Decision Making on Control & Monitoring Equipment Replacement with Sustainability Consideration

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Abstract

At the end of life (EOL) of an asset or equipment, the failure rate and operating and maintenance costs will increase, so that the equipment needs to be replaced. For control and monitoring equipment, obsolescence is one of the causes of equipment entering the EOL phase. To reduce the growth of WEEE produced by control and monitoring equipment replacement activity, and limitation in capital investment cost, replacement decision making is needed with several sustainability factor consideration. This paper aims to study the addition of sustainability criteria in control and monitoring equipment decision making and implement it in a steel manufacturer industry in Indonesia. Result shown that sustainability can be a consideration in control and monitoring equipment replacement decision making process, but not as high as reliability and equipment lifecycle criteria.

Keywords
Asset management, Equipment replacement, Decision making, Sustainability, Control and Monitoring Equipment.

1. Introduction
Asset management for capital-intensive industries can be used to assess how effectively a company manages its physical assets to achieve its strategic goals (El-Akruti and Dwight 2013). Asset management activity is important to reach production and quality target (El-Akruti et al. 2013). At the end of life (EOL) of an asset or equipment, the failure rate and operating and maintenance costs will increase, so that the equipment needs to be replaced (Hannaman and Wilkinson 2005; Hartman and Tan 2014; Smith 2011). According to survey, 40% of unplanned downtime is caused by aging equipment, and to address that, 43% of the respondent are going to upgrade and replace the equipment (Plant Engineering 2019).

For control and monitoring equipment, obsolescence is one of the causes of equipment entering the EOL phase. Obsolescence in control and monitoring equipment is closely related to technological changes that cause incompatibility problems with other equipment and the end of manufacturer support, resulting in spare part availability problems (Center for Chemical Process 2018). Based on ARC Advisory Survey, obsolete control and equipment that still used past obsolescence date in the world worth more than 65 billion USD, and more than 75% of 20 years or more plants still use obsolete control and monitoring equipment (Reynolds 2011). The main obstacle in replacing control and monitoring equipment is the relatively high investment cost (Kande et al. 2017; Kumar and Gupta 2014; Lamb 2013; Rojas and Barbieri 2019). In a capital-intensive industry with limited investment costs, the organization must make a decision to choose which equipment to replace first.

From sustainability point of view, replacement of control and monitoring equipment activity can produce waste electrical and electronic equipment (WEEE). In 2019, the amount of WEEE in the world has reached 53.6 Mt or 7.3 kg per capita (Forti et al. 2020). In Indonesia, the amount of WEEE has reached 1.9 Mt in 2020 (Figure 1.), with 13.5% belong to the Large Equipment category (based on Directive 2012/19/EU Annex III), which includes control and monitoring equipment, as shown by Figure 2. (Mairizal et al. 2021). To reduce the WEEE growth, a circular economy concept is needed in control and monitoring equipment replacement activity (Pan et al. 2022). If replacement activities of control and monitoring equipment is not well managed, this can increase the growth of WEEE.

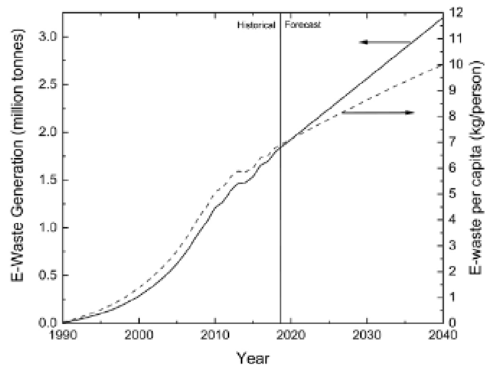

Figure 1. WEEE generated in Indonesia

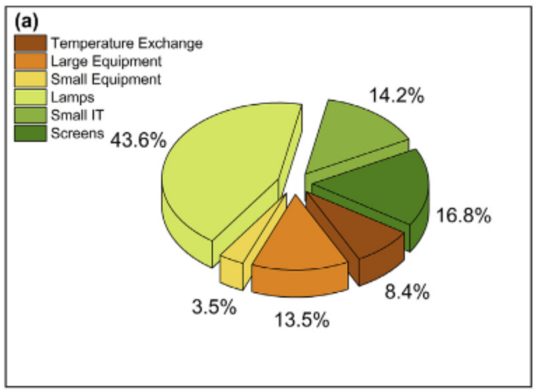

Figure 2. Percentage of each WEEE category in Indonesia

1.1 Objectives

To reduce the growth of WEEE produced by control and monitoring equipment replacement activity, and limitation in capital investment cost, replacement decision priority is needed with several sustainability factor consideration. This paper aims to study the addition of sustainability criteria in control and monitoring equipment replacement decision making in a steel manufacturer in Indonesia.

