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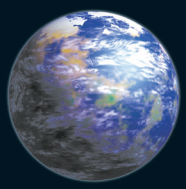
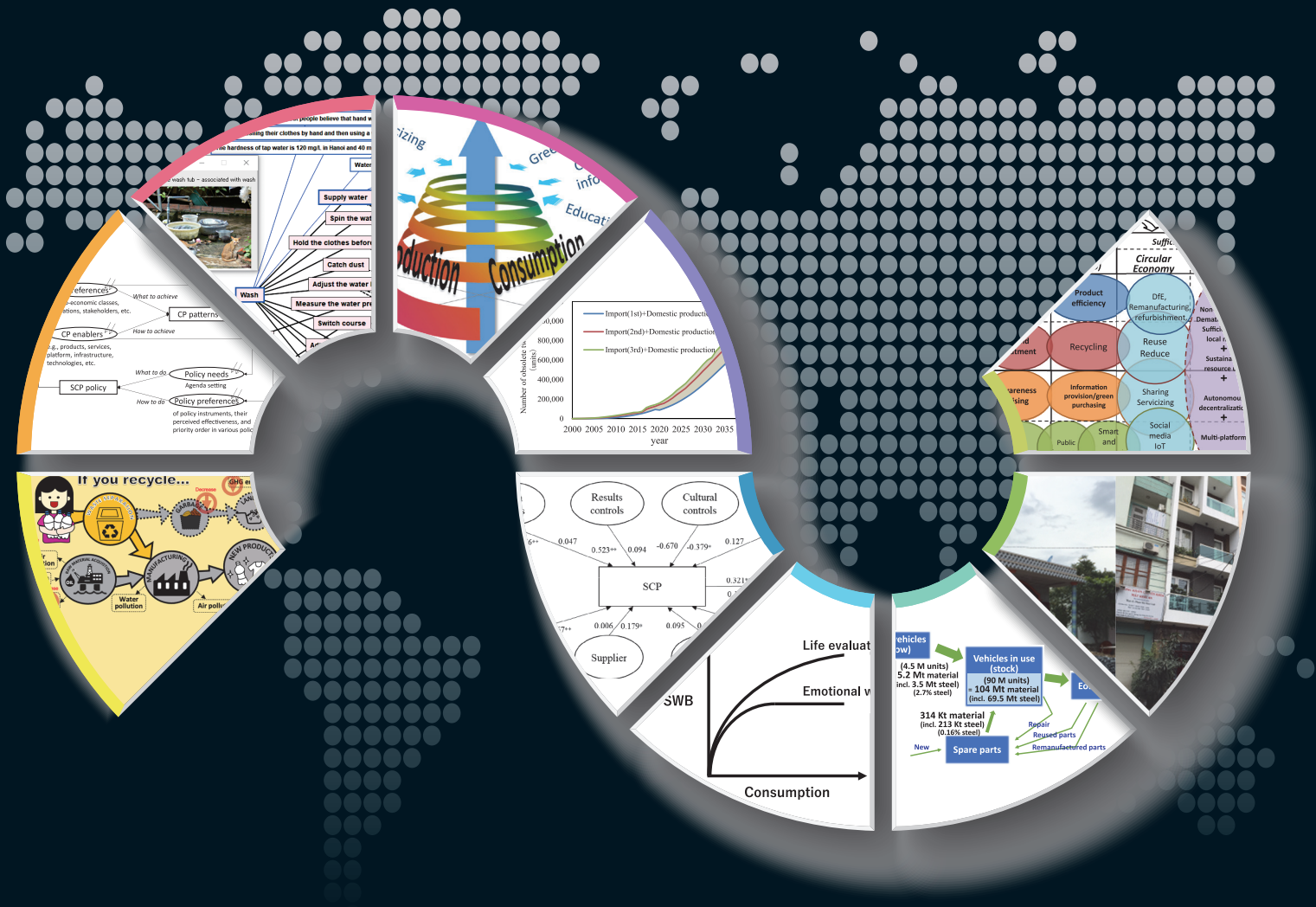


Ensuring Sustainable Consumption and Production Patterns in Southeast Asia



Editorial

It is our great pleasure to issue journal 'Global Environmental Research', which aims to disseminate the results of studies on global environmental issues, studies conducted not only in Japan but also in other parts of the world. Many scientists monitor research in their own fields. However, communications among scientists are not always easy, because the ranges of their fields are so broad, subjects are so diverse, and reports may not be written in an internationally spoken language. This journal is intended to help fill these gaps. Many publications, reports, and other forms of information have been released relating to Japanese studies on global environmental issues in recent years. The primary purpose of 'Global Environmental Research' is to provide information on Japanese research results to scientists internationally and promptly. We also hope that 'Global Environmental Research' will encourage exchanging information among Asian and Pacific regions where local language barriers and limited opportunities exist. International Geosphere-Biosphere Programme (IGBP), International Human Dimensions Programme of Global Environmental Change (IHDP) and other international and interdisciplinary programmes have produced many important results. A new global research platform, 'Future Earth' started to provide the knowledge required to face risks posed by global environmental changes and to seize every opportunity for Sustainable Development Goals (SGDs). The results of these studies need to be distributed worldwide. We hope this journal will also contribute to this end. It was said that the title of the third scientific symposium of the IHDP, 'Global Change, Local Challenge', recognizes that global changes are the results of a variety of local activities shaped by particular cultures, histories, political boundaries, and national policies. We are certain that our 'Global Environmental Research' will serve as a transmitter of information on local activities about global change.

Teiji WATANABE

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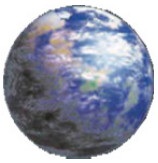

Ensuring Sustainable Consumption and Production Patterns in Southeast Asia

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Ensuring Sustainable Consumption and Production Patterns in Southeast Asia

Preface

This special issue, *Ensuring Sustainable Consumption and Production Patterns in Southeast Asia*, addresses the twelfth goal of the Sustainable Development Goals (SDGs) adopted by the United Nations in 2015. According to the United Nations, increased consumption and production have brought wealth to people and have halved the absolute poverty rate in Asia over the last two decades. However, current unsustainable patterns of resource and energy use and greenhouse gas and waste emissions, which are projected to keep increasing, are posing significant threats to the global environment.

It is not clear what sustainable consumption and production (SCP) patterns are required in Asia and what actions should be taken to ensure them and by whom. Asia's economy has been growing with unprecedented rapidity, resulting in drastic changes to businesses and lifestyles and widening spatial and social class disparities in the region in terms of economic benefits and environmental risks. What kinds of SCP policies should be adopted and what are the differences between them and the policies being implemented by developed nations such as EU countries? Additionally, the emergence of the coronavirus pandemic in 2020 has changed consumption and production patterns around the world, and our actions for SCP must be revisited and adjusted to the new context. The "Policy Design and Evaluation for Establishing Sustainable Consumption and Production Patterns in the Asian Region (PECoP-Asia)" research project has been attempting to find answers to these questions, with a focus on Southeast Asia.

This special issue aims at summarizing the project's research results and providing up-to-date suggestions on SCP policy in Asia. The structure of this special issue is as follows: The first two articles discuss the development of SCP policy in Asia as an introduction to the special feature. The first article, written by Hirao et al. integrates the outcomes of the PECoP-Asia project. The authors reveal three versions of SCP policy and emphasize that the situation in Asia calls for all three versions to be implemented in a strategic manner. They also present four directions and 13 opportunities for SCP policy in Asian countries. The 13 opportunities include insights gained in light of the coronavirus pandemic. The second article, by Hotta et al., further elaborates the three SCP policy versions, 1.0 to 3.0. The authors argue that a life-cycle approach is important in SCP 2.0, and they devise and explain a new approach for SCP 3.0, "envisioning-based policy making (EnBPM)."

The articles thereafter present the results of 10 research groups: Onozuka et al. propose a method for quantifying narrative scenarios based on the concept of participatory backcasting for better envisioning; Tasaki and Kojima discuss regional and local characteristics in Asia that may potentially affect SCP patterns and policies in Southeast Asia; Kobayashi et al. propose a framework for locally oriented product design using an extended function-structure map and a mixed prototyping environment; Wu et al. analyze how individual environmental-management control tools for companies promote SCP activities at Thai and Vietnamese companies; Phuphisith et al. evaluate the effectiveness of providing information with life-cycle thinking in changing consumer behavior; Matsumoto et al. analyze consumer acceptability of remanufactured products; Yoshida et al. survey and discuss the actual use of air conditioners by households in Vietnam and policy approaches for reducing energy consumption when cooling; Murakami et al. investigate actual disposal of motorcycles in Cambodia and measures for resource recycling; Tsurumi et al. discuss subjective well-being in Asia, which is the ultimate goal of SCP; and Takagi et al. illustrate the management of SCP linkages with economic, social and environmental agendas connected with the SDGs.

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Guest Editors
Tomohiro TASAKI
Masahiko HIRAO

Policy Development for Reconfiguring Consumption and Production Patterns in the Asian Region

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Abstract

Ensuring sustainable consumption and production (SCP) patterns in the Asia region is a high-priority policy issue but challenged by a number of obstacles and the emergence of the coronavirus pandemic in 2020. This article argues that not only conventional policy approaches but also alternative approaches are needed in Asia to decouple socio-economic development and increases in environmental loads from people's sense of well-being. To achieve human and planetary well-being under the situation of compressed development, four strategic courses of SCP policy are presented. These four courses are SCP policy expansion, enhanced linkage of consumption and production (CP), system transition and bottom-up approaches. Policy makers in Asia should keep these courses of action in mind and utilize opportunities, 13 of which are outlined here, to mainstream SCP. The 13 SCP opportunities, the key words of which include among others experience, genuine wealth, local design, digitalization, infrastructure, indigenous wisdom, collaboration and challenges, indicate entry points for Asian SCP policy development in the 2020s. Finally, based on these, the authors have devised an SCP case matrix and produced 43 example SCP cases for better application of the suggested SCP policy approach in the Asian region.

Key words: Asia, evidence-based policy making, sufficiency approach, sustainable consumption and production (SCP), Sustainable Development Goals (SDGs), system transition

1. Introduction

Economic growth over the past few decades has brought affluence to people around the world and reduced poverty. The extreme poverty rate has dropped considerably in most developing regions in the last two decades, reducing rates by between 46% and 94% in Asia (UN, 2015a). Significant negative impacts on the environment and societies have surfaced, however. Global resource consumption and environmental loads such as greenhouse gas (GHG) emissions and waste discharge have increased to support a wealthier consumer lifestyle, and economic disparities among regions and countries are rising. These tendencies are expected to increase and expand even further in the future.

Today, the Asian region is the world's cradle of production. Its economic growth is remarkable, with consumption and accompanying environmental impacts expanding at a rapid pace (UN ESCAP, 2021a). Between 2000 and 2017, the material footprint of the Asia-Pacific region increased at the largest and fastest pace in the world, and GHG emissions in the Asia-Pacific region were also remarkable (IRP, 2017). Per capita income is still low (UN ESCAP, 2021a), and environmental impacts in the Asia-Pacific region will continue to increase at the fastest pace in the world for now, with the region's share in global environmental impacts expected to rise.

One course of action for the future is the expectation that the conversion to high-value-added industries and industries with high levels of resource productivity will

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continue. With a focus on intellectual capital, the number of patents worldwide almost doubled from 14 million to 30 million over the past 19 years from 1992 to 2010 (Yagi & Managi, 2017), but the proportion from developed countries decreased from 97% to 88%. The application of intellectual capital in developing countries is expected to increase in the future.

In addition, future changes in technology will be notable, such as digitization, including ICT (information and communication technology), AI (artificial intelligence) and IoT (Internet of Things). Although these technologies may lead to a reduction in environmental impacts as a result of improved efficiency, there is also a danger that they will result in an increase in environmental loads due to increased consumption of new kinds.

