STAKEHOLDER ENGAGEMENT IN SUSTAINABLE OPERATIONS MANAGEMENT: EVIDENCE FROM SOCIAL MEDIA ANALYTICS

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Stakeholder Engagement in Sustainable Operations Management: Evidence from Social Media Analytics

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CERTIFICATE OF ORIGINALITY

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Abstract

Since operations management is closely related to the efficiency of energy and materials as well as social benefits, it is necessary for firms to shift towards sustainable operations management (SOM) to achieve common sustainable development goals. Information systems (IS) play a critical role in SOM. We first investigated the role of IS on firms' sustainable development through a Systematic Literature Network Analysis (Chapter 2). This study discovered three main research domains (sustainable competitive advantage, environmental sustainability, and sustainable online social communities) and two emerging research domains (the role of IS in developing countries and sustainable information infrastructures). Based on our findings, we develop the framework for the role of IS in SOM. Furthermore, we found that few studies mentioned the role of IS in promoting stakeholder engagement. The inclusive engagement of multiple stakeholders can promote the implementation of sustainable development goals. Stakeholder engagement implies that firms engage in dialogue with stakeholders to determine their social, environmental, and economic concerns. Firms' OM will become more sustainable in the process of meeting the needs of stakeholders. The improvement of stakeholder engagement needs effective communication strategies. Social media, an advanced IS, is an efficient channel for firms to improve stakeholder engagement. However, it is an issue for most firms to communicate their SOM on social media since not all social media posts generate high stakeholder engagement. Therefore, this study aims to help firms understand how to engage stakeholders through exploring stakeholder engagement in firms' SOM using social media. In chapter 3, we collected 25,106 social media posts from 19 fashion brands and classified them into three operations closely related to sustainable practices (i.e., product design, manufacturing, and recycling). We train a Natural Language Processing technique machine to mimic how the stakeholders interpret brands' communications about SOM. We found that sustainable product design and recycling initiatives generated stronger stakeholder engagement. However, sustainable manufacturing had insignificantly positive effects on stakeholder engagement. Then we extended our research to the Chinese context since China is a significant market for many firms. China is transforming from single economic development to sustainable development. Chinese stakeholders have started engaging in firms' SOM, but few studies have focused on this. Therefore, we collected 37,007 social media posts from 22 brands on Sina Weibo to investigate the extent of stakeholder engagement with firms' SOM in China (Chapter 4). We found that sustainable product designs generated stronger stakeholder engagement. However, sustainable manufacturing and recycling practices had

insignificantly positive effects on stakeholder engagement. Our findings can help firms engage Chinese stakeholders more efficiently. We also compare the findings in chapter 3 and those in Chapter 4 to better understand the differences between stakeholders in different countries. However, it is hard for firms to guarantee the successful launch of new product designs sometimes since they cannot keep the balance among multiple stakeholders. We analyzed 32,006 tweets from 33 global automobile manufacturers and found adverse stakeholder engagement with vehicle electrification and automation (Chapter 5). Since employees are major stakeholders, we analyzed international job creation records from 33 global automobile manufacturers and found that job creation can improve stakeholders' adverse social media engagement. We are the first to investigate how stakeholder engagement improves firms' SOM. Our studies provide a more comprehensive understanding of stakeholder engagement in SOM from different perspectives.

Publications arising from the thesis

Zeng, F., Lee, S.H.N., & Lo, C.K.Y. (2020). The role of information systems in the sustainable development of firms: A systematic literature network analysis. *Sustainability (Basel, Switzerland), 12(*8), 3337–3365. https://doi.org/10.3390/su12083337

Zeng, F., Lo, C.K.Y., & Lee, S.H.N. (2022). Will communication of job creation facilitate diffusion of innovations in the automobile industry? *Sustainability (Basel, Switzerland), 14*(1), 36-57. https://doi.org/10.3390/su14010036

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Chapter 1: Introduction

Economic development worldwide severely compromises environmental sustainability (e.g., plastics pollution, water pollution, greenhouse emission) and social sustainability (e.g., sweatshop, child labor). Since the 1950s, more than 8.3 billion tons of plastics have been produced globally, of which about 60% are non-biodegradable and thus pollute the environment.[1] Over the past 150 years, industrial activities have almost doubled the amount of carbon dioxide in the atmosphere, accelerating global warming.[2] In addition to these environmental concerns, human rights issues still plague manufacturing industries. For instance, the factory that makes clothes for Boohoo pays workers only £3-4 per hour, which is far lower than the minimum hourly wage of £8.72.[3]

OM plays a critical role in sustainable development since OM (e.g., production design, manufacturing, recycling) is closely related to the efficiency of energy and materials (Drake & Spinler, 2013). Data from Tetra Pak shows that 48% of a product's carbon footprint comes from manufacturing.[4] Luxury carmakers Bentley Motors use renewable energy to supply the operations in manufacturing, which significantly reduced their carbon footprint by about 14,000 tonnes of carbon dioxide equivalent in one year.[5] Levi's made 100 thousand pair of jeans with recycled water saving 12-million-liter water.[6] Regarding social sustainability, Farmers and workers in the fair-trade program can receive a fair-trade premium of more than 500 million euros. They have funded numerous activities beneficial to the core producers in their systems (e.g., education, training for farmers, etc.)[7]. Thus, to achieve common sustainable development goals, firms are necessary to integrate sustainability into their operations management (i.e., shifting towards sustainable operations management) (Hardcastle, 2013). Sustainable operations management (SOM) for a business means "to structure and manage its

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[1] https://www.unep.org/interactive/beat-plastic-pollution/

[2] https://climate.nasa.gov/causes/

[3] https://www.theguardian.com/business/2020/aug/28/boohoo-leicester-factories-went-to-war

[4] https://www.greenbiz.com/article/boost-sustainability-your-manufacturing-operations

[5] https://www.automotivelogistics.media/sustainability/bentley-includes-logistics-in-carbon-reduction-initiative/42499.article

[6] https://www.ecowatch.com/levis-makes-100-000-pairs-of-jeans-with-100-recycled-water-1881869424.html

[7] https://www.fairtrade.net/impact/overview

business processes to obtain competitive returns on its capital assets without sacrificing the legitimate needs of internal and external stakeholders and with due regard for the impact of its operations on people and the environment" (Kleindorfer, Singhal, & Van Wassenhove, 2005, p. 489).

Information systems (IS) play a vital role in SOM, especially in the era of big data. In the past, firms extensively relied on IS to increase the efficiency of OM (i.e., the economic sustainability of SOM) (Kumar et al., 2018). A majority of IS research has thus focused on understanding and implementing improvements to the efficiency of OM (Guha & Kumar, 2018). Firms utilize IS to inform and connect stakeholders in the supply chain, synchronize supply and demand, and co-create value (Manavalan & Jayakrishna, 2019). IS can improve efficiency, increase productivity, reduce errors and optimize inventory (Manavalan & Jayakrishna, 2019). Further, IS can contribute to the environmental aspects of firms' SOM through developing energy consumption systems, optimizing delivery truck routes, extending component life, and improving product safety (Watson et al., 2010). For example, DHL Express constructed an IS, the Smart Truck Project, to optimize their routes and shorten transportation time and thus pollutant emissions (Hong et al., 2021). The Internet of Things can help inform firms of the end of the life of their products so that they can take the initiative to repair salvageable products or recycle scrapped products (Awan et al., 2021). Further, IS also contributes to the social aspects of SOM. For instance, blockchain can increase the transparency of a supply chain. For example, Walmart, together with Jinluo, used blockchain to develop the IS to monitor food safety in the pork supply chain in China (Hong et al., 2021). Stakeholders can monitor firms' supply chains, ensuring firms will strictly fulfill their commitments to sustainable development. Firms can also consider soliciting consumer feedback on social media to improve OM (Choi et al., 2020).

As there is great interest in and pressure to implement sustainable development in all aspects of operations management, we investigated the role of IS on firms' sustainable development through a Systematic Literature Network Analysis (SLNA) (Chapter 2). This study discovered three main research domains (sustainable competitive advantage, environmental sustainability, and sustainable online social communities) and two emerging research domains (the role of IS in developing countries and sustainable information infrastructures). We found that the research on sustainable competitive advantage and environmental sustainability accounts for the majority of topics, but the research on sustainable online social communities is quite scarce.

Furthermore, we found that few studies mentioned the role of IS in promoting stakeholder engagement, which is crucial for firms' SOM (De Luca et al., 2022). According to the definition of SOM, firms should understand and satisfy the needs of stakeholders (Kleindorfer, Singhal, & Van Wassenhove, 2005; Roscoe et al., 2020). Efficient stakeholder engagement requires clear communication with each stakeholder through IS such as social media (Saieg et al., 2018). Social media, an advanced IS, can improve transparency and promote information sharing between firms and stakeholders to improve operational decision-making (Roscoe et al., 2020). Social media is an effective channel for firms to communicate with stakeholders about their SOM (De Luca et al., 2022). However, most firms have difficulties in communicating their sustainability practices on social media since not all social media posts generate the same level of stakeholder engagement (Zizka, 2017). Ineffective engagement may increase decision-making costs (Li et al., 2018). Therefore, we aim to help firms understand how to engage stakeholders through exploring stakeholder engagement in firms' SOM using social media.

Stakeholder refers to "the group or individual who can affect or is affected" by a firm's OM (De Luca et al., 2022) p.1). Stakeholders include consumers, suppliers, employees, governments, shareholders, and society (De Luca et al., 2022). Stakeholders have resources that can be used as inputs to OM, such as capital, materials, knowledge, and time (Freeman et al., 2004). For example, consumers pay for the products or services that meet their needs, employees devote valuable knowledge and time to the firm's operations, and suppliers provide the firm with materials. Stakeholders can adjust their resources to reward or punish the firms, depending on whether their needs are met (Surucu-Balci et al., 2020). The extent to which the firms meet the stakeholders' expectations determines their success (Oliver, 1991).

Stakeholders can also affect firms' SOM by denouncing their unsustainable practices. After the collapse of a garment factory in Bangladesh, many people began strongly criticizing fast fashion brands for ignoring workers' safety and rights. A report from the Kantar Group revealed that more than 75% of British grocery shoppers would boycott brands that neglect environmental sustainability in production. Governments may even punish firms for their unsustainable practices. Employees strike in cases of unfair treatment. The media and non-governmental organizations can mobilize public opinion to support or oppose the activities of an organization (Roscoe et al., 2020). In contrast, firms' sustainable practices may improve their relationships with key stakeholders (Attig et al., 2013). Sustainable products (e.g., those produced through a sustainable supply chain) also have higher demand in the market (Cillo et al., 2019). Investors and creditors prefer firms implementing SOM (Zhou et al., 2018).

Firms are motivated to gain the loyalty of stakeholders to increase their investment in the firm's resources (Surucu-Balci et al., 2020). To this end, firms engage in dialogue with stakeholders to determine their concerns about economic, environmental, and social sustainability, which is defined as “stakeholder engagement” (Surucu-Balci et al., 2020, p.2). Engagement is the core of building relationships with stakeholders, creating value, and thus achieving sustainable development (Denktas-Sakar & Surucu, 2020). The inclusive engagement of multiple stakeholders can promote the implementation of sustainable development goals because sustainable development is related to the interests of human beings (Guan et al., 2019). Stakeholder engagement allows firms’ operations management to achieve triple-bottom line rather than solely focusing on their shareholders. Therefore, firms’ OM will become more sustainable in the process of meeting the needs of stakeholders.

Stakeholder engagement in SOM includes sharing information, responsibilities, and resources and jointly planning, implementing, and evaluating social and environmental sustainability in OM (Roscoe et al., 2020). An effective communication strategy can help firms generate mutual understanding and satisfy more stakeholders, improving stakeholder engagement (De Luca et al., 2022). Social media could be one effective communication strategy (De Luca et al., 2022). Social media is defined as “a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content” (Kaplan & Haenlein, 2010, p. 61). Social media allows for a free communication environment without time and space constraints and has become an important low-cost tool for stakeholder engagement (Zhang & Lin, 2015). Stakeholders can share their perceptions without interruption through a direct and continuous dialogue with firms on social media, accelerating communication and allowing them to monitor business practices on a broader scale (Surucu-Balci et al., 2020). Social media has become a vital channel for stakeholders to obtain environmental information and engage in firms’ environmental management and supervision (Li et al., 2018). Through social media, firms can construct an information-rich social network, reach a more extensive range of stakeholders, and understand stakeholders’ requirements, improving firms’ operational efficiency (Lam et al., 2016). Therefore, social media is an effective communication tool for firms to engage stakeholders in their SOM.

Stakeholder engagement on social media involves specific interactive experiences comprising positive cognitive and emotional dimensions, which can trigger promotional behaviors (e.g., giving likes, and sharing social media posts) (Viglia et al., 2018). The "positive cognitive dimension" means that stakeholders are interested in firms' activities (Dijkmans et al., 2015). A "positive emotional dimension" implies that stakeholders feel good about some practices (Dijkmans et al., 2015). Thus, the engagement rate on firms' posts (i.e., giving likes, comments, sharing) can determine stakeholder engagement on social media (De Luca et al., 2022). Social media data make stakeholder engagement measurable. Previous studies may research firms' SOM based on Corporate Social Responsibility (CSR) reports. However, CSR reports only allow one-way communication (i.e., reading). Firms cannot measure stakeholder engagement since they cannot receive feedback or data about stakeholders with CSR reports. Thus, social media is a better channel for firms and scholars to research stakeholder engagement since it can quantify stakeholder engagement (e.g., the number of likes). Previous OM studies have used social media data to investigate stakeholder engagement (Denktas-Sakar & Surucu, 2020). Therefore, we assume that social media would be an ideal channel to explore how to make stakeholder engagement in SOM more efficient and to determine which aspects of SOM generate higher stakeholder engagement. We select the number of likes to measure stakeholder engagement on social media. Giving likes implies that stakeholders have engaged in and approved firms' practices mentioned on social media posts (Srinivasan et al., 2022). Moreover, giving likes is the easiest engagement option for stakeholders (Srinivasan et al., 2022).

In chapter 3, we collected 25,106 social media posts from 19 fashion brands and classified them into three operations closely related to sustainable practices (i.e., product design, manufacturing, and recycling). We assumed that OM that met more Sustainable Development Goals (SDGs) would be considered more sustainable. Then, we adopted a data-driven approach (i.e., the Natural Language Processing technique) to train a machine to mimic how the stakeholders interpret brands' communications about SOM. We found that sustainable product design and recycling initiatives generated stronger stakeholder engagement. However, manufacturing achieving more SDGs had insignificantly positive effects on stakeholder engagement. Our findings can help firms make correct decisions on engaging stakeholders in their sustainable operations. Specifically, firms should select more eco-friendly materials for manufacturing, especially recycled plastics. However, manufacturing processes have the potential to meet stakeholders' approval, and the issues involved are often more controversial. Firms need to adjust their current communications with key stakeholders on manufacturing. To our best knowledge, we are the first to demonstrate the impact of social media reactions to SOM through a large-scale data-driven approach. Further, this study may help firms make decisions and formulate operational strategies, which is a significant aspect of OM.

Then we extended our research to the Chinese context since China is a significant market for many firms. Culture, language, and policies create the need for different approaches to engaging stakeholders. China's economic aggregate is second only to the United States (Xie et al., 2021). However, China's rapid development has promoted the vigorous use of natural resources, increasing pressure to shift towards sustainability (Xie et al., 2021). Since 2009, China has been the largest carbon dioxide emitter and energy consumer (Guan et al., 2019). However, China is transforming from single economic development to sustainable development (Guan et al., 2019). Chinese stakeholders have begun to engage in firms' SOM through practices such as boycotting unsustainable products (e.g., toxic milk powder) (Li et al., 2018). Governments may also engage with firms' sustainable production (e.g., offering an environmental protection tax and subsidies for recruiting fresh graduates) (He et al., 2021). The media has begun exposing firms' unsustainable production practices (e.g., CCTV's 315 Gala).[8] Chinese stakeholders have started engaging in firms' SOM, but few studies have focused on this (Li et al., 2018). Therefore, we collected 37,007 social media posts from 22 brands on Sina Weibo to investigate the extent of stakeholder engagement with firms' SOM in China (Chapter 4). We found that sustainable product designs generated stronger stakeholder engagement. However, manufacturing and recycling practices that achieved more SDGs had insignificantly positive effects on stakeholder engagement. Our findings can help firms engage Chinese stakeholders more efficiently. We also compare the findings in chapter 3 and those in Chapter 4 to better understand the differences between stakeholders in different countries.

In previous studies, we found that sustainable product designs generate stronger stakeholder engagement. New product designs should meet multiple stakeholders' demands (de Guimarães et al., 2021). In fact, firms are hard to guarantee the successful launch of new product designs since they cannot keep the balance among multiple stakeholders (Choi et al., 2020). We used electronic vehicles (EVs) and automated vehicles (AVs) as examples of sustainable product

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[8]https://gamingsym.in/cctvs-315-party-revealed-that-some-of-the-old-altar-sauerkraut-buns-were-pickled-in-soil-pitsjingdong-taobao-and-master-kong-instant-noodle-flagship-stores-have-removed-laotan-sauerkraut-related-p/

designs and investigated stakeholder engagement with these products (Chapter 5). We analyzed 32,006 tweets from 33 global automobile manufacturers and found adverse stakeholder engagement with vehicle electrification and automation. Governments have vigorously promoted EVs and AVs, but other stakeholders seem to have less engagement because of the immature technology and the impact on employment structures. Therefore, promoting sustainable product design is still an issue. Employees are major stakeholders because these groups occupy a vital position in firms' OM (Roscoe et al., 2020). Therefore, we analyzed international job creation records from 33 global automobile manufacturers and found that job creation can improve stakeholders' adverse social media engagement. These findings can help firms understand their stakeholders and make correct decisions on sustainable product designs, creating higher efficiency using limited resources. Meanwhile, this study highlighted the role of employees in promoting sustainable product designs.

We mainly conducted an empirical study to collect stakeholder engagement data better. We used social media data since it can reflect realistic public opinions and offer expanded information to researchers, which allows us to explicate the phenomena from a broader perspective (Hirschberg & Manning, 2015). Considering the way of stakeholder engagement, social media enables firms to communicate with their stakeholders and collect feedback through various responses, such as likes, comments and shares (Manetti & Bellucci, 2016). Thus, social media allows us to measure stakeholder engagement with the number of likes.

In addition, with the rapid development of IT analytical tools, OM scholars can adopt innovative big data analytics (e.g., social media data) to explore wider unknown OM areas, making this the best era for OM empirical studies (Melnyk et al., 2018). Firstly, we used Python to mine the social media data. We collected data from retail firms since this industry is one of the important research fields in OM (Mehra et al., 2018). Secondly, we used MySQL to store our data. Thirdly, we adopted a machine learning method (i.e., Natural Language Processing) for data annotation. Machine learning methods can deal with a larger data set and show data-driven findings from a more objective and macro perspective.

Therefore, it is possible to gain SOM insights from analyzing social media data, as previous literature has shown. Surucu-Balci et al. (2020) found that social media posts related to social responsibility had higher engagement. Denktas-Sakar and Surucu (2020) investigated stakeholder engagement in three-party logistics firms, while Surucu-Balci et al. (2020) focused on stakeholder engagement in the container shipping market. However, study on stakeholder engagement in SOM area using social media data is still in its preliminary stages. To help firms understand how to engage stakeholders, we investigated the relationship between stakeholder engagement and SOM. Meanwhile, we also filled the research gap on how social media promotes the role of stakeholders in SOM. Moreover, our studies also contribute to the OM-Marketing interface, a new area in OM. This is because improving stakeholder engagement involves communication methods such as advanced multimedia technologies (e.g., video, Virtual Reality) and promotion (e.g., coupons, points in VIP cards).

In summary, this thesis tracks global interest in sustainable development. Our studies provide a more comprehensive understanding of stakeholder engagement in SOM from different perspectives, which may help firms engage stakeholders in their SOM. Figure 1 shows the positions of four studies. Social media is an ideal medium through which to collect stakeholders' opinions. Firms can improve the efficiency of their SOM by gaining a better understanding of stakeholders' expectations. Efficient SOM can improve resource utilization, reduce costs, create long-term business value, and benefit society.

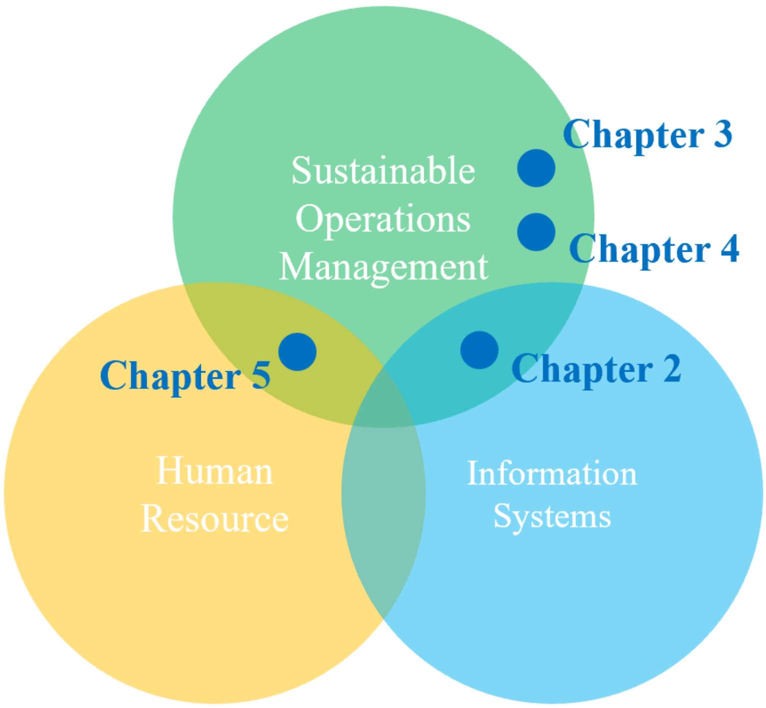

Figure 1. The positions of four studies

Chapter 2: The Role of Information Systems in the Sustainable Development of Firms: A Systematic Literature Network Analysis

Abstract: Information Systems (IS) play an important role in improving the efficiency of firms' operations and supply chains, which links to sustainability. Therefore, this study conducted a systematic literature network analysis to review 132 articles that discuss current trends in the IS discipline. Based on a citation network analysis, this study discovered three main research domains (sustainable competitive advantage, environmental sustainability, and sustainable online social communities) and two emerging research domains (the role of IS in developing countries and sustainable information infrastructures). Furthermore, a main path analysis was conducted to understand the knowledge structure of each research domain. This addresses how different trends are reflected in the IS literature related to improving firms' competitive advantages and environmental sustainability. The results found that the sustainable competitiveness of firms is improved by the synergy between IS and other recourses within the firms. Green IS initiatives not only solve the issues of environmental sustainability but also enhance sustainable competitive advantage (e.g., stock price). This study also discusses the factors affecting the sustainable online social community, such as structural dynamics (i.e., membership size, communication activity), social dynamics (the basic nature of interactions among members), participation costs, and topic consistency. Overall, the IS literature is highly focused on three areas—economy, environment, and society, which supports the Triple Bottom Line theory.

Keywords: information systems; citation network analysis; sustainable competitive advantage; environmental sustainability; online community; sustainability; social media

1. Introduction

Information Systems (IS) help to support firms' operations, management, and decision-making processes (Bulgacs, 2013). IS are not only comprised of the combination of information and communication technology (ICT) but also the way in which people interact with these technologies in support of business processes (Kroenke, 2015). In this sense, well-functioning IS are special types of work systems in which humans or machines perform processes and activities that use resources to produce specific products or services for customers (Alter, 2003, 2013). IS for firms' operations management (OM) is a pyramid of systems covering transaction processing systems at the bottom to management IS, decision support systems, and executive

IS at the top and supporting decision-making in every part of the supply chain (Laudon, 2020). For example, IS are involved in each phase of fashion firms' operations and supply chain, from fashion design (i.e., artificial neural network and smart retail systems), demand forecasting (i.e., big data, cloud computing, extreme learning machine), sourcing and production (i.e., RFID), inventory and transportation management (i.e., vendor managed inventory), to retailing (i.e., smart retail systems, return management systems) (Choi, 2016). Further, IS may play a critical role in sustainable operations management (SOM), especially in the era of big data.

As a source of maintaining economic sustainability, IS have helped improve firms' performances by increasing the efficiency of firms' OM (Dehning & Stratopoulos, 2003; Hevner et al., 2004). Previous literature found that firms can improve firm performance by reducing costs and delivery time, and enhancing customer service and reliability with the help of ICT implementation (Daneshvar Kakhki & Gargeya, 2019). Consequently, the potential of IS to enhance management decision-making capabilities and productivity by adopting firm resource systems, supply chain collaboration support systems (Hadaya & Cassivi, 2012), and social reference systems to support sustainable social commerce sales, have been explored (Lee et al., 2015). Firms utilize IS to accelerate information sharing in the supply chain in order to enhance responsiveness, synchronize supply and demand, and co-create value (Manavalan & Jayakrishna, 2019). IS for inventory management can reduce errors, optimize inventory and coordinate with transportation planning (Manavalan & Jayakrishna, 2019). They indicated that IS can help firms maintain economic sustainability.

IS directly assist in environmentally sustainable operations, such as implementing greenhouse gas emission tracking systems within a logistics process (Hilpert et al., 2013), indexing system for green supplier evaluations (Shi et al., 2015), and optimizing delivery truck routes (Hong et al., 2021). Firms adopt IS to promote environmental sustainability in OM. Integrating Enterprise Resource Planning application, supply chain management software, and Internet of Things technology, fashion brand Everlane provides transparent information for the whole production, which includes sourcing different components and costs, labor conditions, carbon footprint, and environmental impacts (Ballard, 2018). JD.com implements information technology to establish the systems of electronic invoices, which helped to saved 91 tons of paper.[9] The Internet of Things can help inform firms of the end of the life of their products so that they can take the initiative to repair salvageable products or recycle scrapped products (Awan et al., 2021). With the help of Augmented Reality (AR) technology, some retailers (e.g., ASOS, Amazon) give their consumer a picture of the clothes worn on their body in reality, which helps the consumer find suitable products and reduces carbon emissions from lower rate of refund.[10] Therefore, IS have helped firms to implement environmentally sustainable operations to meet global environmental challenges and respond to stakeholders' requirements (Elliot, 2011; Seidel et al., 2017).

Further, IS also contributes to the social aspects of SOM. Social media, as an advanced IS, provide an efficient channel for stakeholders to monitor and engage in firms' OM (Choi et al., 2020).. They Stakeholders may expose firms' unsustainable practices on social media, which ensures that firms will strictly fulfil their commitments to sustainable development. In addition, block chain can increase the transparency of a supply chain. For example, Walmart, together with Jinluo, developed a block chain traceability system to monitor food safety in China's pork supply chain (Hong et al., 2021). Therefore, IS can help firms' OM achieve social sustainability.

Recently, most firms have increased IS spending on OM since IS can help firms achieve SOM in economic (e.g., improve efficiency of OM), environmental (e.g., reduce pollution) and social (e.g., improve transparency of work condition) aspects (Kumar et al., 2018). However, there are still many problems in the IS implementation. A recent survey found that many executives are concerned about IS implementation because 70% of all IS initiatives did not reach their goals.[11] Out of USD $1.3 trillion that was spent on IT in 2018, approximately $900 billion was estimated as wasted.[12] In terms of IS academia, a high amount of literature has continuously made important contributions to research on sustainability also (Brocke et al., 2013; Henry et al., 2013; Junker & Farzad, 2015; Recker, 2016; Seidel et al., 2017). Thus, this study aims to understand the role that IS play in firms' SOM from the IS perspective. To be specific, the

[9] https://www.marketing-interactive.com/features/sustainability-and-ecommerce-why-you-need-to-think-green-even-online/

[10] https://www.klarna.com/knowledge/articles/how-to-make-your-e-commerce-business-more-sustainable-overnight/

[11] https://hbr.org/2019/03/digital-transformation-is-not-about-technology

[12] https://hbr.org/2019/03/digital-transformation-is-not-about-technology

objectives of this study are 1) to describe the nature of sustainability in IS related articles since 1993; 2) to identify the key research domains of sustainability issues in IS; 3) to analyze how sustainability is discussed in IS literature and find key research gaps for future research; and 4) to explore how IS contribute to SOM. To achieve the objectives of this study, the Systematic Literature Network Analysis (SLNA) was used to understand the nature of sustainability in IS and key research domains, while the Main Path Analysis (MPA) was conducted to identify important milestones in the theoretical development.

2. Information systems and sustainable development

Business value from investment on IS can only be generated through business improvement and innovation (i.e., product, service innovation, improved business process) (Peppard & Ward, 2004). In other words, firms realized sustainable competitive advantages through good cooperation between the IS and firms' OM including knowledge sharing in the entire supply chain, healthcare and omnichannel retailing and recommendation systems (Kettinger et al., 1994; Kumar et al., 2018). In the past, a small number of IS review papers focused on the role of IS in the sustainable development of firms, such as Peppard and Ward (2004), Wade and Hulland (2004) and Piccoli and Ives (2005). Peppard and Ward (2004) indicated that resource-based theory is suitable to explain the role of IS in sustainable competitive advantage. IS capability, as one kind of resource, supports and improves the operations of firms, enhancing firm performance in the long-term (Peppard & Ward, 2004). Wade and Hulland (2004) also agreed that the complementarity of IS and other resources affected sustainable competitive advantage and highlighted that this is moderated by the firm's factors (i.e., strong top managers) and environmental factors (i.e., stable business environment, turbulent business environment). To be specific, in the context of strategic initiatives, a sustainable competitive advantage is achieved by IT resource barriers (i.e., IT assets, IT capabilities), complementary resource barriers, IT project barriers (technology characteristics, implementation process), and preemption barriers (switching costs, value system structural characteristics).

The deterioration of the natural environment brings risks and opportunities to firms (Melville, 2010). IS research can contribute to the knowledge link between information, firm, and natural environments, to the innovation of environmental strategy, to the creation and evaluation of eco-friendly systems, and to the improvement of the environment (Melville, 2010). Therefore, Melville (2010)'s review paper discussed the factors that promote or inhibit the adoption of environmentally sustainable business practices (i.e., culture), the relationship between environmentally sustainable business practices and business performance, and the relationship between IS and the environmental performance of a supply chain. Firms are considered key contributors to environmental sustainability because of their global, national, and/or local innovation and rapid change capabilities (Elliot, 2011). Elliot (2011) analyzed the challenges of environmental sustainability, including accessing the state of environmental deterioration, the acceleration towards deterioration caused by human activities, and the uncertainty of the human response to deterioration. They describe how people face these challenges through reviewing previous studies in the areas of environment, society, governments, industries and alliances, firms, and individuals and groups within firms.

In a word, previous articles only focused on one aspect. For example, Wade and Hulland (2004) and Piccoli and Ives (2005) focused on economic sustainability while Melville (2010) and Elliot (2011) focused on environmental sustainability. However, according to Elkington (1994)'s Triple Bottom Line theory, economic sustainability, environmental sustainability, and social sustainability integrate in a whole organic unity. In addition, no review studies explore Systematic Literature Network Analysis (SLNA) in the description of the role of IS in the sustainable development of firms entirely and systematically. To fill the research gap, this study discusses the role of IS in the sustainable development of firms from the perspective of integrating the economy, environment, and society.

3. Methodology

3.1 Study design

In order to achieve the objectives of this study, a review study was employed to build a solid knowledge structure for IS and sustainability (Paré et al., 2015). Consequently, this study employed SLNA to understand the role of IS in the sustainable development of firms. SLNA includes Systeamtic literature review (SLR) and Citation Network Analysis (CNA). SLR includes descriptive analysis of primary studies, and thematic analysis to synthesize the knowledge (Durach et al., 2017). SLNA is data-driven SLR since it use CNA and MPA to support study synthesis in SLR (Colicchia & Strozzi, 2012). CNA can reduce the variability in the coding of primary studies and help to synthesize study through objective clustering algorithms (Colicchia & Strozzi, 2012). MPA determine the knowledge structure of research domains through weighting algorithms, which can avoid "expectancy bias" in analyzing and synthesizing primary study data (Durach et al., 2017, p. 78).

Depending on the research objectives, different review types, such as review studies—narrative review, descriptive review, and theoretical review—can be considered. For the IS discipline, narrative reviews and theoretical reviews are the most common review studies (Paré et al., 2015). Given that IT schemes are social-oriented technologies, IS require detailed systematic literature reviews, as these can point out relevant studies by using explicit methodology (i.e., main path analysis) (Khan et al., 2003; Paré et al., 2015). Therefore, previous research (Fan et al., 2014; Tang et al., 2018) has also used SLNA to build up knowledge structures in specific research fields, such as supply chain risk management (Colicchia & Strozzi, 2012), occupational health and safety issues in operations management (Fan et al., 2014), and textile dyes and human health (Tang et al., 2018). SLNA can integrate the advantages of systematic literature reviews (SLR), citation network analyses (CNA) and main path analysis (MPA). Therefore, this review study employs SLNA, which combines SLR, CNA and MPA (Colicchia & Strozzi, 2012). SLR refers to the assessment of literature, "on a clearly formulated question that uses systematic and explicit methods to identify, select and critically appraise relevant primary research, and to extract and analyses data from the studies that are included in the rear-view" (Colicchia & Strozzi, 2012, p.418). SLR can be beneficial in the understanding of current trends, to detect existing gaps in scientific literature, and to consolidate emerging topics in other areas (Lagorio et al., 2016). In this sense, SLR can be used as a reliable technique to select appropriate keywords to locate relevant articles on a specific research topic.

SLR includes descriptive analysis and thematic analysis (Durach et al., 2017). CNA and MPA can support thematic analysis objectively (Colicchia & Strozzi, 2012). CNA is suitable for analyzing the dynamics of knowledge evolution as well as building up the knowledge structure (Colicchia & Strozzi, 2012). CNA is defined as "one form of social network in which authors and papers can be represented as nodes, and their mutual interactions (i.e., citations) can be modelled as edges." (Colicchia & Strozzi, 2012, p. 418). CNA can help construct a path for the development of scientific thought (Colicchia & Strozzi, 2012). The citation relationship is created between publications, which implies the spread of knowledge from one document to another, as literature focusing on the same research issues tend to cite each other based on previous knowledge (Calero-Medina & Noyons, 2008; Hummon & Dereian, 1989). Consequently, the software programs Gephi and Pajek were used to convert data for CNA, and further conduct the main path analysis to identify the significant publications in each research domain.

To further examine the knowledge structure of the major research domains, an MPA was conducted through weighting the citations in the cluster to identify the most important citation path (Fan et al., 2014). The main path analysis was conducted using Pajek 5.05, which helped choose the scheme of traversal weight and search for the main path. The traversal weight scheme included the Search Path Link Count (SPLC), Search Path Node Count (SPNC), and Search Path Count (SPLC) (Batagelj, 2003; Hummon & Dereian, 1989). In term of the traversal weight scheme, SPLC was used, as it aids in the simulation of the situation of knowledge diffusion in scientific development, not only for conveying knowledge, but also for assigning the source of knowledge itself (John Liu et al., 2019). For searching in the main path, a global standard search was conducted, which provided the overall most significant main paths in the knowledge dissemination (Colicchia & Strozzi, 2012; Lathabai et al., 2018; Liu et al., 2013; Verspagen, 2005).

3.2 Data collection

A keyword search was conducted using Web of Science (WOS) in June 2019 (Zhang et al., 2019). Different terms were used for IS in sustainability, such as “Green IS” (Henry et al., 2013). The search terms used were "green" and "sustainable*" (Lee et al., 2019) and these terms were searched for in titles, abstracts, keywords, and keyword plus (Bengtsson & Agerfalk, 2011; Liu et al., 2019; Melville, 2010). More importantly, this study used the 8 journals indicated as the leading journals in IS areas by the Association for Information Systems (Bengtsson & Agerfalk, 2011). A number of keywords were used as “TS=("Green" OR "Sustainab*") AND SO=(*European Journal of Information Systems* OR *Information Systems Journal* OR *Information Systems Research* OR *Journal of the Association for Information Systems* OR *Journal of Information Technology* OR *Journal of Management Information Systems* OR *Journal of Strategic Information Systems* OR *MIS Quarterly*).” To be specific, only peer reviewed research and review articles from the period 1993 to 2018 were selected for this study. As a result, a total of 132 articles were collected for systematic literature network analysis. Detailed information is included in Table 1.

Table 1. The journals suggested by the Association for Information Systems

Name	Abbreviation
European Journal of Information Systems	EJIS

Information Systems Journal	ISJ
Information Systems Research	ISR
Journal of the Association of Information Systems	JAIS
Journal of Information Technology	JIT
Journal of Management Information Systems	JMIS
Journal of Strategic Information Systems	JSIS
MIS Quarterly	MISQ

In order to identify key research domains, CNA was employed using a Girvan–Newman algorithm to categorize publications, construct research fields, and identify community structures of citation networks (Chen & Redner, 2010; Fan et al., 2014). CNA allows for the visualization of research domains, which illustrates how studies are interrelated in a specific area and reveals how knowledge structures are created in specific domains (Colicchia & Strozzi, 2012; De Nooy, 2018; Parent et al., 2018). In other words, the citation network presents a directed graph which serves as a network to embody a research domain (Colicchia et al., 2018). In the directed graph, the nodes represent how articles are connected, and the links represent the citation relationship between articles (Colicchia et al., 2018). To further understand knowledge structures, articles were sorted out into several research domains representing a topic in scientific literature (van Eck & Waltman, 2014). Therefore, Girvan–Newman clustering was conducted using the network visualization software program, Gephi (Mathieu et al., 2009).

To find the community boundaries based on identical centrality indexes, Girvan and Newman (2002) proposed an algorithm that "could categorize communities in order to 1) calculate the betweenness for all edges in the network; 2) remove the edge with the highest betweenness; 3) recalculate the betweenness for all edges affected by the removal; and 4) repeat from Step 2 until no edges remain" (p. 7823). They found that many networks present the attribute of community structure in which the network nodes are connected together in tightly knit groups, between which there are only looser connections. Therefore, each community in the citation network may exemplify publications that are related among specific topics (Girvan & Newman, 2002). Modularity refers to the measure of the quality of division of a network ((Newman & Girvan, 2004), p. 8) In the symmetric matrix $\mathbf{e}$ (k × k), $\boldsymbol{e_{ij}}$ the fraction of all edges in the network that link vertices in community **i** to vertices in community **j**. Therefore, the function of modularity is addressed as,

$$Q = \mathrm{Tr}e - \| e^2 \| \quad (1)$$

where $\mathrm{Tr}e$ represents the fraction of edges in the network that connect vertices in the same community, and $\| e^2 \|$ represents the sum of the elements $\boldsymbol{e_{ij}}$ of the matrix $\mathbf{e}$ (Newman & Girvan, 2004). Its quantity measures the fraction of the edges in the network that connect vertices of the same type (i.e., within-community edges) minus the expected value of the same quantity in a network with the same community divisions, but with random connections between the vertices (Newman & Girvan, 2004). When the number of within-community edges, Q = 0, is no better than random, while Q = 1 is the maximum of modularity value, a strong community structure is indicated. Typically, values for such networks fall in the range of about 0.3 to 0.7 (Newman & Girvan, 2004). Therefore, Q ≈ 0.566 posits that the division of the network is effective. The modularity value reaches a peak value of 0.566 at 53 clusters (including the clusters that only have one paper), indicating that it is best to divide the citation network into 53 clusters (Q ≈ 0.566) (Fan et al., 2014; Newman & Girvan, 2004).

To further examine the knowledge structure of the three major research domains, a main path analysis was conducted through weighting the citations in the cluster to identify the most important citation path (Fan et al., 2014). The main path analysis was conducted using Pajek 5.05, which helped us to choose the scheme of traversal weight and search for the main path. The traversal weight scheme included the Search Path Link Count (SPLC), Search Path Node Count (SPNC), and Search Path Count (SPLC) (Batagelj, 2003; Hummon & Dereian, 1989). In terms of the traversal weight scheme, SPLC was used, as it aids in simulating the situation of knowledge diffusion in scientific development, not only for conveying knowledge, but also for assigning the source of knowledge itself (Liu et al., 2019). For searching in the main path, a global standard search was conducted, which provided the overall most significant main paths in the knowledge dissemination (Colicchia & Strozzi, 2012; Lathabai et al., 2018; Liu et al., 2013; Verspagen, 2005). The overall flow of data collection and data analysis is shown on Figure 1.

