

Interpretation of sustainability philosophies into product design for awareness, cohesion, and equity

Laura Isabel Acevedo ^{1,2,✉}, Daniela C. A. Pigosso ^{1,2} and Tim C. McAloone ^{1,2}

¹Technical University of Denmark, DTU Construct, Denmark,

²Technical University of Denmark, Centre for Absolute Sustainability, Denmark

✉ liana@dtu.dk

Abstract

Throughout time, the definition of sustainability has been interpreted differently and different philosophies have consequently emerged, each with its own vision of a sustainable society. At the same time, manufacturing firms have focused on environmental improvements, but social aspects have often been neglected. This study identifies 11 philosophies and 51 product design strategies contributing to sustainability awareness, cohesion, and equity, set to ensure social sustainability integration at a manufacturing firm level.

Keywords: sustainability, sustainable design, social equity, cohesion, sustainability awareness

1. Introduction

Efforts on sustainability within the manufacturing sector have traditionally been oriented towards diminishing negative environmental impacts whilst creating economic benefits, for example: increasing economic growth; maximising efficiency in the consumption of energy, materials, and other resources; and reducing environmental impact of products across their life cycles (Ciliberto *et al.*, 2021).

To truly meet the pressing sustainability challenges of our time, we must go beyond merely "doing better" towards doing "good enough" for the environment and for society (Hauschild, 2015). For manufacturing companies, this means offering products and services that add positive value to society, without resulting in harm, either directly or indirectly. Social equity implies not only remediating negative social impacts through a company's activities, but also designing products to provide positive opportunities for society, especially for those with limited resources (Musaazi *et al.*, 2015). Moreover, social cohesion - defined as *the degree of solidarity within a team or social system* (Arnette *et al.*, 2014, p. 148) - focuses on the interrelationships formed inside and outside an organisation.

Throughout recent decades, growing knowledge and actual occurrence of severe environmental impacts and incidents, social unrest, political agendas (among others) have given rise to multiple schools of thoughts - or movements - that promote the need to transition to more sustainable modes of operating societies. This study defines these movements as "sustainability philosophies", which through their principles list the necessary conditions for sustainable modes of operating and living (Glavič and Lukman, 2007). Therefore, if an organisation implements one philosophy, their business processes like product design must be executed with these principles in mind (Glavič and Lukman, 2007). Some philosophies encompass the three sustainability pillars: environment, economy, and society (Elkington, 1999); whereas others focus on only one or two.

For manufacturing companies, product development/design (PD) and operations are key for the implementation of sustainability (Pigosso *et al.*, 2014). To ensure social equity, products can be designed to ensure customer and societal needs are met during the various phases of sourcing,

production, usage, and end-of-life (Arnette *et al.*, 2014). Research has shown that ensuring social cohesion inside an organisation can create a positive atmosphere that stimulates communication, resolving conflicts amicably, comfortable environment to present ideas, influencing positively product performance (Shaner *et al.*, 2016).

Organisations contribute to social cohesion outside of their organisation through community involvement and development. This includes promoting and supporting education, promoting cultural activities, facilitating human rights education and awareness raising, conserving, and protecting cultural heritage, and promoting the use of traditional knowledge (ISO 26000, 2010). As explained by Vilochani *et al.* (2023), current strategies towards sustainable product design are mainly focused on diminishing environmental impacts; even though social and economic aspects are gaining traction, there is still a need to identify strategies that can also improve the social dimension of sustainability through design. This study aims to address this identified gap by eliciting product design related strategies linked to Awareness, Cohesion, and Equity (ACE). This study uses Murphy (2012)'s framework of policy concepts linking social and environmental imperatives. One of the author's concepts, participation, was not used because no link was found to product development or design. Section 1 of the paper provides an introduction that contains a state-of-the-art and definition of the three main terms. Section 2 details the Methodology. Section 3, Insights and Discussion, elaborates on the philosophies, their strategies, and how they contribute to awareness, cohesion, or equity. Finally, section 4 contains the conclusion.

1.1. State-of-the-art

1.1.1. Awareness

Awareness on social sustainability aspects is found to be less targeted by companies and organisations; however, education is a key policy goal in sustainable development initiatives that increases sustainability awareness (Murphy, 2012). Sustainability awareness can be cemented inside an organisation by integrating sustainability into everyday business life; this includes, knowledge management, clearly defining processes and roles for employees, considering sustainability related issues into purchasing, providing the correct information to consumers, and informing them on sustainability (Baumgartner and Rauter, 2017). Firms can facilitate the diffusion of sustainability orientation through formulating environmental management policies, elaborating sustainability reports, and establishing channels for inter-functional communications of sustainability goals (Shou *et al.*, 2019).

1.1.2. Cohesion

Social cohesion is defined as the *glue that binds society together* (Moustakas, 2023, p. 1028), and comprises well-being, belonging, social participation, tolerance, and equal opportunities (Murphy, 2012). Cohesion can be constructed both within and outside the organisation. Within an organisation, studies point out that ensuring social cohesion promotes innovation (Nakata and Im, 2010; Shaner *et al.*, 2016), whereas outside an organisation, cohesion is achieved through organisation's contribution to "community involvement and development" by promoting education, learning opportunities, conserving cultural heritage, and more (ISO 26000, 2010; Murphy, 2012).