By contrast, rapid economic growth has exaggerated economic disparities, for example, between urban and rural areas. More developed countries in Asia have higher shares of older rural residents and the urban-rural gap in services such as electricity can be wide, particularly in less developed countries (UNDP, 2016). Attention must be paid to these types of unstable elements among Asian societies. In addition, along with the growth of agribusiness, relocation of industries to rural areas, development of local cities and increased numbers of migrant workers, it is possible for households even in rural areas to enjoy a consumer lifestyle that is not much different from those of urban residents, making a living using products from domestic cities and foreign markets (Rigg and Vandergeest, 2011; Rigg et al., 2012). As such, the driver to maintain "self-sufficient"-type farm villages in these areas is weakening.

Using only the roads taken by developed countries as a reference will result in a failure to stay current with global trends. There are two significant differences with the paths taken by developed countries: (1) (latent) changes in consumer lifestyles and values and (2) changes in production patterns based on technological changes as represented by digitization. Whittaker et al. (2010) also pointed out differences in development, focusing on the speed of development and associated consequences, calling it "compressed development."

As described in the 2030 Agenda for Sustainable Development and indicated as the twelfth of the 17 sustainable development goals (SDGs) (UN, 2015b), the shift to sustainable consumption and production (SCP) patterns is an urgent agenda in Asia. Asian countries have already introduced many policies to accelerate the transition to SCP patterns in areas including, but not limited to, cleaner production, waste management and green public procurement. However, against the backdrop of rapid industrialization resulting in the urbanization and expansion of the middle-class, those conventional policy measures contribute mainly to efficiency of production. They will not be enough to address the challenges mentioned above.

In addition, the COVID-19 pandemic starting in 2020 changed consumption and production (CP) patterns all over the world significantly. According to the IEA (2021), global energy demand in 2020 declined by 4%, the largest decrease since World War II. Many attempts have been made to understand the influences of COVID-19 and foresee CP patterns in the future. For example, Echegaray (2020) described changes in 12 domains of daily practice (such as work, education, leisure, mobility and housing) qualitatively and discussed their potential future. Boons et al. (2020) also discussed the effect of the COVID-19 on eight types of practices and various levels of retaining new practices: (1) recovery, (2) collapse, (3) accelerated transition to digitalization and (4) accelerated transition to sustainable development, as well as rebound effects. In fact, a projection by the IEA (2021) indicated a rebound of global energy demand in 2021 exceeding the pre-COVID 2019 level. Tasaki et al. (2021a) applied a workshop method and identified 48 changes in five domains, distinguishing between those likely to return to the "old normal," which accounted for 48% of the changed CP patterns, and those likely to become the "new normal." With regards to policy for recovery from the COVID-19 pandemic, UN ESCAP (2021b) discussed recovery strategies of Asia-Pacific cities taking this opportunity to build back better for sustainable, healthy and resilient urban development. SCP policy has to consider the influences of the COVID-19 pandemic on top of its evolution in the past.

This article argues SCP policy development to ensure SCP patterns in Asia. We will first explain the authors' research project on SCP, called "Policy Design and Evaluation to Ensure Sustainable Consumption and Production Patterns in the Asian Region (PECoP-Asia)," and then present four strategic courses for SCP policies which policy makers should keep in mind. Then, we present 13 opportunities to mainstream SCP in Asia and their application.

2. Development of Courses of SCP Policy

Figure 1 illustrates the SCP concept. It is vital to

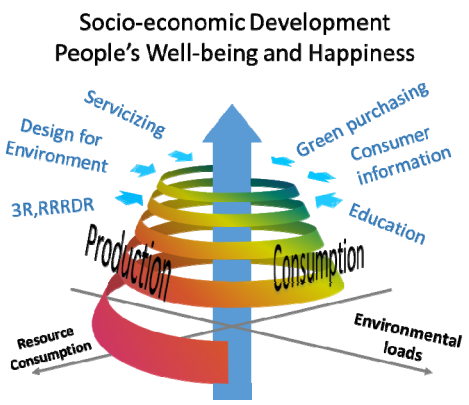

Fig. 1 Concept of Sustainable Consumption and Production (SCP).

establish SCP patterns that decouple socio-economic development and increases in environmental loads from the real sense of securing people's well-being and happiness.

The PECoP-Asia project is a research project launched in 2016, gathering 11 research groups in Japan from different fields: systems engineering, urban engineering, sociology, policy science, environmental economics and business administration. The project aims to design policy packages for achieving SCP patterns in the Asian region. Each group approaches this common goal from its field of expertise using various stakeholders' practices and considering characteristics of respective areas, including their economy and lifestyles.

A task force established during the project made a draft policy report for SCP policy makers by integrating research results and policy recommendations of all research groups. The Asia-Pacific Roundtable on Sustainable Consumption and Production (APRSCP) reviewed the draft and proposed several viewpoints that it had found lacking, e.g., the importance of bottom-up approaches.

The first version of the policy report proposed four courses of SCP policy and 12 opportunities for SCP policymaking (PECoP-Asia, 2018). Based on the policy report, a policy brief was compiled and publicized in a side event of the United Nations High-Level Political Forum on Sustainable Development 2018 (PECoP-Asia & APRSCP, 2018). In 2020, we revised the first version considering the effect of the COVID-19 pandemic as described in the Introduction.

3. Four Strategic Courses of SCP Policy

To respond to the environmental, economic, and social problems mentioned in the introduction and to achieve the SDGs all over the world, it is necessary not only to treat the "symptoms" of individual issues, but also to transform human activities fundamentally and change our governance (Kanie & Biermann, 2017). Geels et al. (2015) explained that there are three different positions for SCP: reformist, revolutionary and reconfigurative positions. The latter two positions take transformation into account, paying more attention to it.

This section proposes four strategic courses that SCP policies shall pursue to achieve the SDG 12 goals with a target year of 2030 as described below. These courses of action are in line with future mid- to long-term policies in the "Asia Pacific Regional Roadmap for Sustainable Consumption and Production" (see UNEP and APRSCP (2017) for the latest version) and the Cebu declaration of APRSCP (2021).

3.1 SCP Policies are Expanding from the Environmental Policy Domain to the Socio-economic Technology Domain

SCP policies must include contents suited to the context of each country, as argued by Tasaki and Kojima (2021) in this special issue. Many Asian countries have strengthened SCP policies covering areas such as cleaner production, renewable energy, waste management and consumer information. These policies cover the conventional targets among the range of the SCP policies that have expanded for the last four decades. SCP policies have also changed institutional and regulatory structures to some extent, as reflected in SCP National Action Plans, providing the platform for inter-ministerial coordination and partnerships with the private sector and other stakeholders.

Figure 2 illustrates policy goals and the growth of menus according to the expansion of policy issues based on Hotta et al. (2021). As shown in the first column, SCP

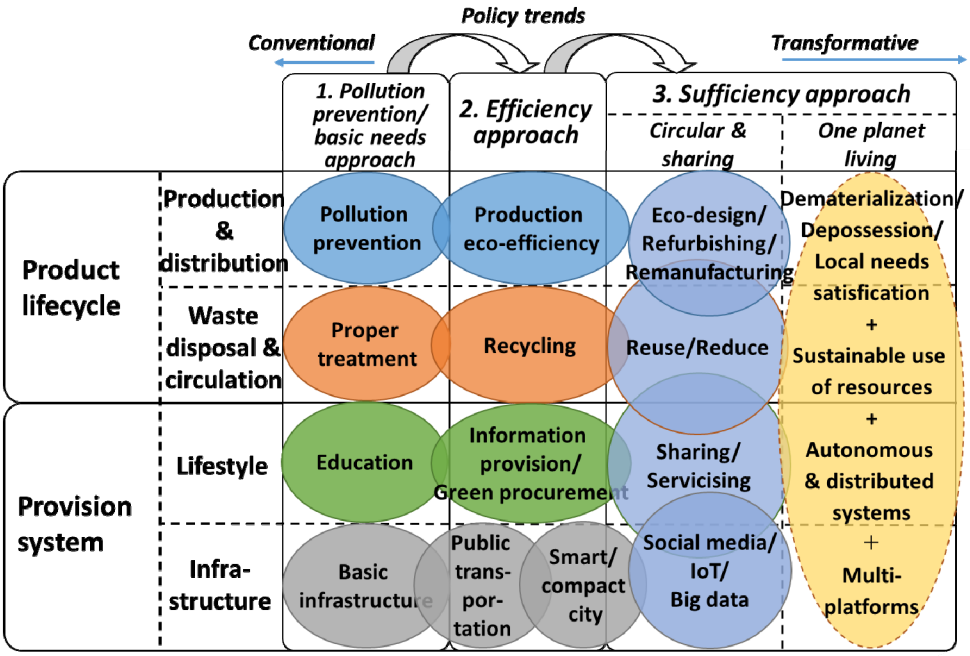

Fig. 2 Expanding focus and menu of SCP policies.

policies have conventionally focused on pollution prevention such as cleaner production and proper treatment by introducing so-called end-of-pipe measures into industrial processes. This version of SCP policies is named SCP 1.0. In the second column, it then includes an efficiency approach for products and services shown for separating environmental loads and economic growth associated with the use of energy and resources. This version is referred to as SCP 2.0.

Recently, alternative approaches beyond pollution prevention and efficiency have gained wider attention as a result of the SDGs and the Paris Agreement, which have fostered momentum toward decarbonization. This version is referred to as SCP3.0. As shown in the third column, circular economy (EC, 2015) and sharing economy (Belk et al., 2019) are contributing to the decoupling of consumption of non-renewable, natural resources from the welfare and well-being of society as a whole, and have become popular. In the meantime, societies in Asia are witnessing the emergence of innovative business models based on digitization, contributing to a substantial reduction of resource and energy use in the production process, as well as alternative models for meeting demands of the people. SCP 3.0 is thus oriented for one-planet living, employing more integrated systems thinking as shown in the third column. In SCP3.0, consumption and production are the means for prosperity and sustainability. SCP policies focus on transforming lifestyles and business models from efficiency to sufficiency, and thus contribute to human and planetary well-being. Figure 3 shows the hierarchical structure of these three versions of SCP policies.

It is very important to emphasize here that SCP is not anymore limited to the environmental policy domain such as pollution control, waste management and recycling, cleaner production, eco-labelling or consumers' awareness but has expanded to the socio-economic-technology policy domain such as infrastructure building, welfare, business development, local development and innovation. Two SCP workshops have also confirmed this point (Tasaki et al., 2021b).

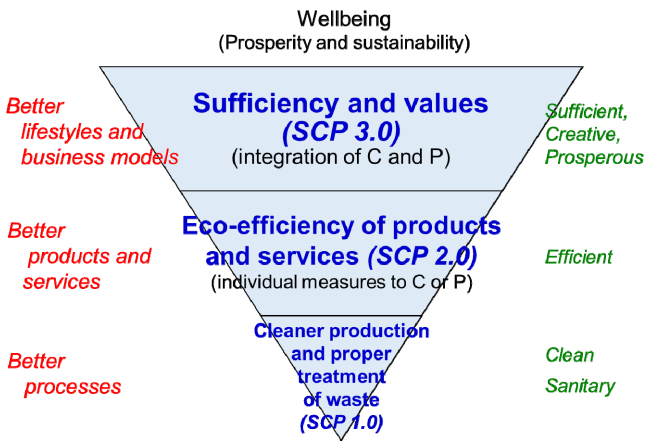

Fig. 3 Three versions of SCP.

A policy mix to achieve specific policy goals does not have to be uniform, but must be able to maximize the effects of SCP policies effectively through flexible and strategic combinations depending on the industrial, consumption and urban structures of each country. Roughly speaking, developed countries have responded to changes from SCP 1.0 through SCP 2.0 to SCP 3.0 gradually. In Asian developing countries where economic growth is rapid, however, all three versions are necessary. SCP 1.0 is for local Asian communities, placing importance on safe local living spaces. SCP 2.0 is for global Asian exporters of products for globalized markets. Without globalized eco-commodities, the current global economy cannot be sustained. SCP 3.0 is for Asia itself, calling for a sufficient, creative and prosperous Asia in the future without compromising sustainability.

