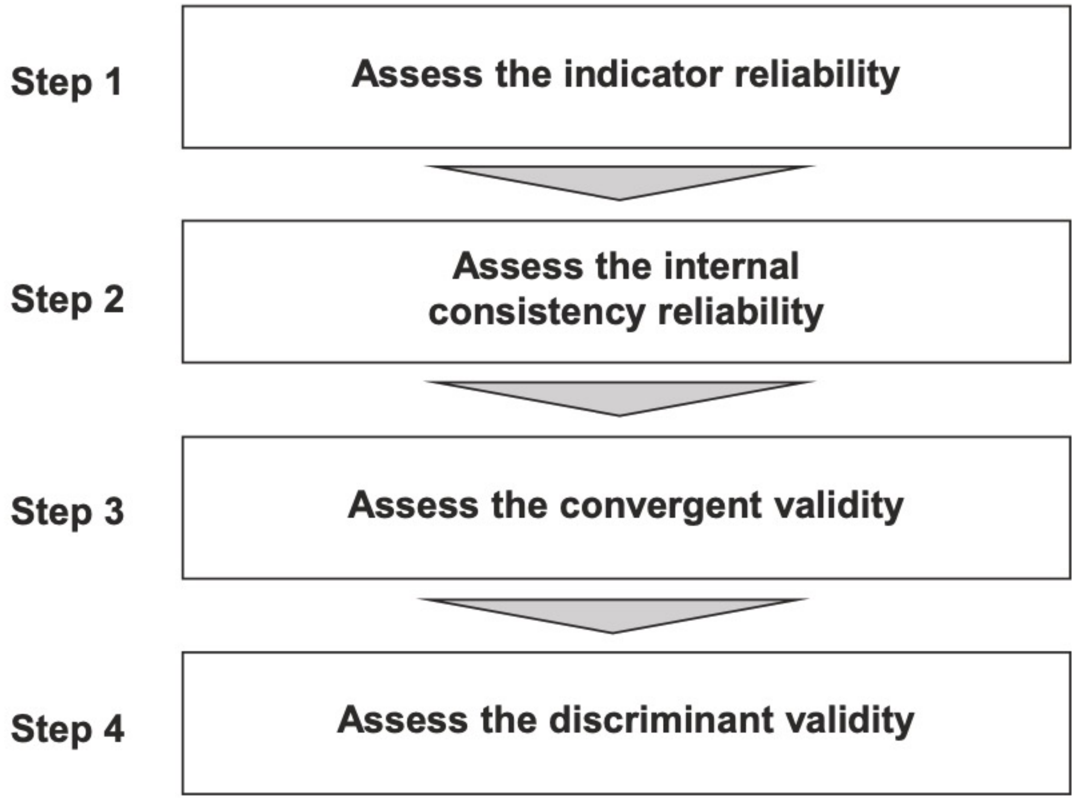
Practical Example – UTAUT



1. Test Measurement Model
    1.1. “Reflective”
    1.2. “Formative”

2. Test Structural Model

3. Conclude on hypotheses


Step 1
Assess the indicator reliability
Step 2
Assess the internal consistency reliability
Step 3
Assess the convergent validity
Step 4
Assess the discriminant validity

Indicator Reliability

- How much of each indicator’s variance is explained by its construct?
- Indicates the **communality** of an indicator.
- **Indicator loadings** above **0.708** are recommended,
    - construct explains more than 50 percent of the indicator’s variance, thus providing acceptable indicator reliability

Indicator Consistency Reliability

- “the extent to which indicators measuring the same construct are associated with each other”
- **composite reliability (rhoC)**
- **Cronbachs Alpha**
- **Dijkstra’s rho (rhoA)**
- 0.60 and 0.70 are considered “acceptable in exploratory research,”
- 0.70 and 0.90 range from “satisfactory to good.”
- Values above 0.90 (and definitely above 0.95) are problematic, since they indicate that the indicators are redundant, thereby reducing construct validity
- rhoA usually lies between the conservative Cronbach’s alpha and the liberal composite reliability and is therefore considered and acceptable compromise between these two measures.