1.1.3. Equity

Equity touches the social and economic pillars sustainability (Musaazi *et al.*, 2015), and entails contributing to gender equality; equality before the law; freedom of expression; equal opportunities and treatment (ISO 26000, 2010; Murphy, 2012); social cooperation with non-profit organisations; and implementation of corporate social standards (Stopper *et al.*, 2016). Design strategies can be developed with respect to equity *by ensuring linkages with society; to consider non-traditional markets; to eliminate social problems* (Arnette *et al.*, 2014, p. 384). Furthermore, social impacts can be created through and product development (and subsequent production) by considering affordability and manufacturing wage impacts; employing minority groups; location and income distribution (Musaazi *et al.*, 2015).

2. Methodology

To elicit and categorise product design related strategies linked to the social (ACE) pillar of sustainability, this study consisted of a systematic literature review (SLR), following the protocol of [Biolchini et al. \(2005\)](#). The results presented in this article are part of a larger study, which focuses on how which sustainability philosophies exist and how these each support corporate sustainability strategies. To answer this question, an extensive SLR was performed to identify existing philosophies; their principles, which are the building blocks that must be respected for the implementation; contribution to the environmental and social aspects from [ISO 26000 \(2010\)](#); economic aspects from [Baumgartner and Rauter \(2017\)](#); circular economy-related business processes [CIRCit \(2019\)](#), including product design or development; contribution to societal needs from [Circularity Gap Reporting Initiative \(2021\)](#); and other relevant sustainability strategies.

The first step of the SLR comprised the creation of a search string, using the following terms: (sustainab* OR degrowth OR sufficiency OR "triple bottom line") AND (compan* OR industr* OR firm* OR business* OR sector* OR organi?ation* OR corporat* OR management OR leader* OR "decision-making" OR strateg*) AND (philosoph* OR program* OR method* OR mechanism* OR initiative* OR agreement* OR narrative* OR approach* OR action* OR practic* OR concept* OR framework) AND ALL (manuf* OR product*). The filters used to discard the articles are shown in Table 1. This process resulted in 90 articles and 19 potential philosophies.

These philosophies and their principles were analysed and revised in an expert focus group including the PhD student and project supervisors, authors of this study. During this activity, nine philosophies were accepted. Of the other ten, three were classified as strategies, since they aim to eliminate violations to the philosophies' principles ([MacDonald, 2005](#)); four were classified as tools, as they assist in the implementation and monitoring of strategies (*ibid*); two were grouped together; and one required more information to be included. Additionally, during this activity, six other potential philosophies that didn't come up in the first search string were shortlisted. The expert focus group ended with nine official philosophies and seven potential philosophies.

To include these potential philosophies in the assessment, a second search string was run with their names as follow: ("Philosophy Name") AND (defin*) or ("Philosophy Name") AND (compan* OR business* OR industr* OR organi?ation* OR enterpris* OR corporat*), which resulted in 63 articles. After this process, two philosophies were rejected and five were included. This resulted in 15 philosophies that met the inclusion criteria in Table 1. The SLR and data gathering process was done with a total of 153 articles.

Table 1. SLR iteration process

Activity	Description
1. Search String #1	
Filters:	F1: Article title and keywords; F2: Abstract; F3: Introduction and Conclusion; F4: Full Body
Inclusion criteria:	The study must be on the implementation of a sustainability philosophy. The study must be on a principle of the philosophy. Scientific articles like journal and conference papers.
2. Expert Focus Group	Classification of philosophies according to principles and focus.
	Rejection and acceptance of each philosophy.
3. Search String #2	
Filters:	Most cited and most recent. Same filters and inclusion criteria as search string #1.

During the SLR process, business processes analysed included: (1) business models, (2) production and operations, (3) product development, (4) after-sale services, (5) end-of-life operations, (6) supply chain, (7) marketing, and (8) research and development. The research question for this study was "Which

sustainability philosophies contribute to awareness, cohesion, and equity and in how do their contributions manifest themselves through PD?" To answer this question, articles that covered the "(3) product development (PD)" process were included. The selected articles were studied, to elicit relevant strategies to support the elements regarding social sustainability awareness (A), societal cohesion (C), equity (E), respectively. The relevant PD strategies were collected and clustered based upon the similarities, across philosophies. Table 2 contains the number of articles related to each aspect.

Table 2. Number of studies covering each aspect

Awareness	Cohesion	Equity
37 studies	27 studies	21 studies

3. Insights and Discussion

3.1. Overview of sustainability philosophies

Of the 15 philosophies identified in the SLR, 11 sustainability philosophies were selected for this study since they embrace PD as a key leverage for the integration of sustainability into manufacturing companies. Table 3 provides a brief description of the philosophies.