3.2 Strengthening Linkages between Consumption and Production is a Key Emerging Movement

The conventional pattern of economic development is driven by mass production and consumption. Value chains have expanded across the world through specialization and subdivision. Consequentially, the distance between consumers and producers has become wider. In these circumstances, improved efficiency at each point will not be enough to achieve SCP, and the linking of the subsystems of consumption and production (referred to as "CP linkage") will play an important role.

Conventional policies have tried to strengthen the CP linkage by providing better information such as through environmental labelling, certification and footprint indicators. Alternative approaches have been introduced recently. Figure 4 shows five types of linkages for strengthening CP linkages for the case of a CP system regarded as constructed of four subsystems: processing and manufacturing (including natural resource extraction), provision, consumption, and circulation. Three of the linkages (blue, green and red) are to strengthen CP linkages between final consumption and the other three elements, and two (purple and yellow) are to strengthen the CP linkages within each consumption or production subsystem.

The first linkage (green) is feed-back from consumption to design and production which enables proper quantities to be produced and on-demand production and localized/customized production to be achieved. The second linkage (red) is circularity, and enables circular production, remanufacturing, recycling and life extension, considering lifecycle management of products/parts/materials. The third linkage (blue) is product use without ownership, and enables implementation of product service systems, function provision, sharing, lease and servicizing. The fourth linkage (purple) is within consumption, and makes C2C sharing and reuse possible. The fifth linkage (yellow) is industrial symbiosis, in which material, by-products,

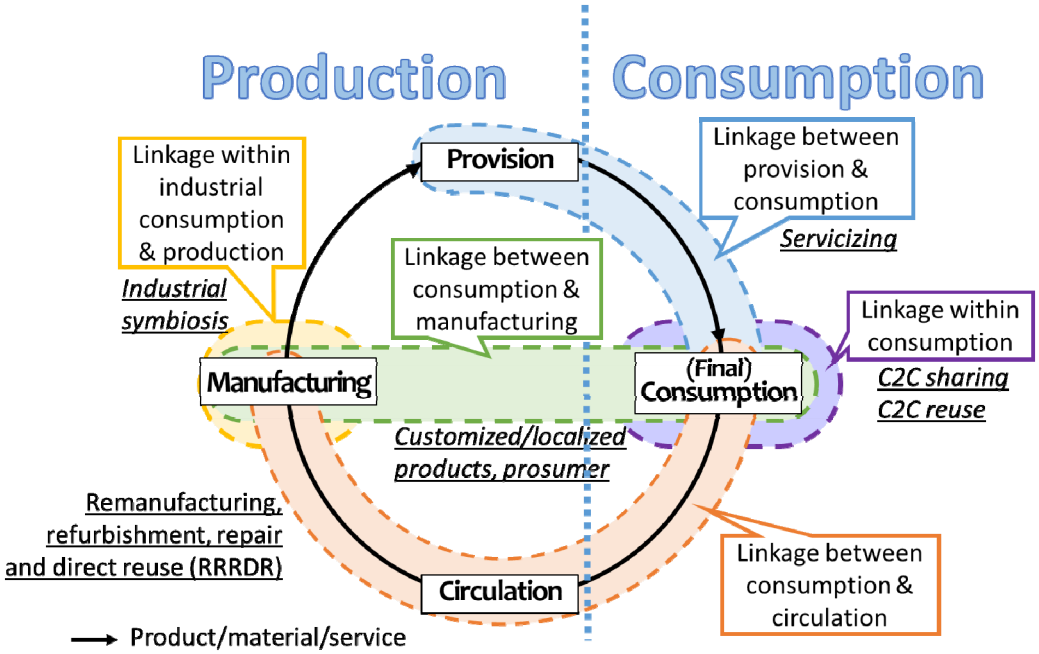

Fig. 4 Five types of linkages between consumption and production.

waste, water and energy are exchanged and utilized, between industries in as efficient a way as in natural systems.

3.3 Transition to SCP is a Socio-technical Regime Shift Requiring Successive Changes in Social Practices, Technology Use in Daily Life and Associated Infrastructure

CP patterns are framed by and embedded in existing regimes, such as taxation and education, and infrastructure, such as logistics and energy provision systems, and maintained/updated by the accumulation of daily practices of people and organizations (Spaargaren, 2011; Shove, 2016; Spurling et al., 2013). Raising the awareness of consumers can sometimes influence their behavior for the time being; however, behavioral changes will not take root unless they are associated with changes in the wider contexts of their day-to-day living, including moving, eating, caring for family, working, learning, resting and so on.

Therefore, it is necessary to transform our socio-technical regimes/systems in such ways as has been attempted repeatedly in the transition research field (Köhler et al., 2019). This includes changing social mechanisms and modes of technology use to create and provide services and new infrastructure and institutional settings. The recent Cebu declaration (APRSCP, 2021) also paid much attention to this approach in the Asian context, referring to two courses of action: 1) innovative transition through green future development and 2) systematic transformation through a green development agenda. Examples include mobility and energy; resource- and energy-saving practices in workplaces; community-based initiatives to build capacity for reducing; reusing and recycling; and others.

3.4 Bottom-up Approaches are Necessary for Enhancing Effectiveness and Acceptance of SCP Policies across the Region.

The above-mentioned SCP courses need to be triggered by local- and community-level initiatives in addition to national/international-level agenda setting. However, there exist huge gaps between international/national agendas (long-term and mid-term goals) and local concerns. Actions therefore need to be incubated in "arenas" where multi-stakeholder partnership is formulated and various buds of co-creation grow in collaboration beyond the boundaries of the conventional stakeholders, as opposed to simply upscaling successful initiatives, to enhance the effectiveness and acceptance of SCP policies.

4. Emerging Opportunities for SCP

This section discusses 13 opportunities for SCP based on the strategic considerations raised above.

4.1 Opportunity 1: Experience Matters

In the long term, experiential or intangible consumption is even more important in pursuing people's happiness. CP patterns that contain both tangible and intangible elements create well-being.

According to the results of a questionnaire survey (Tsurumi et al., 2020a), material consumption increases subjective well-being to a certain level, while relational (non-material) consumption continues to increase the level of subjective well-being as consumption increases. That is, intangible experiential consumption plays an important role for our subjective well-being in an affluent society, which Asian emerging countries are becoming. It also widens opportunities for a sharing economy,

Opportunity 8, and dematerialization. In addition, among people who take better care of their possessions, this effect was reversed (Tsurumi et al., 2020b). Therefore, if people own fewer products but have a strong attachment to them, they can retain happiness while decreasing material consumption. This opportunity is in line with the traditional way of life in Asia in aspriing for a better life.

4.2 Opportunity 2: Genuine Wealth

Measuring society's genuine wealth and its components as needs, including risk avoidance needs, in a form that accords with the present time, is the basis of creating a new CP pattern.

In the future, perceptions of social change will be transformed, which means that a new evaluation axis will be needed. There are also trends that measure the subjective conditions of people, such as their degree of happiness and anxiety (Tasaki et al., 2010). From an economic perspective, new indicators are being proposed based on a discussion called "Beyond GDP" that captures wealth as stock (e.g., inclusive wealth, new capital wealth indicators) rather than capturing wealth as flow. These indicators convert different types of capital, such as infrastructure, human resources and the natural environment into monetary units and comprehensively measure them, with attention paid to the accumulation of capital for sustainability (Dasgupta et al., 2015; Managi, 2016). The inclusive wealth indicator (Managi & Kumar, 2018; Yamaguchi et al., 2019) has recently been utilized in both developed and developing countries (Dasgupta, 2021; UNEP, 2021). Even local governments use the indicator to rely on and sustain precious local capital (Managi & Tanaka, 2018). By replacing GDP, the new measurement of genuine wealth can change the course of development.

4.3 Opportunity 3: Environmental Policy Reinforcement

The trends exemplified by the Paris Agreement and ESG (environment, social and governance) investments reinforce the policies at the government level while promoting environmental measures such as decarbonization and corporate initiatives. The loss from delayed action to initiatives and criticism toward the managerial short-termism is intensifying.

There are emerging trends that encourage the development of environmental policies, such as the Paris Agreement and ESG investment, with increased attention to the necessity of accelerating global movements towards decarbonization and sustainability. The recognition that current environmental measures will increase competitiveness in the market is expanding. In this way, the "game change" phenomenon is already occurring. A growing number of companies are involved in advancing SCP, the SDGs and ESG with increasing popularity across the globe. Active participation by developing countries, especially emerging economies, is inevitable, and it is crucial to ensure such actions are practical.

Attention has to be paid to insufficient management resources at companies in Asian developing countries. Yagi and Kokubu (2020) therefore proposed a phased corporate management framework with five stages. It is necessary to consider not only the external environment of companies but also their internal situation for effective actions for SCP with the understanding that delayed actions have become a company risk.

4.4 Opportunity 4: Circular Economy

The CE (circular economy) and sustainable value chain concepts upgrade environmental and industrial policies toward integrated measures. The concept also advances cross-border standardization and collaboration, and promotes CP patterns that reduce adverse effects from raw material extraction to the end of life.

The CE concept involves material selection that makes little or no distinction between primary materials and secondary recycled materials. It also promotes improvements in the quality of secondary materials, components and products through RRRDR (remanufacturing, refurbishment, repair and direct reuse) (see Matsumoto et al. (2021) for remanufacturing in Asia). Value chain management seeks to enhance product designs to better suit consumer lifestyles while enhancing overall environmental efficiency across the lifecycle.

Promoting industrial symbiosis is also key to a circular economy. In Asia, there is a sufficient margin for recycling through inter-industrial and transboundary symbiosis for steel slag, aluminum dross and waste (Cravioto et al., 2021). Impacts on the environment and humans can be reduced by symbiosis utilizing industrial waste as resources. Additional effects can be generated through the transboundary movement of waste for symbiosis while proper measures are taken under frameworks such as the Basel Convention, because not all industries presumed to be present in developed countries necessarily exist in those countries in Asia (Ori et al., 2014).

For a circular economy, material sorting plays an important role. It is necessary to consider ways to use human resources and infrastructure in the informal sector and reorganize formal systems, since there is a possibility of affecting poverty and labor.

4.5 Opportunity 5: Sophisticated Information Provision

Knowledge about designing and customizing information provision for a behavioral shift is progressively accumulating.

Simple information provision alone has limited power to change consumer behaviors (e.g., Thaler & Sunstein, 2008; SWITCH-Asia, 2014). Recent developments in fields such as behavioral economics have

emphasized new and diverse ways to provide information and influence consumer choice. Such insights, including tailoring environmental information to guide consumer's decisions, can be utilized in SCP policies to make them more effective.

It is necessary to devise ways to provide more effective environmental information. Specifically, it is important to provide relevant environmental information at each stage of decision-making by consumers and others for purchasing or selecting a product or service.

4.6 Opportunity 6: Design for Local Needs

Product and service design that reflects people's needs in a local context and the "new normal" era moves the consumer market.

A disproportionate focus on product quality can lead to overconsumption as well as diminish consumer satisfaction through function fatigue. Product design should seek to improve human sufficiency by not only adding new features but also streamlining and simplification. Such designs should cohere throughout the entire product lifecycle without undue emphasis on the optimization of production processes. Localized product design is an entry point for SCP to achieve appropriate quality at a reasonable price while preventing overconsumption.

In local-oriented design that corresponds to regional diversity, the following two perspectives are important: (1) that of what should be cut from functions and structures of products in developed countries (concept of subtraction) or what should be recognized as minimum necessary requirements (concept of addition), and (2) that of improving sufficiency throughout life, not the optimization of individual products. Support techniques and tools for local-oriented product design have been put forward by Kobayashi et al. (2021) in this special issue.