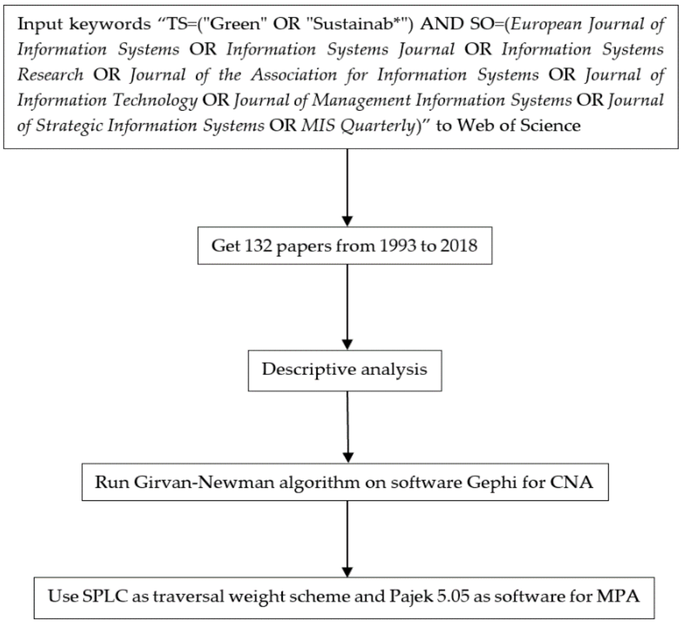

Figure 1. The flow of data collection and data analysis

4. Findings

To understand the overview of the status of sustainability in IS literature, SLR was employed by collecting a total of 132 articles through a keyword search, and descriptive statistics were extracted. For descriptive statistics, several factors were examined, such as journal distribution, period of publication between 1993-2019, methodologies, and research context depending on industry and country. Subsequently, MPA was conducted to identify research domains in the theoretical development.

4.1. Descriptive analysis

4.1.1 Distribution of articles by journal

Based on the Association for Information System criteria, 132 articles from the eight leading journals were analyzed (Appendix A). From the list of eight journals, articles that were related to sustainability and IS included 25% from MISQ, 19% from JSIS, 12% from EJIS, 12% from JMIS, 9% from JAIS, 8.33% from ISJ, 6% from JIT, and 4% from ISR (Figure 2).

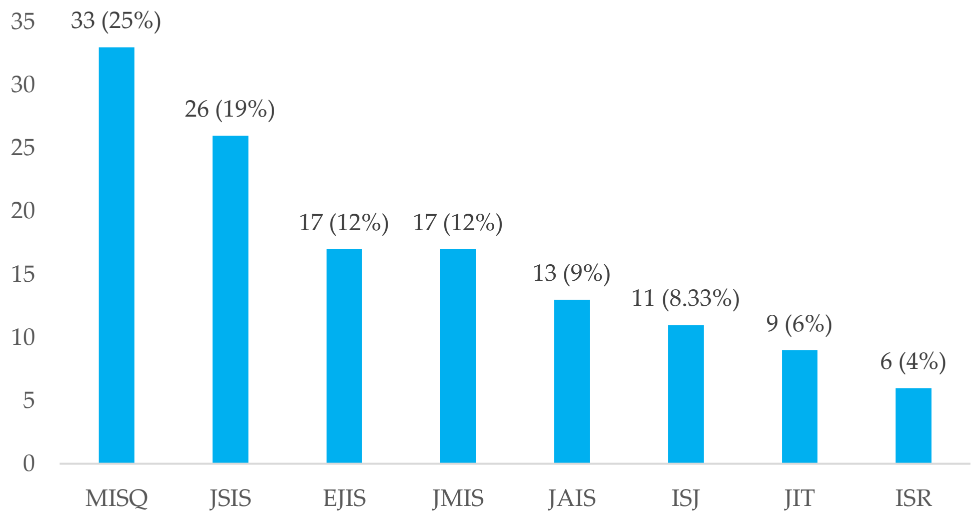

Figure 2. Article distribution by journal.

4.1.2. Distribution of articles by year of publication

A total of 132 articles published from 1993 to 2018 were collected (Figure 3). Based on the yearly distribution of articles, the number of articles related to sustainability in IS gradually increased until 2011. Although there was a slight reduction of articles from 2004 to 2008, it shows an incremental escalation of sustainability in IS articles until 2018. However, the peak years for IS articles among the 8 journals was found to be between 2011 and 2017. It may be because the United Nations set up 17 sustainable development goals in 2015, which triggered more research interest in sustainability.[13] In addition, news related to sustainability and environmental issues were highlighted in those years.[14] Consequently, many articles related to environmental sustainability have been published since 2009 (Brocke et al., 2013; Elliot, 2011; Melville, 2010). MISQ published a special issue on IS and environmental sustainability in 2013. Furthermore, the Association for Information Systems established a special interest group for green research in 2010 to promote better solutions for preventing environmental degradation and climate change (Seidel et al., 2017). Based on the yearly distribution of articles, the average rate of IS articles published between the period 1993 and 2018 is reported to be 5.08 articles per year.

[13] https://www.un.org/sustainabledevelopment/sustainable-development-goals/

[14] https://fortune.com/2019/07/29/earth-overshoot-day-climate-change/

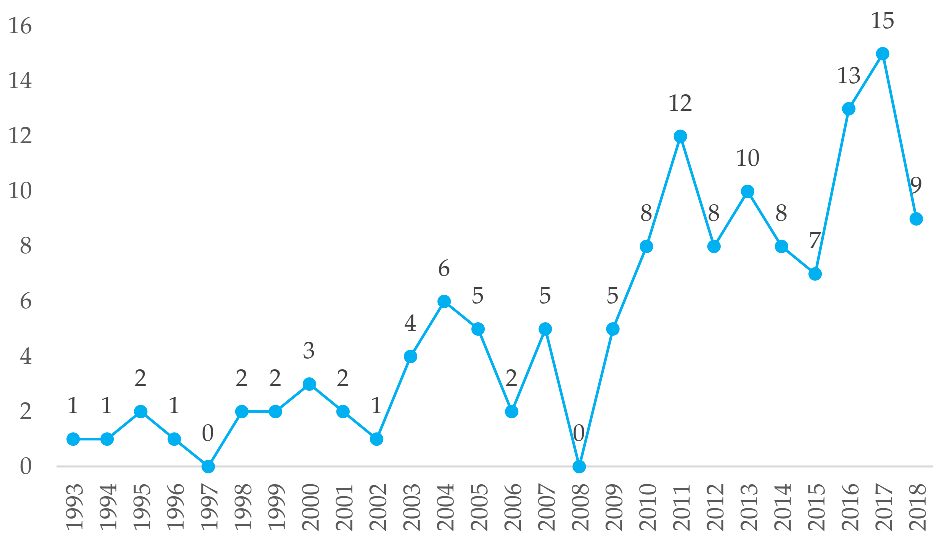

Figure 3. Article distribution by year of publication.

4.1.3. Distribution by article type

Different research approaches were employed in IS literature related to sustainability, but they were mainly categorized into six types of research approaches: empirical, conceptual, modelling, design science, review, experimental, meta-analysis, and simulation (Figure 4). Accordingly, empirical studies were the most common type of article from IS literature on sustainability, while experimental studies were the least common type. After this, to understand research directions, further analysis for the 77 empirical studies was conducted with the data collection method, data analysis method, and research contexts.

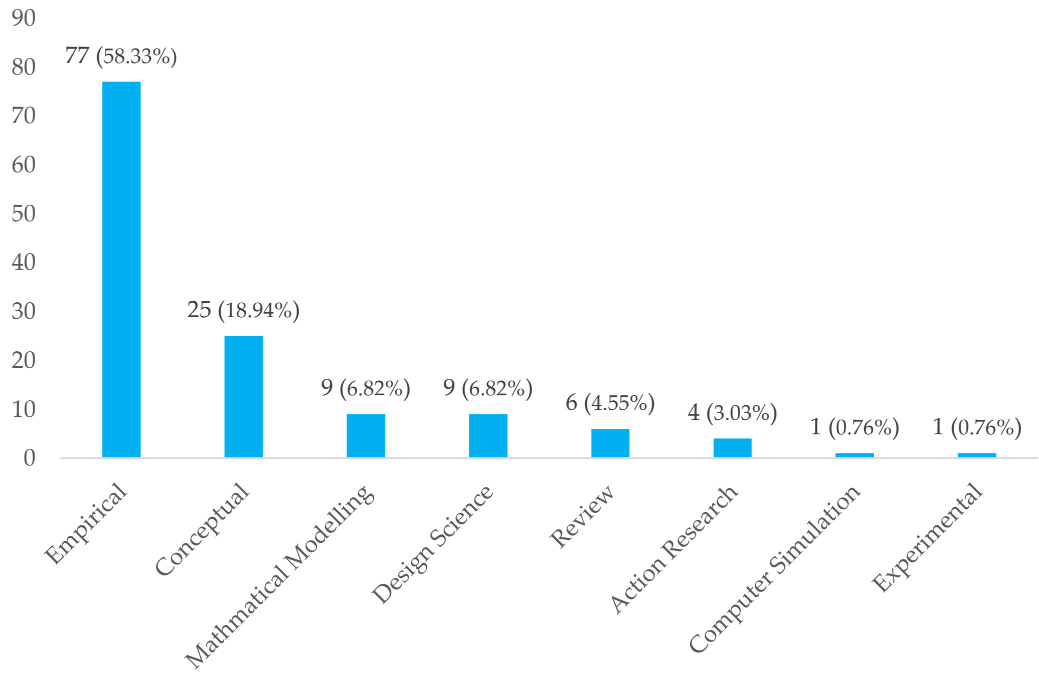

Figure 4. Distribution of articles by type.

4.1.4. Methodologies used in empirical studies

Out of the 77 empirical studies, four main data collection methods were used, such as archival, multi-source, surveys, and interviews (Figure 5). Accordingly, the archival method was shown to be the predominant data collection method and interviews were the least used data collection method.

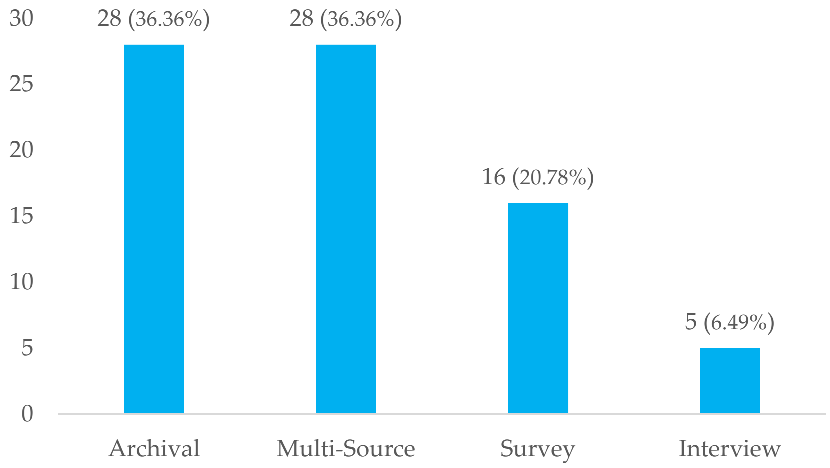

Figure 5. Distribution of data collection methods in empirical studies.

In terms of empirical studies, five main data analysis methods were explored, such as statistical modelling, content analysis, mixed methods, narrative case analysis, and process views (Figure 6). Accordingly, the statistical model method (i.e., regression, structural equation modelling) was shown to be the predominant data analysis method and the process view was the least used data analysis method (Srivastava & Shainesh, 2015).

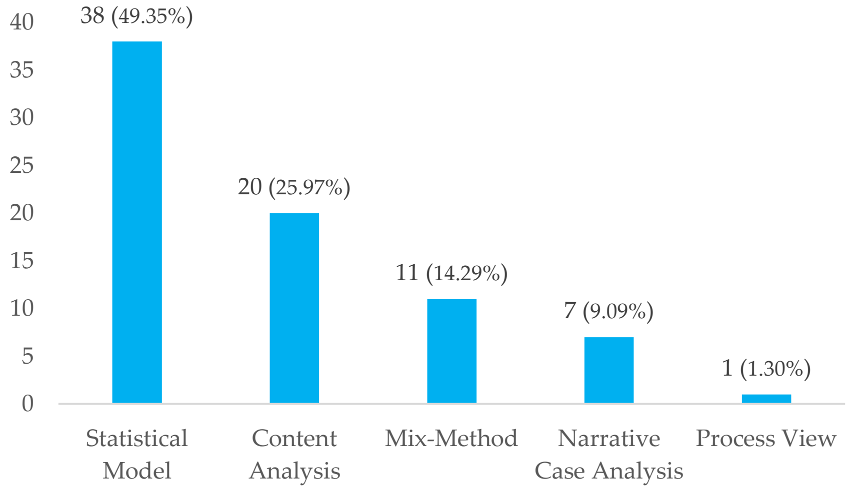

Figure 6. Distribution of data analysis methods in empirical studies.

4.1.5. Research context in empirical studies

We further considered data collection sources to classify articles by country. Out of the 77 empirical studies, five countries—the USA, the UK, India, Canada, and China—were predominantly examined in IS literature (Table 2). For empirical studies, 28 (36.36%) studies mostly focused on the USA, and three (3.90%) studies focused on China, respectively. This implies that a lot of the research on IS has been highly focused on developed countries. In order to study the relationship between the physical and informational components of green projects, Watson et al. (2011) compared four green transportation projects from four countries (France, the US, Singapore, and Chile).

Table 2. Research context: Countries (N = 77)

Country	**Number (%)**
USA	28 (36.36%)
UK	7 (9.09%)
India	4 (5.19%)
Canada	3 (3.90%)
China	3 (3.90%)
Australia	2 (2.60%)
Germany	2 (2.60%)
The Netherlands	2 (2.60%)
Malaysia	1 (1.30%)

Spain	1 (1.30%)
Brazil	1 (1.30%)
Greece	1 (1.30%)
Denmark	1 (1.30%)
Singapore	1 (1.30%)
Mexico	1 (1.30%)
Switzerland and Germany	1 (1.30%)
France, USA, Singapore and Chile	1 (1.30%)
UK, Spain, Demark and the Netherlands	1 (1.30%)
Not specific	16 (20.78%)

Besides region and country, the top five industries were studied in IT healthcare, government, manufacturing, and retail (Table 3). For empirical studies, 15 (19.48%) studies mostly focused on the IT industry, while two (3.90%) studies focused on the agriculture and transportation industries, respectively. For instance, to understand the levels of business information intensity, Griffiths and Finlay (2004) compared financial services and retail manufacturing. Nishant et al. (2017) explored different industries in industrial and commercial machinery, computer equipment, electronics, electrical equipment and components, business services, and communications. Interestingly, the studies that discussed the role of IS/IT in the establishment of sustainable competitive advantages were more inclined to study firms in different industries. This is because, regardless of industry sector, findings can be similar and applicable to different industries (Bharadwaj, 2000; Dehning & Stratopoulos, 2003; Mithas & Rust, 2016).

Table 3. Research context: Industries (N = 77)

Industry	**Number (%)**
IT	15 (19.48%)
Healthcare	11 (14.29%)
Government	6 (7.79%)
Manufacturing	5 (6.49%)
Retail	3 (3.90%)
Agriculture	2 (2.60%)
Transportation	2 (2.60%)

Others	20 (25.97%)
Not specific	13 (16.88%)

4.1.6. Discussion and implications

Based on a systematic literature review, a total of 132 articles in IS literature were selected, particularly focused on sustainability. Although sustainability research has existed for quite a long time, there is a relatively limited amount of studies on the IS discipline (Bengtsson & Agerfalk, 2011; Melville, 2010). Therefore, to describe the nature of sustainability in information systems-related articles since 1993, a systematic literature review was employed to analyze a total of 132 articles.

The overall finding from the systematic literature review was that most articles established research through designing empirical studies. Empirical studies were conducted to explore how IT can improve the environmental sustainability of corporate operations, and how green IS initiatives can be implemented as a part of a corporate strategy towards the firm's sustainability process (Bharadwaj, 2000; Hedman & Henningsson, 2016). Hu et al. (2016) found that environmental awareness, industry norms, internal readiness, and customers' and equity holders' attitudes were key drivers in green IT practices. Other important influences were government regulations and their competitors. Therefore, Hedman and Henningsson (2016) asserted that green IS initiatives should be a part of a corporate strategy if it is in line with the firm's agenda. Few studies identified research approaches that were explored in design science, action research, mathematical modelling, computer simulation, and experimental methods. Design science and action research, as IS-specific scientific paradigms, might be used in the future. In the past, IS scholars explored a design science approach to assess different frameworks in the area of environment sustainability. This includes the role of information systems in stimulating energy-efficient behavior in private households, the quantification of location-based investment incentives in renewable energy support mechanisms, and the sensemaking support systems in environmental sustainability transformations (Loock et al., 2013; Piel et al., 2017; Seidel et al., 2018). As design science provides a problem-solving paradigm that helps define ideas, practices, and technological capabilities, the use of information systems can be efficiently integrated (Denning, 1997; Gholami et al., 2016; Tsichritzis, 1998).

On the other hand, the action research approach is a combination of practice and theory, which helps solve practical problems and expand scientific knowledge (Mckay & Marshall, 2001). Action research could be summarized as a two-stage process including the “diagnostic” stage and the “therapeutic” stage (Blum, 1995, p.1). During the whole process, action researchers bring knowledge of action research and general theories, whereas clients bring practical knowledge (Baskerville & Myers, 2004). Baskerville and Myers (2004) believed that the action research approach can provide a prospective way to improve the practical relevance of IS research. Therefore, the action research approach is a powerful tool to study in the interaction between IS, humans, the environment, and society (Mckay & Marshall, 2001). Due to recent environmental and societal problems, both the design science approach and the action research approach can help provide possible suggestions for practical business solutions, theoretical and academic, in IS (Gholami et al., 2016).

Particularly with empirical studies, the archival method is predominantly used for primary data analysis in IS literature, followed by questionnaires and interviews. Numerous archival approaches posited that managerial IT skills are positively related to sustainability, and competitors’ knowledge of competitive advantage is negatively related to sustainability (Dehning & Stratopoulos, 2003). In addition, the articles that discussed the effect of corporate IS/IT capability on sustainable competitive advantage were more likely to collect data from widely circulated journals in the US, including those from the CompStat database and InformationWeek. This is because, since 1991, InformationWeek has identified about 40 to 50 firms (out of the 500) each year as the "leaders" in IT technology in their respective industries, and has provided data such as IT budget and the size of IT staff, which can help researchers quantify corporate IT capability (Bharadwaj, 2000; Mithas & Rust, 2016).

Furthermore, most studies using the empirical approach were conducted in developed countries, such as the United States and Europe, which shows an importance to study developing countries’ IS studies. This may be because issues of sustainability have been highlighted in many developed countries longer than in developing countries. This would lead to many changes and shifts in the environments and standards of operations for firms in developed countries. As many developing countries are becoming suppliers for developed countries or manufacturers, it is becoming increasingly important to adopt higher standards for sustainable operations. As numerous empirical studies have focused on the IT industry with less focus on manufacturing, it is important to explore how IS can improve sustainability and enhance firm performance in developing countries.

4.2 Thematic analysis

4.2.1 Results from CNA

Among the 132 articles, the six domains were captured as environmental sustainability, sustainable competitive advantage, sustainable online social communities, the role of IS in developing countries, sustainable technology infrastructures, and the scattered articles cluster. Out of 32 papers (24.24%), the environmental sustainability issue was shown to be the largest and most populated research domain. The second largest research domain, with 31 papers (23.48%), can be termed as “sustainable competitive advantage” followed by the third largest research domain with nine papers (6.82%) focusing on sustainable online social communities. On the other hand, two emerging research domains were captured and divided into the role of IS in developing countries, and sustainable technology infrastructures. Emerging research domains were domains which focused on similar topics but had low connectivity. One of the emerging research domains, with four papers (3.03%), was classified as “the role of IS in developing countries.” Another emerging research domain, with three papers (2.27%), was referred to as “sustainable technology infrastructures.” On the other hand, the 53 papers that could not be included in any research domain (40.16%) were classified as the “scattered articles” cluster. Detailed information is illustrated in Figure 7.

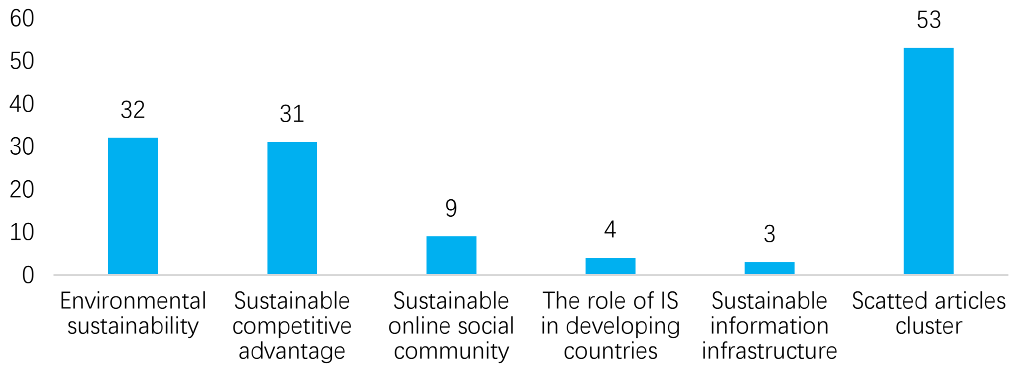

Figure 7. Research domain classification.

Interestingly, it was found that the sustainable competitive advantage research domain had associations with the environmental sustainability research domain and sustainable online social communities, respectively (Figure 8). Benitez-Amado and Walczuch (2012) stated that information technology capabilities are able to promote environmental strategies which would be a significant moderator of the effects of information technology on firm performance. Meanwhile, Dao et al. (2011) indicated that focusing on developing sustainability capabilities might not only serve the environment and people, but also help firms generate value that could enhance profitability and provide a sustained competitive advantage. Among the connections between the sustainable competitive advantage research domain and sustainable online social communities, Wade and Hulland (2004) was related to Butler (2001), as both studies explored from the perspective of the resource-based view.

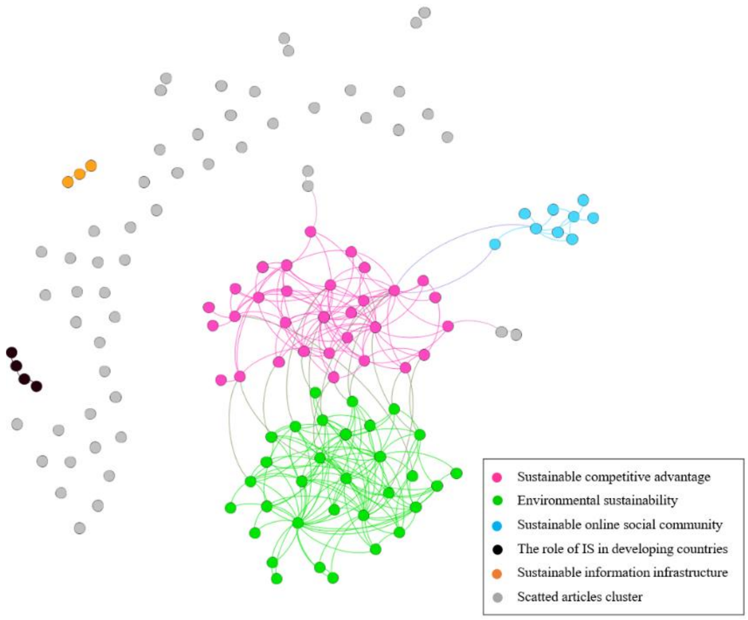

Figure 8. Research domain classification of sample publications.

4.2.2 Results from MPA

4.2.2.1 Results from main clusters

To further examine the knowledge structure of the three major research domains (i.e. sustainable competitive advantage, green IS, and sustainable online social communities), a main path analysis was conducted through weighting the citations in the cluster to identify the most important citation path (Fan et al., 2014).

4.2.2.1.1 Sustainable competitive advantage

The sustainable competitive advantage was captured through the main path analysis (Figure 9). The majority of articles used the resource-based theory (RBT) as the research framework to investigate the relationship between information systems and sustainable competitive advantage (Bharadwaj, 2000; Doherty & Terry, 2009; Jarvenpaa & Leidner, 1998; Mata et al., 1995; Nevo & Wade, 2011; Piccoli & Ives, 2005; Wade & Hulland, 2004). The RBT defines firm resources as "all assets, capabilities, firm's processes, firm's attributes, information, knowledge, etc. controlled by a firm" (Barney, 1991, p. 101). Two conditions have to be realized to achieve a sustainable competitive advantage: 1) maintaining resources that are valuable and rare, and 2) preventing competitors from replicating processes (Doherty & Terry, 2009; Wade & Hulland, 2004). Therefore, RBT has predominantly been used in IS research because IS are positioned as one of the strongest resources and as a corporate strategy which can improve firm performance (Wade & Hulland, 2004). The key contribution of each paper is shown in Table 4.

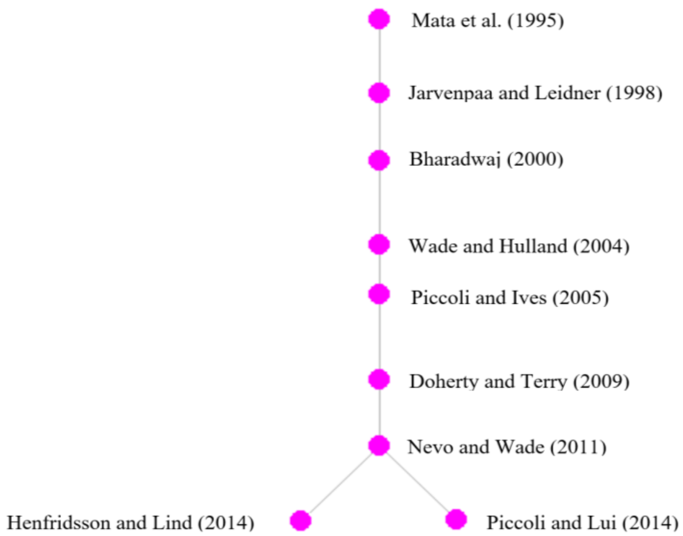

Figure 9. Main path of sustainable competitive advantage.

Table 4. The key contribution of each paper

Authors	**The kinds of IS resources affecting sustainable competitive advantage**
Mata et al. (1995)	Managerial IT skills
Jarvenpaa and Leidner (1998)	• The role of social and governmental relationships outside the firm • Dynamic capabilities (i.e. strategic vision, flexibility)
Bharadwaj (2000)	Higher IT capability with a combination of IT infrastructure, human resources, and IT-enabled intangibles
Wade and Hulland (2004)	• "Inside-out" resources • "Spanning" resources • "Outside-in" resources

Piccoli and Ives (2005)	• IT resources barrier • Complementary resources barrier • IT project barrier • Pre-emption barrier
Doherty and Terry (2009)	• "Outside-in" IS resources • "Spanning" IS resources
Nevo and Wade (2011), Henfridsson and Lind (2014), Piccoli and Lui (2014)	Synergies between firm's resources and IT assets
Future direction	Integrate the concept of complexity and dependency to explain the relationship between IT assets and complementary resources

In the 1990s, studies in IS for sustainable competitive advantage were focused on a firm management's ability to improve and exploit IT applications to support and enhance other business functions, because competitors can easily buy or replicate tangible IT resources. In addition to focusing on managing IT within an firm, Jarvenpaa and Leidner (1998) have suggested the role of social and governmental relationships outside the firm to enable firms to improve sustainable competitive advantage via IS. Jarvenpaa and Leidner (1998) found that dynamic capabilities, including strategic vision and flexibility, coupled with trusted core capabilities, could be key factors influencing internal and external changes in an unstable environment which lacks an IT infrastructure and culture (Jarvenpaa & Leidner, 1998). Similarly, Bharadwaj (2000) pointed out that firms could achieve better performance when they have higher IT capability with a combination of IT infrastructure, human resources, and IT-enabled intangibles. For instance, a strong top management commitment to IS could possibly help develop IS resources through isolating mechanisms such as time compression diseconomies, resource connectivity, and social complexity (Bharadwaj, 2000; Wade & Hulland, 2004). In the context of the strategic initiatives that rely on IT, Piccoli and Ives (2005) name the four erosion barriers as the IT resources barrier, complementary resources barrier, IT project barrier, and pre-emption barrier, that support IT through response-lag driving factors independently or in combination with each other to maintain competitive advantage. The response-lag drivers of IT resource barriers encompass IT capabilities (i.e., technical skills, management skills, relationship assets) that link to the complementary strengthening of resource barriers through IT-dependent strategic initiatives (i.e., top management commitment, corporate culture) (Piccoli & Ives, 2005).

Wade and Hulland (2004) focused on the use of three firms' resources, such as inside-out, spanning, and outside-in, to enhance competitive advantage. Inside-out IS resources refer to how responsive firms respond to the market requirements and opportunities via technological development and cost controls, while outside-in IS resources strive to achieve market responsiveness, managing external relationships to enhance consumer loyalty, and to understand competitors (Wade & Hulland, 2004). Spanning IS resources combine inside-out IS resources and the outside-in IS resources that are considered in the management of IS/business partnerships and IS management and planning (Wade & Hulland, 2004). Based on the findings of Wade and Hulland (2004) study, outside-in and spanning IS resources were shown to have more influence than inside-out IS resources on either initial competitive advantage or long-term competitive advantage (Wade & Hulland, 2004). When firms reside in stable business environments or high munificent and complex environments, inside-out resources may have a higher impact on firm performance. Otherwise, outside-in resources and spanning resources have a stronger impact on firm performance with firms in turbulent business environments and high complexity environments (Wade & Hulland, 2004). A later study by Doherty and Terry (2009) further extended Wade and Hulland (2004) study to posit that implementing IS initiatives to successfully achieve sustainable competitive advantages may depend on the "outside-in" and "spanning" IS resources.

To explore sustainable competitive advantage, Nevo and Wade (2011) extended the studies of Bharadwaj (2000) and Wade and Hulland (2004). If IT assets and firm's resources are properly combined in a particular context as value, rarity, appropriateness, imitability, sustainability, and imperfect mobility, it is possible to create positive synergetic results (Nevo & Wade, 2011). A recent study by Nevo and Wade (2011) found that the value, rarity, and inimitability of the resultant IT-enabled resource created better synergetic impact, increasing positive firm performance. That is to say, value and rarity may influence operational benefits, while value and inimitability drive stronger strategic benefits (Nevo & Wade, 2011). Similarly, Piccoli and Lui (2014) supported Nevo and Wade (2011) view by suggesting that synergies between firm resources and IT assets may play an important role in developing the competitive impact of IT-dependent strategic initiatives. This view was carried out in Henfridsson and Lind (2014) study by using IS to implement sustainability strategies that can become a competitive advantage for a variety of firm's sub-communities. Therefore, the interaction between IT assets and complementary resources may be established as features that are only held via IT-dependent strategic initiatives. This could lead future research used to integrate the concept of complexity and dependency to explain the relationship between IT assets and complementary resources (Piccoli & Lui, 2014).

4.2.2.1.2 Environmental sustainability

IS can be important resources in achieving environmental sustainability, but environmental sustainability was not discussed in IS literature until the late 2000s (Melville, 2010) (Figure 10). This may be because people lack a universal understanding of the potential impact of climate change and the salient factors needed to achieve environmental sustainability (Elliot, 2011). Watson et al. (2010) addressed how energy informatics can contribute to environmental sustainability. Considering IS as a firm's change process which assists belief formation, sustainability actions, and environmental and firm performance outcomes, Melville (2010) established a belief–action–outcome (BAO) framework linking macrostructure (society, natural environment, firm) with micro-structure (individual) to describe three aspects of sustainable beliefs that are regulated by IS. Thus, firm and individual actions to enhance sustainability practices can be motivated by sustainable beliefs, and both environmental and financial performance outcomes can be brought through actions. The key contribution of each paper is shown on Table 5.

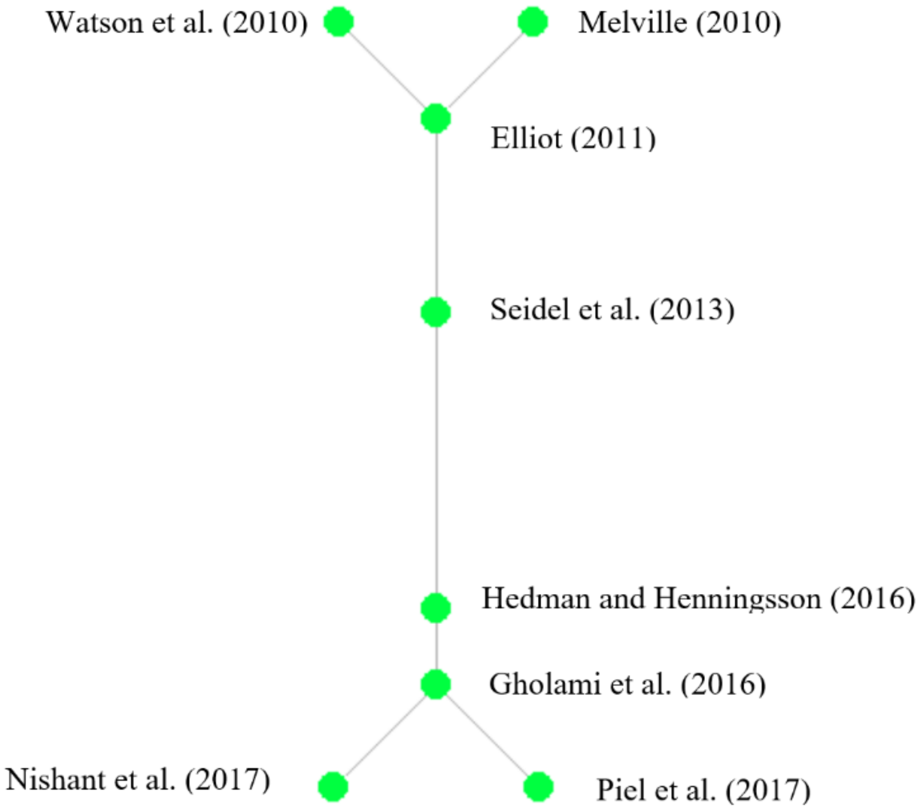

Figure 10. The main path of environmental sustainability.

Table 5. The key contribution of each paper

Authors	Key contributions
Watson et al. (2010)	How IS academia contributes to environmental sustainability from four aspects: research, education (i.e., develop energy informatics), journals and associations
Melville (2010)	The factors that promote or inhibit the adoption of environmentally sustainable business practices (i.e., culture), the relationship between environmentally sustainable business practices and business performance, and the relationship between IS and environmental performance of supply chain
Elliot (2011)	The challenges to environmental sustainability including accessing the state of environmental deterioration, the acceleration to deterioration caused by human activities, and the uncertainty of human response to deterioration. How people face the challenges through reviewing previous studies in the areas of environment, society, governments, industries and alliances, firms, and individuals and groups within firms.
Seidel et al. (2013)	Key affordances of green IS enabling firm transformation through firm sense-making and sustainable practices. Reflective disclosure Information democratization Output management Delocalization
Hedman and Henningsson (2016)	Green IS initiatives could contribute as one type of firm's projects if it aligned with the firm's agenda
Gholami et al. (2016)	Future IS research on environmental sustainability has to position itself as more solutions-oriented and has to utilize IS knowledge in more practical and innovative ways to tackle environmental and social issues.
Nishant et al. (2017)	Green IT had a positive impact on market returns which could provide better assurance for the long-term performance of investments
Piel et al. (2017)	IS can provide solutions to inform policy decisions, and integrate intermittent renewable energy sources
Future direction	Provide more solutions for environmental sustainability issue Use sentiment analysis to measure the response of all stakeholders to green IS initiatives Why do some green IS initiatives have high abnormal returns in stock market

Numerous studies (Elliot, 2011; Hedman & Henningsson, 2016; Piel et al., 2017) studied how

IS enhanced the firm's transformation towards environmental sustainability. Elliot (2011) emphasized how human behavior has changed toward the environment by discussing how the relationship between human beings and technology can improve environmental sustainability. Seidel et al. (2013) suggested providing a way to understand changes in sustainability themes (firm sense-making) and to initiate work practices that are in line with sustainability goals (sustainable practicing). Therefore, they explained the key benefits of green IS as the enabling of firm's transformation through firm sense-making and sustainable practices. The main benefits of green IS encompass reflective disclosure (allowing monitoring, analysis of the performance of current practices), information democratization (all the individuals in the firm can access and use the information related to sustainability from multiple sources), output management (directing individuals' work actions to follow certain boundary conditions to reduce negative environmental impact), and delocalization (changing work practices to become less location-dependent and consequently reducing the negative impact from resource movement) (Seidel et al., 2013).

Hedman and Henningsson (2016) established a green IS firm response model to show the interaction between green IS initiatives and the firm's sustainability process. Green IS initiatives could contribute as one of the types of firm's projects if it aligned with the firm's agenda (Hedman & Henningsson, 2016; Hedman & Kalling, 2003). In this way, green IS projects can influence future green IS initiatives and implement a better sustainability process. However, Gholami et al. (2016) argued that future IS research on environmental sustainability has to position itself as more solutions-oriented and has to utilize IS knowledge in more practical and innovative ways to tackle environmental and social issues. This view was supported by Gholami et al. (2016) and Piel et al. (2017) which suggests that IS can provide solutions to inform policy decisions, and integrate intermittent renewable energy sources. Likewise, a lot of literature suggests that design science research can guide the future research direction of environmental sustainability in IS (Brandt et al., 2018; Seidel et al., 2018). A recent study by Nishant et al. (2017) found that green IT had a positive impact on market returns which could provide better assurance for the long-term performance of investments. Similar to Nishant et al. (2017) findings, Loeser et al. (2017) also suggested that it is important to explore how environmental sustainability can impact economic sustainability. Especially, shareholder considered that the decision support systems (e.g., carbon calculators) have more potential to improve firms' environmental and financial performance since decision support systems allow firms to design and execute initiatives to target their carbon footprint and manage the lifecycle environmental impact of products and services (Nishant et al., 2017). For instance, Piel et al. (2017) developed a decision support system to promote the effective use of renewable energies. To establish community-driven environmental sustainability, Tim et al. (2018) strongly suggested that social and environmental sustainability go hand in hand.

Based on IS literature on environmental sustainability, previous studies focused on how IS have contributed to solving environmental issues and problems in human society. However, more studies on environmental sustainability in IS literature were found to focus on firms' environmentally sustainable transformations in later literature. It is important to pinpoint how environmental sustainability is not only looking into business practices to use for short-term performance, but rather to position itself as a crucial practice in IS literature.

4.2.2.1.3 Sustainable online social communities

As one of the emerging areas, articles on sustainable online social communities constitute the third largest research domain (Butler et al., 2014). Online communities are highly accessible and are self-rising, decentralized IS (Mindel et al., 2018). IT offers a technological infrastructure for potential social activities, but it does not guarantee that individuals will participate in such online social activities (Butler, 2001). If a social structure cannot exceed individuals' expectations, it may be unable to attract new members and thus become unsustainable (Butler, 2001; Ridings & Wasko, 2010). Therefore, promoting participation in an online community is an important issue in IS literature (Bock et al., 2015; Butler, 2001; Butler et al., 2014; Guo et al., 2017; Phang et al., 2015; Ridings & Wasko, 2010). The development path of sustainable competitive advantage cluster is shown on Figure 11 while the key factors affecting sustainable online social community in concluded and shown on Table 6.

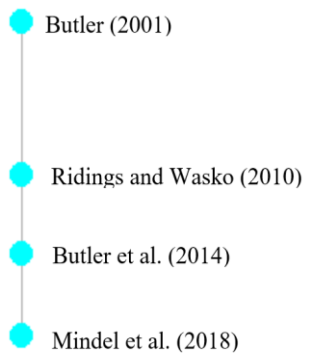

*Figure 11***.** The main path of sustainable online social communities.