Table 3. Sustainability philosophies that embrace product design and development

<i>Philosophy</i>	<i>Acronym</i>	<i>Description</i>
<i>Absolute Sustainability</i>	AS	Encourages industries to reduce their activities of environmental sustainability in absolute terms and benchmark them (Hauschild, 2015).
<i>Blue Economy</i>	BE	Complements the GE by calling for a better coordination of management and protection of oceans' cultural and natural integrity (UNEP et al. 2012 in Wenhai et al., 2019).
<i>Circular Economy</i>	CE	Resource input and waste, emission, and energy leakage are reduced by slowing, closing, and narrowing material and energy loops (Ellen MacArthur Foundation, 2013a, 2013b, 2013c in Ciliberto et al., 2021).
<i>Doughnut Economics</i>	DE	Visualizes a society that operates between the social dimensions from the SDGs, and the PB's ecological dimensions (Raworth 2012 in Stopper et al., 2016).
<i>Green Economy</i>	GE	Organisations must commit to (1) low carbon, (2) resource efficient, and (3) being socially inclusive (UNEP, 2011a in Loiseau et al., 2016).
<i>Natural Capitalism</i>	NC	Provides a new vision of industrial systems with respect to their products, business models, technology use, and use of natural resources (Lovins et al., 1999).
<i>Planetary Boundaries</i>	PB	Defines a safe operating space for humanity to maintain a Holocene-like state for development (Rockström et al, 2009 in Clift et al., 2017).
<i>Sustainable Development Goals</i>	SDGs	Proposes 17 goals to ensure natural resources are conserved, safeguard the environment, and improve humanity's living conditions (United Nations 2015 in Bai et al., 2022)
<i>Sufficiency Economy</i>	SuE	Late King Bhumibol Adulyadej established firms must balance profitability and ethical considerations (Chaisuwan, 2021).
<i>The Natural Step</i>	TNS	Strategic approach for society to function and grow within boundary conditions (Robert K.H. et al., 2002 in Korhonen, 2004)
<i>Triple Bottom Line</i>	TBL	Development of business and society through the balance between economic, environment, and social dimensions (WCED 1987 in Wu et al., 2015).

During the expert focus group, the philosophies were classified according to their principles and how they visualise sustainability transition paths. This is illustrated in Figure 1. For instance, PB and AS principles prioritize the environmental pillars and their principles revolve around Earth's carrying capacity (Clift *et al.*, 2017; Moshrefi *et al.*, 2019). DE and NC visualise sustainability as the economic dimension being embedded within the societal dimension, which in turn is embedded within the environmental dimension (Kuo and Hsiao, 2008; Stopper *et al.*, 2016). Similarly to these two philosophies, TNS presents boundary conditions within which we can operate (Missimer *et al.*, 2017). CE, BE, and GE highlight the importance of sustainable resource use for economic benefits, with potential social benefits as well (Ciliberto *et al.*, 2021; Loiseau *et al.*, 2016; Wenhai *et al.*, 2019). TBL and SDGs depict sustainability as an equal distribution between the three pillars (Neri *et al.*, 2021). However, the Stockholm Resilience Center has tried to promote the SDGs in the distributive-based way as well (Rockström and Sukhdev, 2016), since concerns on social and environmental aspects keep increasing (Singh and Rahman, 2021). Finally, SuE encourages firms to meet societal needs instead of only delivering products and services (Bocken and Short, 2016).

