Selection strategy implementation of cleaner production using ISM and AHP Method in Chemical Laboratory of Service Industries

D Rimantho and D Ardinia

Abstract. The chemical analysis in the service industry cannot be separated from energy use, water, consumables, and chemicals related to the amount of waste produced. The number of hazardous solid waste generated in the CRS Chemical Laboratory division has increased in certain months, ranging from 400-600 kg. This shows the low implementation of green production in the company. Therefore, the purpose of this study is to analyze the key criteria and determine the best strategies to reduce waste. The method used in this study is Interpretive Structural Modeling to find key criteria and the Analytic Hierarchy Process method to determine the priority selection of cleaner production implementation strategies. This study uses a questionnaire distributed to four experts. The results showed that there were nineteen sub-criteria analyzed in determining key criteria. The sub-criteria for lack of awareness from both individuals and organizations regarding changes for the better is a key criterion in the application of cleaner production. Furthermore, the best alternative calculation results using the AHP method obtained by the implementation of periodic green production socialization to employees has the greatest valuation of 0.57 with a Consistency Ratio (CR) of 0.09. Further research is needed to evaluate the alternatives chosen.

Keywords: Analytic Hierarchy Process (AHP), Interpretive Structural Modelling (ISM), Key Criteria, Priority, Cleaner Production

1. Introduction
The development of environmentally friendly industries has become a global demand to support the achievement of sustainable development that is successful currently. In 1992, clean production was emphasized as an important means of achieving sustainable development in Agenda 21, which was adopted at the United Nations Conference on Environment and Development [1]. Cleaner production was introduced by the United Nations Environment Program (UNEP) in May 1989 and was officially proposed in September 1989 at the Promotion on Cleaner Production seminar in Canterbury. Indonesia agreed to adopt the definition conveyed by UNEP that clean production is preventive and integrated. Therefore, the strategy needs to be applied continuously to the production process and product life cycle with the aim of reducing risks to humans and the environment.

Cleaner production is an environmental management strategy that is directed towards prevention and is integrated so that it can be applied to the entire production cycle. It has the aim to increase productivity by providing better levels of efficiency in the use of raw materials, energy, and water,
encouraging better environmental performance through reducing sources of waste generation and emissions and reducing the impact of products on the environment from product life with designs environmentally friendly, but effective in terms of cost.

Study conducted by Shah describes that clean production can be applied at all levels of decision making in the industry with its main focus of applying cleaner technologies and techniques, and can be applied to various sectors (for example, industry, infrastructure, housing, and hospitality services) and organizational size (from large petrochemical plants to small company industries) [2]. In other countries, the application of cleaner production has also been widely applied. In the study described by Vukadinovic et al. in Serbia, the application of clean production is carried out in large petrochemical companies by optimizing steam systems and modification [3]. The steps implemented led to a reduction in total energy consumption by 6% and a reduction in greenhouse gas emissions by 9 tons of CO2. In Laos, the application of cleaner production was also applied at the Manoluck Hotel [4]. After the hotel implemented clean production, there was a 65% reduction in specific energy consumption and greenhouse gas emissions, 76% in water consumption, wastewater generation and a significant reduction in the waste generation for disposal by waste sorting and composting for use as a soil conditioner. Based on the description shows that net production can be applied in various industrial sectors both manufacturing and services.

In Indonesia, the application of cleaner production has contributed significantly to the batik industry [5], which can improve environmental performance in terms of reducing the concentration of BOD, COD, and TSS by 85%, 89%, and 98% respectively in waste generated. The clean production option implemented is to substitute a material input strategy that is replacing chemical dyes with natural dyes during the coloring process.

The CRS Chemical Laboratory Division also has issues related to environmental management. This can be known from the activities or activities carried out, such as the use of energy, electricity, water, hazardous chemicals, and other consumables that will be related to the amount of waste produced. Related to the amount of waste generated both solid and liquid waste, the amount of waste should still be more minimized because in the actual situation there is still the use of consumables and chemicals that are not yet efficient.