Table 6. The key factors affecting sustainable online social community

Authors	Key factors
Butler (2001)	Membership size Communication activity
Ridings and Wasko (2010)	Basic nature of interaction among members Relationship between members
Butler et al. (2014)	participation costs topic consistency cues
Mindel et al. (2018)	Provision Appropriation Revitalization Equitability
Future direction	The difference between types of stakeholders' (i.e., producer, provider and appropriator) actions in an online community

Based on members' time, energy and other resources, online social communities attract and retain members that can provide benefits including information and social support (Butler, 2001). Accordingly, Butler (2001) found that membership size and communication activities in online social communities had an influence on sustainability activities. More specifically, the influence of membership size on an online social structure to attract and retain members can be mediated by communication activity. To some extent, constructing a community is a process that collects resources provided by members, and communities need to attract a large pool of members, as this is the main source of benefit (Butler, 2001). Therefore, membership size is used to measure resource availability (Butler, 2001). Likewise, Ridings and Wasko (2010) argued that it is necessary to investigate the effect of the reciprocal interactions between the structural dynamics (i.e. membership size, communication activity) and social dynamics (i.e. the interactions among members). On the other hand, Jones et al. (2004) suggested that when information overloading hinders advantages and benefits, one coping strategy to deal with continuously changing communication behavior is to leave the community (Jones et al., 2004). In other words, more resources do not always lead to better communication activities, but they can allow for social interaction between members to preserve the community. Moreover, as individual efforts increase, the retained members also increase, but communities may sacrifice their ability to attract new members in the process (Ridings & Wasko, 2010).

Butler (2001) only focused on the effect of structural dynamics (i.e., membership size) on community sustainability, while Ridings and Wasko (2010) combined structural dynamics and social dynamics (i.e., the interactions among members) when examining community sustainability. By extending the findings of Butler (2001) and Ridings and Wasko (2010), Butler et al. (2014) highlighted how technology that changed users' participation experiences affected the sustainability of online social communities due to the effects on members' behavior and thus the function of the community. By examining the influence of the cost of participation (e.g., how much time and effort is required to engage with the content provided in a community), and topic consistency cues (e.g., how strongly a community signals that the topics that may appear in the future will be consistent with those it has hosted in the past), Butler et al. (2014) found that there is a curvilinear relationship between community resilience and topic consistency cues. More specifically, community resilience was greater when community platforms presented low and high topic consistency cues, while it became low when platforms showed moderate topic consistency cues (Butler et al., 2014).

Mindel et al. (2018) integrated the empirical evidence and theoretical contributions from previous literature on the sustainability of online communities. They reviewed 73 studies and developed a global view on how online communities mitigate the impact of their high degree of openness to sustainable participation. They proposed a new mode of governance, "polycentricity", because people usually communicate together to find a sensible way of sharing resource, rather than depending on central governance. Generally, in online social communities, stakeholders are producers (the architects and sponsors of the infrastructure that enable the system), providers (the people who provide information to the system), and appropriators (the people who extract information from the system) (Ostrom, 1990). A sustainable online community allows stakeholders to continuously derive value (Mindel et al., 2018). Feedback on value derived by stakeholders affects the evolution of an online community's polycentric governance practices (Mindel et al., 2018). In addition, sustainability is constructed by provision, appropriation, revitalization, and equitability (Mindel et al., 2018). Sustainable online communities are premised on a system of complements constructed by continuous provision and appropriation as well as revitalization and equitability (Mindel et al., 2018). Online social communities are highly accessible to both content consumers and producers, so individuals can join for free and leave at any time, which may lead to high fluctuations in consumer and producer participation (Mindel et al., 2018). Therefore, online communities usually operate under conditions of uncertainty that make them more vulnerable to collective action threats including free-riding, congestion, pollution, violation, and rebellion (Mindel et al., 2018). Individual providers and appropriators' collective action threats create vulnerabilities to the sustainability of an online community (Mindel et al., 2018). Polycentric governance practices of boundary regulation, shared accountability, incremental adaptation, and provider recognition can reduce collective action threats and increase the sustainability of an online community (Mindel et al., 2018). In the future, Mindel, Mathiassen, and Rai's (Mindel et al., 2018) findings can be applied to study firm's IS, such as open-access firm-sponsored systems and crowdsourcing initiatives created for soliciting ideas or specific tasks from information providers.

4.2.2.2 Emerging cluster

Two emerging research domains were captured through the main path analysis. The first emerging research domain focused on how IS help developing countries, including establishing health information systems (Braa et al., 2007; Braa et al., 2004), and telecentres (Madon, 2005). The second emerging research domain focused on the technology infrastructure for sustainable IS (Ribes & Finholt, 2009; Ribes & Polk, 2014; Venters et al., 2014).

4.2.2.2.1 The role of IS in developing countries

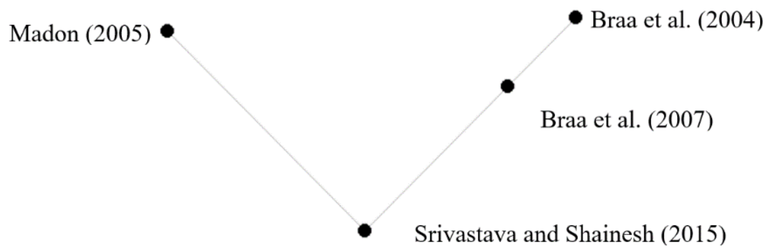

Figure 12. The research domain of the role of is in developing countries.

The first emerging domain by Srivastava and Shainesh (2015) related to how IS can assist the convergence of developing countries by connecting the knowledge streams from two different sources, such as from Madon (2005), and Braa et al. (2004) (Figure 12). One of the sources from Madon (2005) and Srivastava and Shainesh (2015) emphasized the digital divide as an unbalanced distribution of Information Communication Technology (ICT) resources amongst different societal groups. Using the example of the Akshaya project in Kerala, Madon (2005) identified five key issues in the sustainability of telecentres, which included building corporate confidence, working with the government, renewing grassroots campaigning involving the legislative system, and continuing the support of political champions. However, Madon (2005)'s dominant viewpoint considered telecentres valuable only in which (1) governments have sufficient resources to provide the necessary digital goods, and (2) society is capable enough to transform the digital goods into desired outcomes. Therefore, Srivastava and Shainesh (2015) argued that this view may have constrained applicability in developing countries where the majority of the population does not have accessibility to basic capabilities, such as healthcare and education. This suggestion was anchored in a service-dominant logic, which investigates how to bridge the digital divide in developing countries. From a service-dominant perspective, ICTs can help bridge the service divide to enhance the capabilities of service-disadvantaged segments of society. However, such service delivery requires the innovative assembly of three interactional resources, such as knowledge, technology, and institutions (Srivastava & Shainesh, 2015). In addition, Srivastava and Shainesh (2015) extended the research agenda from Braa et al. (2004) and Braa et al. (2007) in respect to the usage of ICT in the healthcare sector in developing countries. More particularly, Braa et al. (2004) explored the sustainable health information system program across the developing countries by looking at political support, the development of health information systems, and training and education. Braa et al. (2007) further proposed the concept of flexible standards as a key element in a sustainable infrastructure development strategy and highlighted the importance of developing flexible standards for health information systems in developing countries.

4.2.2.2.2 Sustainable information infrastructure

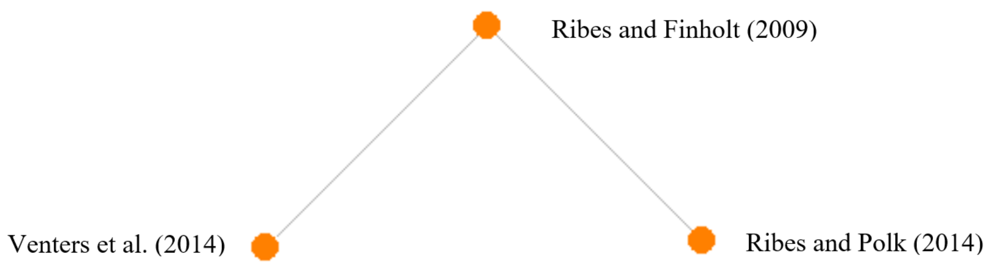

Figure 13. The research domain of sustainable information infrastructure.

The second emerging domain relates to sustainable information infrastructure divergence in which Ribes and Finholt (2009)'s study lays the foundation for the studies of Ribes and Polk (2014) and Venters et al. (2014) (Figure 13). Sustainable infrastructure is intended as a long-term invisible support structure (Ribes & Finholt, 2009). Maintaining the sustainability of an information infrastructure can be challenging in its planning, design, implementation, and maintenance (Ribes & Finholt, 2009). Previous studies in the field of information infrastructure primarily focused on socio-technical concerns, which neglect the importance of circumstances and the particularities of change in which infrastructures must be flexible (Ribes & Finholt, 2009). Thus, Ribes and Polk (2014) proposed three areas—socio-technical, technoscientific, and institutional—to match the forms of flexibility to the heterogeneity of changes an infrastructure may encounter. Ribes and Polk (2014) suggested technoscientific flexibility as a form of adaptability and resilience that is, perhaps, most central to a research infrastructure, in that it supports scientific research and the dramatic transformations objects that research undergoes.

On the other hand, Venters et al. (2014) addressed how emerging tensions can extend Ribes and Finholt (2009)'s study on information infrastructure development and evolution. At different temporal dimensions, Venters et al. (2014) identified three coordination tensions, such as obtaining adequate transparency in the present, modelling an infrastructure in future, and the disciplining of social and material inertias in the past. In addition, Venters et al. (2014) emphasized the dynamic aspects of sustainable information infrastructure, which implies social and material agencies that enact information infrastructure in multiple dimensions of time in a dynamic interplay. Therefore, the sociometrical approach of Venters et al. (2014) established an innovative perspective for future studies on digital infrastructures and their coordination.

4.2.2.3 Scatters

Lastly, another research domain with unclassified articles was captured in which the articles focused on similar topics but featured references that were not connected to the other articles. A majority of these articles discussed how firms enhanced sustainable competitive advantage through IS/IT-enabled tactics, such as knowledge management (Zyngier & Burstein, 2012), customer analysis based on big data (Kitchens et al., 2018), and social commerce (Lee et al., 2015). Given that IS play a significant role in inter-firm collaboration, Kumar and vanDissel (1996) analyzed the basic features (i.e., configuration, coordination mechanism, etc.) of three types of inter-firm systems, such as information resource inter-firm systems, value/supply chain inter-firm systems, and networked inter-firm systems. More specifically, studies for particular inter-firm systems examined e-marketplaces (O'Reilly & Finnegan, 2010), supply chain collaboration systems (Hadaya & Cassivi, 2012) and inter-firm knowledge sharing

(Loebbecke et al., 2016). Few studies examined the sustainable business model for IT firms such as online dataset services (West, 2000), game firms (Roquilly, 2011), mobile apps (Lee & Raghu, 2014), mobile data services (Kankanhalli et al., 2015), and telemedicine services (Peters et al., 2015).

5. Discussion and limitations

A total of 132 articles were captured from eight leading IS journals that focused on sustainability from the period 1993 to 2018. Out of the eight leading IS journals, most articles were published in *MISQ*, and the empirical study was recognized as the primary research method. Although a majority of previous studies focused on exploring developed countries, there has been a dramatic shift towards examining developing countries, as those countries are becoming more important players in the global supply chain.

Due to increasing social issues regarding sustainability in many different areas, this study conducted a systematic citation network analysis on how the sustainability issue is discussed in IS literature. This study is one of the few that reviews studies to adopt the SLNA research method in the IS discipline. As SLNA integrates the advantages of SLR and CNA, SLR was used to investigate the nature of sustainability in IS, whereas CNA helped to locate the main research issues and analyze the dynamic knowledge evolution within each research issue. We discovered three main research domains (sustainable competitive advantage, environmental sustainability, and sustainable online social communities) and two emerging research domains (the role of IS in developing countries and sustainable information infrastructures). These research domains explicated the mechanism by which IS support sustainable development. In other words, they tend to explain the role of IS in sustainable development from the perspective of IS management. IS management focus on the formation of IS strategy, the coordination between IS and business goals, the use of IS to achieve organizational transformation, the application of IS in global issues, and so on (Avgerou, 2000).

There is a lack of discussion about the contribution of IS to SOM. However, OM plays a critical role in sustainable development since OM (e.g., production design, manufacturing, recycling) is closely related to the efficiency of energy and materials (Drake & Spinler, 2013). IS play a critical role in OM (Kumar et al., 2018). To achieve common sustainable development goals, it is necessary for firms to integrate sustainability into their operations management (i.e., shifting towards sustainable operations management) (Hardcastle, 2013). Most firms have increased IS spending on OM since IS can help firms achieve SOM in economic (e.g., improve the efficiency of OM), environmental (e.g., reduce pollution), and social (e.g., improve the transparency of work conditions) aspects (Kumar et al., 2018). Thus, we develop the framework for the contribution of IS to SOM (Figure 14) based on our SLNA findings. Responsiveness serves as the mediator for the relationship between IS and SOM since the main advantage of IS lies in their ability to respond to various problems in firms (Avgerou, 2000).

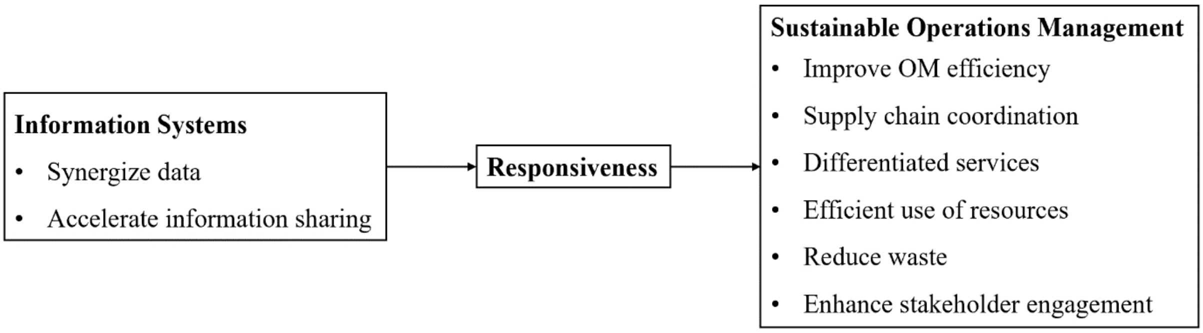

Figure 14. The framework for the contribution of IS to SOM

In essence, the market is dynamic (Gunasekaran & Ngai, 2004). Firms are attempting to use IS to improve their OM to respond to market demand more flexibly so as to maintain economic sustainability (Gunasekaran & Ngai, 2004). Firms may achieve market responsiveness through spanning IS that includes outside-in IS and inside-out IS (Wade & Hulland, 2004). Outside-in IS help to manage external relationships to enhance consumer loyalty and understand market demand, while inside-out IS help to develop efficient resource allocation, improve technology, and control cost to respond to market demand (Nevo & Wade, 2011; Piccoli & Lui, 2014; Wade & Hulland, 2004). Further, IS can synergize data better so that they can synergize the firm's resources and improve sustainable competitive advantage (Henfridsson & Lind, 2014; Nevo & Wade, 2011; Piccoli & Lui, 2014). IS help to improve the accurate information flow to increase the accuracy of decision-making in OM (Gunasekaran & Ngai, 2004). For instance, Aeroflot, a Russian airline firm, constructed information systems to significantly improve its operations. Their information systems provide management with not only an instant overview of more than 450 key performance indicators but also information about aircraft performance and even preventive maintenance (Furr & Shipilov, 2019). In the hospital, IS can schedule the patients and shorten the wait times to improve the quality of healthcare operations. Further, firms use IS to share the information in the supply chain and integrate the activities of internal production and external suppliers so as to generate supply chain collaboration to respond to the changing market demand flexibly and timely. In addition, IS promote responsiveness from differentiated services, allowing firms to compete on factors other than price (Gunasekaran & Ngai, 2004).

High responsiveness implies that production meets the market demand, which can reduce waste in production. IS may consider environmental data in decision-making to better support firms in predicting and preventing unsustainable OM (Fiorini & Jabbour, 2017). IS also can reduce the waste in production through their improvements in supply chain coordination (Simpson et al., 2007). In addition, IS can support some eco-friendly operations such as pollution control, carbon management systems, and environmentally friendly products and service delivery. For instance, Uber increased the usage of taxi services and reduced air pollution through its advanced route planning system (Hong et al., 2021). Therefore, IS, as a competitive resource, can help firms respond to increasingly severe environmental regulations and support the environmental aspect of SOM. Nishant et al. (2017) found that green IT had a positive impact on market returns which could provide better assurance for the long-term performance of investments. Green IS can improve sustainable competitive advantage in OM such as attracting environmentally conscious consumers (Nishant et al., 2017). It is worth noting that IS can help the firm achieve SOM through reflective disclosure (allowing monitoring and analysis of the performance of current practices) and information democratization (all the individuals in the firm can access and use the information related to sustainability from multiple sources) (Seidel et al., 2013). For instance, people may discuss firms' pollution on social media, which can monitor the environmental impact of firms' OM.

In the Web 2.0 era, people can freely express their requirements and preferences regarding the firm's products and services on social media (i.e., online community). Therefore, social media can be understood as an IS that collects stakeholders' messages in real time. From a resource-based view, social media can be considered as a resource that communicates with internal and external stakeholders. Firstly, social media also enable employees in different workplaces to work and collaborate virtually, overcoming geographic boundaries, reducing costs, and improving efficiency. For example, through an internal social media platform named connect. BASF, BASF enabled its 112,000 global employees across 88 business units to work and collaborate, increasing project efficiency by up to 25% (Gerald et al., 2014). Social media provide a firm with an open and accessible resource that enables it to become closer to its customers. Social media contain a wide range of perspectives from different reviewers and thus is considered as a superior choice for understanding customer requirements (Li et al., 2013), enabling the firm to improve quality management and enhance customer satisfaction. For example, fast fashion retailer Zara leveraged Facebook, a popular social media platform, to gain customer feedback and increase customer responsiveness, perceived value, and commitment, thus enhancing customer satisfaction. Social media (e.g., Dell's IdeaStorm platform) also allows customers to participate in new product design and innovation (Chan et al., 2021). Jarvenpaa and Leidner (1998) have suggested that IS can help firms to keep social and governmental relationships outside the firm. Doherty and Terry (2009) further indicate that outside-in IS initiatives have a larger influence on achieving sustainable competitive advantages. Thus, firms should consider how to communicate with external stakeholders in online communities to promote sustainable competitive advantage. Social media facilitate firms' information flow and knowledge sharing across internal and external social networks, which enhance internal and external collaboration and allow firms to be more customer-oriented, contributing to operational efficiency and innovativeness improvement (Lam et al., 2016).

Important ways that can influence engagement on online social communities were found to be structural dynamics (i.e., membership size, communication activity) (Butler, 2001), social dynamics (the basic nature of interaction among members and the relationship between members) (Ridings & Wasko, 2010), and technology factors (i.e., participation cost and topic consistency) (Butler et al., 2014). For a firm's online communities, polycentric governance practices can be used to mitigate collective action threats and keep the sustainability of online communities (Mindel et al., 2018). In the era of Web 2.0, firms increasingly participate in interactions with stakeholders through online communities (Lee et al., 2018). To enhance the communication with stakeholders on social media, firms need to consider structural dynamics, social dynamics, and technology factors. For example, firms should develop communication activities on social media to enlarge membership size and collect more stakeholders' opinions. Topic consistency demonstrated that stakeholders might pay attention to firms' SOM continuously. Therefore, firms should update their SOM on social media continuously.

Stakeholders can expose and spread firms' unsustainable operations on social media, which can supervise and improve firms' SOM. The information capacity of social media enhances information sharing between stakeholders, which permits firms effective compliance with environmental and social requirements (Butler, 2011). In addition, firms are motivated to communicate their SOM with stakeholders on social media, which can enhance stakeholders' preferences and maintain sustainable competitive advantage (Lee et al., 2018). In the next chapter, we will investigate stakeholders' reactions to firms' SOM on Twitter, which can provide decision support for the firm on SOM.

Although the findings of this study are valuable to IS literature, there are some limitations that can be improved in future studies. First, to focus on IS literature, the leading eight IS journals were selected. However, this limits how sustainability in IS literature is being presented in academia from different disciplines. Future research can be extended to a wider pool of journals to truly understand how the IS literature is changing the trends of knowledge and to learn about the future direction of firms utilizing IS in their systems. Second, this study collected 132 articles to understand the trends in IS literature. Although this is adequate sample size for main path analysis and CNA, expanding the sample size would help in comprehending the trends in IS literature. Third, the findings of this study, using a keyword search, were insightful for determining the direction of academia and firms in IS. Therefore, it would be better to explore IS studies with more keywords related to sustainability, supply chains, and agile logistics in IS literature.

Appendix A.

Table A1. Classification results

Research domain	Articles
Sustainable competitive advantage	Atkins (1998); Benitez-Amado and Walczuch (2012); Bharadwaj (2000); Dehning and Stratopoulos (2003); Doherty and Terry (2009); Feller et al. (2012); Gable (2010); Gordon et al. (2005); Griffiths and Finlay (2004); Grover et al. (2009); He (2004); Hedman and Kalling (2003); Henfridsson and Lind (2014); Hidding (2001); Iyer et al. (2006); Jarvenpaa and Leidner (1998); Kettinger et al. (1994); Lim et al. (2013); Madon (1999); Mata et al. (1995); Mithas and Rust (2016); Nan and Tanriverdi (2017); Nevo and Wade (2011); Nevo and Wade (2010); Peppard et al. (2000); Peppard and Ward (2004); Piccoli and Ives (2005); Piccoli and Lui (2014); Rai et al. (2006); Ravichandran and Lertwongsatien (2005); Wade and Hulland (2004)
Environmental sustainability	Abbas et al. (2018); Bengtsson and Agerfalk (2011); Bose and Luo (2011); Brandt et al. (2018); Butler (2011); Chan and Ma (2017); Cooper and Molla (2017); Corbett (2013); Corbett and Mellouli (2017); Dao et al. (2011); DesAutels and Berthon (2011); Elliot (2011); Gholami et al. (2016); Hanelt et al. (2017); Hasan et al. (2017); He et al. (2011); Hedman and Henningsson (2016); Hu et al. (2016); Ketter et al. (2016); Loeser et al. (2017); Loock et al. (2013); Marett et al. (2013); Melville (2010); Nishant et al. (2017); Petrini and Pozzebon (2009); Piel et al. (2017); Pitt et al. (2011); Seidel et al. (2018); Seidel et al. (2013); Tim et al. (2018); Watson et al. (2010); Watson et al. (2011)
Sustainable online social community	Bock et al. (2015); Butler (2001); Butler et al. (2014); Chen et al. (2018); Chengalur-Smith et al. (2010); Guo et al. (2017); Mindel et al. (2018); Phang et al. (2015); Ridings and Wasko (2010)
The role of IS in developing countries	Braa et al. (2007); Braa et al. (2004); Madon (2005); Srivastava and Shainesh (2015)
Sustainable information infrastructure	Ribes and Finholt (2009); Ribes and Polk (2014); Venters et al. (2014)
Scatted articles cluster	Adomavicius et al. (2012); Anderson et al. (2017); Assimakopoulos and Tsiligirides (1993); Bapna et al. (2018); Briggs et al. (2003); Brown et al. (2004); Cho et al. (2007); Demirezen et al. (2016); Epstein (2013); Gaskin et al. (2016); Gleasure and Feller (2016); Grimsley and Meehan (2007); Gupta and Zhdanov (2012); Hadaya and Cassivi (2012); Huang et al. (2017); Iacovou (1999); Jha et al. (2016); Kankanhalli et al. (2015); Kartseva et al. (2010); Kitchens et al. (2018); Kloor et al. (2018); Lee and Raghu (2014); Lee et al. (2015); Levi et al. (2003); Li et al. (2016); Loebbecke et al. (2016); Ma and McGroarty (2017); O'Reilly and Finnegan (2010); Parker and Weber (2014); Peters et al. (2015); Rajao and Marcolino (2016); Ramarapu and Lado (1995); Rishika et al. (2013); Roquilly (2011); Ruth (2012); Saeed et al. (2005); Sandeep and Ravishankar (2015); Santos et al. (2013); Saravanamuthu (2002); Shaw (2007); Thies et al. (2018); Tyworth (2014); Vaast et al. (2017); Van Slyke et al. (2007); West (2000); Zyngier and Burstein (2012)

Chapter 3: Stakeholder Engagement in Firms' Sustainable Operations Management

Abstract

Responding to stakeholders, some firms are making open commitments to adjust their operations management in order to meet their Sustainable Development Goals (SDGs). However, most firms cannot devote an equal amount of resources to each process in sustainable operations management (SOM), and thus they must prioritize among them. Meanwhile, stakeholders also have different priorities for firms' SOM. Thus, firms need to engage stakeholders in SOM when they decide which SDGs could maximize their impact on both the firm and society. Social media is an efficient channel for firms to improve stakeholder engagement. However, it is an issue for most firms to communicate their SOM on social media since not all social media posts generate high stakeholder engagement. Therefore, this study aims to help firms understand how to engage stakeholders in their SOM on social media. We collected 25,106 social media posts from 19 fashion brands and classified them into three operations closely related to sustainable practices (i.e., product design, manufacturing, and recycling). We train a Natural Language Processing technique machine to mimic how the stakeholders interpret brands' communications about SOM. We found that sustainable product design and recycling initiatives generated stronger stakeholder engagement. Surprisingly, sustainable manufacturing had insignificantly positive effects on stakeholder engagement. We are the first to use signaling theory to support stakeholder engagement in SOM on social media theoretically. Managerially, our studies may help firms communicate SOM with their stakeholders to improve stakeholder engagement. Specifically, firms should select more eco-friendly materials, especially recycled plastics. However, manufacturing processes rarely meet stakeholders' approval, and the issues involved are often more controversial. Firms need to adjust their current communications with key stakeholders on the subject of manufacturing. Finally, to our best knowledge, we are the first to demonstrate stakeholder engagement in SOM through a large-scale data-driven approach.

Keywords: Sustainable Development Goals, Sustainable Operations Management, Stakeholder Engagement, Social Media Analytics

1. Introduction

To some extent, the current economic development is at the expense of environmental sustainability (e.g., plastics pollution, water pollution, greenhouse emission) and social sustainability (e.g., sweatshops, child labor). Stakeholders require firms to strike a balance between economic, environmental, and social sustainability, and thus firms are moving towards sustainable operations management (SOM) (Jaehn, 2016; Tang & Zhou, 2012). Firms could play a vital role in achieving sustainability in societies and countries where they source, manufacture, and distribute their products, thus meeting the expectations of stakeholders and creating added value such as green brand equity, resulting in increased long-term financial value (Miralles-Quiros et al., 2019). SOM is for a business means "to structure and manage its business processes to obtain competitive returns on its capital assets without sacrificing the legitimate needs of internal and external stakeholders and with due regard for the impact of its operations on people and the environment" (Kleindorfer, Singhal, & Van Wassenhove, 2005) p. 489). The term "stakeholder" refers to any group or individual who can affect or is affected by a firm's operations management (OM) (De Luca et al., 2022). Stakeholders include consumers, suppliers, employees, governments, shareholders, and society at large (De Luca et al., 2022). Employees, shareholders, suppliers, and customers are considered to be major stakeholders because these groups occupy an important position in the firms' OM (Roscoe et al., 2020).

To understand the legitimate needs of stakeholders, firms engage in dialogue with stakeholders to determine their social, environmental, and economic concerns, which is defined as "stakeholder engagement" (Surucu-Balci et al., 2020) p.2). Stakeholder engagement in SOM includes sharing information, resources, and responsibilities to jointly plan, implement, and evaluate environmentally and socially sustainable processes to achieve common goals (Roscoe et al., 2020). Firms need an effective communication strategy to generate mutual understanding and satisfy more stakeholders (De Luca et al., 2022). Social media is defined as "a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content" (Kaplan & Haenlein, 2010) p. 61). Social media provides an open and collaborative environment for corporate communication (Swani et al., 2014); thus, firms reporting their SOM practices on social media can receive immediate feedback from stakeholders. Stakeholders can share their perceptions without interruption through a direct and continuous dialogue with firms on social media, which accelerates communication and allows them to monitor business practices on a broader scale (Denktas-Sakar & Surucu, 2020). Firms communicate about their SOM on social media to reduce information asymmetry and increase stakeholder engagement (Fieseler & Fleck, 2013). For instance, Patagonia usually reports its SOM practices on social media (Ram et al., 2013). As a result, their revenue has doubled in just eight years (from 2002 to 2010) (Ram et al., 2013), and they have received substantial stakeholder engagement on social media. Thus, social media is one of the effective channels for stakeholder engagement in firms' SOM.

Stakeholder engagement on social media involves specific interactive experiences comprising positive cognitive and emotional dimensions, which are able to trigger promotional behaviors (e.g., giving likes, sharing social media posts) (Viglia et al., 2018). In other words, stakeholders may give the likes to social media posts when they are interested in firms' activities and/or feel good about a firm's activities (Dijkmans et al., 2015). Thus, we can measure the level of stakeholder engagement through the number of likes a social media post get. Previous studies may research firms' SOM based on Corporate Social Responsibility (CSR) reports. However, CSR reports only allow one-way communication (i.e., reading). Firms cannot measure stakeholder engagement since they cannot receive any feedback or data about stakeholders with CSR reports. Thus, social media is a better channel for firms and scholars to research stakeholder engagement since it can quantify stakeholder engagement (e.g., the number of likes). Previous OM studies have used social media data to investigate stakeholder engagement (Denktas-Sakar & Surucu, 2020). Therefore, we assume that social media would be an ideal channel to investigate how to make stakeholder engagement in SOM more efficient and to determine which aspects of SOM generate higher stakeholder engagement. Twitter is one of the most common social media platforms used by firms to communicate their efforts toward SOM (Barbeito-Caamaño & Chalmeta, 2020). More than 60% of Fortune 500 firms actively use Twitter as a preferred social media platform to disseminate information (Swani et al., 2014).

The level of stakeholder engagement with firms' SOM practices on Twitter could vary greatly. For example, stakeholder reactions to recycling plastics could be extremely different for two globally recognized brands. Yet, the rationales for these differences in stakeholder engagement towards SOM practices have not been widely investigated. This motivated us to ask, "1) Which SOM practices generate higher stakeholder engagement? 2)Why are there significant differences in stakeholder engagement between different processes in the SOM and across firms?"

"The tides are turning. @parleyxxx meets performance to create unique footwear and

apparel made with Parley Ocean Plastic. #adidasParley"[15]. – Adidas: 8443 likes, 350 retweet

"Have you heard about our Community Trade recycled plastic? "These women were incredible, proud of the work they did and total bosses." - Pixie Geldof. Find out more about the waste pickers behind the project here: https://t.co/Ea9NygrRD#CommunityTradePlastic."[16]. - The Body Shop: 9 likes, 2 retweet

It has been indicated that failure to engage stakeholders could cause unexpected resistance in the implementation of decisions (de Gooyert et al., 2017). Thus, understanding stakeholders' perspectives on firms' SOM would help firms align their sustainability efforts with the market, generating stronger customer loyalty, brand equity, and, most importantly, have a greater impact on their committed SDGs. Against this backdrop, we aim to help firms engage their stakeholders in SOM more efficiently.

To achieve our research objective, we investigated how international firms committed to SOM communicate on social media platforms because this was the most effective way to obtain a large dataset of firm-stakeholder communications. Yet not all firms in manufacturing sectors need to communicate on social media, in particular, the firms in the upper stream of the supply chain. As gatekeepers, retailers can promote the sustainability practices of the whole supply chain by providing information about their own SOM practices (e.g., setting up product standards) and communicating with stakeholders on issues related to SOM so as to improve stakeholder engagement (Youn et al., 2017). Therefore, downstream members of the global supply chain (i.e., business-to-customer) are more relevant to our research questions and context. We selected international fashion brands as our samples, because (1) the fashion industry accounts for 3-10% of greenhouse gas emissions globally; (2) fashion brands use social networks extensively to monitor fashion events in real time, bringing greater visibility and accessibility to brands (Barbeito-Caamaño & Chalmeta, 2020); and (3) only the fashion industry has made a clear, united, and open commitment to the UN's SDGs (i.e., the Fashion Pact signed at the G7 summit in Paris 2020), allowing us to shortlist international firms with a strong commitment.

15 https://t.co/pI0hqQYAwS

16 https://t.co/oYjb1kw5HS

We proposed a data-driven approach to help understand how stakeholders interpret a firm's SOM practices from social media platforms, which contributed to the studies of social media analysis. Although much of the literature (e.g., Barbeito-Caamaño and Chalmeta (2020); Saxton et al. (2019)) has previously explored corporate social responsibility communication, there have been no studies that specifically focus on OM and thus cannot precisely address our research questions. OM is critical for firms' business. Therefore, we used a neural network algorithm to develop a Natural Language Processing (NLP) engine that can label brands' social media posts into one or multiple OM and SDG categories, respectively. This engine mimics the stakeholders' general engagement in firms' SOM, determining the relationship between the firms' SOM and the stakeholder engagement.

We found that sustainable product design and recycling can generate higher stakeholder engagement. However, sustainable manufacturing has an insignificantly positive effect on stakeholder engagement. We are the first to investigate how stakeholder engagement improves firms' SOM. We contribute to the SOM literature by opening the 'black box' of stakeholder engagement in SOM. Meanwhile, we found that sustainable product design and recycling are interpreted as an effective signal to engage stakeholders. We used countersignals (i.e., likes) to measure stakeholder engagements so that we could examine the effectiveness of signals about SOM. Our research extended the signaling theory. OM studies extensively adopt the signaling theory to explain the signals in the OM area. Scholars have devoted less attention to the signals of SOM. We are the first to use signaling theory to support stakeholder engagement in SOM on social media theoretically. Managerially, our studies may help firms communicate SOM with their stakeholders to improve stakeholder engagement. Methodologically, we innovatively measure stakeholder engagement with social media data and adopt the machine learning method (i.e., Natural Language Processing).

2. Literature review

2.1 Signaling Theory

Signaling theory aims to explain the relationship between the sender and receivers of signals (Connelly et al., 2011). The goal of signaling is to acquire information from the market to resolve the extensive information asymmetry between firms and stakeholders (Connelly et al., 2011). Generally, stakeholders are hard to identify whether firms' OM (e.g., product design, manufacturing) are sustainable (McDonald & Oates, 2006). In contrast, stakeholder engagement strategy encourages symmetric communication between firms and stakeholders

(De Luca et al., 2022). Therefore, firms are necessary to send some signals about SOM to stakeholders, which can reduce information asymmetry and enhance firms' competitive advantage (Taoketao et al., 2018; Yu et al., 2017). The absence of adequate communication causes information asymmetry, leading to less favorable perceptions of a firm regardless of its good SOM practices (Eberle et al., 2013).

Firms' SOM could be positive signals (Taj, 2016). By sending a positive signal to society, companies can influence the views of stakeholders and encourage them to communicate with each other (Pecot et al., 2018). For example, consumers tend to trust the firms, which are beneficial to consumers and society (Louis et al., 2019). when consumers receive signals about firms' sustainable practices, they tend to share this information and recommend products from this firm to others on social media (Oghazi et al., 2018). Consumers who receive recommendations may purchase products and services from sustainable firms, which can help to enlarge market share (Pecot et al., 2018). What is more, the Internet, especially social media, makes it easier for stakeholders to share firm-related information (Dang et al., 2020a). Signaling theory indicates that the receiver, the signals, and the signaling environment play a vital role in interpreting the sender's signals (Connelly et al., 2011). Previous studies have ignored the way receivers perceive brands' sustainability efforts, as this is difficult to test empirically. In this paper, social media is the signaling environment. The signalers represent the firms, while the receivers are the stakeholders. Stakeholders provide feedback through giving likes to a social media post in reaction to the corresponding SDGs they perceive (through a machine learning classifier in this study). The signals are the social media posts (i.e., tweets) related to firms' SOM.

2.1.1 Signaling environment

We selected Twitter as the signaling environment since Twitter can be used to effectively and quickly communicate with a firm's stakeholders (Schmidt et al., 2020). On Twitter, firms (i.e., senders) can send short and specific tweets (i.e., signals) that can be interpreted by stakeholders (i.e., receivers). Stakeholders can discuss firms' SOM on social media widely and in real time so that stakeholders can identify misleading information and monitor firms' SOM (Lyon & Montgomery, 2013). The publicity, transparency, and immediacy of social media (i.e., Twitter) provide an environment that makes it easy to test both the signal itself and the behavior of the receiver (Saxton et al., 2019). Twitter records stakeholders' engagement behaviors such as retweeting, comments, and giving like, which make the level of stakeholder engagement measurable. Measurable stakeholder engagement represents the effectiveness of signals. The effectiveness of signals is defined as "the extent to which the signaled information is readable by the receiver" (Yu et al., 2017, p. 552). Thus, the SOM signal is effective when it has higher-level stakeholder engagement. This also implies that the SOM practices mentioned in the post meet the requirements of stakeholders. When firms are aware of stakeholders' dissatisfaction with their SOM, they can correct their practices and send out signals again in time.

2.1.2 Signaler

Today, firms must take stakeholders into account when making decisions (Stevenson, 2018). Many firms have adjusted their business strategies and operations to demonstrate their commitment to sustainability (Amran et al., 2015; Freeman, 2010; Zahller et al., 2015). For instance, sending a signal to employees that the firm is making efforts to achieve environmental and social sustainability has positive effects on employee performance (Gabler et al., 2020). We mainly observed firm-generated content on social media (i.e., tweets) that provides critical information on their SOM practices in this study (Chung, Animesh, Han, & Pinsonneault, 2020). In addition, Tweets from a firm's official Twitter account can be used to disseminate key information to stakeholders since they comply with Regulation Fair Disclosure practices set by the Securities and Exchange Commission.[17]

2.1.3 Signal

Previous OM studies have used the signaling theory to investigate signals such as return time leniency (Rao et al., 2018), supplier ties (Yan et al., 2020), and corruption risks (Kim & Wagner, 2021). However, scholars rarely investigate the SOM signals. We adopt UN SDG to determine whether a signal is related to SOM or not, and measure how sustainable it is. A signal will be considered as SOM signal if it achieves at least one SDG. SOM is more sustainable if it can achieve more SDGs. To be more specific about what a firm can do to achieve sustainability, the UN has defined seventeen SDGs that should be achieved by 2030.[18] Previous OM studies have mapped OM such as materials, human resource management, production, investment, and logistics onto SDGs (Ike et al., 2019; Salvia et al., 2019). For example, Ike et al. (2019)

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17 https://www.sec.gov/news/press-release/2013-2013-51htm

[18] https://www.undp.org/content/undp/en/home/sustainable-development-goals.html

indicated that waste management is associated with SDG14. Life below water, while employee training is connected to SDG4. Quality education. Each SDG has different interpretations and specific requirements for the firms' operations (Le Blanc, 2015).

Table 1. SDGs

No.	Name	No.	Name
1	No poverty	10	Reduced inequality
2	Zero hunger	11	Sustainable cities and communities
3	Good health and well-being	12	Responsible consumption and production
4	Quality education	13	Climate action
5	Gender equality	14	Life below water
6	Clean water and sanitation	15	Life on land
7	Affordable and clean energy	16	Peace, justice and strong institutions
8	Decent work and economic growth	17	Partnerships towards the goals
9	Industry, innovation and infrastructure		

Signals have different attributes (e.g., signal cost, breath) that can influence the effectiveness of communication (Connelly et al., 2011). We ignore signal cost since there is very little cost involved in sending signals on social media. Saxton et al. (2019) defines breadth as "the scope of the signal topic" (p. 362). They further indicate that broadly focused CSR accounts are more likely than narrowly focused accounts to generate retweets. Extending their studies, we further investigate whether a social media post with more aspects on SOM will get higher receivers' engagement or not. Meanwhile, a post will be stronger signal when it mentions some SOM practices that achieve more SDGs and vice versa (Kharouf et al., 2020). If firms send a stronger signal to the stakeholders, it will get higher stakeholder engagement (Kharouf et al., 2020). Thus, we assume that SOM (i.e., OM that achieve more SDGs) can achieve higher stakeholder engagement.

2.1.4 Receiver

The receiver is the stakeholder "who can affect or is affected by the achievement of the firm's objectives" (Freeman, 2010, p.46). Stakeholder theory suggests that firms carry out sustainable practices based on the interests of different stakeholder groups (e.g., investors, employees, consumers) so as to obtain their favor and maximize profit (Gong et al., 2019). The manner in which stakeholders endorse firms' SOM through the lens of SDGs is still unknown in the OM literature. We use countersignals to capture stakeholder engagement (Connelly et al., 2011). On social media, signals are transmitted in the form of discrete messages, while countersignals are sent in the form of audience likes, comments, and sharing these messages (Harris et al., 2021). On Twitter, SOM signals appear in the form of firms' tweets, while receivers' approval of these signals can be observed by the "liking" of these tweets (Saxton et al., 2019; Saxton & Waters, 2014). The number of likes of a specific post can measure stakeholder engagement in SOM (Saxton & Waters, 2014). More likes in the tweets generated by firms indicate that stakeholders are more interested, which can be used as an indicator to determine increased engagement (Lee et al., 2018). Increased stakeholder engagement indicates that a specific signal (i.e., OM that achieves SDG(s)) has a larger range of interests. Thus, Twitter with more likes can be regarded as separate from other signals, which implies that they are more effective in their signaling capability (Connelly et al., 2011). Therefore, firms can use stakeholder engagement to identify the key environmental and social factors which can improve firms' SOM (Reyes-Menendez et al., 2018).