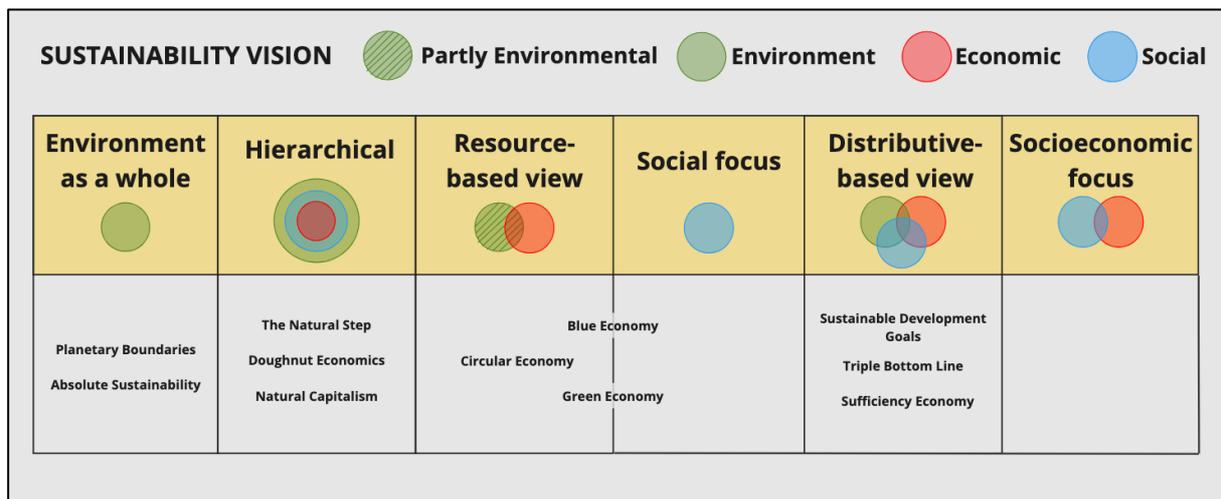


Figure 1. Sustainability vision distribution of the philosophies

3.2. Findings on ACE

In total, 51 strategies have been derived across the 11 selected philosophies: 27 for Awareness, 7 for Cohesion, and 17 for Equity. These were subsequently clustered based on similarities and resulted in 13 strategies for Awareness (Section 3.2.1), 7 for Cohesion (Section 3.2.2) and 13 for Equity (Section 3.2.3). No article mentioned cohesion or equity with respect to PD, nor did they mention sustainability awareness. Only two articles mentioned social equity and four used the term “sustainable transition” (Clift *et al.*, 2017; Desing *et al.*, 2020). Tables 4 to 6 provide a consolidation of these strategies. The complete list of strategies for each aspect can be found in the supplementary material.

3.2.1. Awareness

Despotović *et al.* (2021)'s model to measure environmental awareness was adapted to cover sustainability awareness in design processes. Their model was created to understand farmers' awareness with respect to adopting cleaner agricultural practices. The four dimensions are knowledge, value, attitudes, and behaviour. Of the 13 strategies identified during the SLR, this study could only link strategies related to behaviour, which according to the authors' model means *any action, voluntary or not, that might influence the environment*, and in this case society (Macovei, 2015 in Despotović *et al.*, 2021, p. 3). Table 4 provides a list of the main keywords of the strategies together with philosophies and references.

Table 4. Strategies and contribution to enhanced awareness on the behaviour dimension

<i>Action</i>	<i>Contribution</i>	<i>AS</i>	<i>BE</i>	<i>CE</i>	<i>DE</i>	<i>GE</i>	<i>PB</i>	<i>NC</i>	<i>SDGs</i>	<i>SuE</i>	<i>TNS</i>	<i>TBL</i>
<i>Conduct process evaluations with tools and frameworks</i>	Quantification of environmental footprints of sourcing of materials, consumption during design process, and product disposal.	•		•	•	•	•		•	•	•	•
<i>Elaboration of policies and reports</i>	Facilitate the diffusion of sustainability orientation.		•	•					•			•
<i>Design for X</i>	Material selection improvement, minimise energy consumption	•		•			•	•	•	•		•
<i>Conduct supplier evaluations</i>	Evaluate environmental and social impacts of suppliers.								•	•		•
<i>Eco-labelling</i>	Educate customers.			•						•		•
<i>Provide training to employees and suppliers</i>	Educate on sustainable development practices, facilitate self-development.			•					•			•
<i>Implement approaches like CSR¹, EMS², PSS³</i>	Integrate social and environmental concerns throughout the organisation.			•		•			•	•	•	•
<i>Green design, recycling, remanufacturing, and green manufacturing</i>	Reduce negative impact of products and processes on the natural environment.			•	•				•	•		
<i>Design more durable products</i>	Implement new business models.			•					•	•	•	
<i>Implement management systems (lean, green, and ISO)</i>	Increase profitability, minimise waste, increase efficiency.	•		•		•		•				•
<i>Ensure closed-loop supply chain management</i>	Minimise waste and reduce energy use through the supply chain.			•					•			•
<i>Technological innovations</i>	Predict, monitor, improve, and more.			•		•		•	•	•	•	•
<i>Create guidelines</i>	Support others to follow suit.						•		•			

The strategies in listed were linked to the behaviour dimension of awareness only, since these are undertaken to minimize mainly environmental and social impacts (Despotović *et al.*, 2021). The study didn't identify strategies that measure knowledge levels of social issues; values, like degree of connectedness to nature; and attitudes, like psychological preferences (ibid). Furthermore, TBL, CE, and SDGs had the widest coverage of strategies since they are more widespread and easier to incorporate than the other philosophies with a stronger social focus.

¹ CSR: Corporate Social Responsibility

² EMS: Environmental Management Systems

³ PSS: Product Service Systems

3.2.2. Cohesion

According to Moustakas (2023), cohesion is achieved by multiple actors coming together to establish partnerships, strengthen communication and cooperation. Cohesion possesses five dimensions (dim.) with three sub-dimensions each. Table 5 only shows the sub-dimensions linked to the identified seven strategies. One of the dimensions is equality indicating a strong link with equity.