Cleaner production is an integrated environmental management strategy that, if properly and truly implemented, will become an alternative company in an effort to increase the efficiency and effectiveness of resource use. Although the actual conditions illustrate that the company has not implemented clean production properly. That is because there are several factors that have the potential to influence and hinder the process of implementing clean production. Thus, the application of a cleaner production process requires appropriate decision making in determining strategies in various types of companies. Numerous researches related to decision-making strategies in solving environmental issues have been done in previous studies. For example, some of these studies include research on renewable energy [6], municipal waste management [7], improving the quality of wastewater in the food industry [8], Strategy for enlightening Environmental Performance of Small Scale Cracker Industry [9], Cleaner Production Application at Small Scale Bakery Industry [10]. However, research related to strategies regarding the application of cleaner production in the analysis services industry has never been done.

Therefore, the purpose of this study is to determine the factors that have the potential to contribute to the implementation of clean production in the CRS Chemical Laboratory division. In order to determine the key factors in the implementation of cleaner production using the ISM method and determine the priorities used in the selection of cleaner production implementation strategies based on the key factors of the sub-criteria by using the AHP method.

2. Methods
Primary data collection was carried out in several ways such as field observations, brainstorming and interviews with employees in the CRS Chemical Laboratory division. The questionnaire method was carried out by giving a list of questions (questionnaire), both openly and closely, to be filled in by
respondents (experts) where the list of questions had been prepared in advance. In this study, the distribution of questionnaires was divided into four stages. The first stage is intended to determine criteria and sub-criteria, the second stage is to determine the contextual relationship between subcriteria for determining key criteria, the third stage to determine alternative proposals, and the fourth stage to determine pairwise comparisons between alternative strategies in implementing clean production. The number of experts used in this study was as many as four people. The experts used in this study have different backgrounds such as academics, environmental experts, company leaders.

One method that can be applied in strategic policy planning is modeling using ISM. In addition, the ISM method can be applied in the analysis of problems that have high complexity that cannot be solved by operational research methods and descriptive statistics. There are several stages in implementing the ISM method, namely:

1. Identification of factors that can be done through literature studies and brainstorming
2. Making contextual relationships between factors based on the purpose of the model being developed
3. Develop a single SSIM interaction matrix. There are 4 symbols used to describe the type of relationship between two factors in the system under consideration.
   a. V: the relationship of factor Ei to Ej, not vice versa
   b. A: factor Ej relationship with Ei, not vice versa
   c. X: interrelated relationship between Ei and Ej (vice versa)
   d. O: indicates that Ei and Ej are not related
4. Make a reachability matrix that changes the SSIM symbol into a binary matrix, i.e., for V, Ei becomes 1 while Ej will be 0, for X, Ei will be 1 and Ej will be 1, for O Ei is 0 and Ej is 1, for A, Ei is 0 and Ej is also 0.
5. Create partitions from the final reachability matrix to different levels
6. Make a graph based on the final reachability matrix
7. Make digraph as ISM models
8. Check for consistency based on the ISM model that has been built

After the key criteria are obtained, the next priority strategy determination is obtained using the Analytic Hierarchy Process (AHP) method. The steps that must be done in the AHP method for solving a problem begin with defining the problem and making the details of the desired solution then the hierarchical structure is made. The pairwise comparison matrix is made for the contribution or influence of each relevant element for each influential criterion at the level above it. Furthermore, the geometric mean value is calculated. After collecting all the paired comparative data, then the inverse values are entered along with entry number 1 along the main diagonal, then priority is searched and a consistency test is sought.

The implementation of the same steps is carried out for all levels and clusters in the hierarchy. Hierarchical composition or synthesis is used to weight the priority vectors by weighting the criteria, and adding up all the weighted priority entries concerned with priority entries from the next lower level, and so on. The result is an overall priority vector for the lowest level of the hierarchy. The final step is to conduct a consistency evaluation for the entire hierarchy. Calculate the Consistency Ratio using the formula: CR = CI / IR. Where CR = Consistency Ratio, CI = Consistency Index, and IR = Random Consistency Index. Check consistency if the consistency ratio (CI / IR) is less or equal to 0.1, then the calculation results can be declared correct. If not, the calculation must be corrected.

