An index model for evaluating water safety plans in the Philippines

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ABSTRACT

Developing a water safety plan (WSP) is now a requirement for all service providers of drinking water in the Philippines. To assist compliance with the Philippine Department of Health (DOH), this study develops an index model that the DOH can use for evaluating WSPs and covers the WSPs of 14 water districts and 11 health care facilities. The WSP Index model was developed using a nine-step process and was tested in 25 WSPs to determine the robustness of its weights and benchmark. Approximately 21 WSPs received a passing mark when the 60% benchmark was used but only nine WSPs passed when the benchmark was raised to 74%. This Philippine model may be utilized by countries in evaluating the WSPs, and further adapted to their local context and considerations.

Key words | auditing, review and assessment, water safety, water safety plan, WSP Index

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INTRODUCTION

Water safety plan (WSP) development has been a key recommendation of the World Health Organization (WHO) Guidelines for Drinking-water Quality, 3rd (WHO 2004) and 4th (WHO 2011) editions. Some countries have embarked on studies to measure the beneficial effects of WSPs on water quality, operations of water utilities, and public health (Gunnarsdottir 2012; Gunnarsdottir *et al.* 2012). With the popularity of WSP initiatives, approximately 90 countries around the world have implemented WSPs and about 40 countries have developed policies or regulations that promote or require WSPs, including the Philippines (WHO 2016).

In the Philippines, the water safety planning approach was introduced in 2006 and was first applied in Maynilad Water Services a Incorporated with support from the Australian government and the WHO. Lessons learned from piloting were replicated by other types of drinking-water service providers in the country. As of June 2016, more than 300 water districts (a local corporate entity that operates and maintains a water supply system in one or more provincial cities or municipalities), ten local-government-managed water systems (a drinking-water service provider operated by a city, or municipal or provincial government), eight water refilling stations (a drinking-water service provider operated by a private entrepreneur that uses a packaged-type water treatment technology and sells or delivers treated water to households or establishments by filling 20-litre plastic containers either owned by the station or by the customers), 11 health care facilities (a place where patients visit to avail themselves of health care services such as hospitals and rural health units), and ten community-based water systems (a drinking-water service provider operated by a community organization) received training on water safety planning. These activities saw the completion of about 65 WSPs.

A nationwide roll-out of WSPs is envisaged by the Department of Health (DOH) as a strategy to curb waterborne diseases. To achieve this, on 4 September 2014, the DOH issued the 'National Policy on WSP' (Administrative Order No. 2014-0027) which requires all drinking-water service providers (the *Listahang Tubig* or Water Register of the Philippines recorded 23,070 drinking-water supply providers as of May 2015 (NWRB 2015)) to develop and implement WSPs within three years. To support the DOH,

doi: 10.2166/ws.2017.015

the Local Water Utilities Administration (LWUA) issued Memorandum Circular No. 010.14 on 1 December 2014 reinforcing the requirement for all water districts to develop and implement WSPs. Given this, the demand for WSP development is expected to increase in the coming years, including its review and approval as specified in the Administrative Order.

The DOH is still in the process of developing guidelines for reviewing and approving WSPs. The completed WSPs have not undergone a formal evaluation to determine if they comply with the DOH requirements of a satisfactory understanding of WSP concepts and processes. To assist the DOH with the issuance of guidelines for the WSP review and approval process, this research attempts to develop an index model for evaluating the acceptability of WSPs. This can serve as the basis for approval of a WSP before its implementation. Considering the 11 steps and five stages of WSP development, it would be helpful for the WSP evaluator to have a tool that guides the review process, summarizing the performance of a drinking-water service provider in developing its WSP. The index value expressed as a single number will facilitate the decision of the approving entity on whether to accept the WSP or not.

MATERIALS AND METHODS

Concepts of WSP review and approval

The WHO WSP guidelines (Davison 2005), which discuss the items to be reviewed and approved in a WSP and the WHO WSP Quality Assurance tool (WHO 2012), which helps appraise the stage of WSP processes including WSP development and implementation, were used in developing the framework of this study. Following a review of the literature, the research found a gap in available models that can serve as a reference for evaluating any type of WSP. This lack of information prompted the study and development of a model for the WSP Index.