Table 5. Strategies and contribution to social cohesion

Dim.	Sub-dim.	Strategies	Contribution	BE	CE	GE	NC	PB	SDGs	SuE	TNS	TBL
Social relations	Social networks	Collaboration with suppliers and other stakeholders	Sharing economy strategies, industrial symbiosis, local production networks, knowledge sharing.	•	•	•	•	•		•		•
		Strengthen international communications	In terms of technology, human talents, and information.	•								
	Trust in People	Corporate governance: stakeholder engagement	Transparency, communication, and accountability.							•		•
Orientation	Feelings of responsibility	Corporate governance: follow laws and regulations	Comply with social order.		•			•	•			•
Shared values	Value Consensus	Organisational model	Develop the model between specialists and users.						•			
Quality of life	Equality and Inequality	Supplier evaluation	Ensure human rights.						•	•	•	•
	Wellbeing, health, living conditions	Design to facilitate a healthy lifestyle.	Design of textile and apparel products for an active lifestyle.							•	•	•

DE and AS' articles did not present any strategies, which is why they were not added to Table 5. TBL, SDGs, and SuE seem to be the most comprehensively relevant to design, since they call for the building of stronger social networks and improving life quality of all stakeholders. CE, TNS, and PB all emphasise the importance of strategies such as involving sustainable supply chain collaboration, sharing economy initiatives, industrial symbiosis, establishing local production networks (Garcia-Muiña *et al.*, 2019; Kang and Na, 2020; Shashi *et al.*, 2021).

3.2.3. Equity

According to Musaazi *et al.* (2015), equity is the most overlooked aspect during design processes since it covers various disciplines and requires government support. Nevertheless, manufacturing strategies can ensure human rights and that products delivered are accessible and affordable (*ibid*). Additionally, social problems can be eliminated by preventing child labour or other forms of abuse (Musaazi *et al.*, 2015). Arnette *et al.*, (2014) provides three dimensions, of which two can be found in Table 6 together

with the 12 strategies. The third dimension, design for non-traditional markets is not included, because no strategies were found that contributed to it nor diversity.

Table 6. Social equity

<i>Cons.</i>	Strategies	Contribution	<i>CE</i>	<i>DE</i>	<i>PB</i>	<i>SDGs</i>	<i>SuE</i>	<i>TNS</i>	<i>TBL</i>
<i>Design to increase worker retention rates</i>	Corporate governance: consider social issues and location for operations.	Job creation, increase affordability of products					•	•	•
	Equal rights to economic resources, natural resources, and new technologies.	Ensure same opportunities to everyone.			•	•			
	Provide training to employees.	Focus on maintaining sustainability efforts.		•		•	•		•
	Designing for public spaces.	Develop social economy initiatives.			•				•
	Base local manufacturing and community development.	Create social value and ethical production.					•		•
	Invest	Contribute to CSR.	•			•			•
	Value optimisation	Keep products at their highest value and utility at all times.				•	•		•
<i>Design to eliminate social problems</i>	Corporate governance: consider social issues and location for operations.	Job creation, increase affordability of products.						•	
	Design to facilitate a healthy and active lifestyle.	Design of textile and apparel products for an active lifestyle.							•
	Incorporate impacts on local and global communities.	Eliminate impacts of sourcing and processing.				•			•
	Corporate governance: ensure workers' rights.	Ensure workers' rights.	•	•		•	•	•	•
	Implement reduce strategies.	Reduce exposure and vulnerability shocks.				•			

AS, BE, GE, and NC do not appear, because no strategies were linked to equity. Strategies to increase worker retention rate could also influence sustainability awareness inside and outside an organisation. For this aspect, TBL, SDGs, and SuE had the widest coverage. This is due to the importance given to the social pillar by these philosophies. Particularly in SuE's case, it encourages companies to go beyond their boundaries and also improve customer's consumption habits (Bocken and Short, 2016); consequently, ensuring positive social impacts, such as equity. One SDGs article presented a list of criteria to ensure equity, but no strategies to do so (Moldavska and Welo, 2019).

3.2.4. Summary

Table 7 presents a summary of philosophies contributing to the three aspects and their corresponding sub-dimensions. All philosophies increase sustainability awareness somehow. However, only some to cohesion and even less to equity. These findings shed light on areas that are still overlooked. Nevertheless, the results also show strategies like designing to facilitate a healthy and active lifestyle, supplier evaluation, and corporate governance can contribute to positively to more than one aspect.

Corporate governance is strongly connected to an organisation's culture and value and is key to integrate social responsibility throughout all their business processes (ISO 26000, 2010).

Table 7. Summary of philosophies linked to ACE

Aspect	Sub-dim.	AS	BE	CE	DE	GE	NC	PB	SDGs	SuE	TNS	TBL
Awareness	Behaviour	•	•	•	•	•	•	•	•	•	•	•
Cohesion	Relations		•	•		•	•	•		•		•
	Orientation			•				•	•			•
	Values								•			
	Life quality								•	•	•	•
Equity	Retention rates			•	•			•	•	•	•	•
	Social problems			•	•				•	•	•	•

4. Conclusion

PD is a complex process and finding strategies that result in positive benefits in the social aspect requires companies to both expand their understanding and change their priorities. Organisations strive to meet their customer needs, but also creating societal contributions is fairly new. The strategies listed in tables 4 to 6 are those related to product design; therefore, through other business processes similar strategies part of the integration of other philosophies can be deployed. For a true sustainable product design process, sustainability and particularly the ACE elements hereof must be integrated at strategic level, which will incorporate this thinking into business model and other processes inside the organisation. All philosophies contribute to awareness raising, nine of them to cohesion, and seven to equity, as seen in Table 7.