2. Literature Review

Some research has been conducted in the area of decision making in equipment replacement. Hart and Cook (1995) describes several criteria that must be considered before making a decision on equipment replacement, namely equipment prices, down time, operator experience, start-up time, long-term productivity, ease of maintenance, spare parts, energy costs, future industrial growth, equipment age, other considerations, and return on investment. Other research in the area of asset replacement decisions considers various factors as cited in Madusanka et al. (2016). Some of the factors considered for asset replacement are the cost of repairing old assets (Rabbani and Shahmohamad 2014), sunk costs (Muñoz-Porcar et al. 2015), lifecycle costs (Akhlaghi 1987; Diniz and Sessions 2020; Hastings 2010; Kelso 2018; McClurg and Chand 2002; Panegossi and da Silva 2021; Yatsenko and Hritonenko 2022), remaining asset life (Gage 2013; Muñoz-Porcar et al. 2015), remaining economic life of assets (Kelso 2018; Muñoz-Porcar et al. 2015; Yatsenko and Hritonenko 2022), future organizational strategic plans (Gage 2013), asset repairability (Gage 2013), failure record (Kelso 2018; Muñoz-Porcar et al. 2015), existing value of assets (Muñoz-Porcar et al. 2015), benefits (Alabdulkarim et al. 2015; Hastings 2010), capacity and capability (Diniz and Sessions 2020; Hastings 2010), how critical these assets are to the production process (Hastings 2010), technology (Hartman and Tan 2014; Hastings 2010; Panegossi and da Silva 2021), obsolescence (Hastings 2010; Kelso 2018), risk (Hastings 2010), equipment price (Diniz and Sessions 2020; Yatsenko and Hritonenko 2022), salvage value (Diniz and Sessions 2020; Yatsenko and Hritonenko 2022), equipment age (Kelso 2018), and usage rates (Kelso 2018).

There are three concepts in economy, namely linear economy, recycling & reuse economy, and circular economy as shown in Figure 3 (Charef et al. 2021). Gloser-Chahoud et al. (2021) study nine level of circular economy from lowest level to highest level, namely recover (R9), recycle (R8), repurpose (R7), remanufacture or recondition (R6), repair (R5), reuse (R4), reduce (R3), redesign (R2), and rethink (R1), as shown in Figure 4. However, implementation of R1 to R3 is in equipment manufacturer's scope. From consumer's side, the highest level of circular economy implementation is reuse (Morsoletto 2020).