4.7 Opportunity 7: Digital Transformation

Digitization technology is a powerful tool for reforming CP patterns and generating diverse options and values.

If emerging economies in Asia follow along the path of economic growth taken by developed countries, consumption of resources and energy can be expected to rise with an increase in the number of products owned, making the realization of SCP increasingly difficult. However, there is a potential to achieve leapfrog development (cf. Fong, 2009). For instance, IoT (Internet of Things) and AI (artificial intelligence) both comprise promising technologies that effectively link digital opportunities to SCP efforts. Integration of such technologies with renewable energy and appropriate technology (Hazeltine & Bull, 1999), and making data accessible to users helps formulate new systems for SCP practices in line with the four strategic courses of SCP policy. In addition, such technologies can expand stakeholders' capacities for changing ways to measure and mainstream SCP implementation.

4.8 Opportunity 8: Sharing Economy

A sharing economy is one pathway to strengthening CP linkages. Take advantage of this opportunity while implementing infection prevention.

With the widespread use of mobile terminals, electronic payment systems, and IoT, it has become easy to connect consumers who want others to use unused possessions and consumers who want to use them. In addition, there are more customs of sharing in Asian countries compared with Europe and the United States (Belk, 2010). The penetration of the sharing economy may increase resource efficiency in the form of increased availability of products. However, whether the environmental load will decrease or increase as a result of sharing depends on the lifecycle characteristics of the products to be shared and sharing systems (Amasawa et al., 2020). Promoting sharing activities and understanding the conditions under which such activities can reduce environmental loads are important tasks of SCP policy and CP transformation.

4.9 Opportunity 9: Infrastructure for SCP

Urban planning, infrastructure development, rules and customs greatly influence the pursuit of lifestyles that align with SCP patterns. It is necessary to balance the development of digital infrastructure supporting online lifestyles and other infrastructure supporting activities that are difficult to perform online.

In many emerging cities in Asia, the development of infrastructure, such as public transportation, sewerage and waste disposal, are far from sufficient and generate problems, such as traffic congestion, air pollution and water pollution. Even if such infrastructure exists, maintenance and operations may not be performed properly. Further improvement and development of infrastructure enabling sustainable lifestyles and support for people having low accessibility to such infrastructure are therefore needed. It is also important to combine various infrastructures properly including digital infrastructures and alternative infrastructures that suit the era of decarbonization. In this sense, existing gaps in infrastructure in Asia provide opportunities for building low-carbon, resource-efficient and inclusive energy, transportation and housing systems because the emerging Asian cities would not have to eliminate old-fashioned infrastructure as cities in developed countries have to.

Rules and customs can inhibit people from practicing more sustainable behaviors as much as infrastructure can. SCP policy should pay attention to such "soft" infrastructure, too.

4.10 Opportunity 10: New Rules & Indigenous Wisdom

New rules and customs that envisage a risk society are emerging with the coronavirus pandemic. Together with traditional regional wisdom like "*mottainai* (wastefulness)" and "sufficiency economy," they are driving the creation of new CP patterns.

The coronavirus pandemic urges people to establish a "new normal." Changing behaviors by changing tacit rules or utilizing indigenous wisdom is an ongoing and enhanced course of SCP policy. One example of the former is the Cool-Biz campaign of Japan, which encourages lighter dress to alleviate the discomfort associated with hotter temperatures brought about from efforts to reduce the energy consumption of air conditioning in offices, trains and other public spaces. This policy was guided by multi-stakeholder partnerships.

The latter, utilizing indigenous wisdom and embedding it into SCP policies, is an approach for improving policy effectiveness. People may not know the term "SCP" but recognize the orientations and importance of SCP policies and tend to embed them into their daily lives. New codes of sustainable business practices should also reflect people's cultural backgrounds. Material Flow Cost Accounting (MFCA) can be seen as one way to reflect *mottainai* in corporate management processes.

4.11 Opportunity 11: Enhancing Collaboration

Cooperation, co-creation and collaborative relationships among stakeholders, both regionally and internationally, are the key to SCP's success.

Multi-stakeholder engagement processes and facilitation mechanisms for good governance are vital for implementation of policies and they enhance ownership of action. (For creating partnerships, see the guidelines by UNU-IAS & UN ESCAP (2018), for example.) There has been significant progress in promoting and implementing SCP in the region through stakeholder involvement, through a continuous effort for knowledge sharing and private-public partnerships. Existing regional policy platforms such as APRSCP, SWITCH-Asia SCP Facility, business entities and expert networks such as PECoP-Asia are valuable channels for driving networking efforts between different SCP-related initiatives

4.12 Opportunity 12: Challenges & Safety Nets

Ensuring a social safety net for people with the courage to try new consumption and production patterns will generate diverse SCP patterns.

Taking on challenges is a key to transforming CP patterns: A challenging spirit helps one envision a nonexistent CP pattern and motivates experimentation with the new CP pattern in a real society. However, challenges fail with a certain probability. If failure brings a high cost to challengers, they will not undertake the challenge. The existence of a social safety net for challengers is therefore important for generating diverse SCP patterns. The scope of SCP policy should thus be expanded to include a variety of attempts to ensure social safety nets.

4.13 Opportunity 13: Social Justice

Proper handling of inequality and social conflicts is the fundamental basis for realizing SCP. New inequality and injustice problems caused by digitalization must be resolved promptly.

Neither benefits nor costs of SCP transitions are necessarily distributed among people evenly. This can cause social conflicts and prevent SCP transition. The coronavirus pandemic has elucidated vulnerable people in our society who may face a more severe situation during a sustainability transition. For example, to switch our society toward decarbonization, coal and oil industries have to be transformed and some workers in these industries will have to change jobs. Thus job/skill training and other programs will be needed to support such workers (e.g., EC (2020) put forward the "Just Transition Mechanism" targeting a fair and just green transition and would mobilize at least €100 billion in investments to support workers, companies and regions most impacted by the transition). Adequate care should also be paid in digital transformation to unfair use of personal information and disproportionate risks to system crashes in the online world. New injustice problems should be identified cautiously and then prevented promptly.

5. Application of Opportunities to SCP Policy Design

To ensure SCP patterns in Asia, we need to have a concrete image of them and then proceed to experiment as the concept of envisioning-based policy making (EnBPM) suggests (Hotta et al., 2021). In this process, continuous and strategic changes are necessary. The 13 SCP opportunities are entry points to the process and are suggested to be incorporated into the experimentation. Figure 5 shows specific example cases of SCP patterns and actions using some of the 13 opportunities for SCP in Asia.

Many ideas can be generated from such cases in line with the context of a target country or region, and it would be preferable that this visioning process itself be implemented in each country or region. We thereby compiled a table called the SCP Case Matrix to serve as a reference for that localized/regionalized process. The matrix shown in Fig. 6 not only presents the ideas of 43 SCP cases but also enables users to search through three aspects: CP patterns, SCP opportunities and stakeholders.

First, the CP patterns and their categories are listed as headings on the left side of the matrix. If users are interested in *what* kind of CP patterns they wish to realize, they search through this left-hand column. If they are

interested in *how* to work on it, they search through the opportunity columns in the middle for an entry point of action. If they are interested in *who* works on it, they search through the right stakeholder columns.

Each of the 43 specific cases is categorized into one of the following seven categories:

- Localized design and utilization of local wisdom
- Circular economy (product and resource circulation)
- Integrated system design of products, businesses and infrastructure (including sharing and digital transformation)
- Policy approaches based on experiential consumption
- New EBPM (EnBPM) for sustainable lifestyles
- Co-creation and social experimentation
- Improvement and importation of conventional SCP policies

These are notable future courses of action for Asian SCP policies. Their further elaboration in line with Asian contexts is expected in Asian countries.

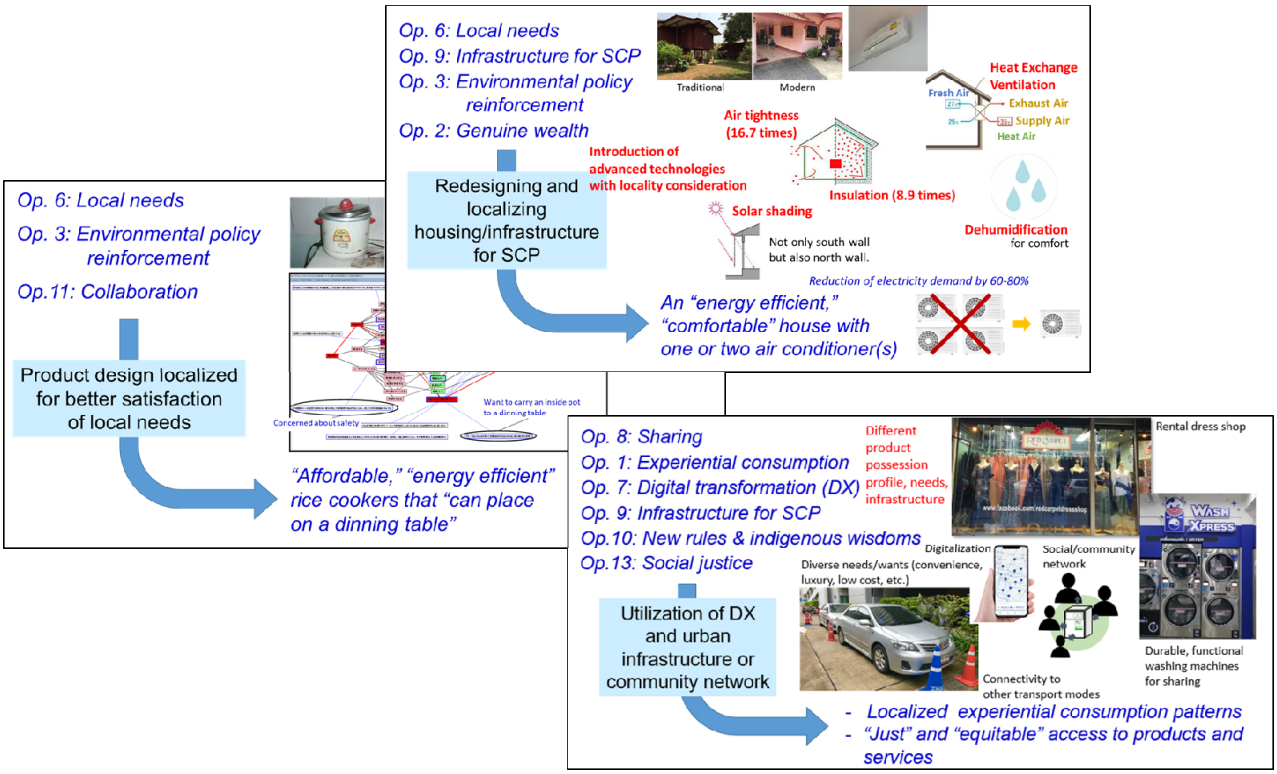

Fig. 5 Specific example cases of SCP patterns and actions using some of the 13 opportunities for SCP in Asia.