2.2 The communication of sustainable operations management on social media

To classify firms' SOM, we consolidated the previous review studies in top OM journals (e.g., *Production and Operations Management*, *European Journal of Operations Management*) to find out the common classifications for SOM. We selected review studies (Jaehn, 2016; Kleindorfer et al., 2005; Tang & Zhou, 2012) since they have made conclusions based on research findings and developed the research framework for SOM, which can provide direction for the classification of OM. For instance, Jaehn (2016) stated that SOM usually involves product development and design, production processes, working conditions, and product recycling. Kleindorfer, Singhal and Van Wassenhove (2005) also mentioned that the firms' carbon footprint would come from several operations, such as product design, manufacturing, and product recycling. In our study, manufacturing includes production and sourcing since producing a good may use many components that need to be purchased from suppliers (Ghadimi & Heavey, 2014). In addition, the impact of a product on the world starts from product design to manufacturing process to ultimate disposal or recycling (Jaehn, 2016; Ma et al., 2014; Zabaniotou & Kassidi, 2003). OM is "the management of systems or processes that create goods" (Stevenson, 2021, p.4). OM tend to maximize the efficiency of business practices within a firm. While supply chain management beyond the firms' boundaries (Qi et al., 2017). We only focus on the OM practices within firms. Therefore, to achieve SOM, firms should improve their operations in an all-around way. Based on these reviews (Table 2), we grouped SOM into three categories: (1) sustainable product design, (2) sustainable manufacturing, and (3) recycling. Sustainable manufacturing includes sustainable production and sustainable sourcing.

2.2.1 Sustainable product design

Sustainable Product design is an important instrument of sustainable development (Kleindorfer, Singhal, & Van Wassenhove, 2005; Tang & Zhou, 2012). In our study, product design refers to the properties of a product, including appearance and function (Luchs & Swan, 2011). Sustainable product design is based on the triple bottom line, namely environmental protection, social expectation, and profit distribution (Lacasa et al., 2016). Sustainable product design involves life cycle design (e.g., using recyclable and sustainable material), modular design, ethical design, and so forth (Drake & Spinler, 2013; Kleindorfer, Singhal, & Van Wassenhove, 2005). For instance, fashion firms can use environmentally friendly and renewable raw materials (e.g., organic cotton, recycled polyester/nylon fibers) to improve the sustainability of products (Abdul-Rashid et al., 2017). Life cycle design can achieve some SDGs such as SDG12. Responsible consumption and production, SDG 14. Life below water and SDG 15. Life on land. Ethical design can achieve some SDGs focus on social responsibility, such as SDG1. No poverty and SDG3. Good health and well-being. Sustainable product design can serve as a signal to communicate environmental sustainability and social sustainability to stakeholders (Diego-Mas et al., 2016).

Applying the principles of sustainable design to new products could achieve higher stakeholder engagement, which makes firms more competitive and profitable (Pamfilie et al., 2013). Consumers, one of the major stakeholders, may pay for sustainable products since they will derive moral satisfaction from buying these products (Steenis et al., 2018). According to the most recent Green Brand Survey of 9,000 consumers in the U.S., Australia, China, Brazil, France, Germany, India, and the U.K., more than 50% of consumers reported sustainable product design as an essential requirement (Chen et al., 2020). The use of sustainable materials by fashion firms meets the expectations of stakeholders and improves stakeholder engagement

(An et al., 2013; Lundblad & Davies, 2016).

We also observed high stakeholder engagement in sustainable product design on social media. For instance, Louis Vuitton generated higher stakeholder engagement when they launched their new exclusively designed Silver Lockit Fluo bracelet for the United Nations International Children's Emergency Fund (UNICEF) to call for the protection of women and children, which meets SDG 1. No poverty and SDG 10. Reduced inequality. The tweet, "New ways to wear your support for @UNICEF to help vulnerable children. #MAKEAPROMISE with a @LouisVuitton Silver Lockit Fluo bracelet, now in new colors. Join us at https://t.co/2HGoJer2Ee UNICEF does not endorse any brand, product or service. https://t.co/RL20Cugd1F" (2018/6/28 9:19:01) got 18,575 likes (average: 1337.99) and 2,854 retweets (average: 259). In addition, sustainable product design can garner positive responses from more diverse stakeholders with different areas of focus if the design is perceived as a way to achieve more SDGs (i.e., become more sustainable). We therefore developed

Hypothesis 1. Sustainable product design generates higher stakeholder engagement on social media.

2.2.2 Sustainable manufacturing

Manufacturing means that the chemical or physical properties of raw materials are altered through a series of production processes that ultimately generate a product (Lin et al., 2009). In our study, manufacturing includes production and sourcing since producing a good may use many components that need to be purchased from suppliers (Ghadimi & Heavey, 2014). Production refers to the whole production process including techniques and workplace management. Techniques include automation and craftsmanship. Automation means that products are produced by machines automatically, while craftsmanship means that products are largely produced by handmade and traditional techniques (Pöllänen & Weissmann-Hanski, 2020). In addition, workplace management includes the selection and design of workplaces (Plijter et al., 2014). Sourcing refers to obtaining products or materials and parts required for production from external sources (Essig, 2011).

Sustainable manufacturing is defined as "the creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources. Sustainable manufacturing also enhances employee, community, and product safety" (Akbar & Irohara, 2018), p. 866). Manufacturing needs to balance environmental sustainability and social sustainability rather than focusing only on economics because of stricter regulations and stakeholders' awareness of environmental protection and corporate social responsibility (Tang & Zhou, 2012). Therefore, firms need to adopt energy-efficient production technologies and reduce waste pollution at first (Atasu et al., 2020; Drake & Spinler, 2013). Secondly, firms should maximize employees' job satisfaction, including things like fair wages, safe production, and flexibility of work times (Jaehn, 2016). Firms' attention to workers' health and safety is not limited to employees in their own factories but also extends to all employees of their suppliers (Kleindorfer, Singhal, & Van Wassenhove, 2005). Only when the sustainability strategy is consistent with that of its upstream suppliers and downstream customers can it generate the greatest benefits (Tang & Zhou, 2012).

We assumed that sustainable manufacturing would achieve higher stakeholder engagement on social media. Sustainable manufacturing (i.e., manufacturing in line with SDGs) can improve resource utilization and reduce waste, which is a win-win situation for stakeholders (Pajunen & Heiskanen, 2012). Firms' manufacturing practices may affect the local environment (e.g., water emission, air emission) and communities (e.g., local income and employment). Stakeholders will consider the impact of manufacturing on local communities and support measures to promote safer and healthier manufacturing so as to ensure workers' health and safety (Diego-Mas et al., 2016). Thus, governments engage in firms' sustainable manufacturing through environmental, health, and safety regulations and supervision (Lo et al., 2014). Society may protest against firms' unsustainable production (e.g., illegal discharge, child labor). Thus, firms need to interact with stakeholders in the process of developing agreements related to workers and eco-friendly manufacturing (Lo et al., 2014). Sustainable manufacturing requires reducing pollution in production without affecting employees' health so as to increase employees' satisfaction in turn to improve employees' engagement (Tseng et al., 2019). In addition, stakeholders also require firms to take responsibility for the social and environmental impacts of their suppliers (D'Eusanio et al., 2019). If upstream suppliers use materials prohibited by the EU hazardous substances restriction law, downstream firms will be immediately affected (Corbett et al., 2009). Firms such as Nike and Apple have been damaged by the use of child labor by their suppliers (D'Eusanio et al., 2019). We observed that The Body Shop receives higher stakeholder engagement when they communicate their sustainable manufacturing practices that meet SDG5. Gender equality, SDG10. Reduced inequality, and

SDG 16. Peace, justice and strong institutions. The tweet, “Did you know? We source our Shea Butter with the Tungteiya Women's Shea Butter Association in northern Ghana, giving a regular income to 475 women. So your fave Shea products care for your skin whilst empowering communities ❤️ https://t.co/Xb8cRWE7vD #CommunityTrade #CareWithShea https://t.co/VV0rfHiOSS” received 57 likes (average: 37.41) and 11 retweets (average: 11.75). Therefore, we assume that if the manufacturing of products can be perceived by stakeholders as achieving more SDGs, they will react positively on social media. We therefore developed the following hypothesis:

Hypothesis 2. Sustainable manufacturing generates higher stakeholder engagement on social media.

2.2.3 Recycling

Recycling products or product parts is considered environmentally sustainable because these practices prevent waste (Jaehn, 2016). Recycling is “the process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new products.” [19] Recycling can improve communities and the environment.[20] Meanwhile, recycling is also one of the requirements of SDG 12. Responsible consumption and production. Firms are increasingly required to be responsible for their products’ entire life, including the end of the product life (Kleindorfer, Singhal, & Van Wassenhove, 2005). In addition, firms will be more likely to consider product recycling due to the reduction of profit margin, the shortening of product life cycles, and the increase in environmental problems (Kleindorfer, Singhal, & Van Wassenhove, 2005). For example, Zara collects people’s used clothes. Product recycling and reusing reduce the destructive impact of waste treatment, raw material extraction, and transportation on the environment (Kleindorfer, Singhal, & Van Wassenhove, 2005). To be specific, the whole recycling process should include collecting used products, reverse logistics, inspection, disposal remanufacturing, and remarketing, which involves many stakeholders (Kleindorfer, Singhal, & Van Wassenhove, 2005; Tang & Zhou, 2012). We observed that The Body Shop received higher stakeholder engagement when they communicated their recycling scheme, which meets SDG 12. The tweet “We've brought back our recycling scheme in store*!

19 https://www.epa.gov/recycle/recycling-basics

20 https://www.epa.gov/recycle/recycling-basics

Find your nearest store to bring back our empty tubs, bottles, tubes and pots & our partners, @TerraCycle, will recycle and repurpose it for you and the planet. https://t.co/rlDHpCArmm #ReturnRecycleRepeat *Selected Stores Only https://t.co/73vN5jwLWh" (2019/5/30 8:30:00) generated 77 likes (average: 37.41) and 34 retweets (average: 11.75). Therefore, stakeholders are likely to respond to firms when they communicate their recycling practices on social media. Thus we developed

Hypothesis 3. Recycling generates higher stakeholder engagement on social media.

3. Methodology

The research methodology involved large-scale data collection, data pre-processing, text classification, and hypothesis testing. We ran a Twitter Search Application Interface (API) on Python 3.7 to collect data. We ran the data-preprocessing and text classification on Orange 3.29. Finally, we conducted regression analysis for hypothesis testing and a robustness check on SPSS 25. Figure 1 displays the steps of the research methodology used in this study. The following sections will provide details.

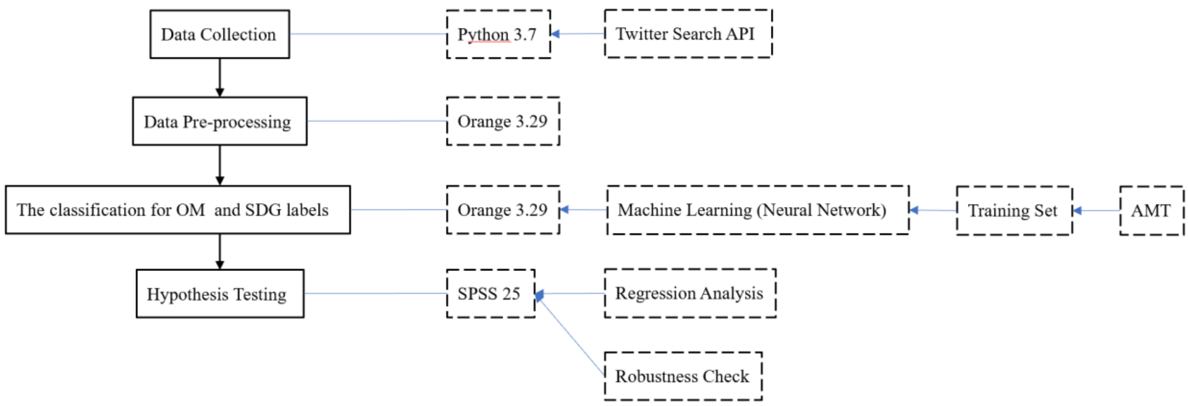

Figure 1. The overview of the techniques used in this research

3.1 Data collection

3.1.1 Sample selection

Currently, the global demand for fashion products is steadily increasing (Sandin & Peters, 2018). Due to the rapid change in consumers' tastes, the life cycle of fashion products is very short to meet highly volatile demand (Liu et al., 2013). Fashion brands must continually develop more new products to meet this demand and then introduce these products to the market through social media. Compared to other industries, fashion brands are more likely to interact with stakeholders on social media platforms to understand people's tastes and preferences. In addition, fashion products are usually emotional products because consumers' purchases are affected by the emotional factors aroused by brand associations or popularity (Briano et al., 2010). Meanwhile, fashion products symbolize a person's self-concept and values, leading to a large number of interactions between firms and the public (Khare & Varshneya, 2017). Thus, customers might have a stronger emotional connection to fashion brands with a clear focus on SDGs. Fashion brands' social media accounts have a large amount of product information and stakeholder responses, which was vital to our data collection.

The fashion industry's impact on the environment is second only to that of the petroleum industry since it uses enormous amounts of natural resources, pesticides, chemicals, and labor (Schroeter, 2016; Urbinati et al., 2017). 97% of the materials are new in the fashion industry, while only 3% are recyclable (Bielawski, 2019). The total annual resource input is 98 million tons, including oil for synthetic fiber production, chemical fertilizer for cotton planting, and various chemicals for fabric dyeing and finishing (Bielawski, 2019). The greenhouse gas emission of global textile production is 1.2 billion tons of greenhouse gases every year, more than that of international flights and shipping (Blanchard, 2019). Stakeholder groups have begun to pay more and more attention to the environmental problems caused by the fashion industry and to call for a change in its traditional business operations to offer more environmentally and socially sustainable products (Lo et al., 2012). On the 24th of August 2019, major fashion brands jointly issued the *Fashion Pact*, the only open commitment to promoting industry-level alignment with SDGs.[21] Such joint actions across global brands are uncommon in other industries and further support our choice of the fashion industry for the current study. We reviewed each fashion brand to confirm that it had adopted sustainability as one of its firm's goals, strategies, and operations (Kibbe, 2015; Stevenson, 2018).

We only selected public firms to control for the effect of financial factors on the results. First, we select the signatories (i.e., Adidas, Burberry, Stella McCartney) of the Fashion Pact.[22] The signatories have pledged to work to prevent global warming, restore biodiversity, protect the oceans, and achieve 100% renewable energy by 2030.[23] To avoid selection bias, we also

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[21] https://www.fashionrevolution.org/the-g7-fashion-pact-what-it-is-and-what-its-missing/

[22] https://www.fashionrevolution.org/the-g7-fashion-pact-what-it-is-and-what-its-missing/

[23] https://www.fashionrevolution.org/the-g7-fashion-pact-what-it-is-and-what-its-missing/

included fashion brands that committed to sustainability in their mission statement but were not one of the signatories of the Fashion Pact. We randomly selected nine fashion brands that have made efforts toward sustainable operations from the mass market to the luxury market. We believe the random choice of fashion brands covers all major subsectors of the fashion market and thus reduces potential biases toward a particular group of customers. All selected fashion brands are shown in Table 2.

Table 2. Selected fashion brands

Signatories of the Fashion Pact	Others
Adidas	The Body Shop
Burberry	Uniqlo
Gap	Levi's
H&M	Givenchy
Zara	Vans
Nike	Reebok
Prada	The North Face
Puma	Louis Vuitton
Stella McCartney	
Gucci	
Michael Kors	

3.1.2 Data collection on Twitter

We collected social media engagement data by running a Twitter Application Interface (API) on Python 3.7 (Yuen et al., 2021). In 2020, Twitter had 336 million active users.[24] Compared with Facebook, Twitter allows users to share their views in an accessible public environment (Reyes-Menendez et al., 2018). There are three kinds of tweets: original tweets, retweets, and tweets that reply to other users (Chae, 2015). We aim to investigate stakeholder engagement with firms' announcements of operations that contribute to SDGs. Therefore, this study only considered original tweets created by the official global Twitter accounts of the relevant firms.

[24] https://www.statista.com/statistics/272014/global-social-networks-ranked-by-number-of-users/

If the brand's official global account is not in English, we select the brand's official English account with largest number of followers. For example, UNIQLO's official worldwide account is in Japanese, so we select its official American account. We collected 25,106 tweets from 19 fashion brands from September 25, 2015, to September 23, 2019, because SDGs were announced by the UN on Sept. 25th in 2015. Appendix B presents the explanations of these strings.

3.2 Natural Language Processing text classification

Processing social media data is challenging because it includes a huge amount of information that may be subjective and unorganized (Chan et al., 2016). NLP is "an interdisciplinary field composed of techniques and ideas from computer science, statistics, and linguistics for enabling computers to parse, understand, store, and convey information in human language " (Lee et al., 2018, p. 14). NLP is an appropriate method to use for this study (Chan et al., 2021; Cui et al., 2018). Firstly, AMT workers were asked to use our labels to artificially tag tweets (Lee et al., 2018). Then, this study consolidated AMT's results and created a training set. Based on the training set, we trained NLP classifiers through six techniques, including Decision Tree, k-nearest neighbors algorithm (kNN), Logistic Regression, Neural Network (NN), Naïve Bayes, and Random Forest. We used Orange 3.29 to run data pre-processing and NLP text classification. This study adopted stratified 10-fold cross validation to measure the performance of each classifier and used Area Under Receiver Operating Characteristic (ROC) Curve (AUC), Classification Accuracy (CA), and F1-Score (F1) as performance metrics (Lee et al., 2018). We compared the performance of different techniques according to the number of true samples they were able to identify. We decided to use the NN algorithm because its performance was stable, and it identified relatively more true samples. Considering that our dataset was small, we applied "L-BFGS-B" as a solver to make better NN classifiers.

3.2.1 Orange

We ran NLP on Orange software. Orange software is "a machine learning and data mining suite for data analysis through Python scripting and visual programming" (Demsar et al., 2013, p. 2349). Previous OM studies (Goerlandt et al., 2017; Perko, 2017) have conducted data mining and analysis on Orange software. For instance, Perko (2017) analyzed the probability of default issues on invoice levels and conducted short-term predictions with Orange software. Orange's interactive graphical user interface makes big data analytics easier since scholars can create the workflow of data analysis by combining the widgets (Angeli et al., 2020). The widgets cover several steps for data analysis, such as simple data visualization, data pre-processing, machine learning, text mining, predictive modeling, and model evaluation (Naik & Samant, 2016). We improved our workflow based on the workflow for text classification on Orange's official website[25].

3.2.2 Data pre-processing

The language on social media sites differs from that in mainstream media and often includes words not found in the dictionary (Nagarajan & Gandhi, 2019). A tweet, as unstructured data, can contain up to 280 words, along with videos, images, and hyperlinks (Colditz et al., 2018). Pre-processing aims to remove the non-informative noise and make us focus on the underlying text classification task only, which is the most crucial stage of preparing the high-quality text. We ran data pre-processing on the Orange software. According to the tutorial for text classification on Orange26, data pre-processing is divided into three most common steps, including case transformation, tokenization, and removing stop-word (Hartmann et al., 2019). First, the tweets' text is transformed into a unified instance to reduce the complexity of the dataset (Zhañay et al., 2019). Therefore, all uppercase letters are converted into lowercase. Second, we applied Regexp (default) for tokenization. Tokenization is the method of breaking sentences into words. Finally, we filtered the stopwords.

3.2.3 Training set

The amount of available training data is relevant in that it affects predictive accuracy, which requires human coding (Hartmann et al., 2019). Regarding our training set, we combined a keyword-guided approach with random selection to choose the tweets for AMT to label. Therefore, we adopted a two-step construction for the training set since machine learning techniques could have drawbacks in the context of training, relevancy, and timeliness of the data (Chau et al., 2020). First, classification performance will be affected by bias in the training set since NLP is entirely data-driven (Chau et al., 2020). Second, NLP sometimes cannot understand the actual meaning of context since it ignores expert judgment and experience, and sentence-level writing (Chau et al., 2020). Third, using a generic NLP model may not provide

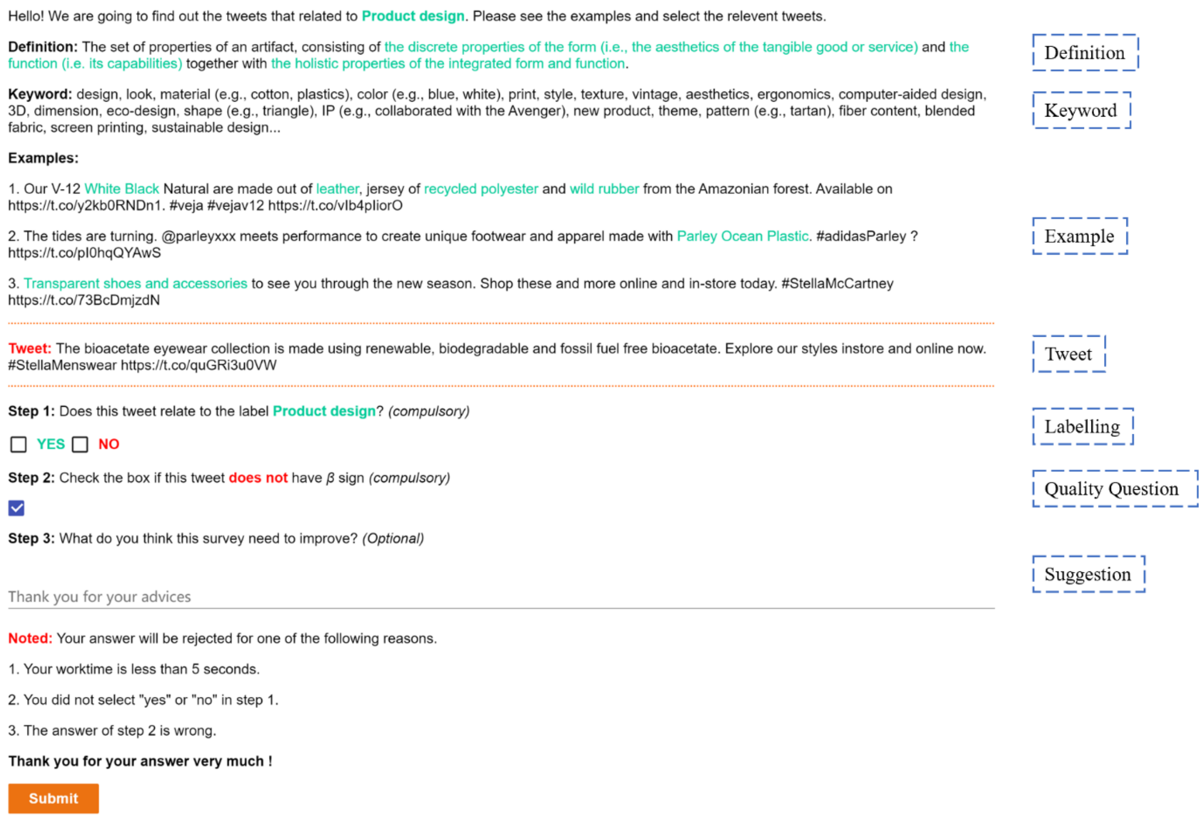
[25] https://orangedatamining.com/workflows/

[26] https://orangedatamining.com/workflows/

the expected accuracy as it was developed a long time ago. People's language use and their perceptions of issues evolve over time. To solve these problems, we adopt a rule-based classification method (e.g., pre-annotation), that is, having experts participate in the formulation of some of these rules (Chau et al., 2020). In addition, the pre-annotation of documents using the rule-based model can accelerate the training process of the NLP model (Georgescu, 2020). Previous studies (Liu et al., 2013; Mudinas et al., 2012) have tried to use dictionary-based classification to annotate the training set for the NLP model. Therefore, in Step 1, based on the OM/SDG literature, we developed a keyword list (see appendix) to search the tweets that have the potential labels, which can provide direction for the AMT coders. Each author, having expertise in OM and sustainability literature, had read and approved the keyword list. We only selected the keywords agreed upon by all authors. Thus, the inter-coder reliability of the keyword list is 100%. The tweets with relevant keywords were seen as candidate tweets while the tweets without any keywords were seen as ordinary tweets. Then, we randomly extracted 10% of the candidate tweets selected by keywords for AMT to label initially. To avoid missing the OM/SDG tweets that carry keywords outside of our predefined list, we instructed AMT coders to label another random 10% of ordinary tweets. This additional step fills the knowledge gap between the academic literature and the latest developments in public understanding of the topics.

AMT is a crowdsourcing marketplace for simple tasks such as text analysis, image identification, and data collection (Lee et al., 2018). In AMT, there are two roles, workers and requesters. Requesters publish the Human Intelligence Tasks (HITs) (e.g., text labeling) on AMT while workers complete HITs to earn profit (Kees et al., 2017). AMT can help scholars conveniently obtain sample data from demographically and geographically diverse (or specific), dispersed, nonstudent participants (Sheehan & Pittman, 2016). Many mainstream studies have successfully applied AMT in data coding (Lee et al., 2018). For example, Lee et al. (2018) used AMT to develop training sets for NLP processing to understand emotions on social media, and we closely followed their steps in this study.

We created a survey for AMT to use to tag the tweets (Figure 2). There are seven parts in the survey. Workers can view the tweets in the Tweet part. In this part, tweet will automatically change to the next one upon completion. Other parts (e.g., Definition, Keyword, Example) will remain unchanged until workers finish labelling all tweets. It was noted that the AMT system could not accept a text with certain signs (e.g., ‘, ’, —). In our data, the sign ’ is usually used in abbreviations (e.g., we've) and subordination relationships (e.g., Tom's). Before uploading the survey to AMT, we removed "'s" when the sign expressed a subordination relationship, while we changed to full type when the sign was used in an abbreviation. We removed other signs when they were rejected by AMT. To construct a reliable survey, we conducted a pilot test by publishing 500 HITs. Thirteen workers participated in the pilot study. One worker suggested that we add the definition of the label into the survey. Then, we started to recruit AMT workers in May 2021. We needed to employ some mechanisms to ensure the accuracy of workers' responses (Yzaguirre et al., 2015). We ensured the accuracy of coding by requesting that five workers evaluate each tweet, and each worker must have completed at least 100 previous AMT tasks with at least a 95% approval rating (Lee et al., 2018; Yzaguirre et al., 2015). To ensure that participants were proficient in English, we only considered American workers. The final label of the tweets was determined by more than half of the answers (i.e., the answers agreed on by at least three people) (Lee et al., 2018).


Hello! We are going to find out the tweets that related to **Product design**. Please see the examples and select the relevent tweets.

Definition: The set of properties of an artifact, consisting of the discrete properties of the form (i.e., the aesthetics of the tangible good or service) and the function (i.e. its capabilities) together with the holistic properties of the integrated form and function.

Keyword: design, look, material (e.g., cotton, plastics), color (e.g., blue, white), print, style, texture, vintage, aesthetics, ergonomics, computer-aided design, 3D, dimension, eco-design, shape (e.g., triangle), IP (e.g., collaborated with the Avenger), new product, theme, pattern (e.g., tartan), fiber content, blended fabric, screen printing, sustainable design...

Examples:

1. Our V-12 White Black Natural are made out of leather, jersey of recycled polyester and wild rubber from the Amazonian forest. Available on https://t.co/y2kb0RNDn1. #veja #vejav12 https://t.co/vlb4pliorO

2. The tides are turning. @parleyxxx meets performance to create unique footwear and apparel made with Parley Ocean Plastic. #adidasParley ? https://t.co/pl0hqQYAwS

3. Transparent shoes and accessories to see you through the new season. Shop these and more online and in-store today. #StellaMcCartney https://t.co/73BcDmjzdN

Tweet: The bioacetate eyewear collection is made using renewable, biodegradable and fossil fuel free bioacetate. Explore our styles instore and online now. #StellaMenswear https://t.co/quGRi3u0VW

Step 1: Does this tweet relate to the label **Product design**? *(compulsory)*

☐ YES ☐ NO

Step 2: Check the box if this tweet **does not** have β sign *(compulsory)*

☑

Step 3: What do you think this survey need to improve? *(Optional)*

Thank you for your advices

Noted: Your answer will be rejected for one of the following reasons.

1. Your worktime is less than 5 seconds.
2. You did not select "yes" or "no" in step 1.
3. The answer of step 2 is wrong.

Thank you for your answer very much !

Submit

Figure 2. The survey for AMT (The example of the Design label).

We took several steps (i.e., attention checks, speeding traps) to mitigate the risks of validity. We added two attention-checking actions. Firstly, we asked workers if there was a β sign in the tweet. Secondly, we checked if workers selected both Yes and No or neither selected Yes nor No. If the complete time period in HIT was less than 5 seconds, this HIT might have been completed by an automatic program (i.e., bots) (Lee et al., 2018). Then, we removed and re-published this HIT. The above measures ensured the accuracy and fairness of the coding process. We believe these measures created a balance between the accuracy of the coding and the number of samples we were able to collect for investigation.

The NLP engine was trained by the set created by AMT. Our NLP is a single-label classifier. Thus, we needed to train 21 NLP classifiers. The training set for each label was different since the number of each label's tweets was different. In addition, Orange did not allow us to run a stratified 10-fold cross validation if the number of true samples was less than 10. In this case, we needed to extract 20% more (10% candidate tweets + 10% ordinary tweets). Finally, the scale of each label's training set is shown in Table 3.

Table 3. The scale of each label's training set

Label	Total	True sample (%)		False sample (%)		Remarks
Design	1900	881	(46.37%)	1019	(53.63%)	
Production	200	53	(26.50%)	147	(73.50%)	
Sourcing	200	43	(21.50%)	157	(78.50%)	
3R	200	93	(46.50%)	107	(53.50%)	
SDG 1	200	27	(13.50%)	173	(86.50%)	
SDG 2	200	46	(23.00%)	154	(77.00%)	
SDG 3	200	74	(37.00%)	126	(63.00%)	
SDG 4	200	17	(8.50%)	183	(91.50%)	
SDG 5	200	42	(21.00%)	158	(79.00%)	
SDG 6	144	20	(13.89%)	124	(86.11%)	Only 72 candidate tweets, so the number of ordinary tweets is also 72. Total 144.
SDG 7	400	27	(6.75%)	373	(93.25%)	Only six true samples were in the first training set. We added 200more tweets to run the second time. This is the final training set.
SDG 8	400	28	(7.00%)	372	(93.00%)	Only five true samples were in the first training set. We added 200more tweets to run the second time. This is the final training set.
SDG 9	200	97	(48.50%)	103	(51.50%)	
SDG 10	200	47	(23.50%)	153	(76.50%)	
SDG 11	320	35	(10.94%)	285	(89.06%)	
SDG 12	200	49	(24.50%)	151	(75.50%)	
SDG 13	330	11	(3.33%)	319	(96.67%)	

SDG 14	528	13	(2.46%)	515	(97.54%)	Only seven true samples were in the first training set. We added 200 more tweets to run the second time. This is the final training set.
SDG 15	200	32	(16.00%)	168	(84.00%)	
SDG 16	320	12	(3.75%)	308	(96.25%)	
SDG 17	200	12	(6.00%)	188	(94.00%)	

To test the accuracy of the NLP, this study processed a 10-fold cross validation using Orange software (Mohasseb et al., 2019). For the performance of each label's classifier, we considered both its AUC, precision, recall, CA, and F1 (Dutta et al., 2020; Lee et al., 2018; Ma & Lejeune, 2020; Turabieh et al., 2019). Regarding these criteria, we first considered AUC since the change in data distributions did not affect AUC (Turabieh et al., 2019). In other words, AUC will not change when the ratio of positive cases to negative cases changes in the dataset (Turabieh et al., 2019). In addition, Ma and Lejeune (2020) indicated that AUC would be a good performance metric when the distribution of labels is highly unbalanced. We preliminarily observed that the distribution of the samples with Label 1 was much smaller than that of the samples with Label 0 in Table 3. Thus, we used AUC as the first performance metric of the classifiers. Orange software defines AUC as "the area under the receiver-operating curve."[27] We only selected the classifier whose AUC value was larger than 0.5 since the classifier cannot provide useful information when its AUC is less than 0.5 (Fawcett, 2006). On the contrary, the closer the AUC is to 1, the better the classifier's performance (Clements et al., 2020). CA is defined as "the sum of all correct predictions on the hold-out test set divided by the sum of all predictions" (Hartmann et al., 2019), p.27).

$$CA = \frac{TP + TN}{TP + TN + FP + FN}$$

Where TP means "Correctly predicted positive values where actual and predictive values are both Yes" (Turabieh et al., 2019, p.35), TN means "Correctly predicted negative values where actual and predictive values are both No" (Turabieh et al., 2019, p.35). FP means "When actual class is No and predicted class is Yes" (Turabieh et al., 2019, p.35). FN means "When actual class is Yes but predicted class in No" (Turabieh et al., 2019, p.35). F1 is a weighted harmonic mean of precision and recall.[28]

$$F1 = \frac{2TP}{2TP + FP + FN}$$

[27] https://orangedatamining.com/widget-catalog/evaluate/testandscore/

[28] https://orangedatamining.com/widget-catalog/evaluate/testandscore/

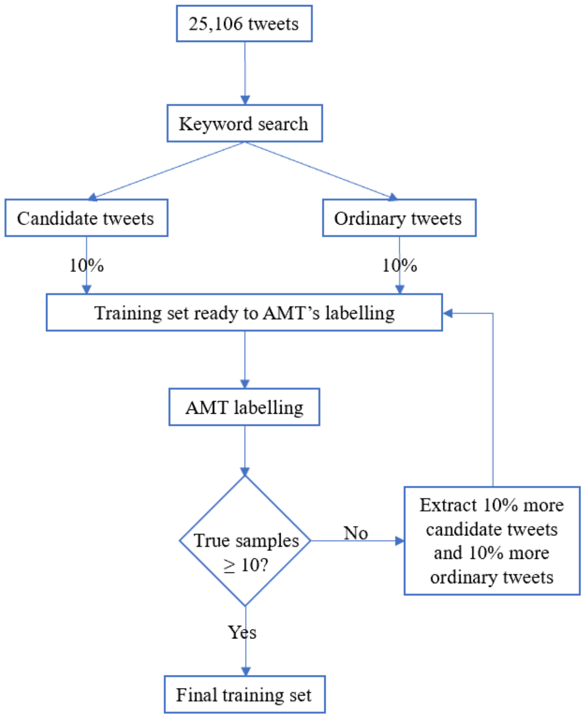


Figure 3. The process of creating the training set

3.2.4 Bag of Words

We ran Bag of Words (BoW) to calculate word frequency. BoW is an effective method to represent documents with a fixed-length numerical vector (Modha et al., 2020; Zhao & Mao, 2018). "The BoW model assigns a vector to a document as $d = (x_1, x_2, \ldots, x_l)$, where x_i denotes the normalized number of occurrences of the ith basis term and l is the size of the collection of basis terms" (Zhao & Mao, 2018), p.794). Basic terms are high-frequency words in the corpus (Zhao & Mao, 2018). The vocabulary size is larger than the number of basic terms and the dimensionality of BoW vectors.

3.2.5 Natural Language Processing

Our study aimed to maximize the text classifiers' accuracy. Therefore, we thoroughly tested all available methods to determine the best solution (Hartmann et al., 2019). At first, we tried six text classification methods, including DT, kNN, RF, NN, NB, and LR. We decided to use NN. Further, we improved the classifiers' performance by using "LBFGS" as the solver in the NN algorithm.

3.2.5.1 Comparison between different algorithms

All text classification methods used default parameters in Orange software. Since the input data was sparse, we could not run the Support Vector Machine for NLP on Orange software. Finally, we compared all classifiers' performance and decided to use NN as the text classification method, which is a more versatile method with the best performance in most social media analysis cases (Hartmann et al., 2019).

kNN "ranks the nearest neighbors of the labeled examples from the training set and uses the categories of the highest-ranked neighbors to derive a class assignment" (Hartmann et al., 2019), p. 23). The number of near neighbors in the same category has a positive effect on the confidence in that prediction (Hartmann et al., 2019; Yang & Liu, 1999). In our kNN classifiers, the number of neighbors is five. We selected Euclidean as the metric and chose Uniform as the weight.

RF is an integrated learning method that can generate a large number of random and irrelevant decision trees (Hartmann et al., 2019). Each decision tree votes on the collection of the test samples, and the most popular class determines the final prediction of the RF classifier (Hartmann et al., 2019). In our RF classifiers, the number of trees was 10. We made sure our RF classifiers did not split subsets smaller than five.

NN is the most parameterized method (Hartmann et al., 2019). NN consists of multiple interconnected nodes, usually layered (Hang & Banks, 2019). Each node in the hidden and output layers transforms the input by

$$f_i(x_i) = \sigma(x_i\beta_i + \alpha_i)$$

where x_i is the input of the ith node, β_i and α_i are the parameters of that node, and $\sigma(\cdot)$ is called the activation function.

Because of its flexible and universal structure, NN can perform well in different classification tasks, which is suitable for dealing with noisy social media data (Hartmann et al., 2019). In our NN classifiers, the neuron in the hidden layers is set up (100). Activation is "ReLu" while the solver is "Adam" (Kingma & Ba, 2014). Regularization α equals 0.0001. We limit the maximum number of iterations to 200. We allow replicable training.

DT is "a non-parametric supervised learning method used for classification and regression."[29] DT creates a prediction model by learning simple decision rules inferred from data characteristics to predict target variables.[30] A tree is considered as "a piecewise constant approximation."[31] In our DT classifiers, we chose to induce a binary tree. The minimum number of instances in the leaves was two. The classifiers did not split subsets smaller than five. The maximal tree depth is 100. The classification will stop if the majority reaches 95%.

Based on the Bayes Rule, the NB text classifier determines the probability that a tweet B is of label A_i by looking at the frequencies of words in the tweet (Fan et al., 2017). Suppose there are n labels A_0 to $A_{(n-1)}$. Determining which category a tweet B is mostly associated with means calculating the probability that tweet B is in the label A_i, written $P(A_i|B)$ for each label A_i. Then we can calculate $P(A_i|B)$ by computing:

$$P(A_i|B) = \frac{\left(P(B|A_i) * P(A_i)\right)}{P(B)} \qquad (1)$$

$P(A_i|B)$ is the probability that tweet B is in the label A_i; that is, the probability that given the set of words in B, they appear in the label A_i. $P(B|A_i)$ is the probability that for a given label A_i, the words in B appear in that label. $P(A_i)$ is the probability of a given label; that is, the probability of a tweet being in the label A_i without considering its content. $P(B)$ is the probability of the occurrence of that particular tweet. The classifier thus can predict the meaning of a sentence based on the above probability.

LR models the probability of some events as a linear function of a set of predictive variables, which is seen as a linear classification algorithm (Onan et al., 2016). In our LR classifiers, the regularization type is "Ridge (L2)." The cost strength is equal to 1. Balance class distribution is not necessary.