Convergent Validity

- Convergent validity is the extent to which the construct converges in order to explain the variance of its indicators.
- The metric used for evaluating a construct’s convergent validity is the **average variance extracted (AVE)** for all indicators on each construct.
- The AVE is defined as the grand mean value of the squared loadings of the indicators associated with the construct (i.e., the sum of the squared loadings divided by the number of indicators).
- Therefore, the AVE is equivalent to the **communality** of a construct. The minimum acceptable AVE is 0.50

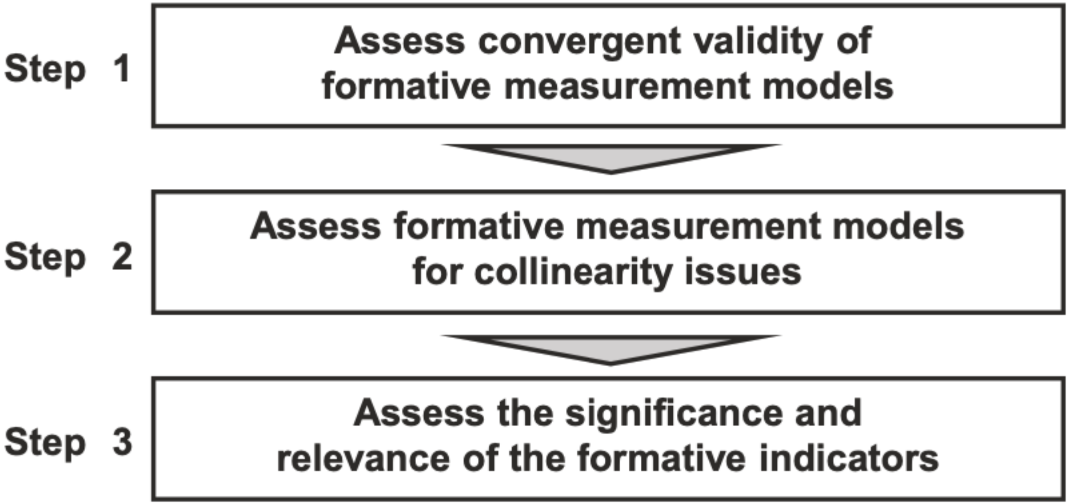
Discriminant Validity

- measures the extent to which a construct is empirically distinct from other constructs in the structural model.
- Fornell and Larcker (1981) is the traditional approach
- Fornell–Larcker criterion does not perform well, particularly when the indicator loadings on a construct differ only slightly (e.g., all the indicator loadings are between 0.65 and 0.85).
- Hence, in empirical applications, the Fornell–Larcker criterion often fails to reliably identify discriminant validity problems (Radomir & Moisescu, 2019) and should therefore be avoided
- As a better alternative, we recommend the **heterotrait–monotrait ratio (HTMT)** of correlations (Henseler et al., 2015) to assess discriminant validity. The HTMT is defined as the mean value of the indicator correlations across constructs (i.e., the **heterotrait–heteromethod correlations**) relative to the (geometric) mean of the average correlations for the indicators measuring the same construct (i.e., the **monotrait–heteromethod correlations**).