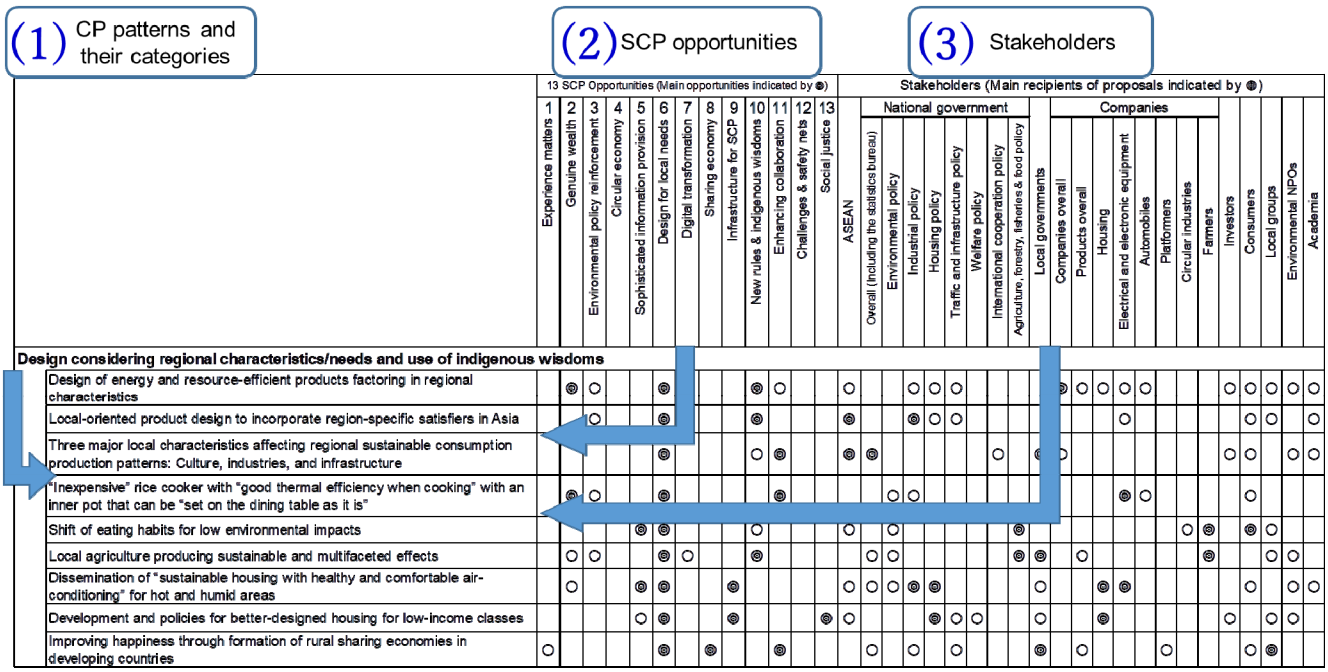

Fig. 6 SCP case matrix.

6. Conclusion and Outlook

Promotion of SCP in Asia is a high-priority issue, and if successful, can make a significant contribution to the prosperity of the world and humankind. This article presents four courses of action for future SCP policies and 13 specific opportunities. All of the 13 opportunities indicate promising entry points for SCP policy development and implementation in the 2020s.

The 13 SCP opportunities shall be supported by two means. Firstly, they should be linked to the SDGs implementation process at local, national and international levels. Such implementation would promote the achievement of Goal 12. To obtain outcomes tackling a wide range of SCP targets, it will be necessary to address efforts comprehensively, not only to implement initiatives in individual sectors in a silo manner. Inter-ministerial coordination as well as stakeholder consultation processes will be the key to SCP.

Secondly, it is necessary to have facilitation mechanisms at the regional level. Existing regional policy platforms such as APRSCP, SCP regional facilitation mechanisms such as the SWITCH-Asia SCP facility, business entities, expert networks such as PECoP-Asia as well as leading national and local governments can put forth an effort to network different initiatives at the regional level. Enhancement of facilitation mechanisms shall play an important role in accelerating the achievement of the SDGs.

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SCP Policy Design for Socio-technical System Change: Envisioning-based Policy Making (EnBPM)

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Abstract

The focus of SCP policy has shifted from management of environmental pollution to wider socio-technical change including infrastructure, lifestyles and business models that are sustainable over decades. This paper first examines the expansion of the SCP policy domain through changes in focus of the following two aspects; product lifecycle policy and policy for changes in provision systems. The authors call for limiting lifecycle-based policy approaches to those that address a socio-technical transition to sustainability. They argue that transition-oriented SCP policy design proposed as envisioning-based policymaking (EnBPM) requires a new approach based on envisioning, social experimentation, a new indicator system to monitor the progress of transition, and development of a new business model. In doing so, they further develop the case for EnPBM and the present direction of potential policy research for developing EnBPM as a policy design approach.

Key words: efficiency, envisioning-based policymaking (EnBPM), social experimentation, sustainable consumption and production (SCP), transition

1. Introduction

Sustainable consumption and production (SCP) is a policy concept aiming at sustainable development that focuses on consumption and production systems. The United Nations Environment Programme (UNEP) defines SCP as "a holistic approach to minimizing the negative environmental impacts of consumption and production systems while promoting quality of life for all" (UNEP, 2015). The focus of SCP policy, however, has shifted from simple management of environmental pollution to promotion of wider socio-technical change including infrastructure, lifestyles and business models that are sustainable over the decades.

Conventional environmental policy has aimed at environmentally-benign consumption and production such as pollution prevention, promotion of green products and services, and inclusion of environmental externalities into economic activities. Recently, especially since around 2015, SCP policies have also come to facilitate more fundamental changes in consumption and production in terms of technology, business models and infrastructure changes.

Hotta et al. 2021 emphasized that this shift could be described as the expansion of the SCP-related policy domain in three phases as shown in Table 1. The 1st phase of SCP (SCP1.0) mainly addressed pollution prevention and cleaner production. The 2nd phase of SCP (SCP 2.0) emphasized increasing efficiency throughout the lifecycle of materials, products and services. Then, in the late 2000s, policy discussions in the SCP-related domain expanded to include systematic transition of socio-technical systems, lifestyles and infrastructure driving consumption and production (SCP 3.0). They also determined that this expansion could be observed in recent international sustainability policy agendas such as the Paris Agreement, and agreements emerging from the G7 and G20 processes. They further argued that the

Table 1 SCP 1.0, 2.0 and 3.0.

Approaches	SCP 1.0	SCP 2.0	SCP 3.0
Major concepts	Pollution prevention, Cleaner production (as an intermediate between SCP 1.0 and 2.0)	Industrial ecology, Resource efficiency, Product lifecycles	One planet living, Sufficiency, Decarbonization, Transition
Key issues	Industrial pollution	Climate change, Waste, Environmental issues associated with consumption	Well-being, Lifestyle, Socio-technical system
Approaches	Installation of end of pipe technologies, Technology and management for cleaner production	Increasing material and energy efficiency	Consensus building, Changes in infrastructure, Changes in lifestyles, New business models
Attitude of policies	React and cure	Anticipate and prevent	Long-term goal setting, Investment, Creating business environments, Innovating and communicating

Source: modification of Table 1 of Hotta et al., 2021.

long-term and middle-term sustainability goals in SCP 3.0 require future-oriented policy design going beyond conventional evidence-based policymaking. Thus, in the era of SCP 3.0, the goals and strategies of SCP policy are not limited to environmental policy areas but expanding to socio-technical system design and transition. This change in the SCP domain poses the following four challenges for policy design: (1) envisioning concrete images of a society that has successfully met its mid-term and long-term goals, (2) policy support for learning from model cases, experimental projects and new businesses to achieve a long-term and mid-term vision, (3) facilitating creative processes among stakeholders and (4) examination of the social implications of innovation towards decarbonization, digitalization and transitioning to sustainable lifestyles and infrastructure. To address these challenges, the authors proposed envisioning-based policymaking (EnBPM). This new approach is defined as a policy approach for addressing "long-term policy concerns such as future visions of sustainable society, social experimentation with such societal visions before full policy implementation based on long-term goals as well as social sustainability." It will require "a more decentralized and collaborative approach for policy design based on working together to envision and realize future directions of society among stakeholders because it puts importance on the social appropriateness of sustainability," unlike Evidence-based Policy Making (EBPM) (Koide et al. 2020).

As the focus of SCP policy has changed and expanded in response to changes in the policy agenda, it is difficult to implement SCP policy effectively without understanding such changes and diversity. The way socio-economic development is understood has changed from referring only to economic development that can be measured by GDP to a form that emphasizes well-being, happiness and sufficiency (European Commission, 2009; Fleurbaey, 2009; Hák et al., 2012; Shrotryia & Singh, 2020; Stiglitz et al., 2018).

Thus, building on the work done in Hotta et al., 2021, this paper argues for further consideration of the direction in which SCP and EnBPM have been headed as a policy design approach for the SCP 3.0 era.

2. Expansion of Policy Domains for SCP

Illustrating the situation through Fig. 1, this section further develops characterizations of different phases of SCP from SCP 1.0 to 3.0 as discussed by Hotta et al., 2021. Figure 1 broadly categorizes the focus of different policy domains in the following two aspects: 1) product lifecycle policy and 2) policy on changes in provision systems. Product lifecycle policy is divided further into that which addresses the upstream part of product lifecycles, i.e., 1-1) production and distribution, and that which addresses the downstream part, i.e., 1-2) wastes and recycling. Policy on changes in provision systems is divided into that which focuses on actors on the demand side, i.e., 2-1) lifestyle, and that which focuses on facilities and such, i.e., 2-2) infrastructure.

SCP 1.0, shown in the first column, aims at preventing direct environmental pollution while continuing economic growth. The policy domain for SCP 1.0 includes 1-1) pollution prevention or cleaner production as an approach for production and distribution, 1-2) cleaning-up and sound management of wastes and recycling, 2-1) awareness-raising campaigns for behavioral changes in citizens' lifestyles, and 2-2) development of basic infrastructure for sanitary, healthy, and convenient lifestyles, including development of roads, cities, housing, public transport and so on.

SCP 2.0, shown in the second column, aims by increasing energy and material efficiency to decouple environmental impacts caused by economic globalization, such as greenhouse gas emissions, from waste generation and economic development. As will be discussed in Section 3, SCP 2.0 focuses on a lifecycle approach to products and services aiming to improve material and energy efficiency. Thus, the policy domain for SCP 2.0 includes 1-1) improvements in the energy and material efficiency of products, 1-2) promotion of recycling at the waste management and recycling stage, 2-1) promotion of green purchasing and information tools such as eco-labels to influence consumption patterns and lifestyles, and 2-2) further promotion of smart and compact cities including public transport infrastructure.

Meanwhile, SCP 3.0, shown in the two right-hand

columns, emphasizes socio-technical change to achieve fundamental reductions in unsustainable consumption of materials and energy while maintaining or increasing the welfare and well-being of society as a whole. The "circular economy" concept emphasizes the transformation of consumption and production systems that depend on natural resources in addition to conventional recycling, and emphasizes technological innovation and the fostering of new businesses. The circular economy, along with decarbonization, has come to be seen as the gateway to conversion to SCP by economies dependent on non-renewable resources.

Therefore, the policy domain for SCP 3.0 as a circular economy may include 1-1) promotion of design for the environment, and repair and refurbishment for production and distribution, 1-2) promotion of reuse and waste reduction for waste management and recycling, 2-1) promotion of sharing and servisizing for lifestyle change, and 2-2) digitalization such as in utilization of social media, IoT, big data and other digital media and information as part of infrastructure development to minimize transaction costs in realizing a circular economy.

Furthermore, the policy domain for SCP 3.0 as "one-planet living" or socio-technical system change is an emerging area which needs envisioning and social experimentation for designing new lifestyles, infrastructure and business models. Potential key concepts for SCP3.0 may include reconsideration of product ownership, dematerialization, attention to local needs, service provision, sustainable resource use, decentralization and multi-functional online platforms.

To reflect economic and social conditions, SCP policy needs to be customized through multi-stakeholder collaboration to incorporate various SCP menus such as sound treatment, recycling, sharing and multi-functional AI-linked online platforms, which are shown in each circle in Fig. 1.

The combination of policy menus for achieving a specific policy goal does not have to be uniform, and the effect of SCP policy can be achieved by flexibly and strategically combining them according to each country's industrial, consumption, urban and other structures. Developed countries have generally responded to the gradual shift from pollution control to efficiency and sufficiency approaches, but in rapidly growing developing countries, simultaneous implementation of SCP1.0, 2.0 and 3.0 will be required.

3. Life-cycle Approach in the SCP 2.0 Era

As discussed in the introduction, since the 1990s, the most influential SCP policy approach can be said to be a life-cycle-based efficiency approach (SCP 2.0). Policy design for SCP 2.0 requires comprehending SCP from the perspective of a product's life cycle, focusing on material destiny from upstream to downstream.