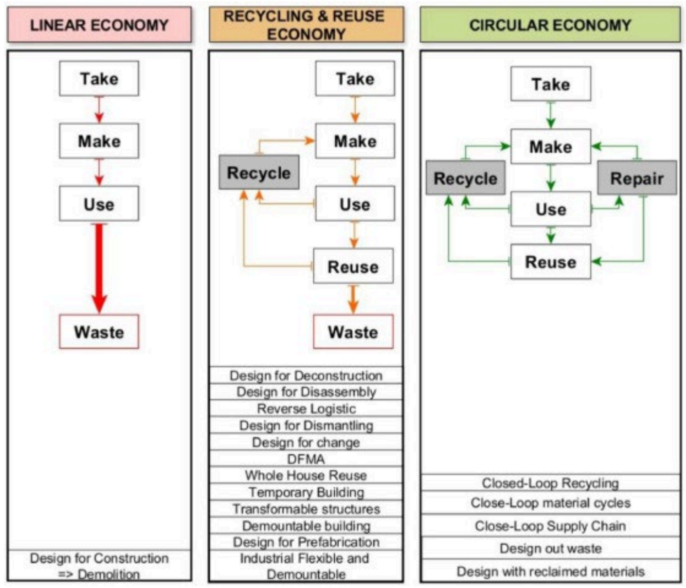

Figure 3. Linear economy, recycling and reuse economy, and circular economy

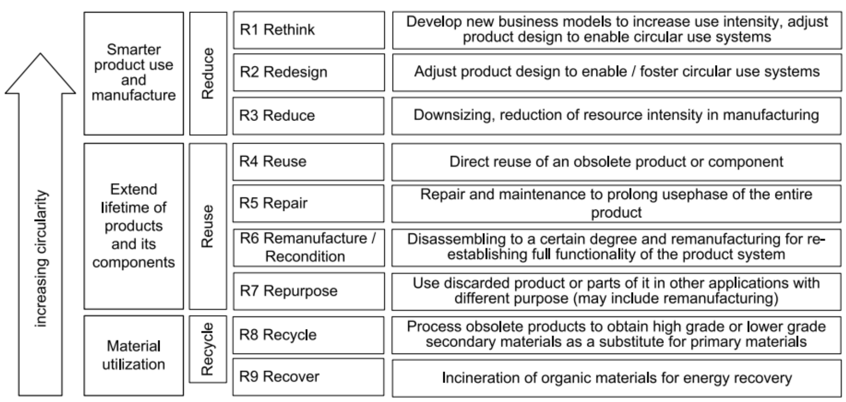

Figure 4. Nine level of circular economy

Sustainable end-of-life (SEOL) become more popular in manufacturing industry. Charef et al. (2021) adopted SEOL concept into asset lifecycle in building information modelling as shown in Figure 5. According to Lu et al. (2018) as cited in Pan et al. (2022), preparation for reuse have been crucial in implementation of circular economy. Abdi and Taghipour (2019) considering greenhouse gas emission in asset replacement and repair decision making, and also stated the needs of considering other sustainability factor in asset replacement decision making. Thus, the goal of this work is to include the sustainability element of the ability to repair (R5) and reuse (R4) into control and monitoring equipment replacement decision making.

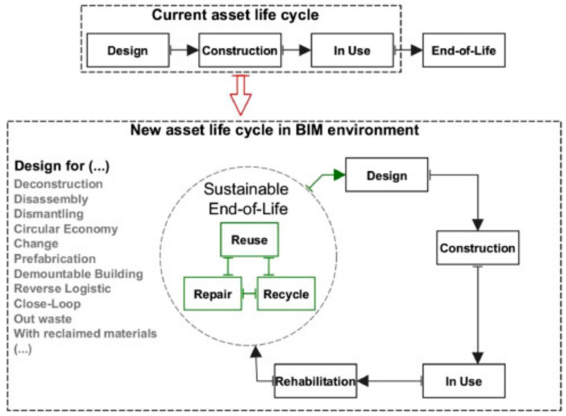

Figure 5. SEOL in Building Information Management

3. Methods

Several criteria and sub-criteria to be considered in control and monitoring equipment replacement decision making were selected from literature review, including sustainability factor, as shown in Table 1. Three experts in a steel manufacturing industry were asked to rank those criteria to find out which criteria is the most important in the decision-making process. The criterion ranking was done by applying one of multi-criteria decision-making tools, i.e., Analytic Hierarchy Process (AHP). AHP can be used to structure decision problems in a thorough and logical manner, as well as to represent and quantify each criterion (Nurcahyo et al. 2018).

Table 1. Control and Monitoring Equipment Replacement Criterion based on Literature Review

Criteria	Sub – Criteria
A. Cost	A1. Replacement cost
	A2. Maintenance and spare part cost of existing equipment
B. Reliability	B1. Historical downtime & failure
	B2. Criticality of equipment
	B3. Maintenance, troubleshooting, and monitoring difficulties
C. Equipment Lifecycle	C1. Obsolescence
	C2. Age of existing equipment
D. Sustainability	D1. Repairability
	D2. Reuse Capability

4. Data Collection

In this section, we present the collected data after calculation with AHP process. Table 2 shows the rank and weight of each criterion based on expert number one, Table 3 shows the result of expert number two, and Table 4 shows the opinion of expert number three on each criterion.

