Sustainable Product Architecture and Supplier Selection (S-PASS)

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Introduction

A decision support tool for considering environmental impact in product architectures and supplier identification is presented for the Cool:SLiCE Platform.

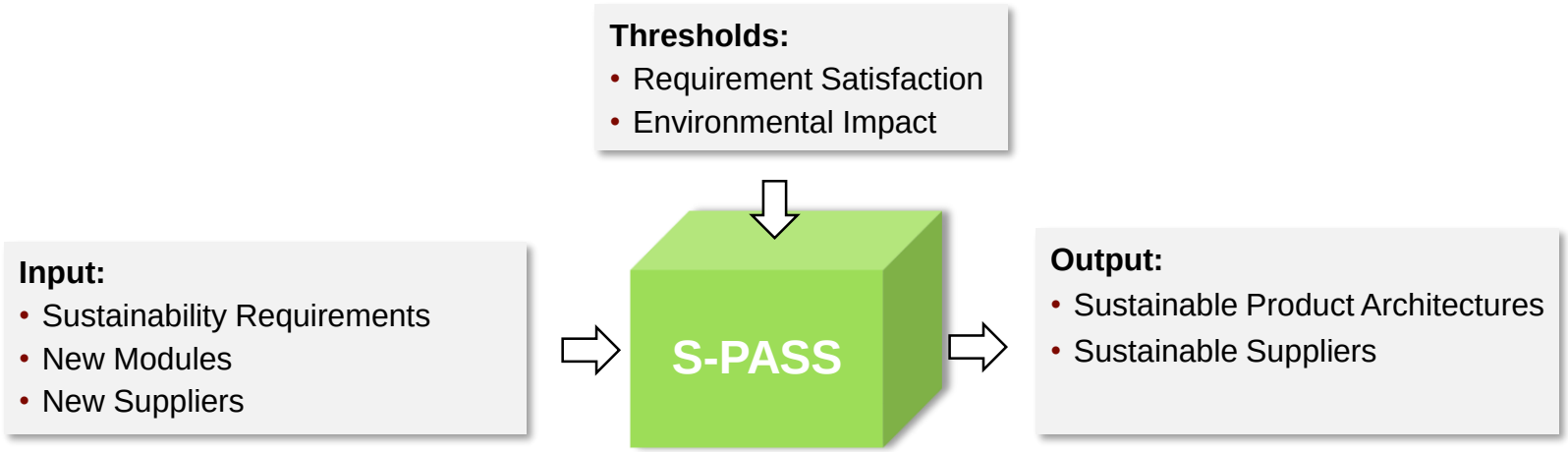
Objectives

- To develop an instrument enhancing students' class activities on sustainable product and service design modules
- To provide an easy to use and effective tool to enable students to determine product architectures and OEM suppliers with consideration of possible environmental impacts

→ **Sustainable Product Architecture & Supplier Selection** (S-PASS) Tool is developed based on ASIT-E*, proposed by Ye et al. (2015).

*Architecture & Supplier Identification Tool with Environmental impact estimation

Overview of S-PASS



Ye, Y., Jankovic, M., Kremer, G., Yannou., B., Leroy, Y., & Bocquet, J-C. (2015). Integration of Environmental Impact Estimation in System Architecture & Supplier Identification. Research in Engineering Design, Accepted pending revisions.

