SIMTITS
Interdisciplinary School of Management and Technology
Institut Teknologi Sepuluh Nopember

JURNAL TEKNOBISNIS
2022 Vol. 8(1), 86-96

Received 25 Mar, 2022; Revised 06 May, 2022; Accepted 27 May, 2022 | DOI: 10.12962/j24609463.v8i1.1411

Circular Economy Business Model in High Frequency Welding Steel Pipe Company: A Case Study

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ABSTRACT

Interest and attention to the circular economy business model have increased rapidly among policymakers, companies, entrepreneurs, and other stakeholders. Circular business models are believed and tested to produce benefits, such as reduced costs and environmental and social impacts. Existing research on circular business model innovation in steel manufacturing companies is still limited, especially in steel pipe manufacturing. In addition, research on applying existing circular business model innovations generally relates circularity to the closed product cycle flow. Based on the above problems, this research develops and selects alternative circular business model innovations in high-frequency welding steel pipe manufacturing companies using the DEMATEL and ANP integration approach. Nine criteria and eight alternative business models were developed based on the literature review. The research results show an alternative circular economy business model that can be applied in circular product and process design.

KEYWORDS: ANP, Business Model Innovation, Circular Economy, DEMATEL, Steel Pipe Manufacturing

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1. INTRODUCTION

A new interest in environmental issues has gradually increased, marked by the increasing attention of academics, practitioners, and the public to environmental issues. This is driving the transition to a low-impact economy. The circular economy model is a model for meeting the global need for a more sustainable economy. The circular economy is a global knowledge community representing the latest wave of movements related to business for coaching (Tóth, 2019). The circular economy can create value-creation opportunities for organizations or companies (MacArthur et al., 2015). The application of circular economy is increasingly being promoted as a solution to a series of challenges, such as waste generation, scarcity of resources, and sustainability of economic benefits (Lieder & Rashid, 2016). The business model refers to how a company or organization runs its business (Miles & Snow, 1978). The business model plays a central and strategic role in explaining the company's activities and performance. Improving sustainability and circularity requires changes in how companies generate value, perceive, and do business. Business model innovation refers to the search for new ways to create value for stakeholders. The focus of business model innovation is to find new ways to generate revenue and determine the value proposition of a company or organization. Innovative new business models are designed to create value while achieving ideal resource use conditions. It is also aimed at increasing profitability through the flow of resources, materials, and products from time to time (Lahti et al., 2018).

Until now, the implementation of business model innovation in steel pipe manufacturing companies is still limited. Meanwhile, research on applying existing circular business model innovations generally links circularity to the closed product cycle flow. Therefore, this paper will examine from a more complex circular economy perspective by developing innovative circular economy business models for steel pipe manufacturing companies. The case study in this research is one of Indonesia's high-frequency welding steel pipe companies. In this paper, the selection of alternative circular economy business models involves the integration approach of DEMATEL and ANP.

2. LITERATURE REVIEW

Innovation plays an important role in a company's competitive advantage. Innovation can substantially affect company performance (Rangus & Slavec, 2017). Innovation is one of the main strategic prerequisites because organizations or companies must improve technology knowledge, utilize capacities, and reach markets from these ideas.

Business model innovation is a transformation and business model development process (Morris et al., 2005). Business model innovation relates to the ability to modify the company. In addition, it can also be described as providing new products and services to consumers. Business model innovation is the successful modification of every element of the business model to differentiate it from competitors. Business model innovation is centered on novelty, where innovation is related to new business model design elements,

for example, adopting new activities, new ways of connecting system structures and activities, and new ways of organizing activities. Business model innovation usually represents a growth strategy. It can be interpreted as modifying the means of value creation to meet customer demands or generating the ability to take over new markets.

The circular economy business model is a form of business model innovation. Circular economy business models can be considered part of a broader group of sustainable business models (N. Bocken et al., 2013). The circular economy business model creates, offers, and delivers value to various stakeholders while minimizing a company or organization's ecological and social costs(Mattos et al., 2022). Circular economy business model innovation combines circular economy principles or practices to guide business model design. Interest and attention to the circular economy business model are increasing rapidly among policymakers, companies, entrepreneurs, and other stakeholders. This is because circular economy business models can generate benefits, such as reduced costs and environmental and social impacts, and can be characterized as impact investments (Mattos et al., 2022). Impact investment refers to using investment capital to help solve social or environmental problems to obtain financial benefits (Quinn & Munir, 2017). The circular economy business model can improve resource efficiency and effectiveness, closing the flow of energy and resources by changing the economic value approach and product interpretation (N. M. P. Bocken et al., 2016).