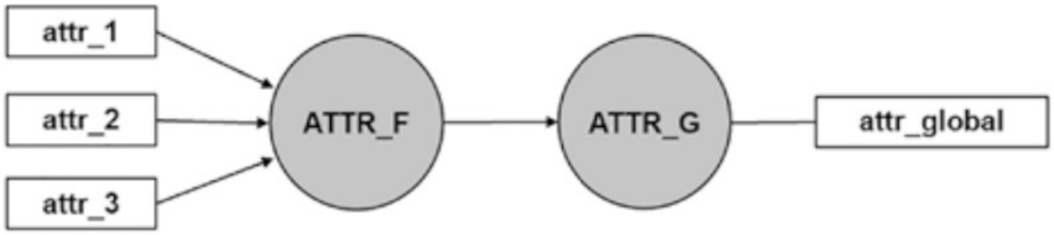
Reflective Measurement-Model Evaluation

	IJHRM (Ringle et al. 2018)	IJCHM (Ali et al. 2018)	IMDS (Henseler et al. 2016)	PACIS (Benitez-Amado et al. 2017)	Proposition
Item reliability	Loadings > 0.7	Loadings > 0.7	Loadings > 0.7	Loadings > 0.7	Loadings > 0.7
Internal Consistency Reliability[1]	Cronbach's Alpha Jöreskog's rho **0.7 < rhoA < 0.95**	Cronbach's Alpha Jöreskog's rho rhoA > 0.7	Cronbach's Alpha Jöreskog's rho rhoA > 0.7	Cronbach's Alpha Jöreskog's rho rhoA > 0.7	0.7 < rhoA < 0.95
Convergent Validity	AVE > 0.5	AVE > 0.5	AVE > 0.5	AVE > 0.5	AVE > 0.5
Discriminant Validity	Fornell Larcker HTMT < 0.9 or HTMT < 0.85 HTMT significantly < 1	Fornell Larcker HTMT significantly < 1	Fornell Larcker HTMT significantly < 1	Fornell Larcker **HTMT < 0.85 or HTMT significantly < 1**	Fornell Larcker HTMT < 0.85, or HTMT significantly < 1

1. Hair et al. (2017b) demonstrates Cronbach's Alpha as the lower bound and the composite reliability as the upper bound of the reliability, whereas rhoA approximates the "true" reliability.


Step 1
Assess convergent validity of formative measurement models
Step 2
Assess formative measurement models for collinearity issues
Step 3
Assess the significance and relevance of the formative indicators