3. Result and discussion

Based on the results of discussions with experts who are parties involved in research in the field, various factors that contribute to causing net production have not been implemented in the company. The factors are divided into five namely human, material, method, machine and environment. The five factors then developed and obtained information about several sub-criteria of the five main factors. Initially from the results of brainstorming obtained 25 sub-criteria that contribute.
After distributing the first questionnaire and calculating the validation of each sub-factor, 19 valid sub-factors were obtained. Several of these sub factors lack of information (MA 1), lack of training (MA 2), inconsistency (MA 3), lack of awareness (MA 4), weak internal communication (MA 5), inappropriate use of materials and electricity (MT 1), the presence of some chemicals that exceed the shelf life (MT 2), the absence of work instruction (WI) about clean production (ME 1), the application of WI about separation waste has not properly (ME 2), the implementation of the engine's internal maintenance schedule has not been carried out regularly (ME 3), there are no appropriate restrictions in the classification of samples (ME 4), the application of the WI regarding the use and placement of machines has not properly (ME 5), the implementation of building maintenance schedules has not regularly (ME 6), old machines (MS 1), machinery often experience problems (MS 2), the existence of improper installation and placement of machines (MS 3), narrow spaces and limited space (LI 1), inappropriate temperatures in several rooms (LI 2), and air polluted from the use of chemicals (LI 3).

Table 1 Structural Self Interaction Matrix (SSIM)

| MA1 | MA2 | MA3 | MA4 | MA5 | MT1 | MT2 | ME1 | ME2 | ME3 | ME4 | ME5 | ME6 | MS1 | MS2 | MS3 | LI1 | LI2 | LI3 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| X   | V   | A   | X   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | X   | V   | V   | V   |
| V   | A   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | X   | V   | V   |
| A   | V   | A   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | X   | V   |
| X   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | X   |
| V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   |
| A   | A   | A   | A   | A   | A   | A   | A   | A   | A   | O   | O   | O   | O   | O   | A   | A   | A   | A   |
| O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | A   | A   | A   |
| A   | A   | O   | V   | V   | O   | V   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   |
| V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   |
| V   | V   | O   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   |
| O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   |
| A   | A   | O   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   |
| X   | X   | A   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   |
| A   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   |
| V   | V   | O   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   |
| V   | V   | O   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   | V   |
| O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   | O   |
| X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   | X   |

Based on the results of the second stage questionnaire that has been filled out by the respondents, the next step is to make a Structural Self Interaction Matrix (SSIM) matrix as in Table 1. Furthermore, based on Table 1 about the SSIM matrix then made in the form of a Reachability Matrix (RM) table by replacing V, A, X, O become numbers 1 and 0. Thus, the results obtained in Table 2. Moreover, after the RM table is obtained with a combined opinion, then the transitivity rule is checked and the Driver Power value is calculated by summing an element horizontally. While the Dependent value is obtained by summing factors vertically as in Table 2.

Then, based on the results of the interpretation of the final Reachability Matrix (RM) matrix, a hierarchy of relationships between factors that contribute to the clean production cannot be drawn up, which can be explained in Figure 1.

Figure 1 provides information that the lack of awareness of both individuals and organizations regarding changes in a better direction (MA 4) is a factor that has the highest value of power drivers or is called a key factor. Diagram aims to classify sub-criteria into four groups. The groups are the result of the calculation of the RM that has been tested for transitivity and arranged by placing on each ordinate (x; y) respectively. Digraph in Figure 2 provides information, such as:

a. Five criteria are in the Sector 1 area: weak driver - weak dependent variables (Autonomous). Sub-criteria included in this sector are not related to the system and may have few relationships, although the relationship can be strong. Criteria in this sector are ME 2, ME 3, MS 3, and LI 1.
The determination of alternative strategies is based on sub-criteria that are key elements like the purpose of the assessment. The previous results showed that the key element was the lack of awareness.
both from individuals and organizations (MA 4). Based on this, several proposed strategies were obtained from the results of brainstorming with company leaders. Some of the proposed strategies are:

a. Conduct training for employees in the CRS Chemical Laboratory division on the implementation of clean production (AS 1).

b. Conduct regular socialization to employees in the CRS Chemical Laboratory division regarding the importance of implementing clean production (AS 2).

c. Conducting checks or supervision related to activities and work environment on a regular basis to support the application of cleaner production in the CRS Chemical Laboratory division (AS 3).

d. Make guidance in the form of work instructions regarding clean production programs (AS 4).