3. METHODS

Data Collection

This research aims to develop a circular economy business model in a steel pipe manufacturing company. The selected steel pipe manufacturing company for the case study is one of the Indonesian manufacturing companies that produces steel pipe manufacturing and coating for oil and gas. The company uses an engineering-to-order production system in the high-mix, low-volume category. This paper uses the process of observation, literature review, discussion, and a questionnaire to determine the criteria and alternative circular economy business models. Direct observation activities are carried out by observing the product production process, machine and process layouts, material flow, material consumption, and waste generated during production. The literature review is used to develop criteria based on the focus on the dimensions of sustainability. as the dimension of sustainability is closely related to the circular economy concept and alternative business models. The discussion is used to develop alternative circular economy business models based on the dimensions of the business model. A questionnaire was also used to obtain information on the most appropriate circular economy business model to be selected and applied in a high-frequency welding steel pipe company. The discussion and filling out of the questionnaire involved three people who were selected using a purposive sampling technique, with the following criteria: 1) having an interest in and mastery of knowledge on issues of the steel pipe industry and circular economy, and 2) having work experience more than 5 years and/or being a decision maker in case study company. Furthermore, from these results, the

questionnaire data were used as input for data processing using the DEMATEL and ANP integration methods.

DEMATEL and ANP Integration Methods

DEMATEL is a comprehensive method for designing and analyzing the structure of a model from the existence of a causal relationship between several factors (Wu & Lee, 2007). It identifies the relationship between the factors concerned. In the case of inner dependencies, DEMATEL is used. The results of the DEMATEL method show that there is a reciprocal relationship between several components. It can be used to find out which factors influence one another or affect each of them. This method consists of the following steps:

1. Create a relationship matrix.
2. Calculate the normalization of the direct relationship matrix.
3. Calculate the relationship matrix in total.
4. Get the inner dependence matrix and map the impact of the relationship.

The next stage is followed by the ANP method, selecting an alternative with the following steps:

1. Develop a linkage model, determine the desired goals or objectives, and determine the criteria for determining choices.
2. Form a pairwise comparison matrix.
3. Calculate the weight of elements or eigenvectors.
4. Calculate the consistency ratio. The consistency ratio should be ≤10%. The decision data assessment must be corrected if the value is more than 10%.
5. Make a priority matrix from pairwise comparisons between clusters, criteria, and alternatives.

An overview of the integrated DEMATEL and ANP approaches is given in Figure 1.

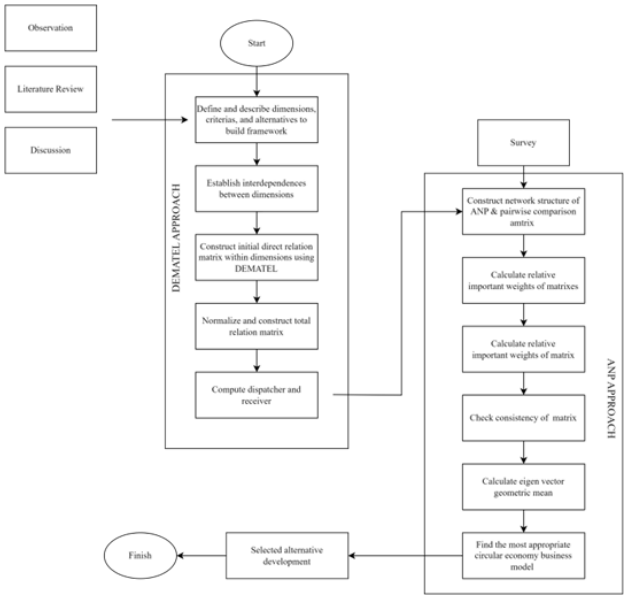

FIGURE 1. A General View of The Alternative Selection Framework

4. RESULTS

A literature review is used to develop criteria based on the dimensions of sustainability. Based on the literature review results, further discussions were held with company practitioners and academics to determine several important criteria in the selection, along with a description. Table 1. shows the criteria used in the selection of alternatives. Then, Table 2 shows alternative circular economy business models.

TABLE 1. Criteria Used in The Selection of The Circular Economy Business Model

Dimension	Criteria	Description	References
1	C1. Cost	CEBM can help minimize company costs.	(Ranta et al., 2018)
	C2. Economic Growth	CEBM provides potential cash inflows.	(Ranta et al., 2018)
2	C3. Work safety and labor health	CEBM considers work safety and labor health.	(Schroeder et al., 2019)
	C4. Behavior and mindset change	CEBM changes stakeholders' behavior and mindset change.	(Bertassini et al., 2021)
	C5. Increase company reputation	CEBM increases company reputation.	(Fortunati et al., 2020)
3	C9. Energy savings	CEBM has an impact on saving the use of non-renewable energy.	(Korhonen et al., 2018)
	C6. Pollution control	CEBM has an impact on pollution reduction.	(Schroeder et al., 2019)
	C7. Resource efficiency	CEBM has an impact on resource efficiency.	(Van Ewijk, 2018)
	C8. Waste reduction	CEBM has an impact on waste reduction.	(Schroeder et al., 2019)