[29] https://scikit-learn.org/stable/modules/tree.html

[30] https://scikit-learn.org/stable/modules/tree.html

[31] https://scikit-learn.org/stable/modules/tree.html

Table 4. Different NLP techniques' performance

Label	Performance Metric	kNN	DT	RF	NN	NB	LR
Design	AUC	0.624	0.712	0.807	0.806	0.848	0.831
	CA	0.556	0.695	0.722	0.734	0.778	0.752
	F1	0.430	0.691	0.715	0.733	0.777	0.749
	Precision	0.646	0.697	0.731	0.734	0.778	0.753
	Recall	0.556	0.695	0.722	0.734	0.778	0.752
Production	AUC	0.680	0.768	0.854	0.800	0.880	0.889
	CA	0.770	0.815	0.800	0.840	0.795	0.820
	F1	0.697	0.808	0.770	0.826	0.803	0.796
	Precision	0.825	0.806	0.797	0.837	0.826	0.823
	Recall	0.770	0.815	0.800	0.840	0.795	0.820
Sourcing	AUC	0.550	0.645	0.656	0.674	0.777	0.738
	CA	0.785	0.800	0.800	0.810	0.800	0.805
	F1	0.690	0.768	0.724	0.757	0.803	0.735
	Precision	0.616	0.771	0.841	0.804	0.807	0.844
	Recall	0.785	0.800	0.800	0.810	0.800	0.805
Recycle	AUC	0.814	0.940	0.981	0.974	0.989	0.988
	CA	0.615	0.935	0.890	0.930	0.950	0.935
	F1	0.530	0.935	0.888	0.930	0.950	0.935
	Precision	0.776	0.938	0.905	0.932	0.950	0.940
	Recall	0.615	0.935	0.890	0.930	0.950	0.935
SDG1	AUC	0.722	0.897	0.927	0.876	0.891	0.959
	CA	0.910	0.955	0.905	0.925	0.750	0.925
	F1	0.890	0.952	0.882	0.912	0.787	0.912
	Precision	0.918	0.955	0.914	0.931	0.877	0.931
	Recall	0.910	0.955	0.905	0.925	0.750	0.925
SDG2	AUC	0.862	0.868	0.985	0.966	0.978	0.989
	CA	0.850	0.955	0.925	0.920	0.705	0.950
	F1	0.826	0.924	0.921	0.919	0.728	0.949
	Precision	0.857	0.955	0.926	0.918	0.871	0.950

	Recall	0.850	0.955	0.925	0.920	0.705	0.950
SDG3	AUC	0.747	0.801	0.880	0.918	0.940	0.904
	CA	0.705	0.815	0.740	0.860	0.760	0.815
	F1	0.663	0.807	0.695	0.855	0.762	0.805
	Precision	0.719	0.820	0.802	0.866	0.840	0.825
	Recall	0.705	0.815	0.740	0.860	0.760	0.815
SDG4	AUC	0.482	0.715	0.749	0.646	0.823	0.804
	CA	0.915	0.960	0.920	0.915	0.510	0.920
	F1	0.874	0.954	0.886	0.890	0.605	0.886
	Precision	0.837	0.962	0.926	0.887	0.906	0.926
	Recall	0.915	0.960	0.920	0.915	0.510	0.920
SDG5	AUC	0.619	0.704	0.825	0.821	0.824	0.846
	CA	0.820	0.800	0.795	0.825	0.705	0.840
	F1	0.762	0.787	0.717	0.801	0.732	0.802
	Precision	0.853	0.781	0.770	0.806	0.826	0.852
	Recall	0.820	0.800	0.795	0.825	0.705	0.840
SDG6	AUC	0.625	0.750	0.913	0.927	0.895	0.974
	CA	0.868	0.938	0.882	0.924	0.840	0.903
	F1	0.813	0.932	0.842	0.911	0.857	0.879
	Precision	0.886	0.937	0.896	0.930	0.893	0.913
	Recall	0.868	0.938	0.882	0.924	0.840	0.903
SDG7	AUC	0.559	0.567	0.737	0.682	0.765	0.804
	CA	0.932	0.945	0.930	0.932	0.300	0.932
	F1	0.900	0.930	0.903	0.908	0.391	0.900
	Precision	0.870	0.941	0.894	0.907	0.901	0.870
	Recall	0.932	0.945	0.930	0.932	0.300	0.932
SDG8	AUC	0.542	0.535	0.635	0.547	0.636	0.666
	CA	0.930	0.927	0.930	0.930	0.250	0.930
	F1	0.896	0.907	0.896	0.896	0.322	0.896
	Precision	0.865	0.901	0.865	0.865	0.889	0.865
	Recall	0.930	0.927	0.930	0.930	0.250	0.930
SDG9	AUC	0.775	0.887	0.932	0.836	0.920	0.952
	CA	0.545	0.860	0.790	0.760	0.760	0.860

	F1	0.414	0.860	0.783	0.760	0.748	0.859
	Precision	0.758	0.862	0.826	0.760	0.808	0.869
	Recall	0.545	0.860	0.790	0.760	0.760	0.860
SDG10	AUC	0.581	0.645	0.654	0.585	0.575	0.616
	CA	0.740	0.795	0.790	0.785	0.550	0.795
	F1	0.700	0.769	0.718	0.727	0.584	0.728
	Precision	0.688	0.773	0.835	0.768	0.671	0.838
	Recall	0.740	0.795	0.790	0.785	0.550	0.795
SDG11	AUC	0.492	0.513	0.588	0.610	0.584	0.561
	CA	0.891	0.884	0.894	0.894	0.469	0.897
	F1	0.839	0.851	0.847	0.857	0.557	0.854
	Precision	0.793	0.840	0.905	0.866	0.828	0.908
	Recall	0.891	0.884	0.894	0.894	0.469	0.897
SDG12	AUC	0.610	0.789	0.866	0.856	0.918	0.910
	CA	0.755	0.870	0.825	0.850	0.875	0.835
	F1	0.650	0.861	0.785	0.831	0.874	0.801
	Precision	0.570	0.868	0.858	0.854	0.873	0.865
	Recall	0.755	0.870	0.825	0.850	0.875	0.835
SDG13	AUC	0.500	0.458	0.676	0.704	0.526	0.653
	CA	0.967	0.967	0.967	0.967	0.085	0.967
	F1	0.950	0.950	0.950	0.950	0.105	0.950
	Precision	0.934	0.934	0.934	0.934	0.917	0.934
	Recall	0.967	0.967	0.967	0.967	0.085	0.967
SDG14	AUC	0.538	0.417	0.782	0.787	0.764	0.929
	CA	0.975	0.975	0.975	0.975	0.214	0.975
	F1	0.963	0.963	0.963	0.963	0.321	0.963
	Precision	0.951	0.951	0.951	0.951	0.967	0.951
	Recall	0.975	0.975	0.975	0.975	0.214	0.975
SDG15	AUC	0.658	0.710	0.859	0.860	0.890	0.896
	CA	0.840	0.890	0.845	0.905	0.775	0.855
	F1	0.767	0.871	0.779	0.887	0.802	0.801
	Precision	0.706	0.887	0.869	0.915	0.873	0.876
	Recall	0.840	0.890	0.845	0.905	0.775	0.855

SDG16	AUC	0.664	0.431	0.731	0.746	0.726	0.774
	CA	0.963	0.963	0.966	0.969	0.156	0.966
	F1	0.944	0.944	0.951	0.958	0.214	0.951
	Precision	0.926	0.926	0.967	0.970	0.964	0.967
	Recall	0.963	0.963	0.966	0.969	0.156	0.966
SDG17	AUC	0.497	0.602	0.738	0.458	0.856	0.777
	CA	0.940	0.940	0.940	0.940	0.765	0.940
	F1	0.911	0.911	0.911	0.911	0.825	0.911
	Precision	0.884	0.884	0.884	0.884	0.938	0.884
	Recall	0.940	0.940	0.940	0.940	0.765	0.940

3.2.5.2 Improvements in Neural Network

For small datasets, Scikit-learn suggests using "LBFGS" as a solver which can converge faster and perform better32. Therefore, we processed the Neural Network with the "L-BFGS-B" solver again (Figure 5) and compared this performance with the previous ("Adam" Solver). We found that most labels' classifiers had higher performance when we used "L-BFGS-B" as a solver (Table 3). However, the performance of the classifiers SDG 3, 11, and 13 became lower. Therefore, we used the Neural Network with the "Adam" solver for the classification of SDG 3, 11, and 13. The results of our classifier are satisfactory because they are greatly larger than 60% (Chan et al., 2021).

Table 5. The comparison of the performance of the Neural Network with the "Adam" solver and the Neural Network with the "L-BFGS-B" solver

Label	Performance Metric	Solver="Adam"	Solver="L-BFGS-B"
Design	AUC	0.806	0.818
	CA	0.734	0.744
	F1	0.733	0.744
	Precision	0.734	0.744
	Recall	0.734	0.744
Production	AUC	0.800	0.884
	CA	0.840	0.840

32https://scikit-learn.org/stable/modules/generated/sklearn.neural_network.MLPClassifier.html

	F1	0.826	0.833
	Precision	0.837	0.834
	Recall	0.840	0.840
Sourcing	AUC	0.674	0.748
	CA	0.810	0.830
	F1	0.757	0.800
	Precision	0.804	0.821
	Recall	0.810	0.830
Recycle	AUC	0.974	0.990
	CA	0.930	0.930
	F1	0.930	0.930
	Precision	0.932	0.930
	Recall	0.930	0.930
SDG1	AUC	0.876	0.951
	CA	0.925	0.950
	F1	0.912	0.946
	Precision	0.931	0.950
	Recall	0.925	0.950
SDG2	AUC	0.966	0.988
	CA	0.920	0.975
	F1	0.919	0.975
	Precision	0.918	0.975
	Recall	0.920	0.975
SDG3	AUC	0.918	0.904
	CA	0.860	0.840
	F1	0.855	0.833
	Precision	0.866	0.847
	Recall	0.860	0.840
SDG4	AUC	0.646	0.811
	CA	0.915	0.910
	F1	0.890	0.887
	Precision	0.887	0.879
	Recall	0.915	0.910

SDG5	AUC	0.821	0.851
	CA	0.825	0.875
	F1	0.801	0.868
	Precision	0.806	0.868
	Recall	0.825	0.875
SDG6	AUC	0.927	0.965
	CA	0.924	0.951
	F1	0.911	0.947
	Precision	0.930	0.954
	Recall	0.924	0.951
SDG7	AUC	0.682	0.786
	CA	0.932	0.925
	F1	0.908	0.907
	Precision	0.907	0.898
	Recall	0.932	0.925
SDG8	AUC	0.547	0.674
	CA	0.930	0.930
	F1	0.896	0.901
	Precision	0.865	0.902
	Recall	0.930	0.930
SDG9	AUC	0.836	0.954
	CA	0.760	0.885
	F1	0.760	0.885
	Precision	0.760	0.888
	Recall	0.760	0.885
SDG10	AUC	0.585	0.640
	CA	0.785	0.790
	F1	0.727	0.765
	Precision	0.768	0.766
	Recall	0.785	0.790
SDG11	AUC	0.610	0.608
	CA	0.894	0.887
	F1	0.857	0.857

	Precision	0.866	0.850
	Recall	0.894	0.887
SDG12	AUC	0.856	0.918
	CA	0.850	0.885
	F1	0.831	0.877
	Precision	0.854	0.885
	Recall	0.850	0.885
SDG13	AUC	0.704	0.692
	CA	0.967	0.967
	F1	0.950	0.950
	Precision	0.934	0.934
	Recall	0.967	0.967
SDG14	AUC	0.787	0.946
	CA	0.975	0.985
	F1	0.963	0.982
	Precision	0.951	0.985
	Recall	0.975	0.985
SDG15	AUC	0.860	0.888
	CA	0.905	0.900
	F1	0.887	0.883
	Precision	0.915	0.903
	Recall	0.905	0.900
SDG16	AUC	0.746	0.791
	CA	0.969	0.975
	F1	0.958	0.973
	Precision	0.970	0.972
	Recall	0.969	0.975
SDG17	AUC	0.458	0.700
	CA	0.940	0.935
	F1	0.911	0.908
	Precision	0.884	0.883
	Recall	0.940	0.935

3.3 Data analysis

We adopted descriptive analysis and linear regression as analysis methods. We used the number of likes as the measure of stakeholder engagement on Twitter because giving likes shows people's recognition of a tweet (Kim & Yang, 2017). We ran a regression analysis with a common logarithm of the number of likes "Lg (Like)" as the dependent variable to mitigate distributional violations and account for the tweets with abnormal numbers of likes (Kanuri et al., 2018). Since Lg (x) requires $x > 0$, we need to adjust the zero value in the number of likes (Kanuri et al., 2018). To adjust the number of likes, we added one to every number since normal distribution does not change when the variable contains a constant.[33] This study also includes several control variables to account for the heterogeneity at the content and environmental levels (Kanuri et al., 2018). First, "Text Length" is used to control for content features that may affect stakeholders' perceptions. Second, we also used "Lg (Retweet)" to control for the effect of retweeting. Third, We used "hashtag" to control the effects of other signals of social media because hashtag represents some popular topics that can influence the communication. Fourth, we used "brand dummies" to control for the effect of brand reputation on social media while we used "year dummies" to control for the yearly economic effects on social media. Final, we used Total assets (million USD) to control the firm size (Saxton et al., 2019).

33 https://blogs.sas.com/content/iml/2011/04/27/log-transformations-how-to-handle-negative-data-values.html

Table 6. Variables

Variables	Explanation
Dependent Variables	
Lg (Like)	Lg of the total adjusted amount of likes on a post
Independent Variables	
SDG	The number of SDGs achieved in a post
Design	A post mentioned content in the field of product design
Design × SDG	A post mentioned product design that met SDG(s)
Manufacturing	A post mentioned content in the field of manufacturing
Manufacturing × SDG	A post mentioned manufacturing that met SDG(s)
Recycling	A post mentioned content in the field of recycling
Recycling × SDG	A post mentioned recycling that met SDG(s)
Control variables	
Lg (Retweet)	Lg of total adjusted number of shared posts
Text Length	Number of words in a post
Total Asset (million USD)	Total asset
Hashtag	Whether the post had hashtag(s) or not
Brand Dummies	Distinguished different brands' posts
Year Dummies	Distinguished posts from different years

4. Findings

4.1 Descriptive analysis

Among 25,106 tweets, Michael Kors accounted for the largest proportion (9.84%) with 2,471 tweets, followed by Reebok (2,430 tweets, 9.68%). The lowest number of tweets was from Nike (126, 0.50%).

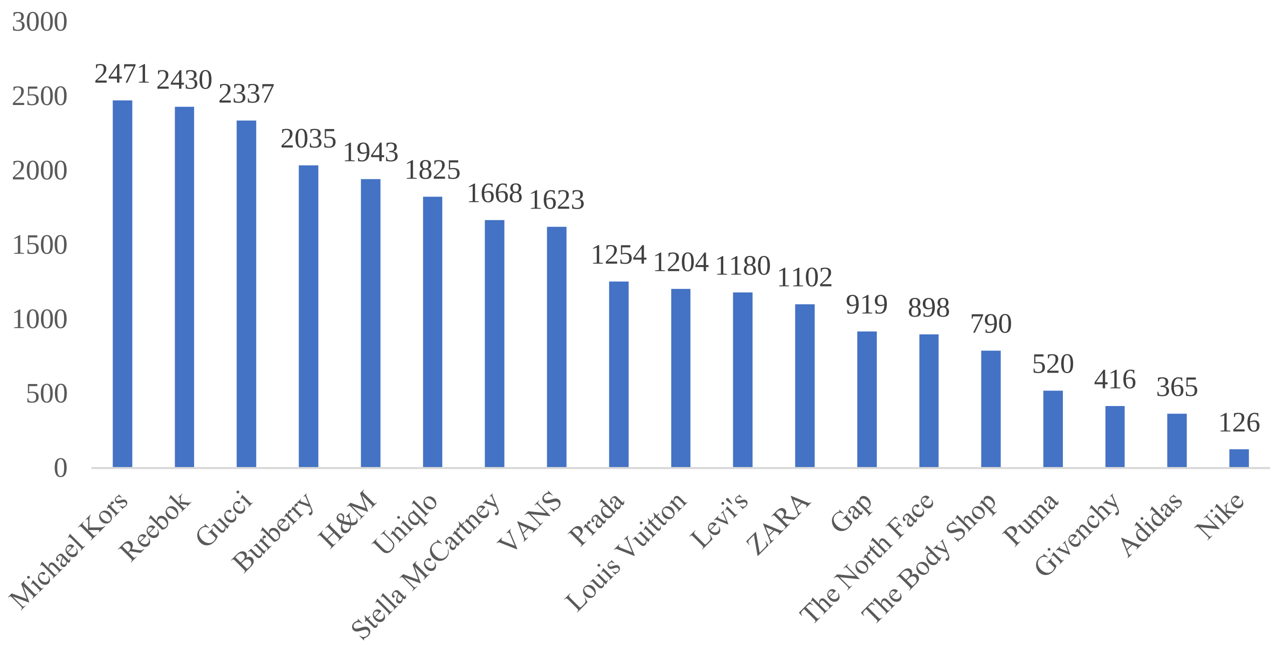


Figure 4. Tweet distribution by brand.

Figure 5 shows the distribution of tweets by the processes of OM and the proportion of SDGs in the tweets about each process of OM. Among 25,106 tweets, there were 10,788 tweets related to OM. Among the OM tweets, 8,760 (81.20%) focused on product design only, 229 (2.12%) mentioned manufacturing only, and 190 (1.76%) emphasized recycling only. 1,609 (14.91%) tweets mentioned multiple OM. Among the 8,760 tweets about product design, there were 1,367 tweets (15.61%) mentioning SDGs. Among the 229 tweets about manufacturing, there were 103 tweets (44.98%%) mentioning SDGs. Among the 190 tweets about recycling, there were 149 tweets (78.42%) mentioning SDGs. Among the 1,609 tweets about recycling, there were 898 tweets (55.81%) mentioning SDGs.

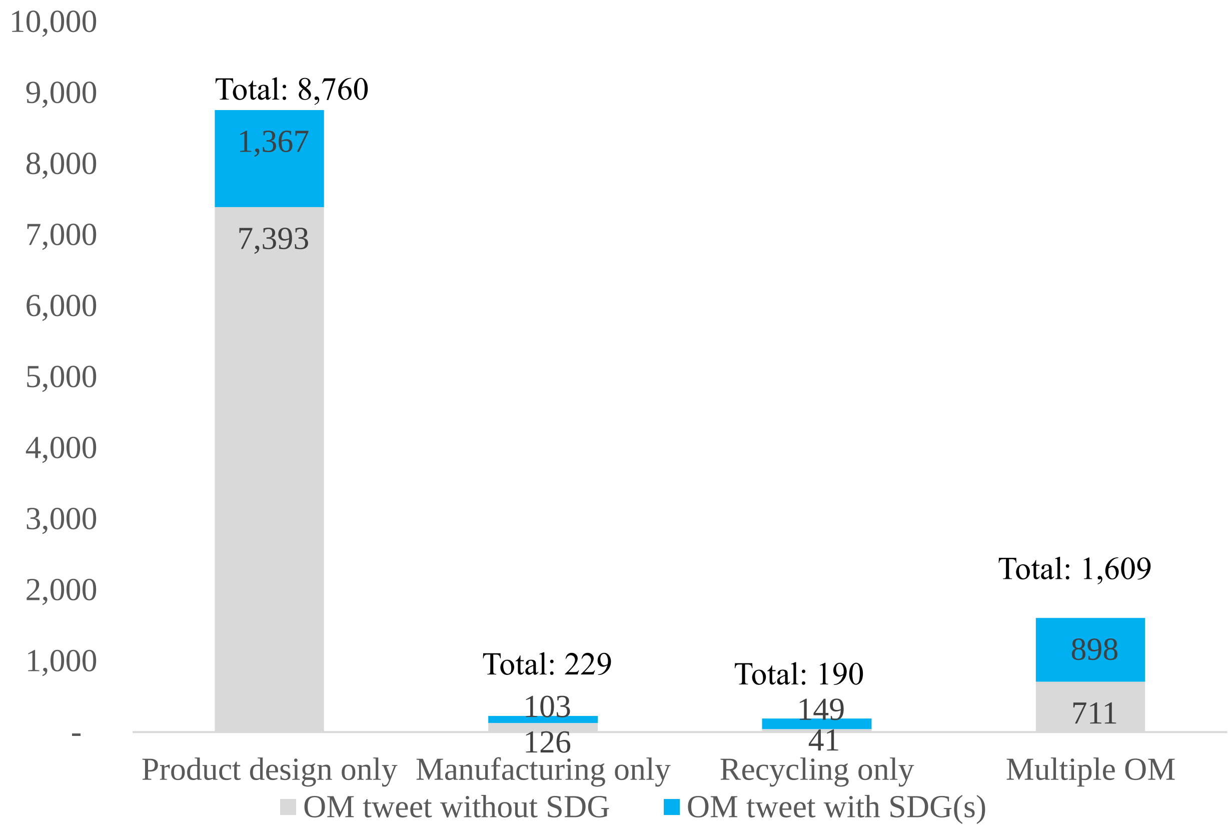


Figure 5. Tweet distribution by the processes of OM and the proportion of SDGs in the tweets about each process of OM

Table 7 displays the descriptive analysis of each category of OM. On average, most SDGs (1.984) were mentioned in a tweet only about recycling. In addition, it was noted that the average numbers of SDGs in the tweets only about manufacturing and recycling were higher than the overall average. The tweets only about manufacturing mentioned up to 10 SDGs/tweet. The tweets only about product design are up to 7 SDGs/tweet. The tweet only about recycling mentioned up to 8 SDGs/tweet. In addition, the tweets about multiple OM mentioned 0.930 SDGs/tweet averagely, which is slightly higher than the overall average. And its tweet mentioned up to 9 SDGs/tweet.

Table 7. Descriptive analysis of each category of OM

Category	The average number of SDGs	Minimum number of SDGs	Maximum number of SDGs
Product design only	0.197	0	7
Manufacturing only	0.664	0	10
Recycling only	1.984	0	8
Multiple OM	0.930	0	9
All posts (include Non-OM)	0.345	0	10

We calculate the number of SDGs in OM post with SDGs to find out which SDGs are mentioned most in each process of SOM. Table 8 indicates that the top 5 SDGS involved in sustainable product design, sustainable manufacturing, and recycling. Among the 1,367 tweets mentioning sustainable product design (i.e., product design contributed to SDGs), most tweets mentioned SG9. Industry, innovation and infrastructure (544, 39.80%), which implies that sustainable product design is related to innovation. Among the 103 tweets mentioning sustainable manufacturing, most tweets mentioned SDG3. Good health and well-being (37, 35.92%) since unsustainable manufacturing (e.g., discharging polluted water into reiver) may affect people's health. Among the149 tweets mentioning recycling, most tweets mentioned SDG12. Responsible consumption and production (95, 63.76%). Interestingly, SDG10. Reduced inequality, SDG3. Good health and well-being, and SDG12. Responsible consumption and production were highly mentioned in each OM category, which implied that stakeholders highlighted peoples' equality and health as well as recycling more in each SOM category.

Table 8. Top 5 SDGs involved in each part of SOM

OM	SDG	Number of tweets
Sustainable product design	SG9. Industry, innovation and infrastructure	544
	SDG10. Reduced inequality	527
	SDG3. Good health and well-being	262
	SDG12. Responsible consumption and production	169
	SDG2. Zero hunger	47
Sustainable manufacturing	SDG3. Good health and well-being	37
	SG9. Industry, innovation and infrastructure	33
	SDG12. Responsible consumption and production	32
	SDG10. Reduced inequality	23
	SDG5. Gender equality	6
Recycling	SDG12. Responsible consumption and production	95
	SDG15. Life on land	56
	SDG3. Good health and well-being	54
	SDG1. No poverty	33
	SDG10. Reduced inequality	24
Multiple OM	SDG12. Responsible consumption and production	584
	SG9. Industry, innovation and infrastructure	423
	SDG10. Reduced inequality	158
	SDG15. Life on land	115
	SDG3. Good health and well-being	54
All tweets (incl. Non-OM)	SDG3. Good health and well-being	2626
	SG9. Industry, innovation and infrastructure	1476
	SDG10. Reduced inequality	1327
	SDG12. Responsible consumption and production	1063
	SDG5. Gender equality	497

4.2 Linear regression

We ran multiple linear regression on SPSS 25.0 to test the hypotheses. Table 9 presents the descriptive statistics and correlations analysis. Table 10 displays the results of the regression analysis with "Lg (Like)" as the dependent variable. Model 1 shows the control variables. We found that Total Asset (.000, $p < .01$) had significantly positive effects on stakeholder engagement, which means that the larger the firm size, the higher the stakeholder engagement. In addition, retweeting (.822, $p < .01$) also had a significantly positive effect on stakeholder engagement. "Text Length" (-.000, $p < .01$), as the control variable, was significantly negative, which implies that people are more likely to engage with shorter tweets. The use of hashtags (-.016, $p < .01$) had significantly negative effects on stakeholder engagement.

Regarding the tweets about OM (Model 1), we found that manufacturing (-.020, $p < .1$) and recycling (-.061, $p < .01$) had significantly negative effects on stakeholder engagement. Product design had insignificantly positive effects on stakeholder engagement. However, referring to model 2, Design × SDG (.015, $p < .01$) had significantly positive effects on stakeholder engagement. The more sustainable the product design (i.e., achieving more SDGs), the higher the stakeholder engagement. In addition, Recycling × SDG (.014, $p < .05$) had significantly positive effects on stakeholder engagement. The more sustainable the recycling, the higher the stakeholder engagement. However, Manufacturing × SDG had insignificantly positive effects on stakeholder engagement. Therefore, H1 and H3 were supported, while H2 was rejected. Product design and recycling can achieve higher stakeholder engagement when they achieve more SDGs.

5. Robustness check

We conducted a robustness check to make sure the consistency of our results. We replaced "the number of SDGs" with "whether use SDG or not" to conduct a robustness check from a different perspective (Table 11). The results showed that Design × SDG (.025, $p < .01$) and Recycling × SDG (.075, $p < .01$) still had positive effects on stakeholder engagement, which implies that product design and recycling may achieve higher stakeholder engagement once they meet SDG(s). The results were consistent with the main results, which indicated that our results were robust. Further, according to the results from the main analysis, stakeholder engagement becomes higher when product design and recycling can achieve more SDGs.

Table 9. Descriptive statistics and correlations; $N = 25{,}106$

		Mean	Standard Deviation	1	2	3	4	5	6	7	8	9	10	11	12
1	Lg (Like)	2.069	.592												
2	SDG	.34	.734	-.092**											
3	Design	.35	.477	.097**	-.147**										
4	Design × SDG	.069	.315	.010	.348**	.298**									
5	Manufacturing	.01	.095	-.033**	.042**	-.070**	-.021**								
6	Manufacturing × SDG	.006	.117	-.013*	.136**	-.038**	-.011	.538**							
7	Recycling	.01	.087	-.022**	.195**	-.064**	-.019**	-.008	-.005						
8	Recycling × SDG	.015	.238	-.020**	.296**	-.046**	-.014*	-.006	-.003	.722**					
9	Lg (Retweet)	1.446	.60079	.922**	-.090**	.071**	-.010	-.036**	-.016**	-.014*	-.012*				
10	Text length	143.21	50.258	.058**	.214**	.089**	.133**	.076**	.057**	.070**	.074**	-.020**			
11	Total Asset (Million USD)	20624.966	24904.619	.204**	.060**	.059**	.076**	-.007	.003	.000	-.001	.184**	.184**		
12	Hashtag	.73	.443	.122**	-.010	.035**	.020**	-.010	-.006	.004	-.004	.128**	.119**	.060**	

Remark: **. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 10. Regression analysis with Lg (Like) as the dependent variable

	Dependent Variable: Lg (Like)								
	Model 0			Model 1			Model 2		
	Coefficient	*SE*	*p*	Coefficient	*SE*	*p*	Coefficient	*SE*	*p*
Constant	.888	.007	.000	.724	.007	.000	.727	.007	.000
SDG							-.009	.002	.000
Design				.001	.002	.627	-.003	.003	.245
Design × SDG							.015	.004	.000
Manufacturing				-.020	.012	.094	-.026	.014	.068
Manufacturing × SDG							.010	.011	.361
Recycling				-.061	.013	.000	-.077	.019	.000
Recycling × SDG							.014	.007	.040
Lg (Retweet)	.822	.003	.000	.822	.003	.000	.823	.003	.000
Text length	-.000	.000	.310	-.000	.000	.557	.000	.000	.865
Total Asset (Million USD)	.000	.000	.000	.000	.000	.000	.000	.000	.000
Hashtag	-.016	.003	.000	-.015	.003	.000	-.016	.003	.000
Brand Dummies	Included			Included			Included		
Year Dummies	Included			Included			Included		
F	9860.358			8849.099			7784.001		
R^2	.911			.911			.911		
Adjusted R^2	.911			.911			.911		
RMSE	.17686			.17679			.17671		
N	25016			25016			25016		

Remark: ** $p < .01$; * $p < .05$; ** $p < .01$

Table 11. Robustness check

	Dependent variable: Lg (Like)								
	Model 0			Model 1			Model 2		
	Coefficient	*SE*	*p*	Coefficient	*SE*	*p*	Coefficient	*SE*	*p*
Constant	.888	.007	.000	.724	.007	.000	.728	.007	.000
SDG							-.009	.003	.004
Design				.001	.002	.627	-.004	.003	.189
Design × SDG							.025	.006	.000
Manufacturing				-.020	.012	.094	-.018	.016	.265
Manufacturing × SDG							-.002	.024	.933
Recycling				-.061	.013	.000	-.115	.028	.000
Recycling × SDG							.075	.031	.017
Lg (Retweet)	.822	.003	.000	.822	.003	.000	.822	.003	.000
Text length	-.000	.000	.310	-.000	.000	.557	-.000	.000	.705
Total Asset (Million USD)	.000	.000	.000	.000	.000	.000	.000	.000	.000
Hashtag	-.016	.003	.000	-.015	.003	.000	-.016	.003	.000
Brand Dummies		Included			Included			Included	
Year Dummies		Included			Included			Included	
F		9860.358			8849.099			7782.701	
R^2		.911			.911			.911	
Adjusted R^2		.911			.911			.911	
RMSE		.17686			.17679			.17672	
N		25016			25016			25016	

Remark: ** $p < .01$; * $p < .05$; ** $p < .01$

6. Discussion

6.1 Summary of findings

According to descriptive analysis, SDG10. Reduced inequality, SDG3. Good health and well-being and SDG12. Responsible consumption and production were highly mentioned in each OM category. SDG9. Industry, innovation and infrastructure is the most commonly mentioned SDG for sustainable product design. Sustainable product designs usually relate to innovation such as new sustainable materials. For example, Adidas works with Parley to use marine waste plastics to create new sustainable materials for their shoes. SDG3. Good health and well-being is the most commonly mentioned SDG for sustainable manufacturing, which means that stakeholders highlighted the effects of manufacturing on people's health. Thus, firms need to pay attention to employee safety, conduct good waste management, and avoid illegal discharge in manufacturing. For example, firms should deal with polluted water with chemical dyes before drainage since polluted water may affect people's health. Patagonia dyes their new workwear denim products with natural indigo, which prevents chemical dyes from contaminating the water. In addition, it is not strange that SDG12. Responsible consumption and production is the most frequently mentioned SDG in recycling since recycling is the main step to achieving SDG12. Responsible consumption and production. Firms may develop more recycling activities for stakeholders.

By focusing on the social media environment, that is, the signal occurred in a noisier and more complex environment than in previous studies, we provide new insights for stakeholder engagement in SOM literature by explaining the different effects of signals (i.e., sustainable product design, sustainable manufacturing, recycling) for stakeholder engagement. This study finds that sustainable product design and recycling can generate stronger stakeholder engagement. However, sustainable manufacturing has insignificantly positive effects on stakeholder engagement. One reason is that fashion brands' marketing campaigns focus more on recycling (e.g., recycled clothes collection services) and product design (e.g., sustainable material used in clothes), which implies that they are closer to consumers than manufacturing. Stakeholders are used to taking action in the environmental aspects when they decide to pursue sustainability (Kagawa, 2007). Furthermore, stakeholders are more likely to discuss environmental concerns on social media, which strive to turn this concern into buying eco-friendly products (Hill & Lee, 2012; Young et al., 2010). On the other hand, the insignificantly positive effect of sustainable manufacturing might reflect that manufacturing is perceived to be distant from stakeholders' satisfaction, and the issues involved are often more controversial.

First, in order to save costs, firms are more willing to outsource production to some countries with low labor costs, especially in the fashion industry. A fashion firm may have a huge network of suppliers across various countries. Some suppliers may be in countries that lack environmental and social regulations (Golini & Gualandris, 2018). Even if the parent firm has developed the process for sustainable manufacturing, suppliers may not implement the process when the parent firm has weak control (Golini & Gualandris, 2018). Second, firms describe their sustainable manufacturing industry in a too boring and technical way, resulting in social media fatigue and low stakeholder participation (Elkbuli et al., 2021). Stakeholders may not understand technical words in firms' sustainable manufacturing. Thus, they are hard to engage in sustainable manufacturing.

6.2 Implications for research

Although a large extent of research has explored SOM, this study is the first to demonstrate stakeholder engagement in SOM through a data-driven approach. Firms need to listen to stakeholders and consider these data-driven insights into SOM practices when they decide which SOM practice could maximize the impact on the firms and their stakeholders. Especially in the current information age, stakeholders are easier to express their views on firms' SOM. Failure to engage stakeholders may cause unexpected resistance in the implementation of decisions and waste firms' resources. Thus, this study investigates the level of stakeholder engagement in different practices in SOM (i.e., sustainable product design, sustainable manufacturing, recycling) to help firms understand how to engage stakeholders. This study provides theoretical evidence for the importance of social media to the relationship between firms and their stakeholders (Etter et al., 2019). In addition, our findings can help firms communicate with stakeholders efficiently, contributing to the studies of the OM-Marketing interface.

We apply the perspective of signal theory to explicate how stakeholders engage in SOM on social media. Our findings indicate that sustainable product design and recycling are interpreted as an effective signal to engage stakeholders, which enriches the literature on signaling theory. Furthermore, we go beyond the binary problem of "whether there are SOM signals" and further introduce UN SDG to measure the strength of SOM signals. Then, we are the first to consider the level of stakeholder engagement on social media (i.e., the number of likes) as countersignals, which extend signaling theory. Countersignals are relatively rarely explored in the literature on signaling theory (Harris et al., 2021). The uniqueness of social media is that it allows presenting firms' signals and stakeholders' countersignals publicly. The social media signaling environment allows linking firms' signals with specific and quantifiable countersignals (i.e., the number of likes), thus allowing to measure stakeholder engagement. By doing so, social media has facilitated the examination of the effectiveness of signals, which cannot be achieved by other disclosure and reporting media (Harris et al., 2021). Thus, this study provides effective evidence that applies signaling theory in the social media environment.

Our data-driven approach is novel and contributive, which also advances social media analysis. We use UN SDGs to measure the level of sustainability in the OM processes, which provide insight into developing the criteria for SOM. We quantify stakeholder engagement with social media data, which makes the findings more objective and specific. In the NLP process, we apply a neural network algorithm to annotate social media, which is a new idea for training the NLP engine.

6.3 Implications for practice

From a practitioner perspective, analyzing the rich information about stakeholder engagement in social media data allows firms to better allocate resources and improve SOM efficiency (Huang et al., 2020). Therefore, our findings are helpful for enabling firms to make correct decisions on how to engage stakeholders in SOM. Firms can explore their stakeholders via social media and investigate their preferences for SDGs using our proposed data-driven approach. Our findings also indicate that fashion firms play an important role in the supply chain and can fully interact with stakeholders on social media. Moreover, firms should enhance the integration between the OM department and the marketing department so that the social media team can quickly and accurately coordinate with the OM team when communicating SOM with stakeholders.

Firms can make efficient product design and recycling practices that contribute to SDGs. To improve stakeholder engagement, firms may launch more sustainable products and recycling campaigns. New product development may be a challenging issue in OM; however, these efforts can be supported by social media analysis (Choi et al., 2020). To be specific, firms can obtain stakeholders' preferences, ideas, and demands for sustainable products from social media (Chan et al., 2017; Stevenson, 2021). In addition, firms can obtain the market reactions to the new sustainable product on social media to evaluate them (Choi et al., 2020). Furthermore, firms can communicate recycling practices with stakeholders on social media.

Although sustainable manufacturing had an insignificantly positive effect on consumer engagement, this just means that firms need to strengthen suppliers monitoring and adjust the way they communicate with key stakeholders about manufacturing practices. Firms may strengthen supplier monitoring through social media and other advanced technologies such as Block Chain. For suppliers, firms may establish manufacturing standards that exceed the requirements of local regulations (Golini & Gualandris, 2018). Furthermore, firms can promote information exchange with their suppliers through social media, which can lead to collaborative product development and timely improve production processes to meet the needs of stakeholders (Irani et al., 2017). In addition, firms may apply advanced multimedia technologies (e.g., Virtual Reality, Augmented Reality) to improve the communication of sustainable manufacturing. Firms can use social media to improve manufacturing to achieve more SDG requirements (Huang et al., 2020). Specifically, firms can identify opportunities to improve manufacturing from their stakeholders' tweets to support process adjustments and redesigns (Singh et al., 2018). Then, firms can share ideas and opportunities for technological redesign within the firm or among supply chain partners on social media so as to improve OM efficiency (Weichhart et al., 2018). Firms need to carefully coordinate and plan their communication with stakeholders on social media. Effective signals should help stakeholders more easily interpret key information. Too much noise and distortion may result in ineffective communication with stakeholders (Connelly et al., 2011).

7. Limitations and future research

First, some tweets could not be labeled correctly, although the automated text classifier performed well in this study. Second, although we have solid reasons for focusing only on the fashion industry, the actual application in other consumer product sectors might not yield the same results. These limitations can be resolved by replicating the study with a larger number of brands in various industries. Thirdly, we are the first to use signaling theory to support stakeholder engagement in SOM on social media theoretically. Future studies may explore stakeholder engagement from other theoretical perspectives. Fourthly, future studies may extend our findings to emerging countries that have different languages and cultures. Different countries have different values on social media (Zhao et al., 2019). Further, we extended our research to the Chinese context since China is a major market for many firms, and factors such as culture, language, and policies create the need for different approaches to engaging stakeholders. China's economic aggregate is second only to the United States (Xie et al., 2021).

However, China's rapid development has promoted the vigorous use of natural resources, bringing increasing pressure to shift towards sustainability (Xie et al., 2021). Due to the rapid popularization of social media, stakeholders have begun to engage in firms' SOM in China (Li et al., 2018) through practices such as boycotting unsustainable products (e.g., toxic milk powder). Chinese stakeholders have started engaging in firms' SOM, but few studies have focused on this (Li et al., 2018). Therefore, it is necessary to research stakeholder engagement in firms' SOM in China in order to help firms understand how to engage stakeholders.

8. Conclusions

This study aimed to investigate how stakeholder engagement is affected by sustainable operations that meet SDGs. The regression analysis results show that sustainable product design and recycling have significantly positive effects on stakeholder engagement, while sustainable manufacturing is insignificantly positive. Firms should be more careful in their social media communications to maximize the benefits of their sustainability efforts. This study illustrates how to use a data-driven approach to develop our research model for SOM research. The procedures can serve as guidelines for future studies to replicate or adapt in other research settings that need to mimic stakeholder engagement on social media.

Chapter 4: Stakeholder Engagement in Sustainable Operations Management in China: Evidence from Social Media Analytics

Abstract

Recently, China has become one of the world's major economies. However, Chinese firms' operations management still exists unsustainable issues, which may cause opposition from stakeholders. Chinese stakeholders have become increasingly engaged in firms' sustainable operations management. This study aims to help firms understand how to engage stakeholders in SOM in China through analyzing social media data. Through analyzing 37,007 posts from 22 fashion brands on Sina Weibo, we found that the more sustainable the product design, the higher the stakeholder engagement. However, sustainable manufacturing was not found to have positive effects on stakeholder engagement. We are the first to examine stakeholder engagement in sustainable operations management in China. The results of this study may be valuable globally because China has become the biggest fashion market in the world (Zhao et al., 2019). We fill a research gap and provide important implications for operations management scholars and practitioners.

Keywords: Sustainable operations management, Sustainable product design, Sustainable manufacturing, Recycling, Stakeholder engagement, China, Social media analytics

1. Introduction

China's reformation increased the country's economic development, turning it into one of the world's major economies (He et al., 2016). China's development is mainly driven by high-speed industrialization (Zhang & Zhang, 2018). From 2012 to 2021, the industry has accounted for more than 30% of China's Gross Domestic Production (GDP),[34] earning it the title of the "World Factory" (Dang et al., 2020a). However, rapid industrialization also causes environmental (e.g., serious air and water pollution, land degradation, waste of resources) and social issues (e.g., unqualified products) (He et al., 2016; Huang & Zhu, 2017). Currently, China is the largest emitter of carbon dioxide and has one of the highest energy consumption rates in the world (Shao, 2019). China's carbon dioxide emissions have basically maintained a consistently upward trend, rising from 3.35 billion tons in 1999 to 10.668 billion tons in 2020.[35] Unqualified products coming from China have endangered people's health, such as melamine-

[34] https://data.stats.gov.cn/english/easyquery.htm?cn=C01

[35] https://www-statista-com.ezproxy.lb.polyu.edu.hk/statistics/239093/co2-emissions-in-china/

tainted milk[36] and toxic clothes[37].