Concepts of an index model

The use of indices is not new in the development realm. Jacobs *et al.* (2004) defined 'index' as an aggregation of indicators of individual performance that integrates a large amount of information in a format that is easily understood and is therefore a valuable tool for conveying a summary assessment of performance in priority areas. According to Sharpe & Smith (2005), it is an aggregation of individual indicators using a certain weighting scheme. Metge *et al.* (2009) said that it is a mathematical combination of several indicators or measures which can be used to describe an entire set of indicators, and allows for an examination of differences between places and across time.

Steps in developing the WSP Index

In formulating a WSP Index, the author considered the steps recommended by OECD (2008) and Jacobs *et al.* (2004). The following procedures were adopted.

Establish a theoretical framework

Figure 1 shows the theoretical framework used in the study, which was derived from the WSP Manual (WHO 2009). It contains WSP stage indicators (i.e., categories of the different steps in developing a WSP); WSP step indicators (i.e., procedures for how to prepare a WSP); and WSP output indicators (i.e. required items to be completed at every step of WSP development). Output indicators are evaluated with a score based on requirements of the WSP steps. The raw scores are consolidated per WSP stage and multiplied by established weights per WSP stage to determine the WSP Index.

Select indicators

As reflected in the framework, the WSP stage indicators are: (1) Preparation; (2) System Assessment; (3) Operational Monitoring; (4) Management and Communication; and (5) Feedback and Improvement (Figure 1). The WSP step indicators include: (1) Assemble the WSP team; (2) Describe the water supply system; (3) Identify the hazardous events and assess the risk; (4) Determine and validate control measures, reassess and prioritize risks; (5) Develop, implement and maintain an improvement/upgrade plan; (6) Define monitoring of the control measures; (7) Verify the effectiveness of the WSP; (8) Prepare management procedures; (9) Develop supporting programs; (10) Plan and carry out a periodic review of the WSP; and (11) Revise the WSP following an incident.

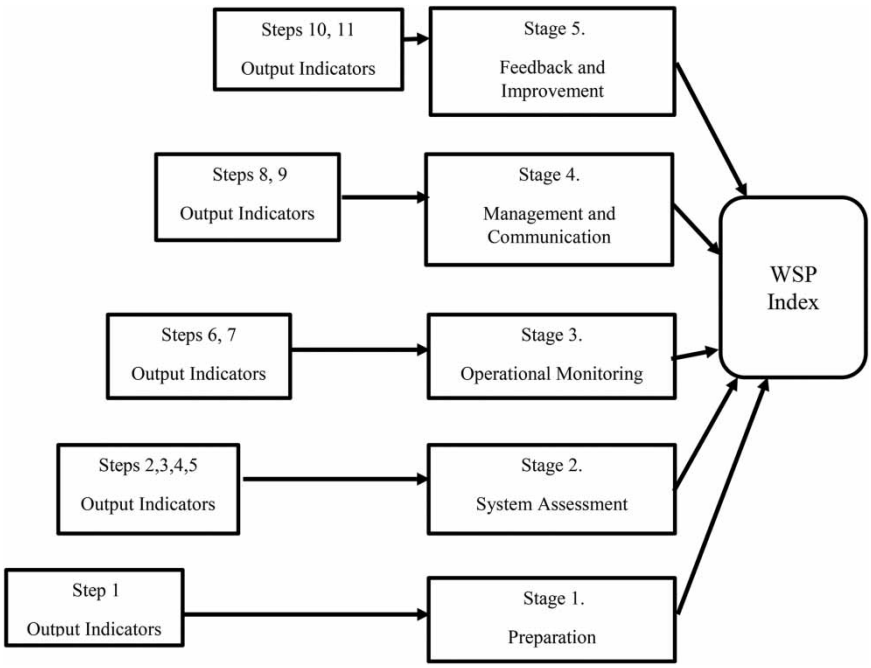

Figure 1 | Theoretical framework of the WSP Index.

Twenty-eight output indicators (Table 1) were identified as the required observable results of each WSP step. These indicators were derived from the WSP Quality Assurance tool (WHO 2012), WSP Manual (WHO 2009), and WSP Manual for Distribution Systems (WHO 2014) using the criteria of Davison *et al.* (2005) and WHO (2011).