TABLE 2. Alternative Circular Economy Business Models

Business Model Dimension	CEBM	Description	References
Value Proposition	Product life extension (BM1)	CEBM aims to increase the service life of product elements and systems through process engineering, including ease of disassembly, rebuild, repair, maintenance, and repair.	1. (Ertz et al., 2019) 2. (Stewart & Niero, 2018)
	Eco-product innovation (BM2)	CEBM aims to create environmentally friendly green products. This CEBM helps increase stakeholder knowledge and awareness about the circular economy.	1. (Wang et al., 2021) 2. (Liao & Tsai, 2019)

Business Model Dimension	CEBM	Description	References
Value creation and delivery	Circular partner and key resources (BM3)	This CEBM focuses on improving new materials, green suppliers, use of renewable energy, reduction of resource consumption, and full use of materials in production recyclable.	(Brown & Bajada, 2018)
	Circular product and process design (BM4)	This CEBM provides planning and design for elements, systems, and products. This design and design include facilitating design improvements, production, maintenance processes, repair processes, remanufacturing activities, and refurbishment.	1. (Lieder et al., 2017) 2. (N. M. P. Bocken et al., 2016)
	Waste recovery and recycling (BM5)	CEBM is developing a production and consumption system for waste materials, both waste during production and products at the end of their useful life.	1. (Grosso et al., 2017) 2. (Singh & Ordoñez, 2016)
	Energy management (BM6)	CEBM which focuses on energy use management. can be in the form of minimizing the use of non-renewable energy or the use of renewable energy.	(Cavicchi et al., 2022)
Value capture	Side product development (BM7)	CEBM focuses on developing by-products that have added value and sales value. CEBM is intended to reduce the use of materials or materials that require costs in procurement or are intended to increase revenue streams.	(Bader et al., 2018)
	Incentivized return and reuse (BM8)	In this CEBM, used products are returned, specially collected, refurbished, and resold.	(Huysveld et al., 2019)

Table 3 shows the Interdependence matrix between criteria. The relationship matrix was created based on discussions with practitioners and academics, using a scale of 0 to 4, where 0 indicates no relationship between criteria, and up to 4 indicates a very strong relationship between criteria. Table 3 shows the results of interdependence between criteria. Then, Table 4 shows the normalization results where the relationship is normalized by dividing the smallest average value between rows and columns. The total relationship matrix is derived from the inverse of the normalized matrix. This matrix is in Table 5.

TABLE 3. Interdependence Matrix Between Criteria

	C1	C2	C3	C4	C5	C6	C7	C8	C9	SUM
C1	0	4	3	4	3	3	4	3	4	28
C2	3	0	4	4	4	4	4	4	4	31
C3	3	3	0	3	4	4	4	4	3	28

	C1	C2	C3	C4	C5	C6	C7	C8	C9	SUM
C4	4	3	4	0	4	4	4	4	4	31
C5	2	4	3	4	0	4	3	4	4	28
C6	4	3	4	4	4	0	3	4	4	30
C7	4	4	3	4	3	4	0	4	4	30
C8	4	4	4	3	4	4	4	0	3	30
C9	4	4	3	4	3	4	4	3	0	29
SUM	28	29	28	30	29	31	30	30	30	

TABLE 4. Normalization Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0.000	0.129	0.097	0.129	0.097	0.097	0.129	0.097	0.129
C2	0.097	0.000	0.129	0.129	0.129	0.129	0.129	0.129	0.129
C3	0.097	0.097	0.000	0.097	0.129	0.129	0.129	0.129	0.097
C4	0.129	0.097	0.129	0.000	0.129	0.129	0.129	0.129	0.129
C5	0.065	0.129	0.097	0.129	0.000	0.129	0.097	0.129	0.129
C6	0.129	0.097	0.129	0.129	0.129	0.000	0.097	0.129	0.129
C7	0.129	0.129	0.097	0.129	0.097	0.129	0.000	0.129	0.129
C8	0.129	0.129	0.129	0.097	0.129	0.129	0.129	0.000	0.097
C9	0.129	0.129	0.097	0.129	0.097	0.129	0.129	0.097	0.000

TABLE 5. Total Relationship Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1.870	2.037	1.954	2.098	2.011	2.131	2.095	2.071	2.098
C2	2.133	2.102	2.155	2.283	2.219	2.349	2.280	2.284	2.283
C3	1.952	2.005	1.861	2.066	2.033	2.152	2.088	2.093	2.066
C4	2.154	2.186	2.150	2.164	2.213	2.343	2.274	2.278	2.278
C5	1.935	2.039	1.959	2.101	1.928	2.161	2.071	2.101	2.101
C6	2.094	2.124	2.090	2.214	2.152	2.163	2.185	2.214	2.214
C7	2.104	2.159	2.073	2.224	2.134	2.287	2.106	2.223	2.224
C8	2.095	2.152	2.092	2.191	2.154	2.280	2.213	2.103	2.191
C9	2.044	2.097	2.014	2.161	2.073	2.222	2.157	2.135	2.047

Furthermore, the final step at the DEMATEL stage is to determine the relationship between criteria by comparing the dispatcher and receiver values with their average values. If the value shows less than the average, the criterion only affects the other criteria (one-way relationship). Criteria for economic growth, behavior and mindset change, and resource efficiency indicate that the criterion affects only the other criteria.