Table 2. Criterion weight based on expert number one

Criteria	Weight	Sub – Criteria	Local Weight	Global Weight	Rank
A. Cost	0,0459	A1.	0,8750	0,0401	7
		A2.	0,1250	0,0057	9
B. Reliability	0,4469	B1.	0,4667	0,2086	3
		B2.	0,4667	0,2086	3
		B3.	0,0667	0,0298	8
C. Equipment Lifecycle	0,0853	C1.	0,5000	0,0426	5
		C2.	0,5000	0,0426	5
D. Sustainability	0,4219	D1.	0,5000	0,2110	1
		D2.	0,5000	0,2110	1
CR : 0,073 (Accepted)					

Table 3. Criterion weight based on expert number two

Criteria	Weight	Sub – Criteria	Local Weight	Global Weight	Rank
A. Cost	0,0801	A1.	0,1250	0,0100	8
		A2.	0,8750	0,0701	4
B. Reliability	0,5191	B1.	0,3631	0,1885	3
		B2.	0,5706	0,2962	1
		B3.	0,0664	0,0344	7
C. Equipment Lifecycle	0,3410	C1.	0,8333	0,2842	2
		C2.	0,1667	0,0568	5
D. Sustainability	0,0597	D1.	0,1667	0,0099	9
		D2.	0,8333	0,0497	6
CR : 0,0758 (Accepted)					

Table 4. Criterion weight based on expert number three

Criteria	Weight	Sub – Criteria	Local Weight	Global Weight	Rank
A. Cost	0,1400	A1	0,6667	0,0933	4
		A2	0,3333	0,0467	7
B. Reliability	0,1911	B1	0,2674	0,0511	6
		B2	0,6689	0,1278	2
		B3	0,0637	0,0122	9
C. Equipment Lifecycle	0,5876	C1	0,2000	0,1175	3
		C2	0,8000	0,4701	1
D. Sustainability	0,0813	D1	0,6667	0,0542	5
		D2	0,3333	0,0271	8
CR : 0,0846 (Accepted)					

5. Results and Discussion

From expert judgement shown on Table 2, Table 3, and Table 4, it can be concluded that each expert has their own perceived value about each criterion in control and monitoring equipment decision-making. We calculate the geometric mean from the result above, as shown in Table 5 as final weight.

Table 5. Final weight of each criterion

Criteria	Weight	Rank	Sub – Criteria	Local Weight	Global Weight	Rank
A. Cost	0,0976	4	A1	0,5575	0,0544	7
			A2	0,4425	0,0432	8
B. Reliability	0,4314	1	B1	0,3613	0,1559	3
			B2	0,5723	0,2469	1
			B3	0,0664	0,0286	9
C. Equipment Lifecycle	0,3163	2	C1	0,5186	0,1640	2
			C2	0,4814	0,1523	4
D. Sustainability	0,1546	3	D1	0,4242	0,0656	6
			D2	0,5758	0,0890	5
CR : 0,0485 (Accepted)						

Based on final weight, sustainability criteria rank third among other criteria, below reliability and equipment lifecycle, but above cost, as shown in Figure 6. Sustainability sub-criteria, reuse and repair capability, rank at fifth and sixth, under criticality, obsolescence, downtime and failure, and age of existing equipment sub-criteria, as shown in Figure 7. In steel manufacturer industry, critical equipment is the most important factor because that equipment can stop the whole production process if failure happened. The reuse capability is important to extend the lifetime other equipment that share the same parts, as the replaced equipment can be reuse as spare part for other equipment. The repairability falls short below because not every electronic part can be repaired, especially the newer generation. From the result we can conclude that sustainability can be deciding factor in control and equipment replacement decision making process, as they rank higher than replacement cost, existing equipment maintenance cost, and maintenance difficulties of existing equipment.