The analysis performed in this study showed the implementation of TBL and SDGs provides the benefit of contributing to awareness, cohesion, and/or equity during design processes. On the awareness aspect, CE and SuE studies provided multiple strategies, whereas, for cohesion, SuE provided more strategies than CE. Similarly on the equity aspect, for equity behind TNS and SuE. This is because, both TNS and SuE provide means for organisations to understand and consider social aspects throughout their operations.

As seen throughout section 3.2, some philosophies didn't present any PD strategies. Nevertheless, strategies from these philosophies, BE, NC, GE, DE, and AS, are other business processes like business model development, production operations, marketing, among others, that result in raising awareness, establishing cohesion, and/or guaranteeing equity. This opens the possibility for companies to strategically implement these philosophies and create synergies among them. For instance, BE promotes preserving marine resources and sustainable coastal development, the latter strongly linked to cohesion. Organisations working with resources of coastal communities could contribute to BE by through PD strategies. Another example is concerning CE, which is more suitable and common in PD strategies but lacking in social and equity. Consequently, bringing the TNS or SuE principles and designing with these in mind, could bring new considerations that can contribute to cohesion and equity.

Furthermore, those philosophies that possess a wider vision of sustainability at a sector or country level (such as BE and AS) may be harder to integrate at a micro (company) scale. The principles of these philosophies can be applied to PD, but there is a need for further research to look into strategies and methods to do so.

TBL, SDGs, CE, and TNS have existed for longer than most of the other philosophies and are thus more widely adopted. A limitation of this study is that it did not include grey literature, such as insights from corporate sustainability reports. Future research could take a deeper assessment by looking into the

organisations that disseminate and support the implementation of philosophies such as NC and DE, in order to reach a more complete view of the link between PD and ACE. This can also be achieved by assessing the publications of the research groups doing the same for BE, GE, PB, and AS. Including these types of literature in an assessment can provide a more thorough view of both existing strategies and those being implemented presently.

For social cohesion and equity to be achieved and widespread, organisations must look into other business processes like production and operations, after-sale services, and more; as demonstrated in this case, design offers this possibility, but it is not enough. Future research could also investigate philosophies' strategies applied throughout organisations, not specifically PD. This would result in a complete assessment of philosophies and strategies contributing to awareness, cohesion, and equity.

This study depicted which philosophies are more suitable for raising awareness, creating social cohesion, and achieving equity. As more and more manufacturing companies decide to embark on their sustainability journeys, it is essential to shed light on those aspects that are not commonly addressed. This paper provides a list of both well-known and lesser known, nascent philosophies, together with strategies to raise sustainability awareness, strengthen social cohesion, and ensure equity. As mentioned in the introduction, strategies for product design are mainly focused on diminishing environmental impacts. This study addresses this gap by showcasing which sustainability strategies improve the social dimension of design. The study aims to highlight product design related strategies linked to Awareness, Cohesion, and Equity (ACE). Organisations, decision-makers, and researchers can use these to implement new strategies with added benefits.

Supplementary material

Complete list of strategies contributing to sustainability awareness, social cohesion, and social equity is available here.

Acknowledgments

This research was supported by the Centre for Absolute Sustainability, from the Technical University of Denmark (DTU). The authors acknowledge the funding support from DTU to conduct this research.

References

- Arnette, A.N., Brewer, B.L. and Choal, T. (2014), "Design for sustainability (DFS): The intersection of supply chain and environment", *Journal of Cleaner Production*, Elsevier Ltd, 15 November, <https://dx.doi.org/10.1016/j.jclepro.2014.07.021>.
- Bai, C., Orzes, G. and Sarkis, J. (2022), "Exploring the impact of Industry 4.0 technologies on social sustainability through a circular economy approach", *Industrial Marketing Management*, Elsevier Inc., Vol. 101, pp. 176–190, <https://dx.doi.org/10.1016/j.indmarman.2021.12.004>.
- Baumgartner, R.J. and Rauter, R. (2017), "Strategic perspectives of corporate sustainability management to develop a sustainable organization", *Journal of Cleaner Production*, Elsevier Ltd, Vol. 140, pp. 81–92, <https://dx.doi.org/10.1016/j.jclepro.2016.04.146>.
- Biolchini, J., Gomes Mian, P., Candida Cruz Natali, A. and Horta Travassos, G. (2005), *Systematic Review in Software Engineering*.
- Bocken, N.M.P. and Short, S.W. (2016), "Towards a sufficiency-driven business model: Experiences and opportunities", *Environmental Innovation and Societal Transitions*, Elsevier B.V., Vol. 18, pp. 41–61, <https://dx.doi.org/10.1016/j.eist.2015.07.010>.
- Chaisuwan, B.-N. (2021), *SUFFICIENCY ECONOMY PHILOSOPHY-BASED SUSTAINABILITY DIMENSIONS IMPACT ON CUSTOMER EQUITY AND BRAND LOYALTY*, *ABAC Journal*, Vol. 41, Bangkok.
- Ciliberto, C., Szopik-Depczyńska, K., Tarczyńska-Luniewska, M., Ruggieri, A. and Ioppolo, G. (2021), "Enabling the Circular Economy transition: a sustainable lean manufacturing recipe for Industry 4.0", *Business Strategy and the Environment*, John Wiley and Sons Ltd, Vol. 30 No. 7, pp. 3255–3272, <https://dx.doi.org/10.1002/bse.2801>.
- CIRCit. (2019), "Circular Economy Sustainability Screening Scoping and Indicator Selection. ", Copenhagen.
- Circularity Gap Reporting Initiative. (2021), *THE CIRCULARITY GAP REPORT 2021*.
- Clift, R., Sim, S., King, H., Chenoweth, J.L., Christie, I., Clavreul, J., Mueller, C., *et al.* (2017), "The challenges of applying planetary boundaries as a basis for strategic decision-making in companies with global supply chains", *Sustainability (Switzerland)*, MDPI, Vol. 9 No. 2, <https://dx.doi.org/10.3390/su9020279>.