Life-cycle thinking for policy intervention usually focuses on the different stages of the life cycle of products and materials in addition to preventing pollution caused by dumping, leakages and emissions from industrial production. Basically, it looks to divide the life cycle of products and materials into resource extraction, production/manufacturing, distribution, consumption, recycling and waste management.

Life-cycle thinking for policy intervention usually places policies regulating environmental impacts in each lifecycle stage, or incorporates environmental externalities in each lifecycle stage or in combinations of different lifecycle stages (Aoki-Suzuki, 2015; Institute for Global Environmental Strategies, 2010). For example, some well-discussed policy instruments at the resource extraction stage are the pricing of excessive material extraction, including material resource extraction charges, taxes on raw materials, and aggregate levies (Aoki-Suzuki, 2015). For the production stage, policy instruments

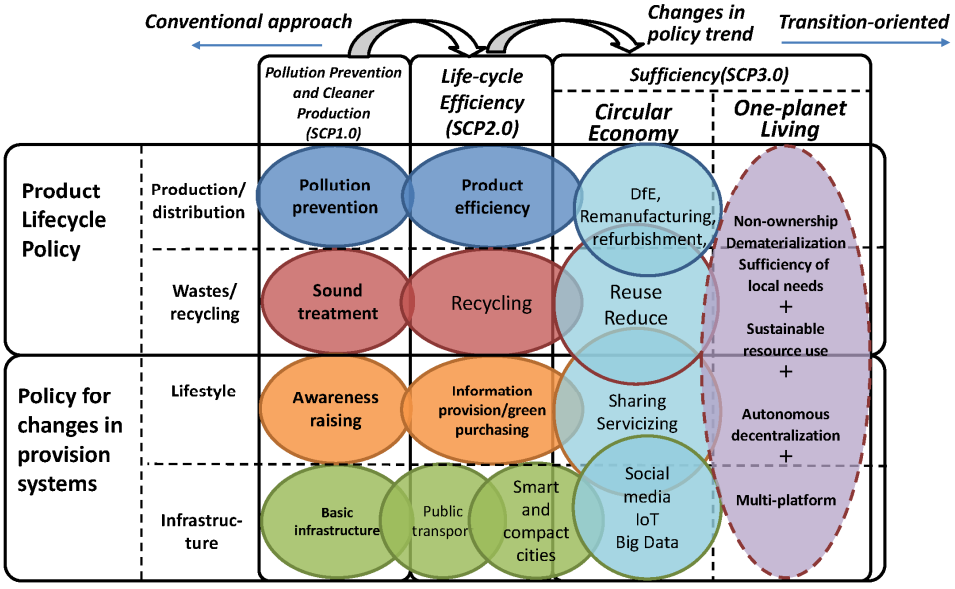

Fig. 1 Shift in policy tools and approaches for SCP.

include environmental management systems (EMS), and promotion of cleaner production and standards for resource efficient products, as well as criteria and standards for eco-design. For the consumption stage, they include eco-labels, awareness-raising campaigns, green procurement, incentive schemes such as deposits and refunds, differentiated VAT and charges for single-use items. The waste management and recycling stage includes instruments such as extended producer responsibility (EPR), pay-as-you-throw (PAYT), municipal waste charges, awareness campaigns, landfill taxes and incineration charges for companies. Although the policy instruments mentioned here do not constitute an exhaustive list, they make up a very common framework for comprehending resource efficiency and material circulation policy areas and perceiving any potential intervention points.

Figure 2 presents an image of the lifecycle-based SCP policy interventions described above.

The lifecycle approach, however, tends to be more effective in considering policy interventions for individual products, services or material streams such as packaging, automobiles, electric and electronic products, food and so on. In addition, since it focuses on product life cycles, it tends to play down the role of consumption as a driving force for product and service systems as opposed to consumption as representing one stage of a whole system.

In this context, the growing popularity of circular economy policies is both an advanced version and a close relative of concepts focusing on product and material life cycles, particularly those focusing on environmentally sound management and the 3Rs (reduce, reuse and recycle) of end-of-life products. This emerging policy concept puts more emphasis on less dependency on primary material consumption, wider use of secondary material cycles and development of new circular business models. In this concept, the specific instruments towards sustainability are not limited to increasing material efficiency of products. Rather, the concept focuses on the transition to much broader systems including business models and infrastructure. The utilization of information and communication technology (ICT), entrepreneurship and innovation to enable the transition is also part of this concept.

4. Envisioning-based Policymaking as a Policy Approach in the SCP3.0 Era

To achieve ambitious medium- to long-term goals such as the Paris Agreement (United Nations Framework Convention on Climate Change, 2015), SDGs (United Nations General Assembly, 2015), and Osaka Blue Ocean Vision (G20, 2019) related to SCP, fundamental changes in socio-economic structure, including business models and lifestyles, are required. In other words, the policy goal is to realize transitions in socio-technical systems, including technological innovation and lifestyle innovation. In this way, to achieve the medium- to long-term goals, it is important to share a vision of embodying the society we should aim for and to accumulate evidence.

The life-cycle approach of policy intervention does not explicitly involve policy design for socio-technical system changes, even those related to institutional reform, infrastructure transformation, innovation, new business models and lifestyle change. It also underplays the role of consumption as a driving force of consumption and production systems.

Thus, it is vital to consider ways 1) to envision future directions based on ambitious middle- and long-term goals for socio-technical change, 2) to conduct social experimentation on new SCP patterns to examine their pros and cons, 3) to monitor the progress of sustainability transition, including development of indicators, and 4) to provide incentives to new business and service models to sustain such socio-technical infrastructure. These are intervention points of an updated SCP approach in a SCP value-creation model.

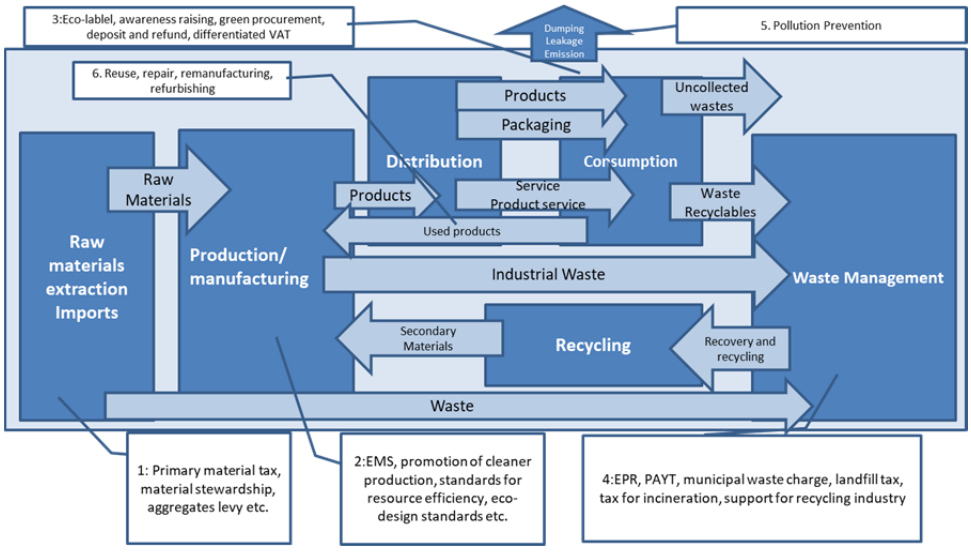

Fig. 2 SCP policy design based on a life-cycle perspective.

4.1 Envisioning and Developing Scenario-based Narratives

One of the most important pillars for EnBPM is "envisioning" as a creative process in social-technical system design for sustainability. For example, the direction of long-term changes in urban infrastructure and lifestyles is often difficult to imagine from the form of workshops among stakeholders alone. Thus, envisioning is crucial as a process for developing a concrete image and road-map, and for generating evidence of the social/economic and technological impacts of achieving these long-term goals in specific local/national contexts. This envisioning process can be supported and facilitated by multi-stakeholder dialogues involving science and policy interactions such as scenario development, modeling analysis and stakeholders' dialogues. It is vital to have a process for co-designing sustainable lifestyles through consensus on changes for infrastructure and business for maintaining or increasing the well-being of a society as a whole.

Application of "envisioning" can be seen in the attempt by Kamei et al. (2021a) to analyze the socio-economic impact of rapid urbanization and possible pathways of sustainable urban development for the long-term future of Bhutan. This approach was originally applied to envisioning future urban development scenarios for Tokyo (Kamei et al., 2021b). Kamei et al. applied a qualitative analysis based on shared socioeconomic pathways (SSPs) for climate change scenario analysis in urban settings. For that purpose, they tried to incorporate the urban context, such as urban planning, spatial analysis, historical/cultural background and detailed urban infrastructure engineering elements, including urban form, buildings and transportation modes. In addition, a stakeholder consultation process was implemented to gain a deeper understanding of the local context. The socio-economic scenario analysis in their study in Bhutan (SSPs Bhutan) proposes decentralized development, conservation of local resources and cultural assets in contrast to the business-as-usual case, where the population influx into the city continues. By utilizing the nine indicators of Bhutan's gross national happiness (GNH) as well as urban planning factors related to quality of life, such as differences in access to infrastructure, energy systems and services between urban and rural areas, the study compared different implications for future development patterns in the different scenarios.

The study showed that urbanization will drive the construction of new urban infrastructure by increasing demand due to the influence of social factors such as education and employment. The study suggests that recent trends in urbanization may exacerbate the social disparities between urban and rural areas. Future projections based on some empirical analyses using existing literature and local experiences can support local-specific strategies for sustainable transition, thereby also increasing the local quality of the living environment and mitigating the emerging social risks associated with ongoing rapid urbanization and socio-technical transition.

4.2 Social Experimentation

Another important pillar of EnBPM is social experimentation. It is not yet clear how society will look after achieving those goals. Thus, social experimentation can be instrumental in examining the effectiveness of different policy options in different social contexts. Social experimentation can also generate evidence of benefits and challenges to achieving these goals in a real setting. It can also generate a narrative for encouraging different stakeholders to contribute their actions and support for a sustainable transition as a way to transform socio-technical systems. Social experiments can motivate citizens and improve their implementation capacity. They open a window for discussing co-creation of a new lifestyle transcending the boundaries of citizens, companies and governments.

For example, the Institute for Global Environmental Strategies （IGES）conducted a study including social experimentation on how macro-level goal-setting for decarbonization (1.5 degree target) could be achieved at the urban and consumer levels by indexing lifecycle environmental impacts (IGES et al., 2019). The 1.5 degree lifestyle agenda has a systematic nature based on interdependence among consumer habits, markets, services, technologies and social rules. Bringing about changes in consumer behavior requires three elements: motivation/intention, ability and opportunity. For consumers to overcome obstacles and smoothly transition to a 1.5-degree lifestyle, it is essential that different stakeholders, such as national and local governments, producers and companies, citizens and civil society organizations (CSOs), play their respective roles and co-create societal visions and lifestyle changes. In particular, the government needs to review existing regulations, indicators for monitoring progress towards goals and transition management to avoid lock-ins. Governments also need to provide infrastructure for sustainable choices, motivate citizens and the business sector to take action, and provide feedback. The business sector must offer innovative products and services and related new business models. Citizens may make sustainable choices, work with governments and businesses to develop products and services and engage in grassroots efforts and dissemination activities in communities, workplaces and schools.

The study aimed at identifying challenges and opportunities for realizing macro policy goals at the micro level. Based on the current footprint of the city and consumer segment and the calculated effectiveness of reducing environmental impacts through lifestyle changes, the study tried to extract options at the living level toward the 1.5 degree target (Koide et al., 2021). It also engaged

with individual households in social experimentation to try to identify options for 1.5 degree lifestyles.