Figure 2 Diagraph Driver Power – Dependence

Then an alternative selection hierarchy structure can be made shown in Figure 3. From the proposed strategy, an alternative selection analysis was carried out by implementing the AHP method. Determining the priority of alternatives is obtained from the results of the fourth questionnaire, using pairwise comparisons of the alternatives to be chosen. The results of the pairwise comparison questionnaire on alternatives are shown in Table 3.
Table 3 The results of the pairwise comparison questionnaire on alternatives

| Alternatives | Respondents | Alternatives |
|--------------|-------------|--------------|
|              | 1 | 2 | 3 | 4 |
| AS 1         | 1/5 | 1/7 | 1/7 | 1 |
| AS 1         | 5 | 7 | 7 | 5 |
| AS 1         | 5 | 5 | 7 | 5 |
| AS 2         | 5 | 7 | 7 | 7 |
| AS 2         | 5 | 7 | 7 | 7 |
| AS 3         | 1 | 1/7 | 1 | 1 |
| AS 4         | 1 | 1/7 | 1 | 1 |

The results of the calculation of the normalization weighting of pairwise comparison judgments between alternatives are shown in Table 4.

Table 4 Normalization weighting of pairwise comparison

| Alternative | AS 1 | AS 2 | AS 3 | AS 4 | Σ | X  |
|-------------|------|------|------|------|---|----|
| AS 1        | 0.19 | 0.16 | 0.39 | 0.40 | 1.15 | 0.29 |
| AS 2        | 0.75 | 0.64 | 0.43 | 0.48 | 2.29 | 0.57 |
| AS 3        | 0.03 | 0.10 | 0.07 | 0.05 | 0.24 | 0.06 |
| AS 4        | 0.03 | 0.10 | 0.11 | 0.07 | 0.32 | 0.08 |

The calculations show that the weight of the priority the alternative selected is AS 2 (socialization green production) with a weight of around 0.29, the second alternative is AS 1 (Training) with a weight of approximately 0.06. The result also shows that the consistency test obtained a CI value of 0.09. Based on the provisions of Saaty that the CI value must be \( \leq 10\% \), then the consistency value can be accepted or in other words, the hierarchy can be stated consistently.

The implementation of cleaner production in the CRS Chemical Laboratory division is still very low. This is due to the lack of awareness from both individuals and organizations to support the implementation of clean production programs. Therefore, to increase awareness, a regular outreach program is needed related to the benefits and importance of clean production both in economic and environmental terms.

Clean production socialization is an initial strategic step that really needs to be done. It aims to increase awareness of both individuals and an organization related to better change. In order to realize the socialization program related to clean production involves several stakeholders to support this program such as managers, supervisors, supervisors, and all employees. Therefore, the first step that will be taken is to form a special team that is responsible for helping to drive the clean production program that will be implemented. The special team will assist in determining the schedule for the implementation of the socialization and the agenda of the activities to be carried out. The form of socialization is to hold a special meeting to review the clean production program and the distribution of leaflets related to the implementation of the clean production program. The meeting will be held at the beginning of each month where all the employees are participants.

The presentation was carried out as a form of implementation of the socialization program. The presentation material consisted of an initial introduction to clean production, an introduction to the benefits of implementing clean production, a discussion of the agenda of activities to be carried out to support the clean production program, to an evaluation of the implementation of clean production. Some things that become notes and findings will be evaluated later to be discussed planning the improvement process.
4. Conclusion
Cleaner production is one of the keys to the success of sustainable development. This study attempts to identify and analyse the key criteria for implementing clean production in a chemical laboratory. In addition, this study also determines strategies for key sub-criteria. There are nineteen factors that contribute to the not yet implemented net production. By applying the ISM method the results of the criteria for lack of awareness from both individuals and organizations regarding better change are key elements. Whereas the alternative strategy that becomes a priority is periodic socialization to employees regarding the importance of applying clean production, the weight of the assessment is around 0.57. This research is the first step in identifying a green production program in the service industry. This research also still has many shortcomings. Thus, further and in-depth analysis and assessment need to be done in subsequent research.

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