Determine the weights

The analytic hierarchy process (AHP) (Saaty 2008) using pairwise comparison was used in determining the corresponding weights of the five WSP stages (Table 2). The weights were calculated using an eigenvector technique and were normalized using a consistency ratio. AHP is considered over other weighting methods due to the involvement of local expert opinion and higher level of transparency of indicators that are inherent features of index development (OECD 2008). The inputs from the local WSP experts made the established weights unique to the Philippines. These inputs are opinions on which WSP stage is considered more important than others. Other countries may adopt the process of establishing the weights from the AHP method using the opinions of their local experts.

Develop a scoring system

The scoring system has a rating that interprets the scores to evaluate the contents and quality of WSP output indicators. The scores and ratings used are: 1 – Poor, if the output did not comply with major requirements and with errors in understanding major concepts; 2 – Fair, if the output has completed major requirements but with errors in understanding major concepts; 3 – Good, if the output has completed major requirements but with errors in understanding minor concepts; 4 – Very Good, if the output has completed all requirements with minor corrections in specific items; and 5 – Excellent, if the indicator has completed all requirements and all concepts are well understood.

Aggregate the indicators to formulate the WSP Index

The WSP Index formula included the weights of the five WSP stages and scores of output indicators. Additive aggregation was used to compute the value of the WSP Index. This method is preferred due to its simplicity, independence from outliers, and compensatory ability for low scores,

Table 1 | WSP output indicators and maximum possible scores[a] per output and per WSP stage

Stage	Step	Output indicator	Maximum possible score per output indicator	Total score per stage
1	1	1. Management support	5	
		2. WSP team	5	
		3. Stakeholders	5	
				15
2	2	4. Users and uses	5	
		5. Drinking water quality standards	5	
		6. Schematic/flow diagrams	5	
		7. System description	5	
	3	8. Risk assessment methodology	5	
		9. Hazardous events	5	
		10. Raw risks	5	
	4	11. Control measures	5	
		12. Residual risks	5	
		13. Significant risks	5	
	5	14. Improvement plan link to risks	5	
		15. Improvement plan details	5	
				60
3	6	16. Operational monitoring plan	5	
		17. Corrective action	5	
	7	18. Compliance monitoring plan	5	
		19. Internal auditing plan	5	
		20. External auditing plan	5	
		21. Consumer satisfaction monitoring plan	5	
				30
4	8	22. SOPs – Normal	5	
		23. SOPs – Incident	5	
		24. SOPs – Emergency	5	
	9	25. Supporting program description	5	
		26. Supporting program plan	5	
				25
5	10	27. Periodic review plan	5	
	11	28. Revision plan	5	
				10
Total			140	140

[a]Maximum possible score of 5 is used per output indicator to determine the maximum possible total score per stage to be used as denominator in the WSP Index formula.

Table 2 | Determination of weights per WSP stage using pairwise comparison of AHP

	Eigenvector								
WSP stage	1	2	3	4	5	Total	Row average	Computed weights	Suggested weights by local WSP experts
1	0.0769	0.0833	0.0541	0.0870	0.0769	0.3782	0.0756	0.08	0.10
2	0.3846	0.4167	0.5405	0.4348	0.3846	2.1612	0.4322	0.43	0.40
3	0.3846	0.2083	0.2703	0.3478	0.3077	1.5187	0.3037	0.30	0.30
4	0.0769	0.2083	0.0676	0.0870	0.1538	0.5936	0.1187	0.12	0.15
5	0.0769	0.0833	0.0676	0.0435	0.0769	0.3482	0.0696	0.07	0.05

$CI = 0.0937$; $CR = 0.084$.

which is needed in a benchmarking exercise. According to OECD (2008), a linear aggregation method is useful when all individual indicators have the same units of measurement and with preferred independence. However, the absolute value of the indicators has a tendency to be lost (OECD 2008).

$$\text{WSP Index} = \sum\left[\frac{(S_1{*}w_1)}{X_1}+\frac{(S_2{*}w_2)}{X_2}+\frac{(S_3{*}w_3)}{X_3}+\frac{(S_4{*}w_4)}{X_4}+\frac{(S_5{*}w_5)}{X_5}\right]$$

where:

$S_1 = s_1 =$ Stage 1: Preparation scores

$S_2 = s_2 + s_3 + s_4 + s_5 =$ Stage 2: System assessment scores

$S_3 = s_6 + s_7 =$ Stage 3: Operational monitoring scores

$S_4 = s_8 + s_9 =$ Stage 4: Management and communication scores

$S_5 = s_{10} + s_{11} =$ Stage 5: Feedback and improvement scores

$w_{i\ (i=1\ to\ 5)} =$ weight per WSP stage (in percent)