4.3 Monitoring Progress towards Sustainability Transition

Another emerging important pillar involves long-term goal setting and planetary boundaries. This is related to measurement of progress towards long-term and middle-term goals, with more emphasis on social issues, well-being and lifestyles, as observed in the policy discourse on sustainability. The framework for planetary boundaries was introduced in research by Rockström (2009) to define the safe operating space for humanity with respect to the planet's biophysical subsystems or processes (Rockström, 2009). This framework was updated in 2015, concluding that climate change, genetic biodiversity, land-system change and biogeochemical flows are already beyond the boundaries of the earth's safe operating zone (Steffen et al., 2015). This concept, emerging from the research community, gradually surfaced into policy discourse in the 2010s. In this discourse, sustainability issues were framed as ways of living as well as systems which enabled and determined those ways of living. This emerging discourse calls for a transition of lifestyles, production systems and infrastructure based on long-term goals that take planetary boundaries including climate change into consideration. At the same time, a certain level of well-being and inclusion of social considerations are also important concerns in this discourse.

Beyond GDP is one such example in this emerging policy discourse (European Commission, 2009). More than 15 national governments and international organizations are conducting initiatives to design social progress, wellbeing and happiness indicators (Cabinet Office of Japan, 2011). The discourse on "beyond GDP" tends to include discussion on how to achieve ways of living that provide sufficiency. This cannot be measured by GDP as the sole indicator. The recent global sustainability goals encourage a fundamental shift in socio-technical systems for realizing high levels of well-being within planetary boundaries. These goals should not only aim to reduce consumption of non-renewable resources but also to change evaluation methods from those associated with monetary value to more comprehensive ways of measuring the well-being of society as a whole. Various types of "Beyond GDP" indicators have been proposed, including subjective well-being, quality of life, environmental indicators, sustainable development indicators, overall progress approaches or the combination of social and environmental aspects, adjusted-GDP approaches and community indicators (Hák et al., 2012).

One alternative approach for capturing various elements of progress in society is to calculate wealth as a stock, rather than capturing it as a flow. Different types of intangible capital, such as infrastructure, human resources and the natural environment are to be taken into account, with a view towards promoting intergenerational well-being. Managi and Kumar (2018) define this type of integrated indicator as inclusive wealth.

This reframing of issues inevitably leads us to reconsider our vision and goals as well as potentially the value system associated with consumption and production practices of the society. Setting new goals or a new vision also requires creation of new indicators to monitor the progress of socio-technical changes. For example, if the circular economy concept is something distinct from conventional waste management and the 3Rs (reduce, reuse, and recycle), it requires a new set of indicators to check the progress of policies promoting the circular economy. These could be progress on the expansion of new business models in line with the circular economy concept, contributing to dematerialization or ensuring less dependence on virgin materials, and assessing any positive social and environmental benefits.

4.4 New Business Model and Service Model Development

Social and technical infrastructure changes driven by long-term goal setting should be mainstreamed by market forces and by new business models and service provision models. As discussed above, if there are no supplies of services or products to satisfy trends towards such long-term goals, consumers will be locked into conventional practices.

The OECD Meeting of the Environment Policy Committee at Ministerial Level held in Paris, from 28 to 29 September 2016 discussed the circular economy concept, with policy makers emphasizing "the importance of new business models and the barriers to increasing their take-up in the circular economy (…) Circular business models, where firms generate economic value by undertaking business activities which close material loops, will become increasingly attractive" (OECD, 2016).

Bocken et al. (2014) also discusses the necessity of recognizing business model innovation as a key to delivering social and environmental sustainability. By reviewing innovative business model examples, Bocken et al. categorized sustainable new business models into the following eight archetypes, 1) maximizing material and energy efficiency, 2) creating value from 'waste', 3) substituting with renewables and natural processes, 4) delivering functionality, rather than ownership, 5) adopting a stewardship (in terms of long-term health and well-being), 6) encouraging sufficiency, 7) re-purposing business for society/environment, and 8) developing scale-up solutions (Bocken et al. 2014).

Since then, more recent discussions on circular economy business models have emphasized increasing expectations towards roles played by ICT in new business for sustainability by decreasing the costs of transactions

and commutations (Lüdeke-Freund et al., 2018). Digitalization may be able to revitalize reuse or sharing by increasing connectivity among users, products and services.

With growing interest in the utilization of ICT, innovation and dematerialization expressed in the circular economy concept, the emerging attention on a sharing economy is also closely related to policy emphasis on innovation and new business models. A sharing economy or collaborative consumption, which entails "peer-to-peer based activity of obtaining, giving or sharing access to goods and services" enabled by information and communications technologies, has the potential to address social issues such as climate change, pollution, localness and community, and under- and over-consumption (Hamari et al., 2016). The sharing economy is framed in several ways, including as an opportunity for improving the economy, introducing sustainable ways of consumption and promoting decentralized and equitable economy, neoliberalism and deregulation (Martin, 2016).

The most important point is that there is a shift in the discourse represented in this concept and that "the term goes beyond the mechanics of production and consumption of goods and services in the areas that it seeks to redefine (examples include rebuilding capital, including social and natural, and shifting from consumer to user)" (Ellen MacArthur Foundation, 2013). It is essential to develop a social business model and promote private investment.

5. Conclusion

In this paper, we have discussed various policy domains and menus under different versions of SCP by focusing on 1) product lifecycle policy, and 2) policy for changes in provision systems. We have also compared how policy approaches may differ between those in the SCP 2.0 era, which focus on a lifecycle approach, and those under SCP 2.0, which require future envisioning for socio-technical system change. In doing so, we mentioned that SCP 3.0 requires a new policy-making approach suitable for a socio-technical system transition. We therefore have further promoted the concept of EnBPM. In particular, evidence for realization of the visions must be accumulated through social experiments. We have identified four important pillars for EnBPM: 1) formulation of a vision for a future society through scenario analysis and narratives leading up to it, 2) evidence from social experiments in which stakeholders participate, 3) an increased role for capital indicators to measure development of social wellbeing, and 4) social entrepreneurs to foster new business models for advancing SCP.

In particular, in future international cooperation on sustainability, the perspectives of investing in social experiments and social innovation will become increasingly important. It is also important to evaluate international collaborative projects in terms of whether they encourage social innovation towards transition to sustainability.

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An Approach to Quantifying Narrative Scenarios for Sustainable Consumption and Production Using Participatory Backcasting

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Abstract

More attention has been paid to sustainable consumption and production (SCP) to explore the desirable linkage between consumers and producers for sustainability. To envision SCP, the authors have developed a workshop-based method for designing backcasting scenarios. The idea is to incorporate expertise, opinions and local knowledge that experts and stakeholders have into the scenario design process. While scenarios are generally described in narrative format, it is necessary to quantify described scenarios to examine how to bridge the gap between the current situation and predetermined goals for SCP. However, it is not easy to quantify backcasting scenarios because there are no systematized methods available in existing studies. This paper thus aims to develop a workshop-based process for undertaking a quantitative evaluation of backcasting scenarios in narrative format.

To develop the quantification process, we conducted a literature review and held experimental workshops. Making scenario quantification feasible and efficient during the workshop, the scenario designers deal with the following two things before the workshop – (1) setting tentative input values and the rationales for them and (2) suggesting discussion points in quantification workshops. In a case study, we evaluated one of the described scenarios for Vietnam, inviting experts to discuss it. The SCP goal was assumed to halve CO_2 emissions related to passenger cars in 2050 from the level of the Business-as-Usual (BaU) scenario. Through the workshop, the experts reached a consensus on the quantification results, which showed that the CO_2 emissions were reduced 60% when half of car users shared a car with 10 users.

Key words: backcasting, scenario design, scenario quantification, sustainable consumption and production, workshop

1. Introduction

As stated in Goal 12 of the Sustainable Development Goals (SDGs), much attention has been paid to sustainable consumption and production (SCP), which refers to the use of services and related products to bring a better quality of life while minimizing the use of natural resources (UNEP, 2015). To clarify the desirable linkage between consumers and producers, a five-year research project (2016–2020) called "Policy Design and Evaluation to Ensure Sustainable Consumption and Production Patterns in Asian Region (PECoP-Asia) was established (PECoP-Asia, 2016)." The focus was on Southeast Asia because resource and energy consumption is projected to increase drastically in response to future economic growth (Bao et al., 2017). Through this project, the authors developed a method for designing scenarios using participatory backcasting to envision SCP, which is far different from our current state of society (Kishita et al., 2019).

Participatory backcasting aims to envisage and explore system innovations and transitions by inviting stakeholders and/or experts to include various knowledge, values, and opinions in backcasting processes, usually to address sustainability problems (Quist et al., 2011). Backcasting first defines a desirable future endpoint (i.e.,

vision) and then looks backwards from the vision to the present to connect the gap between them (Dreborg, 1996; Vergragt & Quist, 2011). In participatory backcasting, workshops are usually used to describe a sustainable vision in a narrative format.

Based on the concept of participatory backcasting, the scenario design process developed in the PECoP-Asia project consists of the following two steps (Kishita et al., 2018):

1. Describe future endpoints (i.e., visions) that achieve SCP and pathways to connect with those visions, presenting them in narrative format taking into account the regional characteristics of Southeast Asia.
2. Quantify narrative scenarios (i.e., stories describing visions and pathways) to test if the scenarios achieve the predetermined goals (e.g., carbon neutrality in 2050) from an environmental viewpoint.

Note that the above steps should be iterative to develop plausible scenarios. These steps are executed at expert workshops to enhance collection of diversified knowledge and views on SCP for Southeast Asia.

In the project, the authors described narrative scenarios at the expert workshops (Step 1) as shown in Table 1 (Kishita et al., 2019). Based on the experts' discussions in the scenario design process, various measures to achieve SCP came to light, such as sharing, remanufacturing and recycling. The focus of this paper is on Step 2, but the problem is that it is not easy to reflect participants' knowledge and opinions sufficiently in the scenario quantification process, particularly when determining plausible values of parameters in a simulation model. This is because no systematized methods for quantifying backcasting scenarios in narrative format are available. Quantification is based on experts' knowledge, which tends to be implicit and not easily transferrable to other cases (e.g., Uwasu et al., 2020; Vita et al., 2019).

To make quantitative scenario creation based on predefined narratives more efficient, we formulated the research question of this study as "How should narrative scenario quantification processes using participatory backcasting be developed and facilitated, particularly in an SCP context?" To address this question, we aimed to develop a workshop-based method for undertaking quantitative expression of backcasting scenarios in narrative format. We assumed that workshop participants using our method would be experts such as researchers because diverse expertise is needed in SCP. In this paper, we develop this method by taking an experimental approach, i.e., prototyping and revising the quantification process using SCP narrative scenarios, which are described by the authors in PECoP-Asia (Kishita et al., 2019).

The rest of this paper is organized as follows: Chapter 2 provides a literature review of participatory backcasting and explains the problems of quantification of narrative scenarios using participatory backcasting. Chapter 3 proposes a method for quantifying narratives in an SCP context. Chapter 4 presents a case study to demonstrate the proposed method using a narrative scenario for Vietnam. Chapter 5 discusses the effectiveness and challenges of the proposed method based on case study results. Chapter 6 concludes this paper.

2. Literature Review

2.1 Participatory Backcasting for Sustainability

Participatory backcasting, which is a normative approach to foresight using desirable or alternative futures involving experts or stakeholders, has grown into an adequate approach to explore system innovations and transitions towards sustainability (Quist et al., 2011). There is an increasing number of scenario projects using participatory backcasting in various domains, such as household heating (Doyle & Davis 2013), SCP (Kishita et al., 2019), and food (Quist & Vergragt 2006). Methodologies for participatory backcasting also have been developed based on such case studies. For example, Quist et al. (2011) proposed a five-step process for participatory backcasting, including strategic problem orientation; future vision development; backcasting analysis; future alternative elaboration and follow-up agenda definition; and embedding of the results and agenda, and follow-up stimulation, (Quist, 2007; Quist et al., 2011). Nikolakins (2020) analyzed how participatory backcasting enabled communities to produce a range of normative scenarios.