These social, environmental, and health-related problems are widely known among stakeholders, thus affecting firms' reputations (Ngai & Singh, 2021). Stakeholders are thus becoming more concerned about the unsustainability of firms' OM (He et al., 2016). Increasingly, consumers are considering sustainability when making purchase and consumption decisions (Taoketao et al., 2018). In a survey conducted by Statista from late December 2019 to early January 2020, 29% of respondents in China expressed concern about climate change, which greatly exceeds the world average (16%).[38] Therefore, it is necessary for firms to respond to the requirements of stakeholders (e.g., government, consumers, media) to implement SOM. The Chinese government has formulated environmental protection measures, such as the energy quota trading system (i.e., carbon emission trading), a green credit policy, and punishment for environmental pollution (He et al., 2016; Zhang & Zhang, 2018). Carbon dioxide emissions in China will peak by 2030 (Jin, 2021). China may make great efforts to achieve the goal of carbon neutrality by 2060 (Jin, 2021). Meanwhile, many non-governmental organizations have emerged in China to devote themselves to environmental protection, such as the Institute of Public and Environmental Affairs (Li et al., 2018). In addition, the media (e.g., 315 Gala held by China Central Television) has exposed multiple product quality problems.[39]

Firms pay a heavy price for their unsustainable OM. For example, the Sanlu Group, the firm that allowed melamine-tainted milk into the market, declared bankruptcy.[40] In contrast, the firm may bolster its reputation when it provides sustainable products to meet consumers' needs (Taoketao et al., 2018). In addition, increasing the price of sustainable products does not lead loyal customers to turn to other suppliers (Taoketao et al., 2018). Therefore, Chinese firms

[36] http://www.china.org.cn/government/central_government/2008-10/08/content_16584095.htm

[37] https://www.usatoday.com/story/news/world/2013/12/17/china-toxic-clothing-greenpeace/4049853/

[38] https://www-statista-com.ezproxy.lb.polyu.edu.hk/statistics/946300/individuals-worried-about-climate-change-worldwide/

[39] https://gamingsym.in/cctvs-315-party-revealed-that-some-of-the-old-altar-sauerkraut-buns-were-pickled-in-soil-pitsjingdong-taobao-and-master-kong-instant-noodle-flagship-stores-have-removed-laotan-sauerkraut-related-p/

[40] http://www.chinadaily.com.cn/china/2009-02/13/content_7472161.htm

urgently need to implement SOM through stakeholder engagement (Huang & Zhu, 2017). In other words, stakeholder engagement allows firms' operations management to achieve sustainability rather than solely focusing on their shareholders.

SOM was still a new concept in China (Yu et al., 2017). Most firms do not know how to implement strategic SOM to create a competitive advantage (Yu et al., 2017). Therefore, we conducted this cross-cultural study to investigate the extent of stakeholder engagement in firms' SOM in China to help firms understand how to engage stakeholders in their SOM. We are the first to investigate how stakeholder engagement improves firms' SOM in the Chinese context.

We used social media data (i.e., Sina Weibo) to measure the extent of stakeholder engagement in SOM. In China, social media plays a vital role in interpersonal communications and has greatly changed people's daily lives (Zhao et al., 2019). The amount of active social media users in China rose from 653 million to 1,040 million in 2015.[41] Sina's financial report for the third quarter of 2020 listed 511million active monthly users as of September 2020, with an average of 224 million daily active users.[42] Sina Weibo is the most influential social media platform in China (Kim et al., 2022; Xie & Liu, 2022). Stakeholders can freely expose firms' unsustainable operations management on Sina Weibo, which can affect firms' reputations and financial performance (Sun et al., 2020). Stakeholders also discuss sustainability issues on social media (Zhao et al., 2019). Thus social media data can quantify stakeholder engagement (e.g., through the number of likes on posts). Therefore, examining social media data is an effective way to investigate stakeholder engagement in firms' SOM in the Chinese context.

We found that the more sustainable the product design (i.e., achieves more SDGs), the higher the stakeholder engagement. However, sustainable manufacturing and recycling have insignificantly positive effects on stakeholder engagement. Thus, sustainable product design is an effective signal to engage stakeholders in the Chinese context, which extends signaling theory. We used large social media data sets to fill the literature gap on stakeholder engagement in SOM rather than widely researching corporate social responsibility reports. Social media

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[41] https://www-statista-com.ezproxy.lb.polyu.edu.hk/statistics/234984/user-number-of-social-networks-in-china/

[42] https://weibocorporation.gcs-web.com/news-releases/news-release-details/weibo-reports-third-quarter-2020-unaudited-financial-results/

allows presenting firms' signals and stakeholders' countersignals publicly. Thus, we can link firms' signals with specific and quantifiable countersignals (i.e., the number of likes) to measure stakeholder engagement, which helps to examine the effectiveness of signals about SOM (Harris et al., 2021). Last but not least, we provide some suggestions to help firms engage stakeholders in SOM.

2. Literature review

2.1 Signaling Theory

Signaling theory aims to explain the relationship between senders and receivers of signals (Connelly et al., 2011). The goal of signaling is to obtain information from the market to resolve information asymmetry between firms and stakeholders (Connelly et al., 2011). Generally, stakeholders have a hard time identifying whether firms' OM (e.g., product design, manufacturing) is sustainable (McDonald & Oates, 2006). In contrast, a stakeholder engagement strategy encourages symmetric communication between firms and stakeholders (De Luca et al., 2022). Therefore, it is necessary for firms to send signals about SOM to stakeholders, which can reduce information asymmetry and enhance firms' competitive advantage (Taoketao et al., 2018). Yu et al. (2017) found that if a firm's sustainability practices were not disclosed to the public, those practices would not improve its competitive advantage. Consumers cannot locate sustainable products when they lack sufficient and reliable SOM information, even if they are willing to pay high prices for sustainable products (Shao, 2019). Signaling theory indicates that the receiver, the signaling environment, and the signal each play a significant role in interpreting the sender's signals (Connelly et al., 2011). In this paper, SOM serves as the signal. The signalers represent the firms, the receivers are the stakeholders (Dang et al., 2020a), and Chinese social media is the signaling environment.

Firms' SOM could be read as a positive signal (Taj, 2016). By sending a positive signal to society, companies can impact the views of stakeholders and prompt them to communicate with each other (Pecot et al., 2018). For example, consumers tend to trust firms that are beneficial to consumers and society (Louis et al., 2019). When consumers receive signals about firms' sustainable practices, they tend to share this information and recommend products from these firms to others on social media (Oghazi et al., 2018). Consumers who receive recommendations may purchase services and goods from sustainable firms, enlarging market shares (Pecot et al., 2018). What is more, the Internet, especially social media, makes it easy for stakeholders to share firm-related information (Dang et al., 2020a).

Regarding Chinese firms, signals about their sustainable practices are related to stronger competitive advantage and higher credit and reputation, which implies that signaling sustainable practices is effective in China (Dang et al., 2020a; Hong & Kim, 2017; Huang et al., 2022; Taoketao et al., 2018; Yu et al., 2017). A firm with more sustainability practices signals that the stability of corporate management ability is higher, resulting in greater access to bank credit loans (Huang et al., 2022). Dogl and Holtbrugge (2014) also found a positive signaling effect of Chinese firms' environmentally sustainable activities on environmental reputation and employee commitment. Meanwhile, sustainability practices as a signal can help Chinese firms attract talent from abroad (Hong & Kim, 2017). A report from the China Chain Management Association showed that more than 70% of respondents would pay 10% more for sustainable services or goods (Wang et al., 2021). 16.2% of consumers in Alibaba's Chinese retail market purchased at least five sustainable products and were willing to pay an average of one-third more for sustainable products in 2015 (Wang et al., 2021). Consequently, we assume that signaling SOM can improve stakeholder engagement.

We adopted the UN SDGs to measure the sustainability of SOM practices. To be more specific about what a firm can do to achieve sustainability, the UN has identified seventeen SDGs that should be achieved by 2030 (Table 1).[43] China is a significant SDG participant and practitioner in the world (Xie et al., 2021). Responding to the UN SDGs, China's government released "China's National Plan on Implementation of the 2030 Agenda for Sustainable Development" and "China's Progress Report on Implementation of the 2030 Agenda for Sustainable Development" in 2016, which developed specific strategies, established departmental coordination mechanisms, and clarified respective responsibilities (Lu et al., 2021, p.2). Stakeholders understand and support SDGs in China (Guan et al., 2019). From 2016 to 2020, the SDG index of China rose from 59.1 to 73.9, and its ranking rose from 76 to 48 (Xie et al., 2021). Therefore, the UN's SDGs are an effective comparison point through which to measure firms' SOM in China.

[43] https://www.undp.org/content/undp/en/home/sustainable-development-goals.html

Table 1. SDGs with their respective abbreviations

No.	Name	No.	Name
1	No poverty	10	Reduced inequality
2	Zero hunger	11	Sustainable cities and communities
3	Good health and well-being	12	Responsible consumption and production
4	Quality education	13	Climate action
5	Gender equality	14	Life below water
6	Clean water and sanitation	15	Life on land
7	Affordable and clean energy	16	Peace, justice and strong institutions
8	Decent work and economic growth	17	Partnerships towards the goals
9	Industry, innovation and infrastructure		

Further, we assumed that SOM that achieves more SDGs could achieve higher stakeholder engagement. Saxton et al. (2019) defined breadth as "the scope of the signal topic" (p. 362). They found that stakeholder engagement will be higher when firms mention more topics in corporate social responsibility on social media. Extending their studies, we further investigated whether a social media post incorporating more aspects of SOM would generate higher engagement. Meanwhile, a post would likely be stronger signal when it mentions SOM practices that achieve more SDGs and vice versa (Kharouf et al., 2020). If firms send a stronger signal to stakeholders, higher stakeholder engagement will result (Kharouf et al., 2020).

We selected Sina Weibo as the signaling environment since Sina Weibo is a major social media channel through which firms can communicate with stakeholders in China (Sun et al., 2020; Yang et al., 2022). As Facebook and Twitter are banned in China, Chinese-owned social media platforms such as WeChat, QQ, and Sina Weibo have been rapidly attracting users (Zhao et al., 2019). WeChat and QQ focus on private conversations, which are similar to Facebook and MSN. Sina Weibo is similar to Twitter and is often called "the Chinese version of Twitter" (Kim et al., 2022) p. 364). Like Twitter, Sina Weibo allows 140 Chinese characters in each post. However, posts on Sina Weibo can contain more content than tweets because each Chinese character represents a complete word (Sun et al., 2020). Similar to Twitter, the publicity, transparency, and immediacy of Sina Weibo provide an environment that makes it easy to test both the signal itself and the behavior of the receiver. In addition, signaling theory emphasizes signals and receivers' feedback to signals (Yu et al., 2017). We use countersignals to capture stakeholder engagement (Connelly et al., 2011). Countersignals mean stakeholders' engagement in the form of likes, comments, and sharing of firms' signals (i.e., the social media messages from firms' accounts) (Harris et al., 2021). Sina Weibo records receivers' feedback behaviors such as sharing, commenting, and giving likes (Sun et al., 2020). Compared to CSR reports, social media allows researchers to test the effectiveness of signals through receivers' feedback behaviors (e.g., the number of likes). The effectiveness of signals is defined as "the extent to which the signaled information is readable by the receiver" (Yu et al., 2017, p. 552). The effectiveness of signals is the key determinant of stakeholder engagement in firms' SOM. Therefore, Sina Weibo enables firms (i.e., senders) to post their SOM (i.e., signals) which can be interpreted by stakeholders (i.e., receivers) (Ngai & Singh, 2021).

2.2 The communication of sustainable operations management on social media

2.2.1 Sustainable product design

Sustainable product design is an important instrument of sustainable development (Tang & Zhou, 2012). Product design includes the properties of a product, such as materials, appearance, and function (Luchs & Swan, 2011). Sustainable product design refers to product designs that achieve economic, environmental, and social sustainability (Lacasa et al., 2016). For example, a product made with recycled materials is considered a sustainable product design (Jaehn, 2016). Product designs may affect consumers' decision-making processes. Chinese consumers are becoming increasingly interested in sustainable products and more knowledgeable about quality brands (Zhao et al., 2019). According to the most recent Green Brand Survey of 9,000 consumers in the U.S., China, Australia, Brazil, India, Germany, France, and the U.K., more than 50% of consumers reported sustainable product design as an essential requirement (L. T. Chen et al., 2020) for purchase. Clients are now more willing than ever to pay for sustainable products (Zhang & Zhu, 2019). For example, Jung et al.'s (2016) interviews showed that Chinese respondents are supportive of eco-friendly faux leather products. Wang et al. (2021) found that Chinese consumers are more willing to buy sustainable luxury goods than ordinary luxury goods. In China, the government makes great efforts to develop a low-carbon economy (Shao, 2019). The active introduction of laws and regulations on the environment and employee rights shows that the Chinese government is becoming increasingly enthusiastic about environmental and social sustainability (Yu et al., 2017). In recent years, the Chinese government has attached great importance to the sustainable development of enterprises and the process of green transformation (Shao, 2019). Therefore, we developed the following hypothesis:

H1. Sustainable product design has positive effects on stakeholder engagement

2.2.2 Sustainable manufacturing

Manufacturing means that the chemical or physical properties of raw materials are altered through a series of production processes that ultimately generate a product (Lin et al., 2009). In emerging countries, sustainable manufacturing focus on "environmentally friendly practices that reduce energy consumption and waste generation, especially manufacturing processes; socially correct practices for a healthy, safe working environment; and social benefits to employees and communities with economically viable outcomes for the firm" (Rauch et al., 2016, p. 866). To be specific, firms need to adopt energy-efficient production technologies, reduce waste pollution, and maximize employees' job satisfaction (e.g., fair wages, safe production, flexible work times) in the manufacturing process (Atasu et al., 2020; Drake & Spinler, 2013; Jaehn, 2016). Energy-efficient production technologies respond to these requirements. Maximizing employees' job satisfaction can enhance stakeholder engagement since employees will be more efficient and passionate in a satisfactory working environment (Kopra et al., 2015). Employees and consumers are considered major stakeholders because these groups occupy an important position in firms' OM (Roscoe et al., 2020). Employee engagement is important when implementing sustainable manufacturing (Vimal et al., 2015).

Purchasing sustainable components from qualified suppliers also play an important role in sustainable manufacturing (Ghadimi & Heavey, 2014). Only when a strategy is consistent with that of its upstream suppliers and downstream customers can it generate the greatest benefits (Tang & Zhou, 2012). For example, BMW disseminates sustainable procurement guidelines through its manufacturing network to guide factories on how to cooperate with suppliers and sub-suppliers to improve their collective impact on society and the environment (Golini & Gualandris, 2018). Therefore, all these components must comply with the buyers' and companies' sustainable development policies(Ghadimi & Heavey, 2014). Meanwhile, Firms' attention to employee health and safety is not limited to employees in their own factories but also extends to all employees of their suppliers (Kleindorfer, Singhal, & Van Wassenhove, 2005).

We assumed that sustainable manufacturing would achieve higher stakeholder engagement on social media. Stakeholders may engage in firms' sustainable manufacturing since stakeholders (e.g., governments, NGOs, media) affect environmental, health, and safety regulations (Lo et al., 2014). Firms' manufacturing practices may affect the local environment (e.g., water emission, air emission) and communities (e.g., local income and employment). For example, the manufacturing of clothes in China causes serious water pollution. Denim clothing not only consumes a significant volume of water through spinning, dyeing, weaving, washing, sewing, and bleaching, but also this polluted water is directly discharged into rivers, which poses a serious threat to the ecological balance (Zhou et al., 2018). Stakeholders may boycott firms that manufacture in an environmentally unfriendly way (Zhang & Zhu, 2019). Therefore, stakeholders consider the impact of manufacturing on local communities and will support measures to promote sustainable manufacturing (Diego-Mas et al., 2016). Employees and consumers may also expose to firms' unsustainable manufacturing practices. For environmentally-conscious customers, the manufacturing process with sustainable certificates not only represents added value but is also the most important determinant in purchasing decisions (Zhang & Zhu, 2019). If firms are committed to protecting employees' interests, employees' satisfaction and loyalty will be higher, thus improving production efficiency and attracting more quality employees (Yu et al., 2017). Therefore, we developed the following hypothesis:

H2. Sustainable manufacturing has positive effects on stakeholder engagement.

2.2.3 Recycling

Recycling is considered as the process of collecting and disposing of waste materials and converting them into new products (Tang & Zhou, 2012). Specifically, the recycling process should include the collection of old products, reverse logistics, inspection, disposal, remanufacturing, and remarketing, which involves many stakeholders (Tang & Zhou, 2012). Recycling can benefit communities and the environment by reducing the destructive impact of waste treatment processes, raw materials extraction, and transportation on the environment (Kleindorfer, Singhal, & Van Wassenhove, 2005). At the same time, recycling reduces the generation of garbage so as to create a more pleasant living environment. Therefore, stakeholders may positively respond to companies when they promote their recycling practices on social media. Therefore, we developed the following hypothesis:

H3. Recycling has positive effects on stakeholder engagement.

3. Methodology

We collected 39,947 Sina Weibo posts from 22 fashion brands through the software program Gooseeker (Li et al., 2021; Tao et al., 2019). We removed 2,940 posts written by other users and shared by firms because these non-original messages do not clearly represent the firms' intentions (Saxton et al., 2019). Since the UN announced its SDGs on Sept. 25, 2015, the time period of data collection was from September 25, 2015, to September 23, 2019. We avoided using data from 2020 to 2022 due to the effects of the COVID-19 pandemic during this period.

We selected the fashion industry as our example because of its market size and significant impact on the environment and society. The industry revenue of "clothing retail" in China grew from 2015 (42.87 billion USD) to 2021 (52.45 billion USD).[44] China has become the biggest fashion market (Zhao et al., 2019) in the world, and fashion firms have used social media to communicate with their stakeholders in China (Zhao et al., 2019). The one-off trends caused by rapid fashion changes and short-lived styles turn fashion products into solid waste, causing negative environmental consequences in China (Liang & Xu, 2018). Compared to other industries, stakeholders may be more engaged in fashion (De Luca et al., 2022). The sample of brands includes both local and foreign brands offered in the Chinese Mainland (Table 2), all from listed firms. The average market share of each brand in the Chinese Mainland from 2015 to 2019 is more than 0.3%,[45] which ensures the generalizability of our sample in relation to all fashion brands that use Sina Weibo to communicate with stakeholders in the Chinese Mainland. The sample of foreign brands is similar to that described in Chapter 3. However, we removed Adidas, Prada, Uniqlo, and Vivienne Westwood because these firms removed some posts from their accounts between 2015 and 2019.[46] In addition, Vans does not have an official account in Sina Weibo. Regarding local brands, we only considered the brands' headquarters in the

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[44] https://www-statista-com.ezproxy.lb.polyu.edu.hk/forecasts/1185748/clothing-retail-revenue-in-china

[45] https://www-statista-com.ezproxy.lb.polyu.edu.hk/forecasts/1185748/clothing-retail-revenue-in-china

[46] Adidas remove their posts before 2021. Prada remove their post before 2016. The Body Shop remove their posts before 2019. Uniqlo remove their posts before November 2021. Vivienne Westwood remove their posts before 2017.

Chinese Mainland to ensure that their operations were under the social system with the same regulations and policies.

Table 2. Selected fashion brands

Foreign Brands	Local Brands
Burberry	361 Degrees
Gap	Anta
Givenchy	Bosideng
Gucci	HLA
H&M	Lining
Levis	Metersbonwe
Louis Vuitton	Semir
Michael Kors	Xtep
Nike	
Puma	
Reebok	
Stella McCartney	
The North Face	
Zara	

We developed a lexicon to classify the OM and SDG categories for each post, which is one kind of rule-based classification (Chau et al., 2020). The advantage of rule-based classification is that expert opinions are taken into account in the classification (Chau et al., 2020). Scholars widely use rule-based classification in social media research (Chau et al., 2020; De Luca et al., 2022). We translated the lexicon used in Chapter 3 through Google Translate[47]. Due to the complexity of human language and the culture difference, machine translators (i.e., Google Translate) are often still only used as assistance translation tools, which implies that the results from machine translators need human corrections (Li et al., 2021). Therefore, we corrected some of them and added new words to the lexicon according to the Chinese context and SDG context. For instance, Google translated "triangular" into "三角形".[48] However, according to

[47] https://translate.google.com/?hl=zh-CN&sl=en&tl=zh-CN&op=translate

[48] https://translate.google.com/?hl=zh-CN&sl=auto&tl=zh-TW&text=triangular&op=translate

SDG 17. Partnerships for the goals, it should be "三邊/三角" that represents the triangular trade and triangular between three countries.[49] Appendix A presents the detailed lexicon.

We adopted descriptive and multiple linear regression as our analysis methods. We used the number of likes as the measure of stakeholder engagement because giving likes shows people's recognition of a tweet (Kim & Yang, 2017). In addition, some posts may cover various OMs. People may not indicate which OM meets an SDG in their posts. Therefore, we only kept the posts that mentioned only one OM strategy. We ran a regression analysis with a common logarithm of the number of likes "Lg (Like)" as the dependent variable to mitigate distributional violations and account for the tweets with abnormal numbers of likes (Kanuri et al., 2018). Since Lg (x) requires $x > 0$, we adjusted the zero value in the number of likes (Kanuri et al., 2018). We adjusted the number of likes by adding one to every number since normal distribution will not change when the variable contains a constant.[50] This study also included several control variables to account for the heterogeneity at the content and environmental levels (Kanuri et al., 2018). First, "Text Length" was used to control for content features that may affect stakeholders' perceptions. In addition, we also used "Lg (Sharing)" to control for the effect of sharing posts. Secondly, we used "brand dummies" to control for the effect of brand reputation on social media since brand names are related to brand awareness and firms' reputation, thus affecting stakeholders' evaluations (Jung et al., 2016). Thirdly, we used "year dummies" to control the yearly economic impact on social media. Fourthly, we used "hashtag" to control the effects of other signals of social media because hashtag represents some popular topics that can influence the communication. Finally, we used Total Asset (million USD) as the financial control (Saxton et al., 2019). Table 3 explains the variables used in multiple linear regression.

[49] https://www.un.org/sustainabledevelopment/globalpartnerships/

[50] https://blogs.sas.com/content/iml/2011/04/27/log-transformations-how-to-handle-negative-data-values.html, access date

Table 3. Variables

Variables	Explanation
Dependent variables	
Lg (Like)	Lg of the total adjusted amount of likes on a post
Independent variables	
SDG	The number of SDGs achieved in the content
Design	A post mentioned content in the field of product design
Design × SDG	A post mentioned product design that met SDG(s)
Manufacturing	A post mentioned content in the field of manufacturing
Manufacturing × SDG	A post mentioned manufacturing that met SDG(s)
Recycling	A post mentioned content in the field of recycling
Recycling × SDG	A post mentioned recycling that met SDG(s)
Control variables	
Lg (Sharing)	Lg of total adjusted number of sharing posts
Text Length	Number of words in a post
Total Asset (million USD)	Total asset
Hashtag	Whether the post had hashtag(s) or not
Brand dummies	Distinguished different brands' posts
Year dummies	Distinguished posts from different years

4. Findings

4.1 Descriptive analysis

Among 37,007 posts, HLA accounted for the largest proportion (14.18%) with 5,248 tweets, followed by H&M (2,893 posts, 7.82%). The lowest number of tweets was from Nike (211 posts, 0.57%).

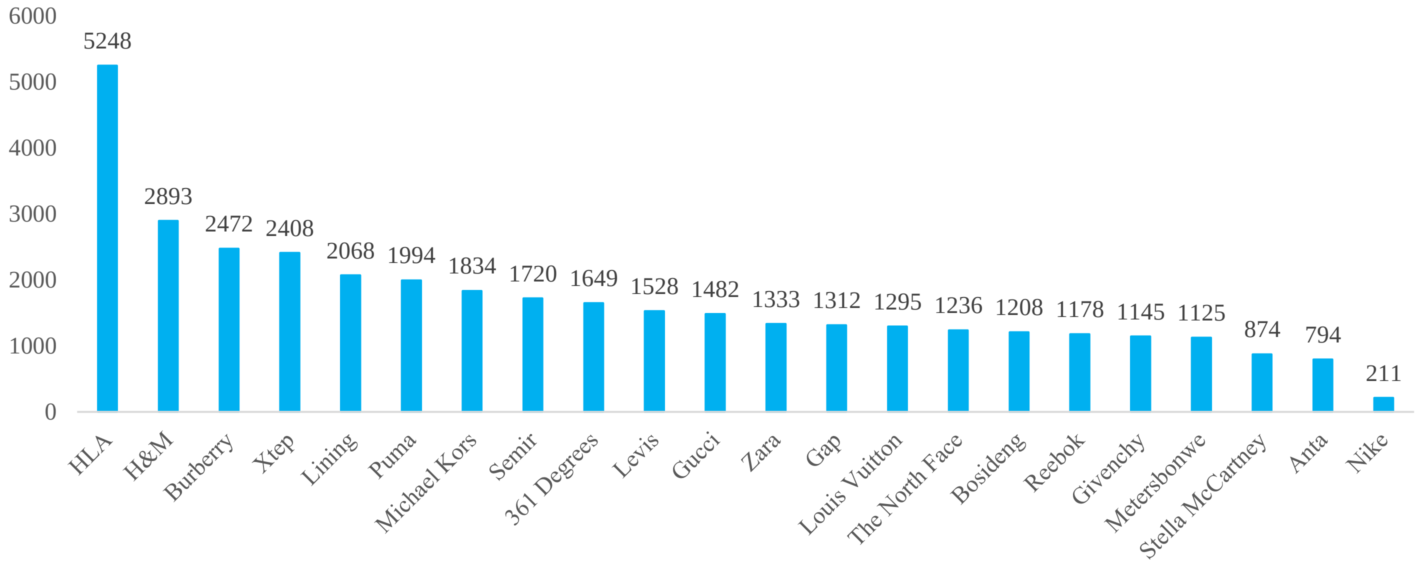

Figure 1. Post distribution by brand.

Figure 2 illustrates the distribution of posts according to the processes of OM and the proportion of SDGs in the posts about each process. Among 37,007 posts, there were 16,026 related to OM. Among the OM tweets, 14,218 posts (88.72%) focused on product design only, 678 (4.23%) mentioned manufacturing only, 60 (0.37%) emphasized recycling only, and 1,070 (6.68%) mentioned multiple OM processes. Among the 14,218 tweets about product design, 6,244 (43.92%) mentioned SDGs. Among the posts about manufacturing, 373 tweets (55.01%) mentioned SDGs. Among the posts about recycling, 53 tweets (88.33%) mentioned SDGs. Among the posts that mentioned multiple OMs, 617 tweets (57.66%) mentioned SDGs. Regarding manufacturing and recycling, more than half of the posts referred to SDG(s).

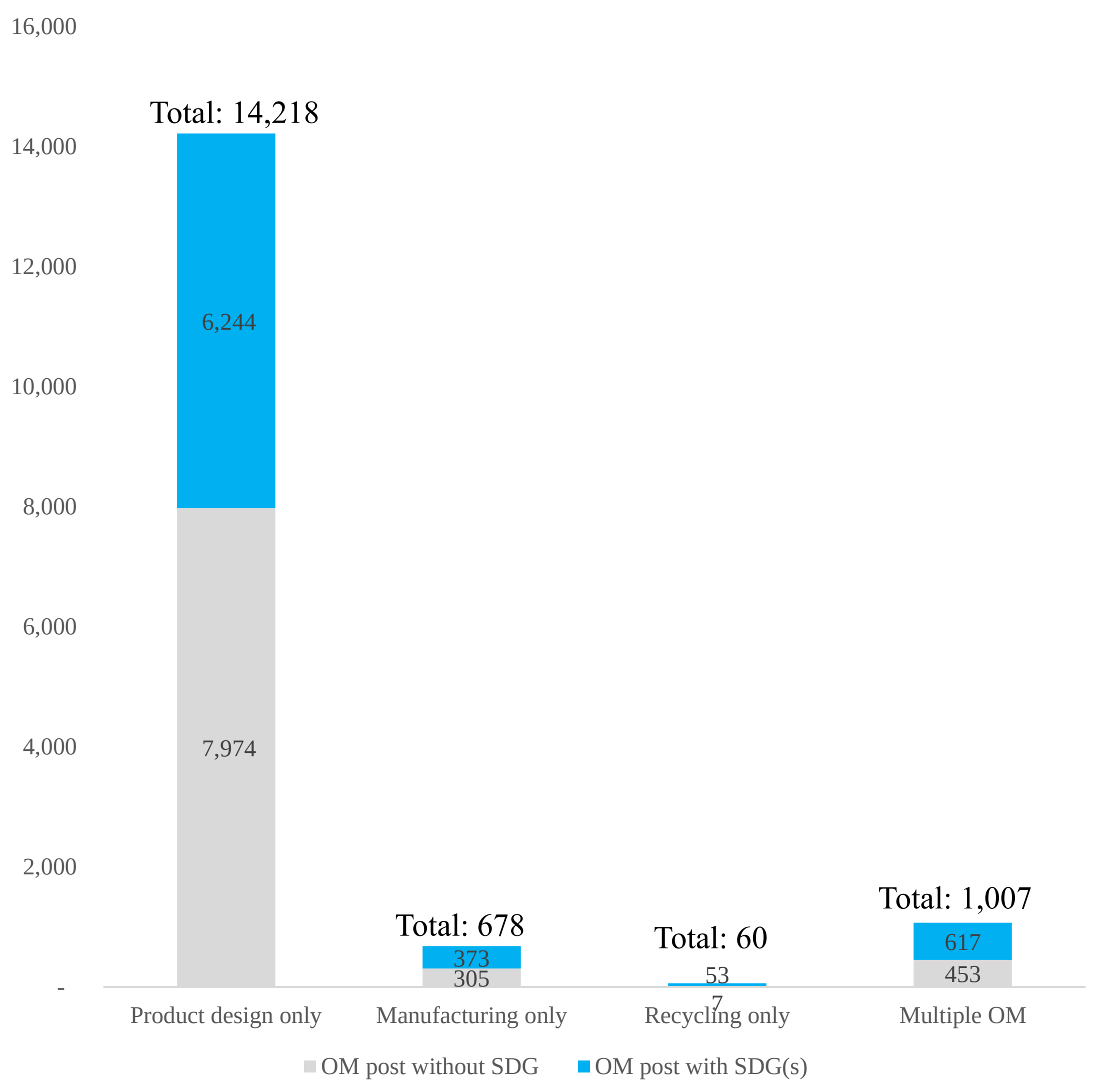

Figure 2. The distribution of posts according to the process of OM and the proportion of SDGs in the posts about each process.

Table 4 displays the statistics of SDGs in each category of OM. On average, most SDGs (2.217) were mentioned in a post about recycling. In addition, it was noted that the average numbers of SDGs in the posts about manufacturing and recycling were higher than the overall average. The posts about manufacturing mentioned up to 10 SDGs/post. The posts about product design mentioned up to 7 SDGs/post. The posts about recycling mentioned up to 6 SDGs/post.

Table 4. The statistics of SDGs in each category of OM

Category	The average number of SDGs	Minimum number of SDGs	Maximum number of SDGs
Product design only	0.739	0	7
Manufacturing only	1.159	0	10
Recycling only	2.217	0	6
Multiple OMs	1.234	0	9
All posts (including non-OM)	0.762	0	10

We calculated the number of SDGs in the OM posts with SDGs to determine which SDGs were mentioned most in each process of SOM. Table 5 indicates that the top 5 SDGs involved sustainable product design, sustainable manufacturing, and recycling. Among the 6,244 posts mentioning sustainable product design (i.e., product design that contributes to SDGs), most posts mentioned SDG17. Partnerships towards the goals (1,465, 23.46%), while SDG13. Climate action and SDG12. Responsible consumption and production appear in more than 1,300 posts. This is because SDG17. Partnerships towards the goals focus on the cooperation between the developed countries and the developing countries such as China. Among the 373 posts mentioning sustainable manufacturing, most mentioned SDG13. Climate action (128, 34.32%). Among the 57 posts mentioning recycling, most mentioned SDG12. Responsible consumption and production (46, 80.70%). Interestingly, SDG17. Partnerships towards the goals, SDG13. Climate action, and SDG12. Responsible consumption and production were frequently mentioned in each OM category. De Luca et al. (2022) found that SDG17. Partnerships towards the goals and SDG13. Climate action are in the most significant group to increase stakeholder engagement on social media, while SDG12. Responsible consumption and production is in the second most significant group. Therefore, we assumed that sustainable product design, sustainable manufacturing, and recycling all have the potential to increase stakeholder engagement.

Table 5. Top 5 SDGs involved in each part of SOM

OM	SDG	Number of posts
Sustainable product design	SDG17. Partnerships towards the goals	1,465
	SDG13. Climate action	1,450
	SDG12. Responsible consumption and production	1,332
	SDG11. Sustainable cities and communities	955
	SDG 8. Decent work and economic growth	871
Sustainable manufacturing	SDG13. Climate action	128
	SDG 9. Industry, innovation and infrastructure	93
	SDG12. Responsible consumption and production	80
	SDG14. Life below water	77
	SDG17. Partnerships towards the goals	71
Recycling	SDG12. Responsible consumption and production	46
	SDG17. Partnerships towards the goals	29
	SDG13. Climate action	9
	SDG11. Sustainable cities and communities	8
	SDG 7. Affordable and clean energy	8
Multiple OMs	SDG12. Responsible consumption and production	194
	SDG13. Climate action	193
	SDG 9. Industry, innovation and infrastructure	131
	SDG11. Sustainable cities and communities	115
	SDG14. Life below water	114
All posts (including non-OM)	SDG17. Partnerships towards the goals	4,694
	SDG13. Climate action	4,230
	SDG12. Responsible consumption and production	3,140
	SDG11. Sustainable cities and communities	2,256
	SDG 8. Decent work and economic growth	2,065

4.2 Multiple linear regression

We ran multiple linear regression on SPSS 25.0 to test the hypotheses. Table 6 presents the descriptive statistics and correlations analysis. Table 7 shows the results of the regression analysis with "Lg (Like)" as the dependent variable. Model 1 shows the control variables. We found that "Lg (Sharing)" (.520, $p < .01$) had significantly positive effects on stakeholder engagement. The use of hashtags (.010, $p < .01$) also had significantly positive effects. On the contrary, "Text Length" (-.001, $p < .01$) as a control variable was significantly negative, which implies that people are more likely to engage with shorter posts (De Luca et al., 2022). Total assets (-.000, $p < .01$) had significantly negative effects on stakeholder engagement, which means that smaller firms may have slightly higher stakeholder engagement.

Regarding the posts about OM (Model 2), we found that product design (.008, $p < .1$) and recycling (.080, $p < .1$) had significantly positive effects on stakeholder engagement, while manufacturing had insignificantly negative effects. However, referring to Model 3, Design × SDG (.007, $p < .1$) had significantly positive effects on stakeholder engagement. Thus, product design can achieve higher stakeholder engagement when it achieves more SDGs. H1 was supported. Notably, the positive effects of product design on stakeholder engagement have more significance when product design becomes sustainable. In contrast, Manufacturing × SDG and Recycling × SDG had insignificantly positive effects on stakeholder engagement. Thus, H2 and H3 were rejected.

5. Robustness check

We conducted two robustness checks to ensure the consistency of our results. Firstly, firms may communicate several SOM processes in one social media post. Therefore, we also considered posts that included multiple OMs and then used the same variable to re-run the linear analysis (Table 8). The results were consistent with the main results, which indicated that our results were robust. Secondly, we replaced "the number of SDGs" with "whether use SDG or not" to conduct another robustness check from a different perspective (Table 9).

Table 6. Descriptive statistics and correlations; $N = 37{,}007$

		Mean	Standard Deviation	1	2	3	4	5	6	7	8	9	10	11	12
1	Lg(Like)	1.760	.760												
2	SDG	.76	1.081	-.058**											
3	Design	.38	.486	.141**	-.016**										
4	Design × SDG	.284	.740	.025**	.515**	.486**									
5	Manufacturing	.02	.134	-.037**	.050**	-.108**	-.052**								
6	Manufacturing × SDG	.021	.248	-.024**	.171**	-.068**	-.033**	.626**							
7	Recycling	.00	.040	.003	.054**	-.032**	-.015**	-.006	-.003						
8	Recycling × SDG	.004	.105	.005	.073**	-.027**	-.013*	-.005	-.003	.849**					
9	Lg (Retweet)	1.053	.995	.786**	.031**	.087**	.056**	-.038**	-.017**	-.001	.002				
10	Text length	99.67	41.795	.072**	.316**	.292**	.263**	.033**	.049**	.029**	.031**	.137**			
11	Total asset (Million USD)	13513.032	23092.483	.177**	-.054**	.224**	.053**	-.006	-.006	-.003	-.001	.085**	.171**		
12	Hashtag	.68	.465	.103**	.058**	-.010	.010*	-.021**	-.010*	.013*	.014**	.132**	.091**	.050**	

Remark: **. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 7. Main Analysis

	Dependent variable: Lg (Like)								
	Model 0			Model 1			Model 2		
	Coefficient	SE	*p*	Coefficient	SE	*p*	Coefficient	SE	*p*
Constant	1.035**	.007	.000	1.035**	.007	.000	1.037**	.007	.000
SDG							.001	.002	.568
Design				.008+	.004	.070	.003	.005	.580
Design × SDG							.007+	.004	.067
Manufacturing				-.006	.014	.672	-.015	.018	.403
Manufacturing × SDG							.008	.010	.437
Recycling				.080+	.046	.084	.055	.087	.522
Recycling × SDG							.010	.033	.758
Lg (Retweet)	.520**	.002	.000	.520**	.002	.000	.520**	.002	.000
Text length	-.001**	.000	.000	-.001**	.000	.000	-.001**	.000	.000
Total asset (Million USD)	-.000**	.000	.000	-.000**	.000	.000	-.000**	.000	.000
Hashtag	.010*	.004	.021	.010*	.004	.019	.010*	.004	.020
Brand dummies	Included			Included			Included		
Year dummies	Included			Included			Included		
F	4574.268			4146.022			3686.027		
R^2	.782			.782			.782		
Adjusted R^2	.782			.782			.782		
RMSE	.355			.355			.355		
N	37,007			37,007			37,007		

Remark: * $p < .05$; ** $p < .01$; + $p < .1$

Table 8. Robustness Check 1

	Dependent variable: Lg (Like)								
	Model 0			Model 1			Model 2		
	Coefficient	SE	*p*	Coefficient	SE	*p*	Coefficient	SE	*p*
Constant	1.035**	.007	.000	1.036**	.007	.000	1.037**	.007	.000
SDG							.000	.002	.906
Design				.009*	.004	.037	.003	.005	.511
Design × SDG							.007*	.004	.044
Manufacturing				-.005	.009	.569	-.012	.011	.284
Manufacturing × SDG							.005	.006	.431
Recycling				.104**	.031	.001	.099+	.055	.075
Recycling × SDG							-.001	.018	.944
Lg (Retweet)	.520**	.002	.000	.520**	.002	.000	.520**	.002	.000
Text length	-.001**	.000	.000	-.001**	.000	.000	-.001**	.000	.000
Total asset (Million USD)	-.000**	.000	.000	-.000**	.000	.000	-.000**	.000	.000
Hashtag	.010*	.004	.021	.010*	.004	.019	.010*	.004	.019
Brand dummies	Included			Included			Included		
Year dummies	Included			Included			Included		
F	4574.268			4147.281701			3687.205		
R^2	.782			0.782104717			.782		
Adjusted R^2	.782			0.781916135			.782		
RMSE	.355			0.35468609			.355		
N	37,007			37,007			37,007		

Remark: * $p < .05$; ** $p < .01$; + $p < .1$

Table 9. Robustness Check 2

	Dependent variable: Lg (Like)								
	Model 0			Model 1			Model 2		
	Coefficient	SE	*p*	Coefficient	SE	*p*	Coefficient	SE	*p*
Constant	1.035**	.007	.000	1.035**	.007	.000	1.036**	.007	.000
SDG							.003	.005	.548
Design				.008+	.004	.070	.002	.006	.715
Design × SDG							.013+	.008	.094
Manufacturing				-.006	.014	.672	-.023	.021	.266
Manufacturing × SDG							.031	.028	.266
Recycling				.080+	.046	.084	-.002	.134	.989
Recycling × SDG							.091	.143	.522
Lg (Retweet)	.520**	.002	.000	.520**	.002	.000	.520**	.002	.000
Text length	-.001**	.000	.000	-.001**	.000	.000	-.001**	.000	.000
Total asset (Million USD)	-.000**	.000	.000	-.000**	.000	.000	-.000**	.000	.000
Hashtag	.010*	.004	.021	.010*	.004	.019	.010*	.004	.022
Brand dummies	Included			Included			Included		
Year dummies	Included			Included			Included		
F	4574.268			4146.022			3686.085		
R^2	.782			.782			.782		
Adjusted R^2	.782			.782			.782		
RMSE	.355			.355			.355		
N	37,007			37,007			37,007		

Remark: * $p < .05$; ** $p < .01$; + $p < .1$

6. Discussion

6.1 Summary of findings

According to the descriptive analysis, SDG12. Responsible consumption and production, SDG13. Climate action and SDG17. Partnerships towards the goals were highly mentioned in each OM category, which is in line with De Luca et al. (2022) sample. SDG17. Partnerships towards the goals is the most commonly mentioned SDG for sustainable product design since SDG17. Partnerships towards the goals focus on the cooperation between the developed countries and the developing countries such as China. SDG13. Climate action is the most commonly mentioned SDG for sustainable manufacturing, which implies that stakeholders are concerned about the greenhouse gas emissions in manufacturing. "Climate action" was listed as the highly important factor in achieving sustainable development in an assessment by 500 experienced sustainable development professionals around the world.[51] Additionally, SDG12. Responsible consumption and production is still the most frequently mentioned SDG in recycling. To achieve higher stakeholder engagement, firms may develop more recycling activities for stakeholders according to the guidelines of SDG12. Responsible consumption and production.