$x_{i\ (i=1\ to\ 5)} =$ total maximum possible score per WSP stage

$s_{i\ (i=1\ to\ 5)} =$ scores per WSP step

Set a benchmark for WSP acceptability

To determine the passing mark for WSPs, a minimum score of 3 in all of the 28 output indicators was considered. The score of 3 means that the drinking-water service provider has completed the major requirements, but with errors in understanding minor concepts in any of the output indicators. This computation resulted in 60% as the minimum WSP Index needed for WSP acceptance. The robustness of this benchmark was tested using sensitivity analysis and it was found that a minimum benchmark of 74% for WSP acceptability is more realistic (Table 3).

Test the WSP Index model

Purposive sampling was used in selecting types of WSPs from the existing WHO project that recently evaluated WSPs. This includes 14 water districts and 11 health care facilities. The author tested the WSP Index formula in 25 WSPs to determine its applicability (Table 4). An Excel spreadsheet was utilized to facilitate computation.

Table 3 | Simulating WSP Index by adjusting the scores of WSP steps

Stage	Step	Output indicator	Max score	Assumption 1	Assumption 2
1	1	1. Management support	5	3	3
		2. WSP team	5	3	3
		3. Stakeholders	5	3	5
2	2	4. Users and uses	5	3	5
		5. Drinking water quality standards	5	3	5
		6. Schematic/flow diagrams	5	3	3
		7. System description	5	3	3
	3	8. Risk assessment methodology	5	3	5
		9. Hazardous events	5	3	3
		10. Raw risks	5	3	3
	4	11. Control measures	5	3	3
		12. Residual risks	5	3	3
		13. Significant risks	5	3	3
	5	14. Improvement plan link to risks	5	3	3
		15. Improvement plan details	5	3	3
3	6	16. Operational monitoring plan	5	3	3
		17. Corrective action	5	3	3
	7	18. Compliance monitoring plan	5	3	5
		19. Internal auditing plan	5	3	5
		20. External auditing plan	5	3	5
		21. Consumer satisfaction monitoring plan	5	3	5
4	8	22. SOPs – Normal	5	3	3
		23. SOPs – Incident	5	3	3
		24. SOPs – Emergency	5	3	3
	9	25. Supporting program description	5	3	3
		26. Supporting program plan	5	3	3
5	10	27. Periodic review plan	5	3	5
	11	28. Revision plan	5	3	5
WSP Index				60%	74%

Note: Assumption 1 – All output indicators have a minimum score of 3.
Assumption 2 – All output indicators with readily available information were given a maximum possible score of 5.

Conduct uncertainty and sensitivity analysis

Potential sources of uncertainty were addressed by conducting the following activities: selection (inclusion or exclusion) of individual indicators; normalization – use of ranking for output indicators; weighting – use of analytical hierarchy process; and aggregation of indicators – use of linear additive aggregation.

Table 4 | Summary of WSP Index of drinking-water supply providers

	WSP Index (%) benchmark = 60%		
	Equal weights	Simple weights	AHP weights
a. Water Districts			
1. Water District A	61	69	68
2. Water District B	76	80	81
3. Water District C	64	63	64
4. Water District D	66	70	71
5. Water District E	79	79	79
6. Water District F	71	72	71
7. Water District G	75	71	70
8. Water District H	63	66	68
9. Water District I	69	72	72
10. Water District J	91	89	87
11. Water District K	89	90	90
12. Water District L	70	76	74
13. Water District M	70	71	73
14. Water District N	52	57	57
b. Health Care Facilities			
1. Health Care Facility A	72	73	71
2. Health Care Facility B	34	39	37
3. Health Care Facility C	82	79	78
4. Health Care Facility D	75	71	70
5. Health Care Facility E	63	69	69
6. Health Care Facility F	80	82	83
7. Health Care Facility G	65	61	58
8. Health Care Facility H	64	56	54
9. Health Care Facility I	89	88	88
10. Health Care Facility J	63	63	63
11. Health Care Facility K	88	88	89