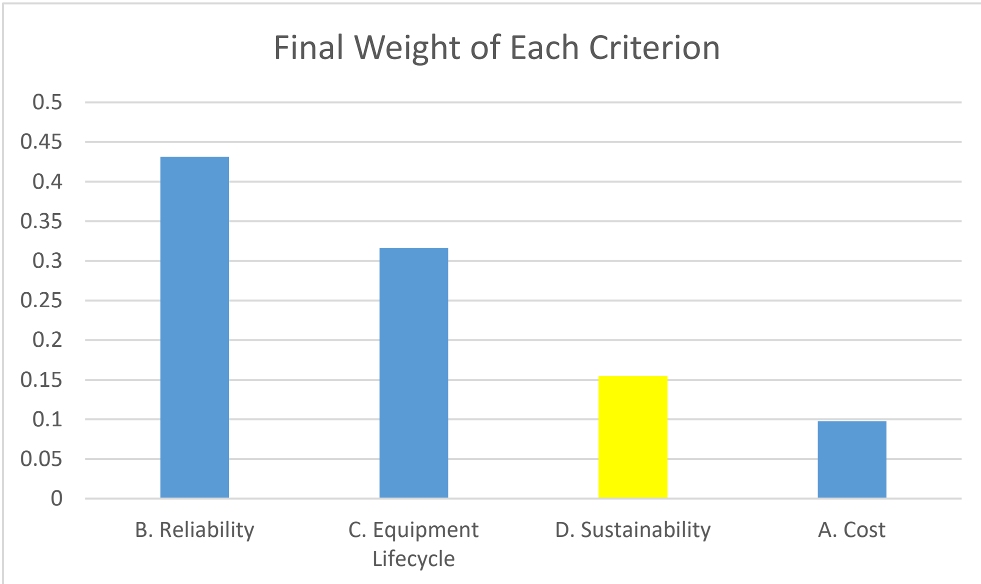

Figure 6. Final Weight of Each Criterion Based on Expert Judgement

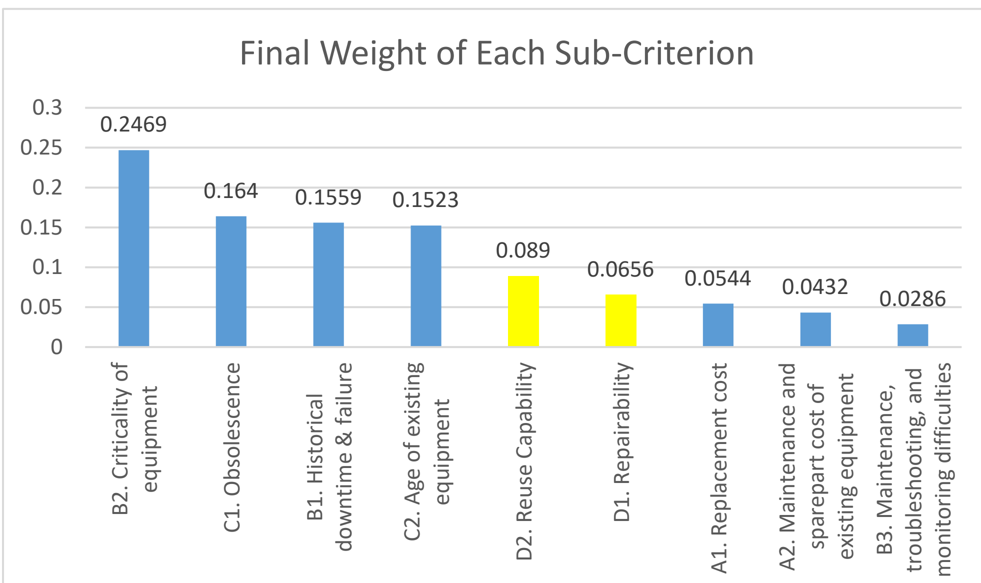

Figure 7. Final Weight of Each Sub-criterion

6. Conclusion

This paper aims to study the addition of sustainability criteria in control and monitoring equipment replacement decision making in a steel manufacturer in Indonesia**.** Several criteria and sub-criteria to be considered in control and monitoring equipment replacement decision making were selected from literature review, including sustainability factor. Three experts in a steel manufacturing industry were asked to rank those criteria using AHP tools. We found that sustainability factor can be implemented as one of the criteria in determining which equipment to replace.

Based on the result, each expert has different perceived value on each criterion. In final weight, sustainability criteria rank third among other criteria, below reliability and equipment lifecycle, but above cost. Sustainability sub-criteria, reuse and repair capability, rank at fifth and sixth, under criticality, obsolescence, downtime and failure, and age of existing equipment sub-criteria. This means that sustainability, in terms of reuse and repair capability, can be deciding factor in control and equipment replacement decision making process.

In the future, this study can be expanded by asking multiple experts from different background and different industry other than steel manufacturer that facing the same problem. This study also needs to be implemented to select which equipment to be replaced first among other equipment, and calculate the benefit of considering sustainability factor in equipment replacement decision making.

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Biography

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