- Desing, H., Brunner, D., Takacs, F., Nahrath, S., Frankenberger, K. and Hischier, R. (2020), “A circular economy within the planetary boundaries: Towards a resource-based, systemic approach”, *Resources, Conservation and Recycling*, Elsevier B.V., Vol. 155, <https://dx.doi.org/10.1016/j.resconrec.2019.104673>.
- Despotović, J., Rodić, V. and Caracciolo, F. (2021), “Farmers’ environmental awareness: Construct development, measurement, and use”, *Journal of Cleaner Production*, Elsevier Ltd, Vol. 295, <https://dx.doi.org/10.1016/j.jclepro.2021.126378>.
- Elkington, J. (1999), “Triple bottom line: Implications for the oil industry”, *Oil and Gas Journal*, Vol. 97 No. 50, pp. 139–141.
- Garcia-Muiña, F.E., González-Sánchez, R., Ferrari, A.M., Volpi, L., Pini, M., Siligardi, C. and Settembre-Blundo, D. (2019), “Identifying the equilibrium point between sustainability goals and circular economy practices in an Industry 4.0 manufacturing context using eco-design”, *Social Sciences*, MDPI AG, Vol. 8 No. 8, <https://dx.doi.org/10.3390/socsci8080241>.
- Glavič, P. and Lukman, R. (2007), “Review of sustainability terms and their definitions”, *Journal of Cleaner Production*, Vol. 15 No. 18, pp. 1875–1885, <https://dx.doi.org/10.1016/j.jclepro.2006.12.006>.
- Hauschild, M.Z. (2015), “Better - but is it good enough? On the need to consider both eco-efficiency and eco-effectiveness to gauge industrial sustainability”, *Procedia CIRP*, Vol. 29, Elsevier B.V., pp. 1–7, <https://dx.doi.org/10.1016/j.procir.2015.02.126>.
- ISO 26000: Guidance on Social Responsibility*. (2010), , Geneva.
- Kang, S. and Na, Y.K. (2020), “Effects of strategy characteristics for sustainable competitive advantage in sharing economy businesses on creating shared value and performance”, *Sustainability (Switzerland)*, MDPI, Vol. 12 No. 4, <https://dx.doi.org/10.3390/su12041397>.
- Korhonen, J. (2004), “Industrial ecology in the strategic sustainable development model: Strategic applications of industrial ecology”, *Journal of Cleaner Production*, Vol. 12 No. 8–10, pp. 809–823, <https://dx.doi.org/10.1016/j.jclepro.2004.02.026>.
- Kuo, N.W. and Hsiao, T.Y. (2008), “An exploratory research of the application of natural capitalism to sustainable tourism management in Taiwan”, *Journal of Cleaner Production*, Vol. 16 No. 1, pp. 116–124, <https://dx.doi.org/10.1016/j.jclepro.2006.11.005>.
- Loiseau, E., Saikku, L., Antikainen, R., Droste, N., Hansjürgens, B., Pitkänen, K., Leskinen, P., *et al.* (2016), “Green economy and related concepts: An overview”, *Journal of Cleaner Production*, Elsevier Ltd, Vol. 139, pp. 361–371, <https://dx.doi.org/10.1016/j.jclepro.2016.08.024>.
- Lovins, A., Lovins, H. and Hawken, P. (1999), “A ROAD MAP FOR NATURAL CAPITALISM”, *Harvard Business Review*, 77, pp. 145–161.
- MacDonald, J.P. (2005), “Strategic sustainable development using the ISO 14001 Standard”, *Journal of Cleaner Production*, Vol. 13 No. 6, pp. 631–643, <https://dx.doi.org/10.1016/j.jclepro.2003.06.001>.
- Missimer, M., Robèrt, K.H. and Broman, G. (2017), “A strategic approach to social sustainability - Part 2: a principle-based definition”, *Journal of Cleaner Production*, Elsevier Ltd, Vol. 140, pp. 42–52, <https://dx.doi.org/10.1016/j.jclepro.2016.04.059>.
- Moldavska, A. and Welo, T. (2019), “A Holistic approach to corporate sustainability assessment: Incorporating sustainable development goals into sustainable manufacturing performance evaluation”, *Journal of Manufacturing Systems*, Elsevier B.V., Vol. 50, pp. 53–68, <https://dx.doi.org/10.1016/j.jmsy.2018.11.004>.
- Moshrefi, S., Kara, S. and Hauschild, M. (2019), “A framework for estimating regional footprint of companies towards absolute sustainability”, *Procedia CIRP*, Vol. 80, Elsevier B.V., pp. 446–451, <https://dx.doi.org/10.1016/j.procir.2019.01.050>.
- Moustakas, L. (2023), “Social Cohesion: Definitions, Causes and Consequences”, *Encyclopedia*, MDPI AG, Vol. 3 No. 3, pp. 1028–1037, <https://dx.doi.org/10.3390/encyclopedia3030075>.
- Murphy, K. (2012), “The social pillar of sustainable development: a literature review and framework for policy analysis”, *Sustainability: Science, Practice and Policy*, Informa UK Limited, Vol. 8 No. 1, pp. 15–29, <https://dx.doi.org/10.1080/15487733.2012.11908081>.
- Musaazi, M.K., Mechtenberg, A.R., Nakibuule, J., Sensenig, R., Miyingo, E., Makanda, J.V., Hakimian, A., *et al.* (2015), “Quantification of social equity in life cycle assessment for increased sustainable production of sanitary products in Uganda”, *Journal of Cleaner Production*, Elsevier Ltd, Vol. 96, pp. 569–579, <https://dx.doi.org/10.1016/j.jclepro.2013.10.026>.
- Nakata, C. and Im, S. (2010), “Spurring cross-functional integration for higher new product performance: A group effectiveness perspective”, *Journal of Product Innovation Management*, Vol. 27 No. 4, pp. 554–571, <https://dx.doi.org/10.1111/j.1540-5885.2010.00735.x>.
- Neri, A., Cagno, E., Lepri, M. and Trianni, A. (2021), “A triple bottom line balanced set of key performance indicators to measure the sustainability performance of industrial supply chains”, *Sustainable Production and Consumption*, Elsevier B.V., Vol. 26, pp. 648–691, <https://dx.doi.org/10.1016/j.spc.2020.12.018>.