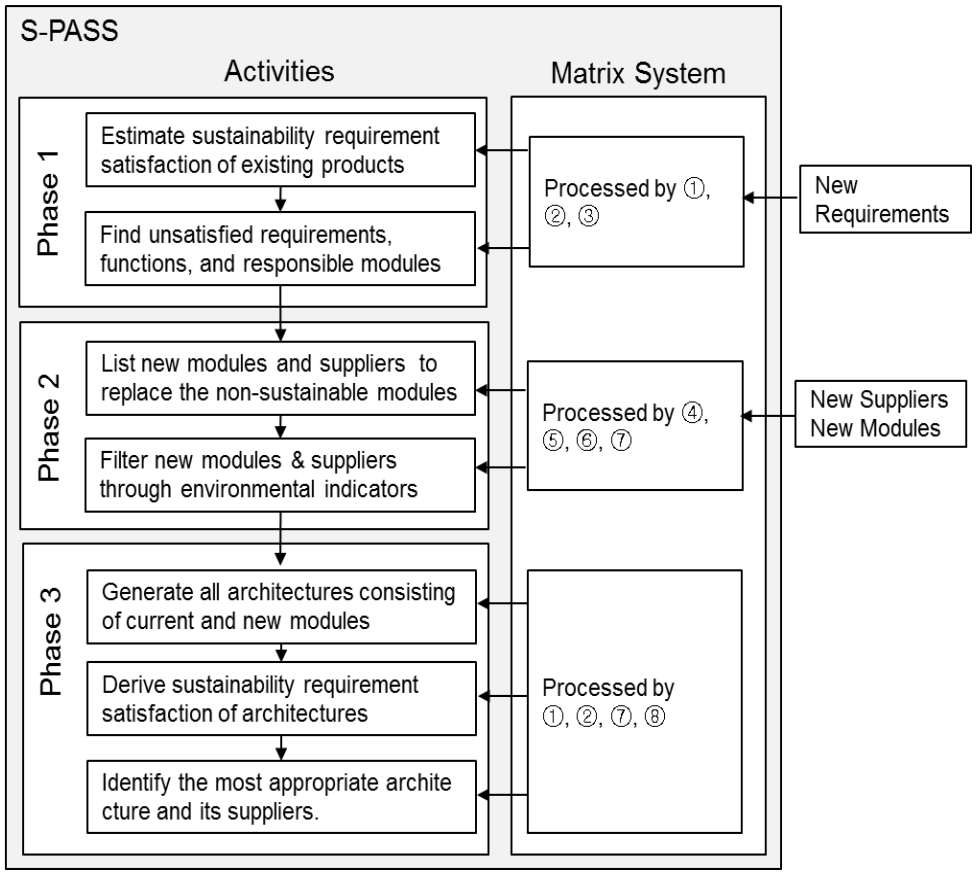
Stucture of S-PASS

S-PASS consists of three phases to identify sustainable product architectures and their suppliers.

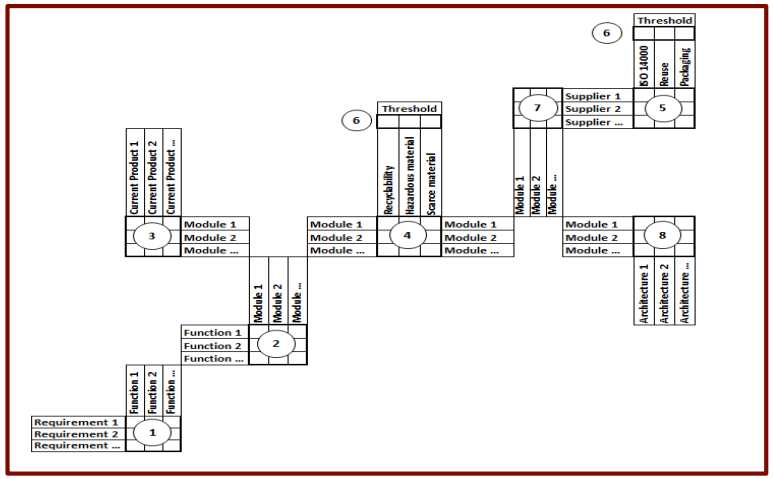
Main Phases of S-PASS

1) Phase 1: Sustainability Requirement Satisfaction of Existing Products
2) Phase 2: New Module & Supplier Filtering
3) Phase 3: Product Architecture & Supplier Selection

S-PASS Framework



Matrix System



Environmental Indicators (Examples)

<u>Module Related</u>

- Recyclability
- Hazardous Material Use
- Scarce Material Use

<u>Supplier Related</u>

- ISO 14001
- Environmental Friendly Packaging
- Use of Recycled Material

Phase 1 - Input

Sustainability Requirement Satisfaction of Existing Products

Objective

- Identify product modules that do not satisfy sustainability requirements and functions

Input Procedure

[Step1]: Construction of Requirements – Function (RF) Matrix

1. Define sustainability requirements (i) for products: $i = r_1, \ldots, r_n$
2. Identify product functions (j) related to defined requirements: $j = f_1, \ldots, f_m$
3. Construct $\mathbf{RF}_{ij}$ = contribution (%) of j to i; $0 \leq \mathbf{RF}_{ij} \leq 1$; $\mathbf{RF}_{i\cdot} = 1$

[Step2]: Construction of Function – Module (FM) Matrix

1. Identify modules (k) in products : $k = m_1, \ldots, m_n$
2. Construct $\mathbf{FM}_{jk}$ = satisfaction level (categorical value) of k to j; 1 (poor) $\leq \mathbf{FM}_{jk} \leq$ 5 (excellent)

[Step3]: Construction of Module – Product (MP) Matrix

1. List considered products (p) : $p = p_1, \ldots, p_n$
2. Construct $\mathbf{MP}_{kp}$ = if k is related to p → 1, if not → 0

Phase 1 - Output

Sustainability Requirement Satisfaction by Existing Products

Output Procedure

[Step1]: Derivation of Function – Product (FP) Matrix

1. $\mathbf{R}_{jk}$ = if $\mathbf{FM}_{jk} > 0$ → 1, if not → 0 : association between functions and modules