Convergent Validity

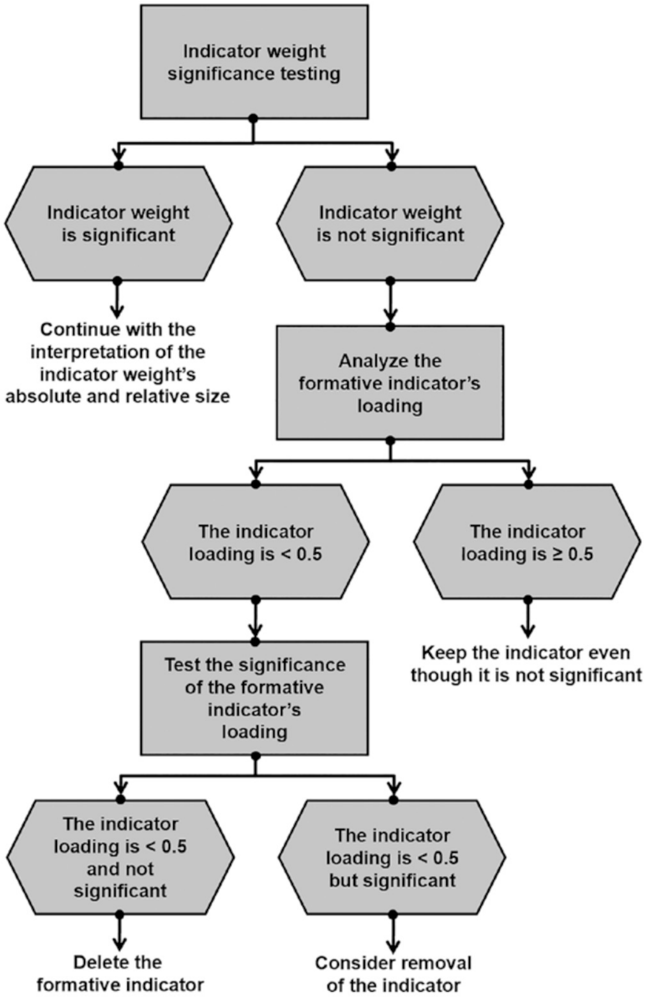


- **Redundancy analysis**.
- researchers must plan ahead in the research design stage by including an alternative measure of the formatively measured construct in their questionnaire.
- Cheah, Sarstedt, Ringle, Ramayah, and Ting (2018) show that a global single item, which captures the essence of the construct under consideration, is generally sufficient as an alternative
- the correlation of the formatively measured construct with the reflectively measured item(s) should be 0.708 or higher, which implies that the construct explains (more than) 50% of the alternative measure's variance.

Indicator Collinearity

- High correlation increases the **standard error** of the indicator weights, thereby triggering type II errors (i.e., false negatives).
- **variance inflation factor (VIF)**
- **VIF** values are higher, the level of collinearity is greater.
- **VIF** values of 5 or above indicate collinearity problems. In this case, researchers should take adequate measures to reduce the collinearity level, for example, by eliminating or merging indicators or establishing a **higher-order construct**
- collinearity issues can also occur at lower **VIF** values of 3

Significance and Relevance of weights



Formative Measurement-Model Evaluation

	IJHRM (Ringle et al. 2018)	IJCHM (Ali et al. 2018)	IMDS (Henseler et al. 2016)	PACIS (Benitez-Amado et al. 2017)	Proposition
Item Reliability	Magnitude & significance of weights **10,000 bootstraps**	Magnitude & significance of weights **Confidence intervals do not include 0** 10,000 bootstraps	Magnitude & significance of weights	Significance of weights **Significance of loadings (but maintain content validity)**	Magnitude & significance of weights Confidence intervals do not include 0 maintain content validity
Multi-collinearity	VIF < 5 or **VIF < 3.33 (conservative)**	VIF < 5	VIF much higher than 1 demonstrates collinearity	VIF < 10	VIF < 3.33
Convergent Validity	**Redundancy analysis**	Redundancy analysis	No mention	No mention	??
Discriminant Validity	n/a	n/a	n/a	n/a	n/a

Structural model evaluation

	IJHRM (Ringle et al. 2018)	IJCHM (Ali et al. 2018)	IMDS (Henseler et al. 2016)	PACIS (Benitez-Amado et al. 2017)	Proposition
Path coefficients	Significance of paths CIs do not include 0 10,000 bootstraps **Evaluate total effects**	Significance of paths CIs do not include 0 No. of bootstraps = 10,000	**Significance of total, direct and indirect paths**	Paths > 0.2 Significance of paths CIs do not include 0	Significance of paths - total, direct, and indirect CIs do not include 0 10,000 bootstraps
Model fit	**Focus on models predictive performance**	SRMR RMS_{theta} **No thresholds**	Fit metrics (d_{uls}, d_g, SRMR) < HI95 quantile	Fit metrics (d_{uls}, d_g, SRMR) < HI95 quantile	**Focus on models predictive performance**
Explained variance (R^2), Effect size(f^2), Predictive relevance(Q^2)	**R^2 > 0.25 (low); 0.50 (medium); or 0.75 (high)** f^2 no threshold Q^2 no threshold	R^2 > 0.25, **f^2 > 0.02 (low); 0.15 (medium); or 0.35 (high)** **Q^2 > 0.02 (low); 0.15 (medium); or 0.35 (high)**	R^2 no threshold f^2 > 0.02 (low); 0.15 (medium); or 0.35 (high)	R^2 no threshold f^2 > 0.02 (low); 0.15 (medium); or 0.35 (high)	R^2 > 0.25 (low); 0.50 (medium); or 0.75 (high) f^2 > 0.02 (low); 0.15 (medium); or 0.35 (high) RMSE