Sensitivity analysis is used to test the robustness of the AHP weights and the WSP Index benchmark of 60%. Table 4 shows that AHP weights are more stringent than equal weights (100% divided by five categories = 20%) and simple weights (maximum possible score of a WSP category divided by the total maximum possible score of 140) in the sense that, for example, Health Care Facility G WSP, with a failing mark of 58% using AHP weights, got a passing mark of 65% and 61%, respectively, in consideration of the initial benchmark of 60%. Sample computations are shown in Tables 5–7 for the WSP Index using different weighting systems. To test the 60% benchmark, scores of output indicators were manipulated using two assumptions:

(1) all output indicators were given a minimum score of 3; and
(2) all output indicators with readily available information were given a maximum score of 5. This test resulted in a 74% benchmark.

Consult WSP experts and stakeholders

Filipino WSP experts from the DOH, LWUA, and the University of the Philippines and other stakeholders of selected water utilities and agencies were consulted to gather their insights and comments on the selected indicators, weights of WSP stages, formula of the WSP Index, and the minimum benchmark of the index for WSP acceptability. All elements of the WSP Index were accepted, except for the weights wherein adjustment to rounded figures was suggested (Table 2). This concept of WSP Index can be further enhanced even for global application by getting the inputs of international WSP experts on similar WSP elements considered in this study.

RESULTS AND CONCLUSION

WSP Index formula

The derived WSP Index formula is composed of WSP output indicators, WSP step indicators, WSP stage indicators, and the established weights using AHP. After determining the weights per WSP stage (Table 2) and the maximum possible scores for WSP output indicators (Table 1), the final WSP Index formula is

$$\text{WSP Index} = \sum\left[\frac{(S_1{*}0.1)}{15}+\frac{(S_2{*}0.4)}{60}+\frac{(S_3{*}0.3)}{30}+\frac{(S_4{*}0.15)}{25}+\frac{(S_5{*}0.05)}{10}\right]$$

This equation was developed using local experts' input on weights and number of output indicators which may

Table 5 | Sample computation of WSP Index for Water District B using equal weights

Stage	Step	Output indicator	Score per output indicator	Total score per stage (A)	Maximum possible score per stage (B)	Equal weights (%) (C)	WSP Index (%) (D)
1	1	1. Management support	5				
		2. WSP team	5				
		3. Stakeholders	5				
				15	15	20	20
2	2	4. Users and uses	1				
		5. Drinking water quality standards	5				
		6. Schematic/flow diagrams	5				
		7. System description	5				
	3	8. Risk assessment methodology	3				
		9. Hazardous events	4				
		10. Raw risks	5				
	4	11. Control measures	3				
		12. Residual risks	1				
		13. Significant risks	3				
	5	14. Improvement plan link to risks	3				
		15. Improvement plan details	3				
				41	60	20	14
3	6	16. Operational monitoring plan	4				
		17. Corrective action	5				
	7	18. Compliance monitoring plan	5				
		19. Internal auditing plan	5				
		20. External auditing plan	4				
		21. Consumer satisfaction monitoring plan	5				
				28	30	20	18
4	8	22. SOPs – Normal	5				
		23. SOPs – Incident	5				
		24. SOPs – Emergency	5				
	9	25. Supporting program description	5				
		26. Supporting program plan	5				
				25	25	20	20
5	10	27. Periodic review plan	1				
	11	28. Revision plan	1				
				2	10	20	4
Total			111	111	140	100	**76**

Sample computation for Stage 1:

$$D_1 = A_1 * C_1 / B_1 = 15 * 20/15 = 20$$

Sample computation for WSP Index:

$$\text{WSP Index} = D_1 + D_2 + D_3 + D_4 + D_5 = 20\% + 14\% + 18\% + 20\% + 4\% = 76\%.$$

Table 6 | Sample computation of WSP Index for Water District B using simple weights