First, we found that sustainable product design can generate stakeholder engagement in the Chinese context. Finished products are close to most stakeholders, especially consumers, and 80% of the sustainability impact of the product is determined at the product design stage (Kulatunga et al., 2014). In addition, governments and media usually introduce sustainable finished products to the public. Chinese consumers thus demonstrate their sustainability awareness by purchasing sustainable products. In addition, firms usually communicate their products' information, such as the use of sustainable materials, in China. Thus, stakeholders are more familiar with sustainable product design, which can generate higher stakeholder engagement.

Second, the positive effect of sustainable manufacturing on stakeholder engagement is insignificant. China was late in implementing sustainable manufacturing; thus, stakeholders have little understanding of what this means. In 2016, the first year of the 13th five-year plan, China started making great efforts toward environmental protection and emissions reduction,

[51] http://sustainability.com/our-work/reports/evaluating-progress-towards-sustainable-development-goals/ s

such as implementing an energy quota trading policy (Zhang & Zhang, 2018). In China, firms also pay less attention to social sustainability in manufacturing (e.g., respect for employees, etc.). The employee is one of the major stakeholders (Roscoe et al., 2020). Employees are less likely to engage in firms' SOM when their job satisfaction is low. In addition, sustainable manufacturing involves many technical terms (e.g., the dyeing process of apparel), which need to be understood by those in relevant industries. SOM information cannot improve stakeholder engagement if it is too difficult for stakeholders to understand (Yu et al., 2017). Furthermore, firms' sustainable manufacturing mainly responds to the requirements of government policies (Yu et al., 2017). Governments may be engaged in firms' sustainable manufacturing; however, this may not be reflected in the social media data since one institution or individual only has one account on Sina Weibo and thus can give one like to a post.

Third, recycling practices had insignificantly positive effects on stakeholder engagement. Recycling practices are more related to environmental concerns. Firms' reputation in emerging economies may be more determined by financial performance and social sustainability (e.g., charity) than their environmental performance (Dogl & Holtbrugge, 2014). Thus, firms may pay less attention to recycling practices. Moreover, a report from Statista in 2020 showed that obtaining higher-quality products was given as the first reason for choosing sustainable products among Chinese consumers.[52] Thus, they prefer to use products for their end-of-life cycle rather than recycling products that still have residual value. In addition, the second-hand fashion market is still immature in China.

In a word, this study revealed that sustainable product design would generate stronger stakeholder engagement. In other words, the more sustainable the product design (i.e., achieves more SDGs), the higher the stakeholder engagement. However, sustainable manufacturing has insignificantly positive effects on stakeholder engagement. These two results are consistent with the results in the U.S. context (Please kindly find in Chapter 3). In addition, recycling probably relates to environmental issues more. Emerging economies paid attention to environmental issues decades later than developed economies (Dogl & Holtbrugge, 2014). Thus, compared to the U.S., recycling cannot generate significantly stronger engagement in China. Table 10 compared the effects of different processes in SOM on stakeholder engagement

[52] https://www-statista-com.ezproxy.lb.polyu.edu.hk/statistics/1241482/china-reasons-for-buying-sustainable-products/

in different contexts.

Table 10. The comparison of the impact of different SOM processes on stakeholder engagement in different contexts

	US	China
Sustainable product design	Significantly positive	Significantly positive
Sustainable manufacturing	Insignificantly positive	Insignificantly positive
Recycling	Significantly positive	Insignificantly positive

6.2 Implications for research

We are the first to examine stakeholder engagement in SOM in China and to use social media data as a measure. This study contributes to the literature about stakeholder engagement in SOM by providing empirical results from a country in transition (i.e., China). SOM in China is quite different from that in other countries in terms of social mechanisms and government regulations. Compared with China, the United States also has more consumer protections (Yu et al., 2017). Canada has good social mechanisms to ensure that firms are accountable to stakeholders such as consumers and employees (Wei et al., 2014). The results of this study may be valuable globally because China has become one of the major markets with exponential growth and strong purchasing power (Zhao et al., 2019).

Our study contributes to signaling theory because it shows that firms' SOM signals on social media will affect stakeholders in China. We also indicate that different SOM signals have different signal effects. The signals of sustainable product design have significant stakeholder engagement is significantly positive. Sustainable product design could be an effective signal to engage stakeholders in firms' SOM in China. Sustainable manufacturing and recycling have the potential to become effective signals, although they have insignificantly positive effects on stakeholder engagement. Therefore, an important contribution of signaling theory is to emphasize that the signaling effect of SOM varies with different processes in SOM.

6.3 Implications for practices

Mining and analyzing social media data can timely and extensively understand the rich information of stakeholders in China so that firms can better identify and understand the opportunities and threats related to SOM (Chae, 2015; Huang et al., 2020). They can investigate which SOMs can increase stakeholder participation and which not, to develop efficient strategies for SOM. Efficient SOM may enhance competitive advantage. Therefore, the results of this study can help firms make correct decisions on how to engage stakeholders in SOM

In order to engage stakeholders, firms should develop more sustainable products. Regarding sustainable manufacturing, firms should respect their employees more since employees are major stakeholders. SOM should be integrated within the mission, values, and culture of the firm, which can win recognition from employees and enhance competitive advantage (Yu et al., 2017). In addition, we suggest that firms change their communications with stakeholders. For example, we suggest that firms use video, VR, and other multimedia technologies to communicate sustainable manufacturing practices, which is more intuitive. Regarding recycling, we suggest using promotions to improve stakeholder engagement. For instance, firms may provide consumers coupons for their next purchase or give points on VIP cards when they recycle. All of these strategies can be communicated on social media (Ngai & Singh, 2021). Thus, firms shall integrate OM teams and the marketing teams to enhance stakeholder participation

7. Limitations and future directions

First, some posts could not be labeled correctly, even though the lexicon was well developed in this study. Second, although we have solid reasons for focusing only on the fashion industry, actual application in other consumer product sectors might not yield the same results. Despite the fact that the firms sampled in this paper account for most of the market share of China's fashion industry, our research was confined to a limited number of firms. The number of global firms we chose was also limited because not all of them use Weibo to communicate with stakeholders in China. These limitations can be resolved by replicating the study with a larger number of brands in various industries. Future studies can implement the triangle method to extend our findings to help firms gain a more comprehensive understanding of stakeholder engagement in SOM.

Appendix A. Keywords

	Google Translation	Addition	Correction
Product Design			
3D	3D		
3d simulation	3D 模擬		
Aesthetics	美學		
blended fabric	混紡面料		
blue	藍色的		藍
CAD	CAD		
collection	收藏	系列	
color	顏色		
computer-aided design	計算機輔助設計		
Concept	概念		
design	設計		
Details	細節		
Dimension	方面		
Drawing	繪畫		
Eco-design	生態設計		
Ergonomics	人體工程學		
fashion design	時尚設計		
fiber content	纖維含量		

Form	形式		
GMO cotton	轉基因棉		
Human factors	人為因素		
inspire	啟發		
IP	IP		
look	看		樣子/款
Material	材料		
Model	模型	模特	
New product	新產品		
organic cotton	有機棉花		有機棉
Original	原來的		原生態
print	打印		印
product	產品		
Prototype	原型		
recyclable material	可回收材料		
screen printing	絲網印刷		
Shape	形狀		
Sketch	草圖		
style	風格		
sustainable design	可持續設計		
texture	質地		
Theme	主題		
top	最佳		
vintage	優質的		復古
Manufacturing			

Dye	染料		染
Plant	植物	種植	
Safe	安全的		
Handmade	手工製作		
Craft	工藝		
Finish	結束		整理
Automation	自動化		
Assemble	集合	裝配	
Bill of materials	材料清單		
quality control	質量控制		
Sewing	縫紉	縫製	
Knitting	針織		
Weaving	編織		
Printing	印刷		
on-time	準時		
delay	延遲		
working condition	工作條件		
production line	生產線		
workers' right	工人權利		
environmental compliance	環境合規		
water usage	用水量		
technology	技術		
sewing	縫紉		
Recycling			
RECYCLE (RECYCLING)	回收	再生	
Circular	圓		循環
close-loop	閉環		

Remanufacture (Remanufacturing)	再製造	
REUSE (REUSING)	重用	再 利 用/再使 用/重 複利 用/重 複使用
used-cloth	舊佈	
pre-owned	二手	
pre-loved	預愛	舊愛
reverse logistics	逆向物流	
reduce waste	減少浪費	
biodegradable	可生物降解	
recyclable fabric	可回收面料	
recycled polyester	再生聚酯	
repurpose	重新利用	
recycled plastic	再生塑料	
SDG1		
basic service	基本服務	
children in need	有需要的孩子	
deprivation	剝奪	
floors	地板	
Hardship	艱辛	
HOMELESS	無家可歸	
microfinance	小額信貸	
Necessity	必需品	
people in need	需要幫助的人士	
poor	貧窮的	
poverty	貧困	

protect	保護	
vulnerable	易受傷害的	
minimum wage	最低工資	
education	教育	
housing plan	住房計劃	
donations	捐款	
shelter	庇護所	
low income	低收入	
disability support	殘疾支持	
SDG2		
agriculture (agricultural)	農業	
Doha Development Round	多哈發展回合	
edible animal	食用動物	
edible plant	食用植物	
food	食物	
hunger	飢餓	餓
hungry	飢餓的	
livestock gene bank	家畜基因庫	
malnutrition	營養不良	
nutrition	營養	
seed	種子	
Starvation	飢餓	飢
food bank	食物銀行	
food support programs	食品支持計劃	
food stamps	食品券	
meal programs	膳食計劃	
bread for the world	世界的麵包	

healthy	健康	
malnutrition	營養不良	
SDG3		
accident	事故	
active	積極的	
antibioticresisance	抗生素耐藥性	
blind or visually impaired	失明或視力受損	
child care	育兒	
complete sleep	完全睡眠	
death	死亡	
defend our water	保衛我們的水	
diseases	疾病	病
epidemic	流行病	
eye care	眼睛護理	
genuine interest	真正的興趣	
get children outside	把孩子帶到外面	
give birth safely	安全分娩	
Give sight	給視線	
Givesight	給予視力	重見光明
GMO-free	無轉基因	非轉基因
gun	槍	
health	健康	
hepatitis	肝炎	
HIV/AIDS	艾滋病	
injury (injuries)	傷害	
life (lives)	生命	

malaria	瘧疾	
Maternal	母體	
mediation	調解	
mental	精神的	
narcotic drug	麻醉藥品	
newborn	新生兒	
obese	肥胖	
paid maternity leave	帶薪產假	
poisoned water	毒水	廢水
polio	脊髓灰質炎	
prevention	預防	
regain their independence	重獲獨立	
restore vision	恢復視力	
safe birth	安全分娩	
safer birth	安全分娩	
see the world	看世界	
substance	物質	
treatment	治療	
tuberculosis	結核	
vaccinate	接種疫苗	
violence	暴力	
water-borne	水性	
well-being	福利	
WorldCancerDay	世界癌症日	
WorldSightDay	世界視力日	
yoga	瑜伽	

insurance	保險		
Psychological age	心理年齡		
retirement	退休		
regular checkup	定期檢查		
nutrition	營養		
workout	鍛煉		
SDG4			
childhood development	童年發展	幼兒發展	
course	課程		
educate (educating)	教育		
Education	教育		
knowledge	知識		
School	學校		
skill	技能		
teacher	老師		
universities	大學		
university	大學		
job placement	工作崗位		
inclusive	包括的		包容
literacy	識字	認字	
numeracy	算術	計算	
college	大學		學院
SDG5			
Discrimination	歧視		
domestic work	家務活		家務
empowerment of women	賦予婦女權力	增強婦女權能	
equal	平等的		平等

exploitation	開發	發展	
gender wage	性別工資		
LADY FIRST	女士優先		
marriage	婚姻		
paid maternity leave	帶薪產假		
reproductive right	生育權		
safe birth	安全分娩		
State of Women (StateofWomen)	婦女狀況		為 女 性/婦女發聲
unpaid care	無償照顧		
violence	暴力		性暴力
woman (women)	女人（女人們）	女性/婦女（女性們/婦女們）	
women's activist	婦女活動家		
SDG6			
clean up (cleanup)	清理		
clean water	乾淨的水		
defend our water	保衛我們的水	改善水質	
desalination	海水淡化		
diarrheal	腹瀉		
Dirty Dam	髒水壩		
drinking water	飲用水		
drinking water	飲用水		
ecosystem	生態系統		
eliminate (eliminating/elimination)	消除		
latrin	廁所		
open defecation	露天排便		

poisoned water	毒水	廢水	
pollute (pollution/polluting)	污染		
prevent the hydro scheme	阻止水電計劃		
provide water	提供水		供水
river	河		
safe fish passage	安全的魚道		
safe water	安全的水		
sanitation	衛生		
Searsville Dam	西爾斯維爾大壩		
toilet	洗手間		
trash from the Delaware River	特拉華河的垃圾		
wastewater	廢水		
water for all	所有人的水		
water harvesting	集水	儲水/蓄水	
water scarcity	水資源短缺	缺水	
SDG7			
charcoal	木炭		
clean	乾淨的		乾淨
coal	煤炭		
efficiency	效率		
electricity	電		
energy	活力		能源
fossil	化石		
fuel	燃料		
gas	氣體		天然氣
green	綠色		

oil	油		石油
reliable	可靠的		可靠
renewable	可再生		
solar	太陽的		太陽能
source	來源		資源
wood	木頭		木
SDG8			
association of grower	種植者協會		
corporate responsibility	企業責任		
decent	體面的		體面
disability (disabilities)	殘疾		
employ	採用	僱用	
entrepreneurship	創業		
Fair trade (Fairtrade)	公平貿易		
family farmer	家庭農民		
financial service	金融服務		
income	收入		
job	工作		
Labour (labor)	勞力	勞動力	
loan	貸款		
local printmaker	當地版畫家	當地染坊	
medium-sized enterprise	中型企業		
pay (paid)	付錢		付
Productivity	生產率		
promote sustainable tourism	促進可持續旅遊業		

social enterprise	社會企業	
social entrepreneur	社會企業家	
train	火車	訓練/培訓
turnover	周轉	
wage	工資	
SDG9		
3-D knit	3-D 針織（3D 針 3D 針織 織）	
Airblasted yarn	噴氣紗	
Clean Color	乾淨的顏色	
computational resource	計算資源	
Dyed with pomegranate, palmetto leaves and citrus peels	用石榴、棕櫚葉和柑橘皮染色	
industrial	工業的（工業）	工業
industrialization	工業化	
industry	行業	
information	信息	
infrastruture	基礎設施	
innovate	創新	
Innovation	創新	
innovative	創新的	創新
Internet	互聯網	
Lightpath	光路	
Removing PFC	卸下 PFC（去除 PFC）	
resilient infrastructure development	彈性基礎設施發展	
resource-use efficiency	資源利用效率	
robotic world	機器人世界	

Startup	啟動		創業
technology	技術		
technology (technologies/technological)	技術（技術/技術）		
value chain	價值鏈		
SDG10			
developed	發達		
disability	失能	殘疾	
disable	禁用		殘疾
discrimination	歧視		
End extreme poverty	結束極端貧困		
equal (inequal)	相等（不等）（平等/不平等）		平等（不平等）
ethnicity	種族		
give shoes in Vietnam	在越南送鞋		
in need	有需要		
invest	投資		
opportunity	機會		
race (racial)	種族（種族）		
religion	宗教		
responsible migration and mobility of people	負責任的移民和人員流動	負責的移民和人口流動	
SDG11			
air	空氣		
basic service	基本服務		
building	建造	建設	
city (cities)	城市（城市）		
community (communities)	社區（社區）		
disaster	災難		

economic	經濟的		
environment	環境		
ground sacred to us	對我們來說神聖的土地		
heritage	遺產		
housing	住房		
national treasure protected	受保護的國寶	受保護的國寶（受保護的國家寶藏）	
public	上市		公共
settlement	沉降		定居
slum	貧民窟		
social	社會的		
society	社會		
tar sands pipeline	焦油砂管道		
The ruin of our coast	我們海岸的廢墟		
transport	運輸	交通	
urban	城市的		
water	水		
SDG12			
Amazonian forest	亞馬遜森林		
Bag Ban	袋禁令		
Big Oil and big Tarpon	大石油和大鰱魚		
Buy less, choose well	少買，選好	買少一點/低慾望	
chemical	化學		
Destroying rainforest for economic gain	為了經濟利益而破壞雨林		
Earth tax	地球稅		
eco brand	生態品牌		
environment	環境		
eucalyptus fiber	桉樹纖維		

fast and cheap fashion	又快又便宜的時尚	快時尚	
FSC-certified	FSC 認證		
impact	影響		
Industrial Hemp	工業大麻		
leftover	剩菜（剩餘）		
natural	自然	天然	
NZ sheep farms	新西蘭羊場		
old fishing net	舊漁網		
one without pesticide, without GMO or fertilizers	一種不含殺蟲劑、不含轉基因生物或化肥		
Organic	有機的		
our movement committed to improving lives all over the world	我們的運動致力於改善全世界的生活		
planet	行星	星球	
Pollution	污染		
protection of our resource	保護我們的資源		
recycle	回收		
recycling	回收		
Regenerative	再生		
remanufature	再製造		
remanufaturing	再製造		
Removing PFC	卸下 PFC	去除 PFC	
renewable	可再生		
resource	資源		
responsibility	責任		
responsible	負責任的		負責任
reuse	重用	再利用/再使用	

reusing	重用	
save	節省	
saving	保存	節省/節約
sustainability	可持續性	
sustainable	可持續的	可持續
sustainably	可持續的	
waste	浪費	
water	水	
wild	荒野	野生
Wornwear	穿衣	舊 衣/穿 過 的衣服
energy	活力	能源
care label	護理標籤	
SDG13		
Amazonian Rainforest	亞馬遜雨林	
Arctic	北極	
carbon dioxide (CO2)	二氧化碳 (CO2)	
carbon footprint	碳足跡	
climate	氣候	
contamination	污染	
COP21	COP21	
Defend our air	保衛我們的空氣	
disaster relief	賑災	
Earth Tax	地球稅	
EarthDay	地球日	
emission	排放	
environment first	環境第一	
environmentally friendly technolog	環保技術	

glaciers	冰川	
greenhouse	溫室	
hot	熱的	
melt	熔化	
oxygen	氧	
Paris Agreement	巴黎協定	
pollution	污染	
sea level	海平面	
slow fashion	慢時尚	
stewards of the planet	地球的管家	
temperature	溫度	
VoteOurPlanet	投票我們的星球	為我們的星球投票
warm	溫暖的	溫暖
SDG14		
acidification	酸化	
agricultural run-off	農業徑流	
aquaculture	水產養殖	
Arctic	北極	
Atlantic	大西洋	
Bag Ban	袋禁令	
Blue Friday	藍色星期五	
coast	海岸	
coastal	沿海	
dolphin	海豚	
eutrophication	富營養化	
fish	魚	
fisher	費舍爾（漁民）	漁民

fishery (fisheries)	漁業（漁業）
fishing	釣魚
Graffiti Pier	塗鴉碼頭
island	島
marine	海洋
marine pollution	海洋污染
maritime	海上
Microfiber Pollution	超細纖維污染
Ocean	海洋
Oceanographic	海洋學
oil drilling	石油鑽探
oil spill	漏油事件
Pacific	太平洋
pesticides	殺蟲劑
plastics	塑料
sea	海
Spawning	產卵
UNCLOS	聯合國海洋法公約
untreated sewage	未經處理的污水
whale	鯨
SDG15	
Amazonian forest	亞馬遜森林
animal	動物
Arable land	耕地
biodiversity	生物多樣性
conservation	保護
Desertification	荒漠化
drought	乾旱

dryland	旱地	
EarthDay	地球日	
ecosystem	生態系統	
endangered	瀕危	
extinct	滅絕	
flood	洪水	
forest	森林	
habitat	棲息地	
in danger	在危險之中	瀕危
insect(s)	昆蟲	
invasive alien	入侵的外星人	
land degradation	土地退化	
land degration	土地退化	
mountain	山	
National Monument	國家紀念碑	
national treasure protected	受保護的國寶	受保護的國家寶藏
nature (natural)	自然	
PFCs	全氟化合物	
plant	植物	
poach	偷獵	
public land	公共土地	
PublicLand	公共土地	
Refuge	避難所	
threatened	威脅	
traffick	販運	販賣
wetland	濕地	
wildlife	野生動物	
SDG16		

abuse	虐待		
accountability	問責制		
accountable	負責任的		負責任
bribery	受賄	賄賂	
bully	欺負		
conflict	衝突		
corruption	腐敗		
crime	犯罪		
defend	保衛		
Democracy	民主		
disappearance	消失		
discriminatory	歧視性的		歧視
exploitation	開發		
freedom	自由		
government	政府		
gun	槍		
hemp	麻		大麻
human right	人權		
illegal	非法的		非法
illicit	非法的		
InternationalDayofPeace	國際和平日		
justice	正義		
kill	殺		
law	法律		
Martin Luther King	馬丁路德金		
Peace	和平		
persecution	迫害		
Syrian refugee	敘利亞難民		

terrorism	恐怖主義		
torture	折磨		
transparent	透明		
violence	暴力		
war	戰爭		
weapon	武器		
SDG17			
B Corp	B 公司	B Corp	
Carbon Fund	碳基金		
Certified B Corporation	經認證的 B 公司		認證 B Corp
coherence	連貫性		
coordinate	協調		
COP21	COP21		
Developed	發達		
developing	發展		發展中
Doha Development Agenda	多哈發展議程		
domestic	國內的		國內/本土
duty-free	免稅		
enabling	啟用	賦能	
export	出口		
Giving Partner	給予夥伴		
GlobalGoal	全球目標		
import	進口		
investment fund	投資基金		
Mobilize	動員		
multilateral trading	多邊貿易		
NewMetrics '18	新指標 '18		
North-South	南北		

parnter	夥伴	
part of a movement	運動的一部分	
part of movement	運動的一部分	
part of our commitment	我們承諾的一部分	
preferential rules of origin	優惠原產地規則	
quota-free	免配額	
Respect	尊重	
share	分享	
Social Entrepreneurship Fund	社會創業基金	
South-South	南南	
stakeholder	利益相關者	
team	團隊	
the technology bank	科技銀行	
together	一起	
triangular	三角形	三邊/三角
VoteBCorp	投票公司	投 B Corp
World Trade Organization (WTO)	世界貿易組織 (WTO)	

Chapter 5: Will Job Creation Facilitate Diffusion of Innovations in the Automobile Industry?

Abstract

The electrification and automation of vehicles are two upcoming trends in the automobile industry. However, these two new technologies have low stakeholder engagement due to road safety, range, and, most crucially, job creation in the automotive and transportation industries. This study investigates whether job creation facilitates stakeholder engagement in the innovations in sustainable product design (i.e., electric vehicles, automated vehicles) in the automobile industry. Analysis of 32,006 tweets from 33 global automobile manufacturers and their international job creation records revealed that job creation can improve stakeholders' adverse social media engagement on vehicle electrification and automation, the latest innovations in transportation and logistics. This study provides some suggestions to help firms understand how to engage stakeholders. Car manufacturers should continually communicate their job creation achievements to gain public acceptance when introducing innovations, which may improve the diffusion of innovations.

Keywords: Diffusion of Innovation; Job Creation; Electric Vehicle; Automated Vehicle; Social Media Analytics

1. Introduction

The electrification and automation of vehicles are two major future trends in the automotive industry (Keith et al., 2020; Naumov et al., 2020). Because the global demand for transportation continues to increase, transportation is a major contributor to greenhouse gas emissions (Keith et al., 2020). Electric vehicles (EVs) reduce the impact of automobiles on the environment (e.g., greenhouse gas emissions) (Keith et al., 2020). Because of advanced planning capability, automated vehicles (AVs) can reduce road accidents, increase effective road capacity, and decrease fuel costs (Fagnant et al., 2016; Greenblatt & Saxena, 2015). Some automobile manufacturers are advancing both of the aforementioned technologies simultaneously in their product innovation, whereas some are innovating their products with advancements in either technology depending on the firms' existing research and development capability, customer base, and stakeholder engagement.

EVs and AVs, as innovations in sustainable product design, have promoted substantial progress in the automobile industry. However, some stakeholders (e.g., employees, consumers) are concerned, causing low stakeholder engagement in EVs and AVs. Innovation usually changes the product design and thus the production process. Some past examples have shown that conflicts caused by employment concerns may arise when new technologies are first introduced. For instance, Walmart workers staged a strike over the retailer's push for automation in Chile in 2019.[53] EVs may have fewer moving parts, which implies that EVs need fewer employees to produce.[54] Frequent layoffs may occur in the automobile industry, causing panic among employees (Reinardy, 2010). Employees' concerns may spread widely since the automobile industry usually is the engine of job creation (JC) with a huge number of employees. Moreover, AVs (by Amazon, Google, Tesla, and Uber) can replace taxi driver and expressman jobs, raising concerns regarding upcoming massive technological unemployment (Piva & Vivarelli, 2018). The U.S. Department of Commerce estimates that at least one in nine auto workers' careers will be affected by the introduction of AVs.[55] Meanwhile, consumers are less willing to purchase EVs and AVs due to high price, low mileage, the risk safety and other concerns about the product performance. The global sales volume of EVs was slightly higher than 2.1 million in 2019, which only accounted for 2.6% of global car sales[56]. The application of AVs has also made slow progress. Recently, an AAA's survey showed that 78% of respondents were fear to

[53] https://www.japantimes.co.jp/news/2019/07/11/business/walmart-workers-strike-retailers-robot-push-chile/#.X0T_HsgzbLY

[54] https://www.detroitnews.com/story/business/autos/2019/09/05/shift-electric-vehicles-radically-change-auto-factories/2208961001/

[55] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3022818

[56] https://www.iea.org/reports/global-ev-outlook-2020

take AVs.[57] As a result, employees and consumers may engage less in EVs and AVs. Employees and consumers are considered major stakeholders because these groups occupy an important position in firms' OM (Roscoe et al., 2020). We assumed that EVs and AVs have low stakeholder engagement.

To help firms understand how to engage stakeholders, we are motivated to investigate whether JC facilitates stakeholder engagement in the innovations in sustainable product design (i.e., EVs and AVs). JC presents the changes in the number of global employees of the firm in the current year compared with that in the last year(s). Firstly, higher level job creation meet the requirement of stakeholders including employees, governments, and society (de Grosbois, 2016; Hepple, 2013; Stewart et al., 2018). Secondly, firms will provide new employees with training on product introduction, corporate culture, operations and so on (Hu, 2003). Therefore, employees can become product experts and answer stakeholders' questions, which can reduce stakeholders' concern and improve stakeholder engagement. In addition, the continuous job creation shows that the firm is high-growth and sustainable (Lund & Hvelplund, 2012). Employees satisfy with the working experience and become brand ambassadors, which can enhance the firm's reputations and improve stakeholder engagement. For example, a majority of Tesla's employees love their work and be willing to introduce Tesla's products to other stakeholders, which may improve stakeholder engagement. We used the diffusion of innovations theory (DOI) as the theoretical ground for this study. We use social media data to measure stakeholder engagement since 1) social media is an effective channel for firms to communicate with stakeholders about their SOM (De Luca et al., 2022); 2) social media allows to quantify the stakeholder engagement (e.g., the number of likes). Previous studies in operations management also used social media data to quantify stakeholder engagement (Denktas-Sakar & Surucu, 2020; Surucu-Balci et al., 2020). Analysis of 32,006 tweets from 33 global automobile manufacturers and their international JC records revealed that JC can

[57] https://www.science.org/content/article/people-don-t-trust-driverless-cars-researchers-are-trying-change

improve stakeholders' adverse engagement in EVs and AVs. Our findings found out the role of JC in the diffusion of innovations, which provide a new insight into the DOI theory. Also our study emphasis the role of employees in sustainable operations management. In other words, firms should keep the balance between environmental impact and social issues in sustainable product design.

2. Literature review

2.1. Theoretical framework

DOI theory takes into account stakeholders' opinions on new technologies (Gkartzonikas & Gkritza, 2019). DOI is defined as "an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003, p. 5). Social media is an ideal space for DOI because it can spread information to a large number of stakeholders (Meng et al., 2018). Previous studies have investigated DOI with social media data, such as Grover et al. (2019). Based on this view, new technologies (i.e., EVs, AVs) as innovations can spread steadily through social media (MacVaugh & Schiavone, 2010). In turn, stakeholders' opinion plays a crucial role in the wider diffusion and adoption of EVs and AVs (Penmetsa et al., 2019). However, innovations may not be attractive to the majority of stakeholders because they are not familiar with new technologies and products (Kamolsook et al., 2019). In addition, new technologies may cause stakeholders' anxiety related to JC (Mokyr et al., 2015)

We assume that JC can improve the diffusions between EVs and AVs based on three reasons. Firstly, higher level job creation meets the requirement of stakeholders including employees, governments, and society. Secondly, higher level job creation means that firms have more employees to diffuse new technologies since employees can act as product experts to introduce the products to stakeholders. Thirdly, the continuous job creation shows that the firm is high-growth and sustainable (Lund & Hvelplund, 2012). Employees satisfy with the working experience and become brand ambassadors, which can enhance the firm's reputations and improve stakeholder engagement.

Figure 1 shows the theoretical framework of this study. We assumed that EVs and AVs might both receive lower stakeholder engagement on social media in the automobile industry. However, Car manufacturers' JC mitigates the negative effect of EVs and AVs on stakeholder engagement.

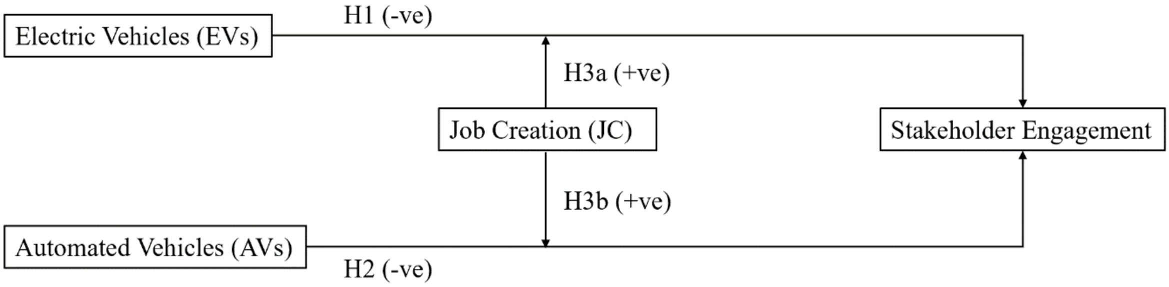

Figure 1. Theoretical framework.

2.2. The diffusion of Electric Vehicles

Despite the benefits of EVs and their increasing market acceptance, the global sales volume of EVs was slightly higher than 2.1 million in 2019, which only accounted for 2.6% of global car sales[58]. According to an automobile industry sales report published prior to the COVID-19 pandemic, among the best-selling cars and sport utility vehicles in the United States in 2019, Tesla Model 3 ranked 19th, with 161,100 units sold.[59] These figures indicate that internal combustion vehicles still account for most car sales, which indicates that EVs have a smaller stakeholder base.

The diffusion of EVs depends on the engagement of a wide range of stakeholders, including automobile users, power firms, automobile manufacturers, and governments (Ball et al., 2021). Ball et al. (2021) found that car users and car manufacturers may boycott EVs. The barriers to the diffusion of EVs are mainly the lack of charging infrastructure, a high price, and lack of

[58] https://www.iea.org/reports/global-ev-outlook-2020

[59] https://www-statista-com.ezproxy.lb.polyu.edu.hk/statistics/276419/best-selling-cars-in-the-united-states/

trust (Biresselioglu et al., 2018). Range anxiety hinders car users' confidence in adopting EVs, especially battery EVs (Illmann & Kluge, 2020). Another reason is that consumers need to readjust the vehicles and change their habits when they adopt EVs (Jansson et al., 2011). In addition, the wide diffusion of EVs means that existing automobile manufacturers need to give up their competencies (e.g., technology, skill, design) around internal combustion vehicles and change to the competencies related to EVs (e.g., battery) (Teece, 2018). EVs may have fewer moving parts, which implies that EVs need fewer employees to produce.[60] EVs may lead to 234,000 job losses at suppliers and automakers by 2030, even though they create 109,000 new jobs in the same timeframe.[61] Even layoff survivors have to learn the new manufacturing processes. Stakeholders may concern about the employment issues caused by EVs (Reinardy, 2010). Moreover, Ball et al. (2021) found that some government is less interested in the promotion of EVs as EVs have little effect on reducing carbon dioxide emissions. Furthermore, power suppliers do not have an efficient operating model for charging services (Lo Schiavo et al., 2013). Therefore, stakeholder engagement in EVs is still relatively low, which implies that stakeholders are less likely to engage in EVs on social media. We develop the first hypothesis as follows:

Hypothesis 1. Compared with conventional internal combustion vehicles, EVs receive lower stakeholder engagement.

2.3. The diffusion of Automated Vehicles

AVs rely on advanced control and sensor systems to transport passengers and goods without human intervention (Greenblatt & Saxena, 2015; Shin et al., 2015). Therefore, the technology behind AVs combines automation and AI. Stakeholders' opinion plays a significant role in the diffusion of AVs (Penmetsa et al., 2019). However, low stakeholder engagement is still one of

[60] https://www.detroitnews.com/story/business/autos/2019/09/05/shift-electric-vehicles-radically-change-auto-factories/2208961001/

[61] https://www.automotiveworld.com/articles/whats-behind-the-tens-of-thousands-of-auto-industry-job-cuts/

the challenges of the wide diffusion of AVs (Nikitas et al., 2021). An online survey with 1533 data showed that more than half of the respondents did not want to pay more for autonomous driving technology.[62] Payre et al. (2014) indicated that people who mainly seek novelty might also get tired of AVs after a period of time. Distrust of autonomous driving technology remains the main obstacle to diffusing AVs (Becker & Axhausen, 2017). Some stakeholders are also worried about the safety of AVs.[63] Other potential barriers to the diffusion of AVs include ethical issues, privacy concerns, cybersecurity, and legal liability (Gkartzonikas & Gkritza, 2019). In addition, AVs (by Amazon, Google, Tesla, and Uber) can replace taxi driver and expressman jobs, raising concerns regarding upcoming massive technological unemployment (Piva & Vivarelli, 2018). 1.7 million drivers might be replaced by Uber's "Otto" program.[64] The introduction of AVs may cause job loss issues, which means that the stakeholders' attitude toward AVs is uncertain (Kyriakidis et al., 2015; Pettigrew et al., 2018). Thus, we develop the second hypothesis as follows:

Hypothesis 2. Compared with conventional cars' technologies related to safety, performance, and operation, AVs receive lower stakeholder engagement.

2.4. Job creation and the diffusion of innovations

Automobile firms are large institutions. Even the automobile industry is the pillar industry of some cities such as Detroit and Stuttgart. The automobile industry is the engine of JC. The global automotive employment figure stood at around 8.4 million in 2005, which was similar to the employment figure of the sixth-largest economy.[65] Regarding European Unions, the automobile industry provided direct and indirect employment opportunities for more than 12.7

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[62] https://deepblue.lib.umich.edu/bitstream/handle/2027.42/108384/103024.pdf?sequence=1andisAllowed=y

[63] http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/PRC-15-49-F.pdf

[64] https://www.smithsonianmag.com/innovation/when-robots-take-jobs-remember-luddites-180961423/

[65] https://oica.net/wp-content/uploads/2007/06/oica-depliant-final.pdf

million Europeans in 2019, accounting for 6.6% of the total employment.[66] In addition, 11.5% of total manufacturing jobs in the European Union are in the automotive industry.[67] Employment in the automotive industry has grown continuously for most of the past decade.[68] Employment in Germany has increased by 120,000 since 2010, while employment in the United States has increased by 327,000 since 2009.[69] In addition, automobile firms can promote upstream enterprises or suppliers to move to the same location and indirectly generate additional employment (Adam et al., 2020; Edmiston, 2004; Jofre Monseny et al., 2018). In May 2005, Hyundai's North American assembly plant opened in Montgomery, Alabama, and eventually hired 3000 employees (Adam et al., 2020). Then, the employment of parts suppliers within the 100 km radius of Montgomery increased from 772 in 2002 to 4008 in 2008 (Adam et al., 2020). On the other hand, each job lost directly in the closure of a large firm may result in the loss of 0.6 to 0.7 jobs in the locally affected industries at the same time (Jofre Monseny et al., 2018).

The power system of an internal combustion engine vehicle may have up to 2000 moving parts. Building a conventional powertrain is the most labor-intensive part of building a car, which creates numerous jobs (Isidore, 2019). An assembly plant for conventional vehicles is estimated to create 2,000 – 4,000 jobs (Adam et al., 2020). For instance, 150,000 U.S. jobs were related to building engines, transmissions, and axles at U.S. factories in 2018 (Isidore, 2019). By contrast, the parts in electric powertrains may be as few as 20 because EVs do not have multispeed gas tanks, exhaust systems, valvetrains, fuel injectors, transmissions, or radiators.[70] According to some estimates, EVs may lead to 234,000 job losses at suppliers and automakers

[66] https://www.acea.auto/figure/employment-trends-in-eu-automotive-sector/

[67] https://www.acea.auto/figure/employment-trends-in-eu-automotive-sector/

[68] https://www.automotiveworld.com/articles/whats-behind-the-tens-of-thousands-of-auto-industry-job-cuts/

[69] https://www.automotiveworld.com/articles/whats-behind-the-tens-of-thousands-of-auto-industry-job-cuts/

[70] https://www.detroitnews.com/story/business/autos/2019/09/05/shift-electric-vehicles-radically-change-auto-factories/2208961001/

by 2030, even though they create 109,000 new jobs in the same timeframe.[71] 75,000 jobs related to building engines and transmissions will be eliminated in Germany by 2030 (Isidore, 2019).

Automobile firms usually relate to services (e.g., 4S stores, financial service), transportation (e.g., taxi drivers, logistics), manufacturing and energy supply, which have a significantly positive effect on local employment (Edmiston, 2004). EVs and AVs will also affect the employment of other industries. From a socio-economic perspective, the widespread adoption of electric vehicles is expected to lead to structural changes in the energy industry (from oil extraction to electricity generation), including changes in employment, income, and profitability (Onat et al., 2019). Ulrich and Lehr (2020) found that lower demand for conventional fuels leads to a loss of more than 4000 jobs in the sector of trade and repair of motor vehicles and petrol stations. The decline in employment in the automotive industry and gas stations has led to a negative net employment effect since 2020 (Ulrich & Lehr, 2020). Meanwhile, AVs (by Amazon, Google, Tesla, and Uber) can replace taxi driver and expressman jobs, raising concerns regarding upcoming massive technological unemployment (Piva & Vivarelli, 2018). Taxi drivers are less likely to change jobs due to sunk costs associated with license ownership and a lack of other skills (Wang & Smart, 2020). Although workers in traditional occupations may attempt to improve their skills, they find it challenging to balance rest and skill improvement (i.e., receiving a college education) (Grigoli et al., 2020; Mellacher & Scheuer, 2020). Taxi drivers are labor-intensive, repetitive jobs, which occupy most of the people's time, so they have no time to learn new knowledge and skills. Most stakeholders indicated that firms adopting AVs must bear the responsibility of job creation (Nikitas et al., 2021).