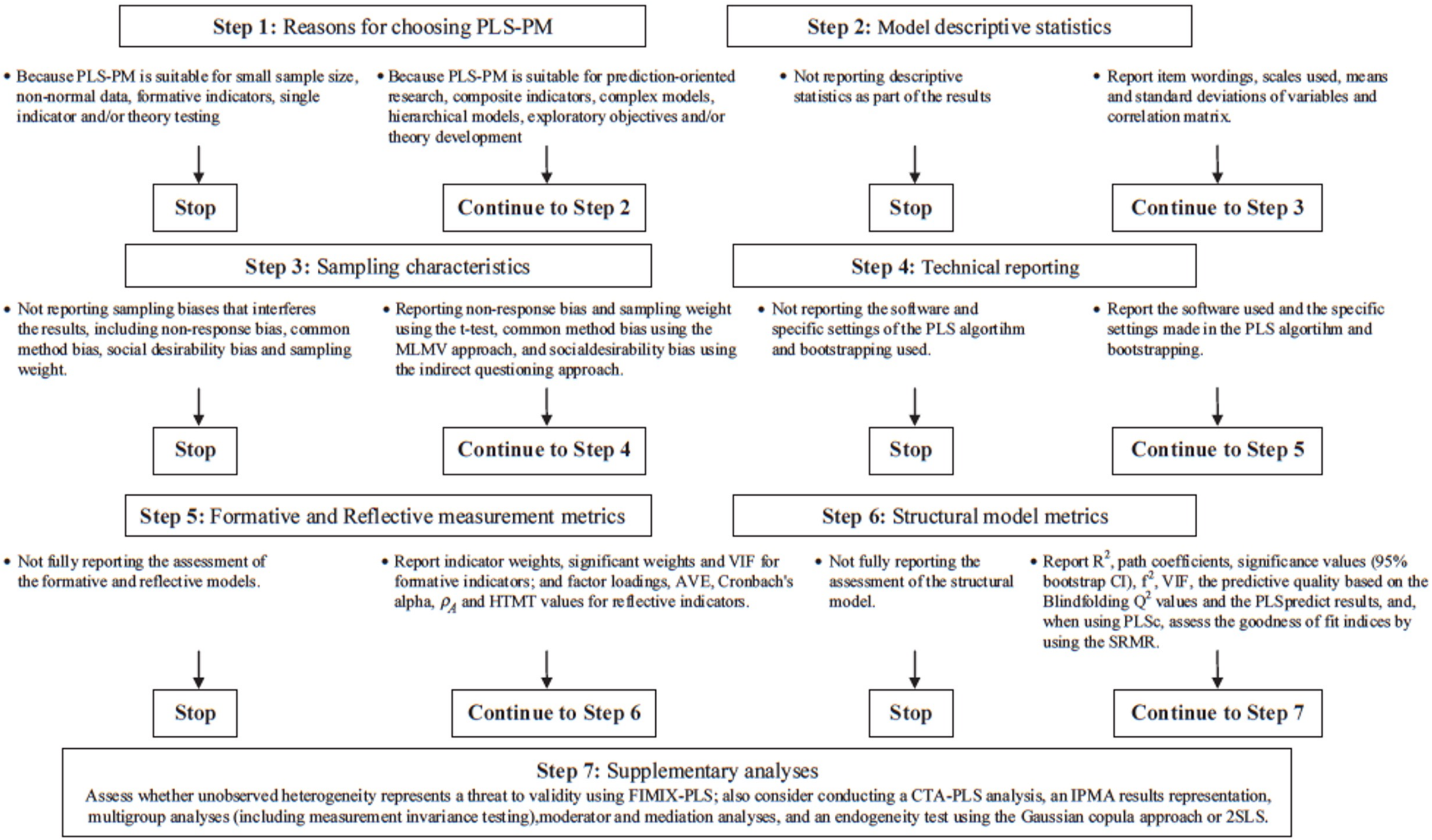


Fig. 2: General Reporting Standards for PLS-PM Analysis.

Thank you
Questions?