Stage	Step	Output indicator	Score per output indicator	Total score per stage (A)	Maximum possible score per stage (B)	Simple weights (%) (C)	WSP Index (%) (D)
1	1	1. Management support	5				
		2. WSP team	5				
		3. Stakeholders	5				
				15	15	11	11
2	2	4. Users and uses	1				
		5. Drinking water quality standards	5				
		6. Schematic/flow diagrams	5				
		7. System description	5				
	3	8. Risk assessment methodology	3				
		9. Hazardous events	4				
		10. Raw risks	5				
	4	11. Control measures	3				
		12. Residual risks	1				
		13. Significant risks	3				
	5	14. Improvement plan link to risks	3				
		15. Improvement plan details	3				
				41	60	43	30
3	6	16. Operational monitoring plan	4				
		17. Corrective action	5				
	7	18. Compliance monitoring plan	5				
		19. Internal auditing plan	5				
		20. External auditing plan	4				
		21. Consumer satisfaction monitoring plan	5				
				28	30	21	20
4	8	22. SOPs – Normal	5				
		23. SOPs – Incident	5				
		24. SOPs – Emergency	5				
	9	25. Supporting program description	5				
		26. Supporting program plan	5				
				25	25	18	18
5	10	27. Periodic review plan	1				
	11	28. Revision plan	1				
				2	10	7	1
Total			111	111	140	100	**80**

Sample computation for Stage 1:

$$D_1 = A_1 * C_1 / B_1 = 15 * 11/15 = 11$$

Sample computation for WSP Index:

$$\text{WSP Index} = D_1 + D_2 + D_3 + D_4 + D_5 = 11\% + 30\% + 20\% + 18\% + 1\% = 80\%.$$

Table 7 | Sample computation of WSP Index for Water District B using AHP weights

Stage	Step	Output indicator	Score per output indicator	Total score per stage (A)	Maximum possible score per stage (B)	AHP weights (%) (C)	WSP Index (%) (D)
1	1	1. Management support	5				
		2. WSP team	5				
		3. Stakeholders	5				
				15	15	10	10
2	2	4. Users and uses	1				
		5. Drinking water quality standards	5				
		6. Schematic/flow diagrams	5				
		7. System description	5				
	3	8. Risk assessment methodology	3				
		9. Hazardous events	4				
		10. Raw risks	5				
	4	11. Control measures	3				
		12. Residual risks	1				
		13. Significant risks	3				
	5	14. Improvement plan link to risks	3				
		15. Improvement plan details	3				
				41	60	40	27
3	6	16. Operational monitoring plan	4				
		17. Corrective action	5				
	7	18. Compliance monitoring plan	5				
		19. Internal auditing plan	5				
		20. External auditing plan	4				
		21. Consumer satisfaction monitoring plan	5				
				28	30	30	28
4	8	22. SOPs – Normal	5				
		23. SOPs – Incident	5				
		24. SOPs – Emergency	5				
	9	25. Supporting program description	5				
		26. Supporting program plan	5				
				25	25	15	15
5	10	27. Periodic review plan	1				
	11	28. Revision plan	1				
				2	10	5	1
Total			111	111	140	100	**81**

Sample computation for Stage 1:

$$D_1 = A_1 * C_1 / B_1 = 15 * 10 / 15 = 10$$

Sample computation for WSP Index:

$$\text{WSP Index} = D_1 + D_2 + D_3 + D_4 + D_5 = 10\% + 27\% + 28\% + 15\% + 1\% = 81\%.$$

vary in other countries depending on the decision of their local WSP experts.

WSP Index computation

The 25 WSPs were evaluated using the WSP Index formula. About 21 of 25 WSPs were found to meet the benchmark of 60%. However, when the benchmark was raised to 74% after the sensitivity analysis, only nine WSPs passed. Specific WSP steps that received low scores were steps 1, 4, 5, 7, 8, 9, 10 and 11. Reasons for low scores are due to the incomplete data submitted and poor understanding of the risk assessment methodology. Incomplete data can be addressed by actual visits to drinking-water service providers. Some available information missed in the WSP submission could be gathered and validated on site to improve the scores.

CONCLUSION

The development and testing of the WSP Index was able to determine the overall status of the selected WSPs and provide a basis for DOH approval upon meeting the established benchmark. The scoring system can serve as a checklist to determine the completion of DOH requirements per WSP step and identify the gaps in understanding WSP concepts. Scores may improve if actual visits to drinking-water service providers could be conducted to gather and validate the readily available information. This consideration will justify the WSP acceptance benchmark of 74% instead of 60%. Other countries may adopt the Philippine model of developing the WSP Index which may have variations in the index equation due to local experts' inputs on weights and indicators. The index model can be further enhanced by its application in other countries provided there is sustained collaboration and input from international WSP experts.

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First received 20 June 2016; accepted in revised form 24 January 2017. Available online 7 February 2017