JC presents the changes in the number of global employees of the firm in the current year

[71] https://www.automotiveworld.com/articles/whats-behind-the-tens-of-thousands-of-auto-industry-job-cuts/

compared with that in the last year(s). JC has potential to improve stakeholder engagement and affect the diffusion of EVs and AVs since 1) it meets the need of stakeholders; 2) it increases the number of product experts whom can reduce stakeholders' concerns; 3) it improve employees' working satisfaction and enhance firms' reputation (Ball et al., 2021).

Firstly, higher level job creation meets the need of stakeholders including employees, governments, and society. Based on Maslow's hierarchy, jobs can satisfy employees' physiological needs (i.e., wages), relationship needs, esteem needs (i.e., a positive management relation with employees), and self-actualization needs (Maslow, 2013; Stewart et al., 2018). In addition, governments will formulate some laws and regulations related to JC (Hepple, 2013). Full employment is a goal of public policy of the government (Farmer, 2010; Niwman, 1958). Furthermore, United Nations' Sustainable Development Goals also call for full and productive employment.[72] Moreover, the awareness of the society on the employment issue is constantly improving, forcing the firm to take action on employment and report the progress to the society (de Grosbois, 2016).

Secondly, creating more jobs will increase the number of internal stakeholders (i.e., employees). Employees can become product experts through Firms' training on product introduction (Hu, 2003). Therefore, higher-level job creation means that firms have more employees to diffuse new technologies. Employees have more expert information about the vehicle (e.g., product information, maintenance methods, and insurance) than other stakeholders so that they can introduce new products to stakeholders more professionally and reduce stakeholders' confusion (Amin et al., 2022; Xiong et al., 2013). This also can reduce the cost of users searching for information related to new technologies and improve the tendency of users to use new technologies (Caiazza & Volpe, 2017). Gebauer et al. (2016) find that employees showed charging technology and demonstration vehicles to consumers, which is more likely to make

[72] https://sdgs.un.org/goals

consumers form a positive attitude towards EVs and AVs. Matthews et al. (2017) further indicate that car dealers play an important role in overcoming resistance to adoption since they are frontline in answer stakeholders' questions about product. In addition, Nikitas et al. (2021) find that it is beneficial for the diffusion of AVs when firms employed more people to develop marketing campaigns for AVs. Further, Saleem and Hawkins (2021) find that employee-created social media content affects consumers' perceptions of expertise, which in turn increases Words of Mouth and purchase intention.

Thirdly, the continuous job creation shows that the firm is high-growth and sustainable (Lund & Hvelplund, 2012). Firms' efforts on JC can improve employees' job satisfaction and performance, which in turn engage employees in firms' communication on new technologies (Du et al., 2015; Sarfraz et al., 2018). EVs and AVs, as innovations, may cause a change in job demand and structure in the auto industry.[73] EVs and AVs have potential to reduce jobs, causing concern and dissatisfaction among stakeholders (Chin et al., 2019). Layoff may be toxic to organizational trust, organizational morale and employees' working satisfaction (Reinardy, 2010). Employees can easily express their dissatisfaction on social media (Miles & Mangold, 2014). Employees' content on social media will affect the engagement of other stakeholders such as potential employees, consumers, suppliers, and business partners (Korzynski et al., 2020).

In contrast, career development opportunities enhance the career prospects of employees, improving employee engagement (Amin et al., 2022). In other words, firms are committed to creating jobs and protecting the interests of employees, which will improve employees' satisfaction and loyalty and attract more excellent employees so as to improve employee engagement (Yu et al., 2017). If employees satisfy with the working experience, they may become the firm's brand ambassadors share their firms' messages with other stakeholders on

[73] https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/meetingdocument/wcms_741659.pdf

social media. This can enhance the firm's reputations and improve stakeholder engagement. In addition, the lack of trust is one of the barriers to the diffusion of EVs and AVs (Becker & Axhausen, 2017; Biresselioglu et al., 2018). On the other hand, trust is a factor in promoting the diffusion of innovation (Caiazza & Volpe, 2017). Firms that emphasize JC can enhance firms' social responsibility so as to obtain greater trust of stakeholders (Chen, 2018; Stawicka, 2021).

In conclusion, higher level job creation meets the stakeholders' need. In addition, higher level job creation means that firms have more employees to diffuse new technologies since employees can act as product experts to introduce the products to stakeholders. Moreover, the continuous job creation can improve employees' working satisfaction, which make employees become brand ambassadors and improve stakeholder engagement. Thus, we assume that car manufacturers' JC can mitigate the negative effects of EVs and AVs on stakeholder engagement.

Hypothesis 3(a). Car manufacturers' JC mitigates the negative effect of EVs on stakeholder engagement.

Hypothesis 3(b). Car manufacturers' JC mitigates the negative effect of AVs on stakeholder engagement.

3. Methods

3.1. Data collection

3.1.1 Sample selection

For sample selection, we mainly focused on mainstream brands from the top 10 global auto groups in 2020.[74] However, Hyundai and Kia were excluded, as they surprisingly do not disclose specific employment data in their annual reports or any other resources. In addition,

[74] https://www.focus2move.com/world-car-group-ranking/

we excluded supercar brands (i.e., Ferrari and Aston Martin) because their customers comprise a minority of the public. Tesla was included as its market capitalization is $245 billion, indicating its position as the world's most valuable automaker (Randewich, 2020). Finally, based on the aforementioned considerations, we collected the data of job creation and tweets from the 33 brands listed in Table 1.

Table 1. Brands included in the study sample.

Brand	Parent Group	American Brand	Parent Group
Mercedes Benz	Daimler AG	Buick	General Motors Firm
Smart		Cadillac	
BMW	Bayerische Motoren Werke AG	Chevrolet	
MINI		Corvette	
Volkswagen	Volkswagen AG	GMC	
Audi		Ford (incl. Ford Trunk)	Ford Motor Firm
Porsche		Lincoln	
Toyota	Toyota Motor Corporation	Chrysler	Fiat Chrysler Automobiles
Lexus		Dodge	
Honda	Honda Motor Co Ltd.	Jeep	
Acura		Ram	
Nissan	Nissan Motor Co Ltd.	Tesla	Tesla Inc.
Infiniti			
Jaguar	TATA Motors Ltd.		
Land Rover			
Peugeot	Peugeot SA		
Citroen			
Renault	Renault SA		
Fiat	Fiat Chrysler Automobiles		
Alfa Romeo			
Maserati			

3.1.2 Data of job creation

To construct the JC variables, we adopted the difference between the parent group's total employees in the current year and its average employee numbers in the previous years (e.g., last year, last two years, last three years). To standardize our data and to ensure our data authenticity, we firstly obtained employment data from annual reports of the selected brand's parent group. We did not use tweets about job creation due to a couple of reasons. Firms hardly talk about their JC on Twitter platforms. Therefore, we could not find a sizable sample of tweets about the job creation of our selected brands. Moreover, as job creation is not a one-off event, a single job creation tweet does not fully reflect a firm's real effort. Job creation is a continual process over time. Stakeholders shall develop an overall impression of the firms' job creation. Thus, compared to tweets about job creation, more precise data for job creation are from the firms' annual reports. If we could not get employment data in an annual report, we checked the parent groups' U.S. Securities and Exchange Commission (SEC) Form 10-K or 20-F, which is also a trustable resource. For some old employment data (e.g., the number of employees in 2012), we checked the data on www.statista.com and www.martrend.net. To be specific, the fiscal years of Toyota, Honda, Nissan, and Tata end on 31 March each year, while others end on 31 December each year.

3.1.3 Data of social media

Then, we ran Twitter's Application Programming Interface (i.e., REST API) on Python 3.7 to obtain tweets from each brand. We downloaded tweets from 25 September 2015 to 25 September 2019. We collected 57,294 tweets from 33 automobile brands. We only included original tweets by the brands, and the brands' replies to others (i.e., the tweets starting with "@") were excluded. Replies were excluded because replies cannot represent the car maker's intention. Firms' retweets (sharing others' posts) were included in the sample for analysis as retweeting indicates the tweets are in line with firm values. Finally, 32,006 tweets were processed for data analysis.

3.2. Rule-Based Classification

In rule-based classification, experts develop some rules (i.e., keywords) to label the text (Chau et al., 2020). The advantage of rule-based classification is that expert opinions are integrated into the classification process (Chau et al., 2020). It is widely adopted in social media studies, such as those by Chau et al. (2020) and Grover et al. (2019). To construct our rule-based classifier, we created a lexicon consisting of words related to EVs, AVs, and other features of vehicles (Appendix A). The lexicon was reviewed for completeness by experts who are researchers in the field of transportation.

3.3. Data analysis

We used hierarchical linear regression for data analysis. We select the number of likes to measure stakeholder engagement on social media. Giving likes implies that stakeholders have engaged in and approved firms' practices mentioned on social media posts (Srinivasan et al., 2022). Moreover, giving likes is the easier engagement option for stakeholders (Srinivasan et al., 2022). As Lg(x) requires $x > 0$, we must adjust the zero value in the number of likes (Kanuri et al., 2018). Because normal distribution does not change when the variable contains a constant, we adjusted the number of likes by adding one to every number[75] and created the dependent variable "Lg (Adjusted Likes)" for regression analysis.

First, we tested the relationship between the tweets regarding EVs and social media engagement and the relationship between the tweets regarding AVs and social media engagement. Second, we examined how JC moderates these two relationships. For the independent variable JC, we adopted the difference between the parent group's total employees in the current year and its average employee numbers in the previous years. We then tested the job creation in one year (JC1), two years (JC2), and three years (JC3) prior to the tweet.

[75] https://blogs.sas.com/content/iml/2011/04/27/log-transformations-how-to-handle-negative-data-values.html.

To explain the content level and environment level heterogeneity, we also created serial control variables, including total assets in million USD, text length, brand dummies, year dummies, and variables related to the basic features of the vehicle. First, for the tweets related to basic car features, we followed the method of Keith et al. (2017) and applied the price, performance, emission, and range as our control factors to mitigate the effect of other performances of vehicles. Total assets (million USD) are controlled for firm size (Saxton et al., 2019). Text length was used to control for the effect of a tweet's length on stakeholder social media engagement, which has been indicated to be correlated with the likelihood of retweets. Finally, year dummies were used to reduce the yearly economic impact on social media, and brand dummies were used to control for the effect of brand reputation on stakeholder social media engagement. Detailed notations and explanations of variables are listed in Table 2.

Table 2. Details of study variables.

Variables	Explanation
Dependent variable	
Lg (Adjusted Likes)	Ln of total adjusted number of likes on a tweet
Independent variables	
EV	Tweets concerning electric vehicles
AV	Tweets concerning automated vehicles
JC1	Changes in the number of global employees of the parent group in the current year compared with that in the last year
EV × JC1	The moderating effect of the change in the number of employees within one year on social media engagement about electric vehicles
AV × JC1	The moderating effect of the change in the number of employees within one year on social media engagement about automated vehicles
JC2	Changes in the number of global employees of the parent group in the current year compared with the average in the previous two years
EV × JC2	The moderating effect of the change in the number of employees within two years on social media engagement about electric vehicles
AV × JC2	The moderating effect of the change in the number of employees within two years on social media engagement about automated vehicles

JC3	Changes in the number of global employees of the parent group in the current year compared with the average in the previous three years
EV × JC3	The moderating effect of the change in the number of employees within three years on social media engagement about electric vehicles
AV × JC3	The moderating effect of the change in the number of employees within three years on social media engagement about automated vehicles
Control variables	
Price	Tweets about price
Performance	Tweets about performance
Emission	Tweets about emission
Range	Tweets about range
Text length	Number of words in a tweet
Total assets (million USD)	Firm's total assets in billion USD
Brand dummies	Distinguish different brands' tweets
Year dummies	Distinguish tweets in different years

In the main analysis, model 1 was used to test the effects of control variables on social media engagement, and models 2–4 were used to test the moderating effect of job creation in different years. To ensure that our results were consistent, we conducted two robustness checks. First, we conducted the analysis without Tesla, as their CEO, Elon Musk, is a very active Twitter user; thus, Tesla's data would have skewed the model. Then, we changed to using the number of retweets as the dependent variable in the robustness check.

4. Results

4.1. Descriptive analysis

Figure 2 shows the distribution of tweets by brand and tweets contributed by brands with the number of likes in the top 100 numbers. Among 32,006 tweets, Nissan accounted for the largest proportion (11.98%), with 3833 tweets, followed by Mercedes Benz (3209 tweets; 10.03%) and Volkswagen (1815 tweets; 5.67%). The lowest number of tweets was noted for GMC (168 tweets; 0.52%). Among 472 tweets from Tesla, the retweeting number of 96 (20.34%) tweets ranked in the top 100.

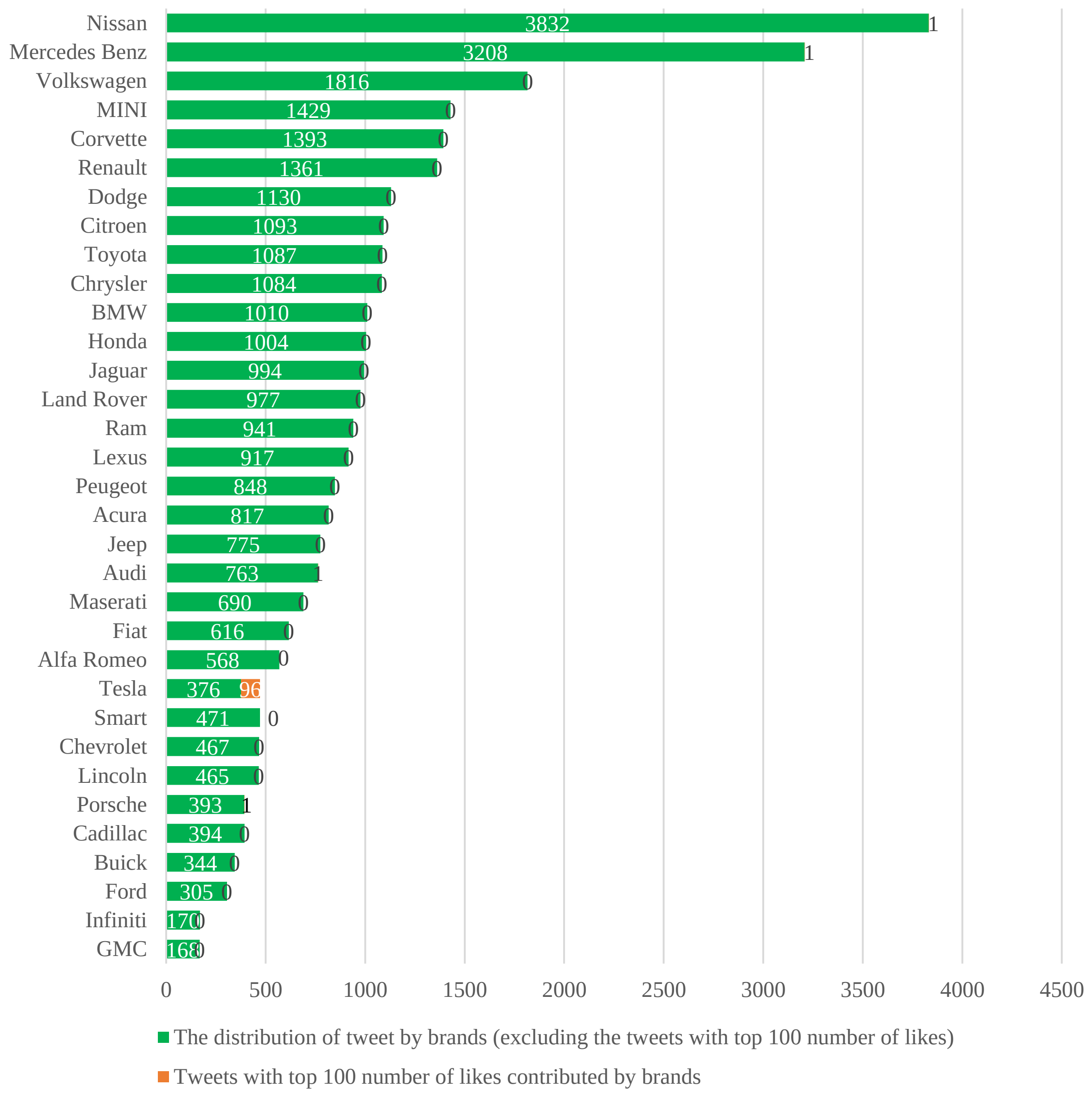

Figure 2. Distribution of tweets by brand and tweets contributed by brands with the number of likes in the top 100 numbers.

4.2. Linear regression

This study used SPSS 25.0 to test the hypotheses. Descriptive statistics and correlations are presented in Table 3. Table 4 displays the regression analysis results with the Lg (Likes) as the dependent variable. Model 1 was used to test the effect of control variables on social media engagement. Regarding the basic features of vehicles, performance (.105, $p < .01$) and emission (.120, $p < .01$) had positive effects on social media engagement, whereas price (−.174, $p < .01$) had negative effects on social media engagement. The range was not significant. This implies that people focus on vehicle performance and emission, with a negative consumer perception of price. Total assets (.00, $p < .01$), as financial indicators, had significantly positive effects on social media engagement. TL (−.001, $p < 0.01$) negatively affected social media engagement, which means that excessively long tweets have negative effects.

Models 2–4 were used for the main analysis. First, variables related to EV and AV were significantly negative in models 2–4, which implies that stakeholders have negative social media engagement for the tweets about EV and AV. Thus, H1 and H2 were supported. Then, we also observed that EV × JC and AV × JC had positive effects on retweeting in models 2–4, which implies that JC mitigates the negative effect of EV and AV on stakeholder social media engagement. This result indicates that stakeholder technology anxiety is indirectly caused by job loss. Thus, H3 was fully supported. Furthermore, we noted that the moderating effect of JC on EV was stronger when firms created jobs in the longer term. By contrast, firms' short-term JC can stimulate to a greater extent the moderating effect of JC on AV. Finally, R^2 (.7192) in model 4 was the highest, indicating that model 4 was the optimal model, and EV × JC3 and AV × JC3 explained most of the moderating effects.

4.3. Robustness check

To ensure the robustness and consistency of the research results, we conducted two robustness checks of our results. First, we re-ran the model, excluding Tesla's data (Table 5) in the robustness check. Model 4 was still the optimal model. The findings remained the same, suggesting that the model was not influenced by bias from Tesla's tweets. In addition, the findings also remained the same when we changed to use of "Lg (Retweet)" as dependent variable (Table 6). Therefore, the category of social media engagement did not influence our findings. Both forwarding and likes can reflect public opinions. Furthermore, R squared in the model with "Lg (Retweet)" as the dependent variable was smaller than that in the model with "Lg (Likes)" as the dependent variable, which meant that Lg (Likes) is more suitable to be the dependent variable.

5. Discussion

Our results indicate that a tweet about EVs is less likely to receive likes compared to all other non-EVs tweets. Stakeholder engagement is negative for AVs compared with traditional cars' technologies on safety, performance, and operations. This explains that the diffusions of EVs and AVs are considerably inert on social media channels. Moreover, we find car manufacturers' JC mitigates the positive effect of EVs and AVs on stakeholder engagement.

5.1. Implications for research

To the best of our knowledge, this is the first study that employed social media datasets to indicate that JC improves DOI in the automobile industry. Social media is an ideal platform to examine DOI since everyone can express their opinions easily and freely on social media. In addition, people's attitudes towards innovations are measurable (i.e., social media engagement) on social media. On Twitter, social media engagement includes giving likes, providing comments, and retweeting. Compared with the data collected using other methods (e.g., surveys and interviews), social media analytics is more suitable for investigating public opinion and is much more suitable in our research context. Our findings indicate that social media engagement should receive greater attention from both academics and senior management for promoting DOI among the public.

First, we adopt social media data to provide evidence that the diffusions of EVs and AVs are still passive, which is consistent with previous studies (Chen, 2018; Mitchell & Olson, 1981). Ball et al. (2021) and Biresselioglu et al. (2018) argued that obstacles to the diffusion of EVs (e.g., charging infrastructures) are substantial rather than incentives for the diffusion of EVs (e.g., ecological awareness, allowance). On the other hand, Biresselioglu et al. (2018) claimed that a lack of consumer acceptance is still taking a big toll as a barrier to diffuse AVs. Tesla is more adept at communicating with the public regarding its technologies, but our robustness test revealed that our prediction applies to all other brands, which is that stakeholders react negatively to EVs and AVs on social media platforms.

JC, as a moderator, can reduce stakeholders' negative reactions and improve DOI. JC is one part of firms' communications on their CSR practices. Previous studies overlooked that job loss may be one of the barriers to the diffusion of EVs and AVs (Gkartzonikas & Gkritza, 2019). According to Maslow's hierarchy of needs, employment is one of the people's significant needs. Thus, job creation is a significant social issue. Consumers tend to identify with firms that they think are socially responsible and recommend them to their friends and others (Dang et al., 2020b). The CEO of Tesla, Elon Musk, emphasizes CSR, for example, by transforming conventional energy sources into renewable energy and reusing space rockets to minimize wastage, which attracts greater public media engagement. This extends the research by Wiengarten et al. (2015), which indicates that CEOs who focus on CSR might enhance firms' financial performance. In addition, social influencer CEOs are more likely to post CSR messages on Twitter to engage stakeholders strategically (Grover et al., 2019). CSR is a long-term investment that can bring benefits not only to the local community but also to the firm itself, which requires that firms' innovations be responsible (Stawicka, 2021). Therefore, in our study, the results indicate that JC that fulfills key sustainable development goals helps brands win public approval of innovations. Our study provides evidence of the relationship between CSR efforts and DOI, which extends the CSR literature.

In addition, firms' new technologies can reach widely and quickly through employees, who are seen as ambassadors. Moreover, employees are also product experts who can answer people's questions about new technologies, share their own experiences with new technologies, and release people's anxiety about new technologies.

5.2. Implications for practice

We observed the failure of the diffusion of EVs and AVs on social media, which implied that firms need to put more effort into social media communication. Communication on social media exceeds the limit of time and space. Therefore, social media allows firms to achieve wider and more immediate DOI. We suggested that JC is a benefit for firms' DOI. Firms may get higher social media engagement when they communicate their efforts on job creation on the topics related to EVs and AVs. Among 32,006 tweets, we only found that there were less than 100 tweets that mentioned job creation on the topic of EVs and AVs. Car manufacturers generally neglect to mention job creation in the diffusion of EVs and AVs. However, when firms mention job creation, they can get higher social media engagement. For example, "#Ford is investing $1.6 billion to upgrade two plants in Michigan & Ohio—and creating or retaining 650 U.S. jobs" received around four times more likes (772) than the average number (201). " #MercedesBenz goes #electric in America—bringing 600 U.S. jobs & a $1 billion investment to #Alabama #switchtoEQ http://benz.me/dmCASE" received 696 likes, approximately 60% more than the average number (457).[76]

Furthermore, JC is one aspect of SOM. In particular, the firm's commitment to job creation is conducive to establishing a responsible public image. In particular, firms' efforts on sustainability have the potential to improve employee satisfaction (Du et al., 2015; Sarfraz et al., 2018). Employees who have satisfactory working experience are more likely to share their firms with their friends and relatives. Consequently, people may engage more in these firms, which improves the diffusion of innovations in these firms.

In addition, this study provides evidence of the significance of employees as ambassadors, which also illustrates that firms need to maintain a high level of employee satisfaction. Currently, AVs still need to run under human supervision. There are still many accidents caused by automatic cars, resulting in people's fear of new technology. Training can educate drivers to become more familiar with AVs and improve the adoption rate.[77] In addition, front-line service personnel with more professional knowledge will be able to engage consumers in the experience of EVs and AVs, thus improving DOI (Saleem & Hawkins, 2021).

[76] https://t.co/9HZjQkkV3M

[77] http://agelab.mit.edu/files/publications/2016_6_Autonomous_Vehicles_Consumer_Preferences.pdf.

Additionally, as promoting innovations is the long-term goal of the government, we suggest that policy makers should promote new labor policies while promoting technology and innovation policies related to EVs and AVs. For instance, Singapore's Ministry of Transport suggests that full AVs adoption will only occur in approximately 15 years because social issues must first be addressed, including job displacement and reskilling, as well as impacts on revenue collection (road tax); measures to resolve these matters can reduce citizens' anxiety when AVs are adopted (Huiling & Goh, 2017). To meet additional demand, policymakers should pay attention to developing charging facilities and the manufacturing of batteries, electrical parts, and machinery (Ulrich & Lehr, 2020). Then, policymakers should communicate new training programs to ease people's anxiety about unemployment caused by new technologies.

5.3. Limitations and future research directions

First, the time period of our data is from 2015 to 2019, which is the embryonic stage of EVs and AVs. With technological development and extensive diffusion, EVs and AVs may have higher stakeholder engagement now. Future studies can examine whether stakeholder engagement in EVs and AVs is increasing currently or not. Second, although retweeting is assumed to represent positive engagement, which is also largely supported by the literature, some retweeting may denote negative sentiments. Future research could use sentiments from Twitter followers as the dependent variable. Third, this study covers the majority of global brands in the auto industry. However, some brands from developing countries may have been neglected (e.g., China). Fourth, it is not clear how social media engagement affects firm performance, as the sentiment of tweets regarding supply chain problems could affect stock market prices (Schmidt et al., 2020). Such effects may also affect firms' innovation and should be investigated. Future studies should measure how public opinion regarding EVs and AVs on social media affects auto firms' stock returns.

In addition, we noted that several international brands communicated the number of jobs they created for the U.S. on Twitter. These car makers obtained several reactions from stakeholders. For instance, "#MercedesBenz goes #electric in America—bringing 600 U.S. jobs & a $1 billion investment to #Alabama #switchtoEQ http://benz.me/dmCASE" received 696 likes, approximately 60% more than the average number (457).[78] Therefore, we assume that the U.S. public may prefer locally produced brands because of the desire to support local employment or because they show a larger commitment to supply products and components made in the local market (Yu & Kim, 2018). Future studies can adopt the number of employees in American sub-firms as a variable and replicate the current study. The current research team could not locate adequate U.S. employment information of most European car makers; thus, this study only focused on the topic in the global context.

Furthermore, future studies can extend the hypothesis and compare the differences between stakeholders' reactions to local manufacturing in different markets. For example, Tesla established new factories in China and Germany to manufacture new models for Chinese and European markets. Tesla's actions corroborate our empirical findings. In particular, the Tesla Shanghai Gigafactory is a wholly-owned subsidiary of Tesla, which is the first foreign car manufacturer with 100% foreign capital in China. The factors (e.g., new job creation on local supply chains and lower prices) affecting the Chinese government's decision to allow Tesla to set up a wholly-owned factory should be investigated. However, Tesla's foreign investment may limit new job creation in the United States. Therefore, how to maintain the balance between foreign investment and local investment in the scenario of EVs and AVs requires further investigation.

Compared to the findings in chapter 3 and 4, we may investigate if stakeholder engagement in sustainable product design may vary at different stages of product lifestyle in the future. EVs and AVs are in the embryonic stage of the product cycle, while fashion products are in the mature stage, which may cause different stakeholder engagement.

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[78] https://t.co/9HZjQkkV3M

Table 3. Descriptive statistics and correlations; *N* = 32,006.

	Variables	mean	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	LG (Likes)	2.117	.626																		
2	EV	.07	.253	.038**																	
3	AV	.02	.134	-.045**	.272**																
4	JC1	1.047	14.212	-.122**	.059**	.010															
5	EV × JC1	.2834	3.075	.003	.340**	-.029**	.211**														
6	AV × JC1	.037	1.720	-.017**	-.022**	.159**	.120**	.159**													
7	JC2	2.178	16.725	-.159**	.085**	.018**	.915**	.208**	.108**												
8	EV × JC2	.510	3.975	.012*	.473**	-.001	.191**	.913**	.133**	.225**											
9	AV × JC2	.080	2.093	-.029**	.006	.280**	.105**	.141**	.888**	.120**	.160**										
10	JC3	3.787	19.319	-.161**	.095**	.016**	.850**	.196**	.097**	.977**	.225**	.115**									
11	EV × JC3	.726	4.914	.017**	.544**	.013*	.171**	.829**	.110**	.215**	.966**	.145**	.231**								
12	AV × JC3	.109	2.412	-.032**	.023**	.332**	.094**	.125**	.807**	.116**	.156**	.976**	.116**	.150**							
13	Price	.00	.031	-.014*	.004	-.004	.002	.003	-.001	.006	.003	-.001	.008	.007	-.001						
14	Performance	.01	.091	.012*	.040**	.000	.017**	.019**	-.004	.020**	.030**	-.005	.021**	.035**	-.003	-.003					
15	Range	.00	.010	.006	.010	-.001	.000	-.004	.000	.001	-.003	.000	.002	-.003	.000	.000	-.001				
16	Emission	.02	.132	.053**	.027**	-.013*	.022**	-.001	-.002	.024**	.007	-.004	.025**	.012*	-.005	-.004	.034**	.023**			
17	Total length	130.11	52.621	-.142**	.213**	.156**	.073**	.028**	.014*	.121**	.075**	.047**	.125**	.100**	.061**	.024**	.057**	-.001	.125**		
18	Total assets	207941.335	130638.511	-.067**	-.047**	-.034**	.329**	.070**	.004	.413**	.081**	.001	.456**	.084**	.002	.029**	.019**	-.001	.062**	.088**	

Remark: *. Correlation is significant at the 0.05 level (two-tailed). **. Correlation is significant at the 0.01 level (two-tailed).

Table 4. Regression analysis with Lg (Likes) as the dependent variable.

Independent variables	Model 1			Model 2			Model 3			Model 4		
	Coefficient	***SE***	***p***	**Coefficient**	***SE***	***p***	**Coefficient**	***SE***	***p***	**Coefficient**	***SE***	***p***
Constant	1.968	.018	.000	2.029	.019	.000	2.021	.019	.000	2.020	.020	.000
EV				-.063	.009	.000	-.079	.010	.000	-.093	.010	.000
AV				-.239	.015	.000	-.245	.016	.000	-.245	.017	.000
JC1				.000	.000	.181						
EV × JC1				.004	.001	.000						
AV × JC1				.008	.001	.000						
JC2							.000	.000	.041			
EV × JC2							.005	.001	.000			
AV × JC2							.007	.001	.000			
JC3										.000	.000	.005
EV × JC3										.005	.000	.000
AV × JC3										.006	.001	.000
Price	-.174	.061	.004	-.179	.061	.003	-.180	.061	.003	-.182	.061	.003
Performance	.105	.021	.000	.106	.021	.000	.107	.021	.000	.106	.021	.000
Range	.018	.193	.925	.004	.192	.982	.011	.192	.954	.018	.192	.926
Emission	.120	.015	.000	.115	.015	.000	.114	.015	.000	.114	.015	.000
Text length	-.001	.000	.000	-.001	.000	.000	-.001	.000	.000	-.001	.000	.000
Total assets	.000	.000	.000	.000	.000	.207	.000	.000	.079	.000	.000	.060
Brand dummies	Included			Included			Included			Included		
Year dummies	Included			Included			Included			Included		
F	1908.600			1736.349			1739.076			1741.235		
R^2	.7149			.7186			.7189			.7192		
Adjusted R^2	.7146			.7182			.7185			.7188		
RMSE	.33439			.33226			.33207			.33193		
N	32006			32006			32006			32006		

Remark: + $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.

Table 5. Regression analysis with Lg (Likes) as the dependent variable.

Independent variables	Model 1			Model 2			Model 3			Model 4		
	Coefficient	***SE***	***p***	**Coefficient**	***SE***	***p***	**Coefficient**	***SE***	***p***	**Coefficient**	***SE***	***p***
Constant	1.958	.018	.000	2.018	.019	.000	2.005	.019	.000	1.998	.020	.000
EV				-.062	.009	.000	-.074	.010	.000	-.082	.010	.000
AV				-.240	.016	.000	-.247	.016	.000	-.247	.017	.000
JC1				.000	.000	.370						
EV × JC1				.004	.001	.000						
AV × JC1				.008	.001	.000						
JC2							-.001	.000	.002			
EV × JC2							.004	.001	.000			
AV × JC2							.007	.001	.000			
JC3										-.001	.000	.000
EV × JC3										.004	.000	.000
AV × JC3										.006	.001	.000
Price	-.176	.062	.004	-.181	.062	.003	-.182	.062	.003	-.184	.062	.003
Performance	.109	.021	.000	.110	.021	.000	.111	.021	.000	.111	.021	.000
Range	.052	.236	.826	.054	.234	.816	.062	.234	.791	.066	.234	.777
Emission	.126	.015	.000	.121	.015	.000	.120	.015	.000	.120	.015	.000
Text length	-.001	.000	.000	-.001	.000	.000	-.001	.000	.000	-.001	.000	.000
Total assets	.000	.000	.000	.000	.000	.049	.000	.000	.007	.000	.000	.002
Brand dummies	Included			Included			Included			Included		
Year dummies	Included			Included			Included			Included		
F	1738.955			1578.537			1580.492			1581.886		
R^2	.694			.698			.698			.698		
Adjusted R^2	.693			.697			.697			.698		
RMSE	.33281			.33071			.33057			.33046		
N	31534			31534			31534			31534		

Remark: + $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.

Table 6. Regression analysis with Lg (Retweet) as the dependent variable.

Independent variables	Model 1			Model 2			Model 3			Model 4		
	Coefficient	***SE***	***p***	**Coefficient**	***SE***	***p***	**Coefficient**	***SE***	***p***	**Coefficient**	***SE***	***p***
Constant	1.477	.019	.000	1.519	.019	.000	1.508	.020	.000	1.508	.020	.000
EV				-.041	.009	.000	-.057	.010	.000	-.068	.010	.000
AV				-.201	.016	.000	-.208	.016	.000	-.211	.017	.000
JC1				.000	.000	.052						
EV × JC1				.004	.001	.000						
AV × JC1				.009	.001	.000						
JC2							-.001	.000	.000			
EV × JC2							.005	.001	.000			
AV × JC2							.008	.001	.000			
JC3										-.001	.000	.000
EV × JC3										.004	.000	.000
AV × JC3										.007	.001	.000
Price	-.157	.062	.011	-.163	.061	.008	-.164	.061	.007	-.165	.061	.007
Performance	.107	.021	.000	.108	.021	.000	.108	.021	.000	.107	.021	.000
Range	-.040	.194	.839	-.050	.194	.796	-.042	.193	.829	-.036	.193	.853
Emission	.128	.015	.000	.124	.015	.000	.122	.015	.000	.122	.015	.000
Text length	-.001	.000	.000	-.001	.000	.000	-.001	.000	.000	-.001	.000	.000
Total assets	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Brand dummies	Included			Included			Included			Included		
Year dummies	Included			Included			Included			Included		
F	1128.763			1024.476			1027.386			1028.613		
R^2	.597			.601			.602			.602		
Adjusted R^2	.597			.600			.601			.601		
RMSE	.33646			.33491			.33462			.33450		
N	32006			32006			32006			32006		

Remark: + $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.

Appendix A

Table A1. Lexicon.

Category	Keyword	Category	Keyword
	electric	AV	intelligentmobility
	ev		intelligent mobility
	EV		automate
	ev.		automateddriving
	#ev		fullyautomated
	allelectric		highlyautomated
	formulae		automated
	formula e		selfdriving
	i3		selfdrivinglaw
	#i3		selfdrivingtechnolog
	i8		y
	#i8		autopilot
	ipace		self driving
	#ipace		self-driving
EV	i-pace		driverless
	#i-pace		autonomous
	prius		automation
	#prius	Price	
	etron		price
	#etron		prices
	Model 3		dollar
	#model3		rent
	model y		lease
	#modely		installment
	model s	Performance	
	#models		0–100
	model x		0–60
	#modelx		accelerate
	#TeslaCharging		accelerated

e-Golf		accelerates
#e-golf		accelerating
#egolf		acceleration
egolf		top speed
etron		maximum speed
EQC		max speed
#EQC		turbo “
VOLT		horse power
LEAF		hp
EQS		v8
#EQ		#v8
#EQC		v6
#EQV		#v6
#EQS		w12
EQV		#w12
EQC		nm
taycan		kw
ehybrid	Range	
PLUG-IN		mile range
PLUG IN		range anxiety
plugin	Emission	
Charging system		co2
Charging station		co2emissionen
Charging point		co2emissions
Charging network		emission
#ChargedWithExcitement		NO2
#ReadyForElectric		diesel
Tesla Destination Charging		g/km
supercharging		l/100km
supercharger		
electrification		
battery		

	batteries
	Tesla
	charging section
	roadster

Chapter 6: Conclusions and Suggestions for Future Research

IS can play a critical role in firms' SOM. For example, IS can accelerate information-sharing among the members of the supply chain so as to enhance supply chain coordination. IS also can control the use of materials precisely, which contributes to environmental sustainability. However, seldom do studies explore how IS (incl. social media) improve stakeholder engagement to enhance firms' SOM. Social media allows for a free communication environment without time and space constraints and has become a significant low-cost tool for stakeholder engagement. Social media is also able to quantify stakeholder engagement. Therefore, we use social media to investigate stakeholder engagement in firms' SOM to help firms understand and engage their stakeholders better. Our research complements the research gap on how IS promotes the role of stakeholder engagement in SOM. Our studies provide a more comprehensive understanding of stakeholder engagement in SOM from different perspectives. Further, our studies illustrate how to use a data-driven approach to develop our research model for SOM research. The procedures can serve as guidelines for future studies to replicate or adopt in other research settings that need to mimic stakeholder engagement on social media. Managerially, our studies may help firms communicate SOM with their stakeholders to improve stakeholder engagement. Theoretically, our studies enrich stakeholder theory, signaling theory, and diffusion of innovations theory. Future studies may explore stakeholder engagement from other theoretical perspectives. Methodologically, we innovatively measure stakeholder engagement with social media data and adopt the machine learning method (i.e., Natural Language Processing).

Firstly, we collected 25,106 tweets from 19 international fashion firms and found that sustainable product design and recycling initiatives generate stronger stakeholder engagement. However, sustainable manufacturing has an insignificantly positive effect on stakeholder engagement. Secondly, we extend our research to the Chinese context. We collected 37,007 social media posts from 22 fashion brands on Sina Weibo, which is a microblogging platform similar to Twitter. In the Chinese context, sustainable product design still generates stronger stakeholder engagement. However, the positive of recycling initiatives on stakeholder engagement becomes insignificant. In addition, sustainable manufacturing still has an insignificantly positive effect on stakeholder engagement. Future studies can replicate the studies with a larger number of brands in various industries. Future studies may change the dependent variable to the number of sharing posts or even firms' value. For example, we can investigate if stakeholder engagement mediates the relationship between SOM and firms' value. We can use stock price to represent firms' values and apply the event study method. To be specific, we regard the day on which the firms post their SOM on social media as the event date. Then we set up some events windows such as [-20,20], [-10,10], [-3,3], [-1.1], [0,1]. Then we check if these events have significant effects on the stock price. Finally, we investigate if stakeholder engagement mediates the relationship between SOM and firms' value.

New product designs should meet multiple stakeholders' demands. In fact, it is hard for firms to guarantee the successful launch of new product designs since they cannot keep the balance among multiple stakeholders. We analyzed 32,006 tweets from 33 global automobile firms and found adverse stakeholder engagement with vehicle electrification and automation (i.e., sustainable product design in the automobile industry). Further, we analyzed international job creation records from 33 global automobile manufacturers and found that job creation can improve adverse stakeholder engagement on social media. Job creation implies that firms' number of employees increases. Employees are major stakeholders because they occupy an important position in the firms' OM (Roscoe et al., 2020). SOM usually relates to innovations. Some stakeholders may not understand technical innovations well. Employees, as product experts, can answer stakeholders' questions and improve stakeholder engagement. Employees can become brand ambassadors as well if firms implement SOM and achieve a higher reputation. For example, a majority of Tesla's employees love their work and be willing to introduce Tesla's products to other stakeholders, which may improve stakeholder engagement. In addition, with the increasing number of employees, stakeholders' concerns about employment may reduce. Future studies can investigate how employees engage other stakeholders (e.g., consumers and suppliers) in SOM. For instance, does employees can improve stakeholder engagement in sustainable manufacturing? In the Chinese context, future studies can study the role of employees in improving stakeholder engagement in recycling.

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