After knowing the relationship between criteria, the next stage is ANP analysis and alternative selection. The first step begins by creating a pairwise comparison matrix. The value used is taken from the results of the geometric average of the data with the number of respondents, as many as 2 practitioners and 1 academician. In this study, the three respondents have the same value weight; there is no partiality towards one of the respondents. Therefore, geometric alignment is carried out on the questionnaire data the respondents have filled in to get the eigenvectors. The weight values of the elements

or eigenvectors for each respondent and the geometric mean are shown in Table 6 and Table 7.

TABLE 6. Eigenvector criteria

Criteria	Eigen Vector (1)	Eigen Vector (2)	Eigen Vector (3)	Eigen Vector Geometric Mean
C1. COST	0.07384	0.06358	0.06676	0.067927
C2. ECONOMIC GROWTH	0.09304	0.09346	0.10054	0.095619
C3. WORK SAFETY AND LABOR HEALTH	0.0405	0.05904	0.06373	0.053413
C4. BEHAVIOR AND MINDSET CHANGE	0.06014	0.07904	0.07545	0.071049
C5. INCREASE COMPANY REPUTATION	0.09857	0.11641	0.11568	0.1099
C6. POLLUTION CONTROL	0.12787	0.14147	0.14093	0.136609
C7. RESOURCE EFFICIENCY	0.21398	0.149	0.14498	0.16658
C8. WASTE REDUCTION	0.15685	0.1577	0.14961	0.154677
C9. ENERGY SAVINGS	0.13522	0.14031	0.14232	0.139251

TABLE 7. Eigenvector alternatives

Alternative	Eigen Vector (1)	Eigen Vector (2)	Eigen Vector (3)	Eigen Vector Geometric Mean
CIRCULAR PARTNER AND KEY RESOURCES	0.05051	0.05707	0.06215	0.056374
CIRCULAR PRODUCT AND PROCESS DESIGN	0.17121	0.17967	0.18679	0.17911
ECO-PRODUCT INNOVATION	0.12914	0.14896	0.14458	0.140631
ENERGY MANAGEMENT	0.20516	0.15734	0.16495	0.17462
INCENTIVIZED RETURN AND REUSE	0.11216	0.1125	0.11205	0.112237
PRODUCT LIFE EXTENSION	0.07309	0.07942	0.06649	0.072808
SIDE PRODUCT DEVELOPMENT	0.1111	0.08775	0.09286	0.096738
WASTE RECOVERY AND RECYCLING	0.14763	0.17728	0.17014	0.164518
CIRCULAR PARTNER AND KEY RESOURCES	0.05051	0.05707	0.06215	0.056374

Based on Table 6, the waste reduction and resource efficiency criteria are the main criteria used in considering the decision-making of the circular economy business model to be implemented, followed by pollution control and energy saving criteria. Meanwhile, the priority of alternative business models that can be applied in high-frequency welding steel pipe manufacturing companies is circular product and process design.

5. CONCLUSIONS

The results of the integration analysis of DEMATEL and ANP show that an alternative business model that high-frequency welding steel pipe manufacturing companies can develop is circular product & process design. The business process of a high-frequency welded steel pipe manufacturing company leads to process design that focuses on producing durable products and optimizing the use of process resources. The process of

optimizing the use of resources can be done by saving resources and repairing and maintaining production resources. A life cycle design strategy integrates a life cycle approach through an enhanced set of design options(Brezet, 1997). A life cycle design strategy can be an approach to help design product and process strategies and alternatives in a more circular direction. Future research can discuss in more detail how technical and strategic forms and steps are in implementing product design business models and circular processes. In addition, it also measures the benefits of implementing alternative circular products and process designs. Life Cycle Analysis (LCA) and Life Cycle Cost Analysis (LCCA) can be used to measure improvements' impact on alternative circular products and process design business models.

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How to cite this article:

Gunawan, M. F., & Singgih, M. L. (2023). Circular Economy Business Model In High Frequency Welding Steel Pipe Company: A Case Study. *Jurnal Teknobisnis,* 8(1): 86 - 96. DOI: 10.12962/j24609463.v8i1.1411