2. $\mathbf{FP}_{jp} = \frac{\mathbf{FM}_{jk} \times \mathbf{MP}_{kp}}{\mathbf{R}_{jk} \times \mathbf{MP}_{kp}}$: average function satisfaction levels of modules in each product

3. If $\mathbf{FP}_{jp}$ is less than 3 for any p → j is not satisfied in at least one of current products

[Step2]: Derivation of Requirement – Product (RP) Matrix

1. $\mathbf{RP}_{ip} = \mathbf{RF}_{ij} \times \mathbf{FP}_{jp}$: satisfaction level of each sustainability requirement for each product

2. If $\mathbf{RP}_{ip}$ is less than 3 for any p → i is not satisfied in at least one of current products

[Step3]: Identification of Non-Sustainable Module

1. List k if $\mathbf{R}_{jk} = 1$ for unsatisfied j in Step 1

2. A set of identified ks shows modules in current products that are non-sustainable and should be replace d with alternatives.

Phase 2 – Input & Output

Module & Suppler Filtering

Objective

- Find new modules and their suppliers to replace the non-sustainable modules from Phase 1

Input Procedure

[Step1]: Identification of New Modules and Suppliers

1. $M = \{m1, \ldots, m_n\}$: new modules; $S_m = \{s1, \ldots, s_k\}$, $m \in M$: suppliers of new modules

[Step2]: Evaluation of Environmental Sustainability of New Modules and Suppliers

1. Set module related sustainability indicators (I_m) and supplier related sustainability indicators (I_s)

   - I_m and I_s should be measured with ordinal or numerical values

2. Evaluate each module and supplier through I_m and I_s

[Step3]: Determination of Thresholds for Module and Supplier Related Sustainability Indicators

1. Determine evaluation values that indicate the least acceptable levels for I_m and I_s

Output Procedure

[Step1]: Checking Modules and Suppliers with Thresholds of Indicators

1. Identify modules and suppliers that are evaluated with an above threshold level in any one of indicators

[Step2]: Elimination Non-Sustainable Modules and Suppliers

1. Eliminate m, which do not satisfy any one of I_m
2. Eliminate m which are provided by s, and do not satisfy any one of I_s

Phase 3 - Input

Product Architecture and Supplier Selection

Objective

- Identify the most sustainable product architecture and associated suppliers

Input Procedure

[Step1]: Reconstruction of Function – Module (FM) Matrix

1. List modules (k*) = existing sustainable modules in Phase 1 and new sustainable modules in Phase 2
2. List functions (j) obtained from Phase 1
3. Construct $\mathbf{FM}_{jk^*}$ = satisfaction level (categorical value) of k to j to l; 1 (poor) ≤ $\mathbf{FM}_{jk^*}$ ≤ 5 (excellent)

[Step2]: Construction of Supplier – Module (SM) Matrix

1. List modules (k*) = existing sustainable modules in Phase 1 and new sustainable modules in Phase 2
2. List all suppliers (s) providing k*
3. Construct $\mathbf{SM}_{sk^*}$ = if k is provided by s → 1, if not → 0

[Step3]: Construction of Module – Architecture (MA) Matrix

1. List modules (k*) = existing sustainable modules in Phase 1 and new sustainable modules in Phase 2
2. A detonates possible product architectures (A = a_1, … a_n)
3. Construct $\mathbf{MA}_{k^*a}$ = if k is considered to be used in a → 1, if not → 0

Phase 3 - Output

Product Architecture and Supplier Selection

Output Procedure

[Step1]: Derivation of Function – Architecture (FA) Matrix

1. $\mathbf{R}_{jk^*}$ = if $\mathbf{FM}_{jk^*} > 0$ → 1, if not → 0 : association between functions and modules

2. $\mathbf{FA}_{ja} = \frac{\mathbf{FM}_{jk^*} \times \mathbf{MA}_{k^*j}}{\mathbf{R}_{jk^*} \times \mathbf{MA}_{k^*a}}$: average function satisfaction levels of modules in each product architecture

[Step2]: Derivation of Requirement – Architecture (RA) Matrix

1. $\mathbf{RA}_{ia} = \mathbf{RF}_{ij} \times \mathbf{FA}_{ja}$: satisfaction level of each sustainability requirement for each product architecture

2. max ($\sum_a \mathbf{RA}_{ia}$) → the most appropriate product architecture

[Step3]: Derivation of Supplier – Architecture (SA) Matrix

1. $\mathbf{SA}_{sa} = \mathbf{SM}_{sk^*} \times \mathbf{MA}_{k^*a}$: suppliers required to realize each product architecture

   - If $\mathbf{SA}_{sa} = 1$ → the product architecture needs the supplier,

     $= 0$ → the product architecture does not need the supplier