- Pigosso, D.C.A., McAlloone, T.C. and Rozenfeld, H. (2014), “Systematization of best practices for ecodesign implementation”, *Proceedings of International Design Conference, DESIGN*, Vol. 2014-Janua, pp. 1651–1662.
- Rockström, J. and Sukhdev, P. (2016), “How Food Connects All the SDGs. Keynote Speech at Stockholm EAT Food Forum”.
- Shaner, M.B., Beeler, L. and Noble, C.H. (2016), “Do We Have to Get Along to Innovate? The Influence of Multilevel Social Cohesion on New Product and New Service Development”, *Journal of Product Innovation Management*, Blackwell Publishing Ltd, Vol. 33, pp. 148–165, <https://dx.doi.org/10.1111/jpim.12327>.
- Shashi, Centobelli, P., Cerchione, R. and Mittal, A. (2021), “Managing sustainability in luxury industry to pursue circular economy strategies”, *Business Strategy and the Environment*, John Wiley and Sons Ltd, Vol. 30 No. 1, pp. 432–462, <https://dx.doi.org/10.1002/bse.2630>.
- Singh, A.P. and Rahman, Z. (2021), “Integrating corporate sustainability and sustainable development goals: towards a multi-stakeholder framework”, *Cogent Business and Management*, Cogent OA, Vol. 8 No. 1, <https://dx.doi.org/10.1080/23311975.2021.1985686>.
- Stopper, M., Kossik, A. and Gastermann, B. (2016), “Development of a Sustainability Model for Manufacturing SMEs based on the Innovative Doughnut Economics Framework”, *International MultiConference of Engineers and Computer Scientists*, p. 967.
- Vilochani, S., McAlloone, T.C. and Pigosso, D.C.A. (2023), “MANAGEMENT PRACTICES FOR SUSTAINABLE PRODUCT DEVELOPMENT: INSIGHTS FROM A SYSTEMATIC LITERATURE REVIEW”, *Proceedings of the Design Society*, Vol. 3, Cambridge University Press, pp. 2505–2514, <https://dx.doi.org/10.1017/pds.2023.251>.
- Wenhai, L., Cusack, C., Baker, M., Tao, W., Mingbao, C., Paige, K., Xiaofan, Z., *et al.* (2019), “Successful blue economy examples with an emphasis on international perspectives”, *Frontiers in Marine Science*, Frontiers Media S.A., <https://dx.doi.org/10.3389/fmars.2019.00261>.
- Wu, L., Subramanian, N., Abdulrahman, M.D., Liu, C., Lai, K. hung and Pawar, K.S. (2015), “The impact of integrated practices of lean, green, and social management systems on firm sustainability performance-evidence from Chinese fashion auto-parts suppliers”, *Sustainability (Switzerland)*, MDPI, Vol. 7 No. 4, pp. 3838–3858, <https://dx.doi.org/10.3390/su7043838>.