As mentioned above, many researchers have paid attention to participatory backcasting. Most of them focus on creating narrative scenarios to describe sustainable visions. On the other hand, narrative scenarios must be quantified for supporting decision-making towards sustainability such as policymaking. This quantification helps to clarify the gap between sustainable visions and

Table 1 Example of SCP narrative scenarios (not exhaustive) (Kishita et al., 2019).

Title	Storyline
A: BICS Society (BICS: Business-Individual-Customer-Sharing)	• Because sharing services are already popular, B2B leasing and B2C sharing are widely used. • Some people become prosumers to satisfy individual needs.
B: Beauty is only skin deep	• Products are designed by coupling a generalized part and customized part. • Because Vietnamese people like new products, customization services are provided using augmented reality (AR) and virtual reality (VR).
C: Infrastructure innovation 2.0	• Sharing and replacement is accelerated by visualizing information for consumers. • An authorization scheme is introduced to improve repair skills in local industry.

the present as well as to discuss how to cross the gap by taking various technological and political measures.

Although research on the quantification of narrative scenarios using participatory backcasting has not been systematized so far, a few relevant studies are available as follows. Vita et al. (2019) created sustainable lifestyle scenarios in European countries with various stakeholders. Based on the described scenarios in narrative format, they evaluated changes in environmental impacts (e.g., CO_2 emissions or water footprints) when various measures assumed in the scenarios were taken using expert and non-expert decisions with Environmentally Extended Multi-Regional Input-Output analysis. In Vita et al. (2019), it should be noted that quantification of narrative scenarios was accomplished after the stakeholder workshops. Uwasu et al., (2020) developed low-carbon energy scenarios with citizen workshops. Attempting to reflect citizens' opinions in the quantification process, they evaluated CO_2 emissions under the various narratives during one citizen workshop using a simplified simulation model.

2.2 Problems to be addressed

As described in Section 2.1, quantification of narrative scenarios using participatory backcasting is becoming important. It is not easy, however, to quantify narrative scenarios during workshops for two main reasons. First, the process of quantification using workshops has not been clearly developed in previous research. Although Vita et al. (2019) and Uwasu et al. (2020) presented their quantification results, they did not clearly describe detailed processes such as how to determine input parameter values for quantification. Second, the quantification process is time-consuming because it is not easy to quantify a narrative scenario while securing internal consistency within it. For example, in Uwasu's study (2020), at least 4 hours were spent on quantification.

3. Methodology

In this chapter, we develop a quantification process based on a literature review and experimental workshops.

3.1 Approach

We took an experimental approach to developing the quantification process in the following two steps: performing a literature review to prototype a quantification process and conducting experimental workshops to verify, modify and update the prototyped process. At the workshops, narrative scenarios describing sustainable consumption and production developed by members of PECoP-Asia (Kishita et al., 2019) were quantified by involving several members of the project as workshop participants along with a scenario designer, who determined the quantitative expression of each target narrative scenario by organizing the opinions of the workshop participants and calculating target indices such as temperature or CO_2 emissions. Here, the predetermined goal of SCP was assumed to halve CO_2 emissions for consumer durables, such as cars, in urban areas compared with the Business-as-Usual (BaU) situation (Bao et al., 2017) in 2050. Such experimental workshops were also used to verify the method proposed in Chapter 5. The details are given below.

3.1.1 Prototyping a Quantification Process

We developed a quantification process based on the literature review presented in Chapter 2. Quantifying backcasting scenarios described in a narrative format at workshops entails three tasks, i.e., (i) selecting or developing a simulation model to enable quantification of narrative scenarios, (ii) determining the input values for the simulation model, and (iii) discussing and validating the simulation results among workshop participants.

3.1.2 Experimental Workshops

We held three experimental workshops online, varying the conditions of the workshops as shown in Table 2.

In the first experiment, we focused on a BICS Society (BICS: Business-Individual-Customer-Sharing) scenario, where sharing services were widely used to reduce CO_2 emissions. The target products were defined by the scenario designers considering the content of the scenario. At the workshops, the participants established input values without referring to any external information. The participants quantified the scenario by changing the input parameters in a trial-and-error manner. For example, the penetration rate of electric vehicles was set at 100%. During the workshop, the participants confirmed a series of input values to achieve the goal of halving CO_2 emissions but the input values were not convincing because of a lack of rationales. For example, participants assumed that all car users no longer owned cars in the scenarios, without a clear rationale. Moreover, in terms of efficiency, the workshop included much repetitive effort because the participants had to check their results each time they changed an input value.

In the second experiment, the scenario designer conducted a sensitivity analysis of two parameters that were most relevant to the content and had a relatively larger impact on quantification results. At the workshop, the scenario designer showed the results of the sensitivity analysis to the workshop participants. The workshop participants could check the quantification results and get a grasp of the situation involving two parameters for halving CO_2 emissions by referring to the results of the sensitivity analysis. Because it had been difficult to determine input values without information in the previous workshop, the scenario designer also collected information relating to the scenario's contents, such as the current state of the target country or results of questionnaire surveys on sharing services. One example

Table 2 List of experimental workshops.

	Experimental workshop 1	Experimental wokshop 2	Experimental workshop 3
Narrative scenario quantified (see Table 1)	A: BICS Society (BICS: Business-Individual-Customer-Sharing)		B: Beauty is only skin deep
Goal to be achieved	To halve CO_2 emissions relating to passenger cars in 2050 compared with those in the BaU scenario		To halve CO_2 emissions relating to refrigerators
Overview of the quantification process	Participants determined input parameter values without any additional information and checked their results	Participants determined two input parameter values proposed by the scenario designer by checking the results of sensitivity analyses	Participants determined two input parameter values by checking the results of sensitivity analyses
Persons involved in the process	One scenario designer and four participants		
Information provided to workshop participants by scenario designers	Scenario storyline	Scenario storyline, information on current situations, future forecasts and the results of sensitivity analyses	
Discussion points	Participants chose discussion points by themselves	Scenario designers chose discussion points	Scenario designers proposed discussion points and participants selected from them
Examples of chenged parameters (discussion points) (not exhaustive)	Penetration rate of electric vehicles, How many people share a car	Penetration rate of car sharing services, Lifetime of shared cars	Electricity consumption of a refrigerator
Outcomes	Confirmed a series of values for realizing SCP but without clear rationales	Confirmed the state of two parameters needed to achieve SCP	Quantification unfinished because the participants determined the values
Feedback from the participants	(+) Participants could discuss whatever they wanted to (-) Too much repetition during the process	(+) Fewer reiterations in the process because it was easy to understand how the results changed when the two values were changed (-) Participants could not propose other discussion points	(+) Participants could choose discussion points (+)Fewer reiterations in the process because it was easy to understand how the results changed when the two values were changed (-) The discussion stopped when the scenario desiger operated the simulation model or serached for information on the model
(-) Difficult to determine the values and rationales			

*(+) indicates positive feedback from the workshop participants and (-) indicates negative or constructive criticisms.

of a determined input value is the lifetime of shared cars, which was set at longer than seven years (Onozuka et al., 2021). In terms of the workshop's efficiency, the number of iterative processes was lower because the participants were able to get a grasp of the situation to achieve that goal easily. However, the participants could not propose other discussion points during the workshop because the scenario designer did not present the results of sensitivity analyses of other parameters. Although the workshop participants could see related information, they felt that it was still difficult to establish plausible input values for what might occur in 2050.

In the third experiment, the target product was changed from automobiles to refrigerators because the content of the target narrative scenario changed to sharing an electric appliance among many people. To address the challenges found in the second workshop, the scenario designer prepared results of sensitivity analyses of ten parameters in advance, considering the content of the narrative scenario. At this workshop, the participants chose discussion points from candidate discussion points proposed by the scenario designer such as the electricity consumption of a refrigerator. Nevertheless, the participants could not determine the input values within the workshop for two reasons. One was a lack of information for determining plausible input parameter values. This time, we quantified narrative scenarios in terms of CO_2 emissions relating to refrigerators. There was less information about refrigerators in Vietnam than about passenger cars. The other reason lay in the workshop's facilitation. During the workshop, if the scenario designer could not recall information, he would try to find it in the simulation model or on the Internet, leaving him unavailable to facilitate the discussion, so the discussion would stop. This may have led to insufficient discussion.

3.1.3 Problems Identified from the Experimental Workshops

Through the experimental workshops, we identified the following three problems:

- The rationales behind the input parameter values are important to consider for reasonably determining the future parameter values described in the target narrative scenarios, e.g., for 2050. For this purpose, sufficient information should be provided to the participants of quantification workshops.
- It is more efficient and effective to limit the number of discussion points, because not all parameters need to be discussed and determined precisely at the workshop.
- It is difficult for scenario designers to facilitate the workshop while operating the simulation model, particularly in a virtual environment.

3.2 Quantification Method for Pre-defined Narrative Scenarios

We developed a quantification method to address the problems found in the experimental workshops (see Section 3.1.3).

To deal with the first problem, we presume that, when setting input parameter values for scenarios, scenario designers need to prepare tentative parameter values and the rationales for them in advance of workshop. Here, rationales are developed mainly based on external information, such as future forecasting reports or statistical reports gathered by the scenario designers. The scenario designers explain these parameter values and their rationales at the workshop to the participants.

To deal with the second and third problems, the scenario designers prepare key discussion points considering storylines of the scenario and sensitivity analyses of input parameters. They also divide the role of scenario designer at quantification workshops between a facilitator and a technical assistant, who is responsible for running the model. Therefore, it is preferable to involve at least two scenario designers.

Fig. 1 gives an overview of the proposed quantification process. A workshop is combined with back-office work done by the scenario designers to make quantification during the workshop more effective and efficient. The process is composed of three phases and each phase includes one or more steps.

Phase 1. Workshop preparation by the scenario designers (Steps 1–3 in Fig. 1)

Before running workshops, the scenario designers do some preparatory work for quantifying the narrative scenarios, which includes:

- Clarifying the problem definition for quantifying narrative scenarios (e.g., scenario to be quantified, goals to be achieved, time horizon, target region, and target products) to share with the workshop participants.
- Developing or selecting a simulation model for quantifying the narrative scenario to make quantification results more convincing.
- Providing tentative input values and their rationales for the simulation model to stimulate discussion among the participants.
- Providing key discussion points to focus on to facilitate workshop efficiency.

Here, we presume that the storyline of the narrative scenario to be quantified has already been developed in advance of quantification.

Phase 2. Discussion by workshop participants (Steps 5 and 6 in Fig. 1)

The workshop participants first check the results of quantification with tentative input parameter values suggested by the scenario designers. The participants then discuss the validity of the suggested input parameter values and the results to modify and determine new input values and their rationales. In this phase, the participants mainly focus on the discussion points suggested by the scenario designers, but the participants can add more discussion points as they need.

Phase 3. Review and modification (Step 7 in Fig. 1)

After the workshop in Phase 2, the scenario designers set the input values and quantify the narrative scenario. The scenario designers may share the quantification results with the participants to have them review the quantification results. Steps 5–7 are reiterated until the participants are satisfied with the quantification results. In cases where the participants suggest modifying the simulation model or request additional information to make quantification convincing, the scenario designers need to conduct part of the preparatory work for Phase 1 again.

4. Case Study

4.1 Overview

To demonstrate the proposed method, we organized two online workshops. The first one was for quantification of narrative scenarios (around 1.5 hours) and the second one was for the workshop participants to review the quantification (around half an hour). Three experts from engineering and economics were invited to the workshop as participants. Two scenario designers were assigned to the first workshop, one to act as a facilitator and the other as a model operator. A scenario in Vietnam developed by members of the PECoP-Asia Project was quantified. The scenario assumed that the key measure to attain SCP would be sharing services to mitigate environmental impacts, while the predetermined goal was to halve CO_2 emissions in 2050 compared with

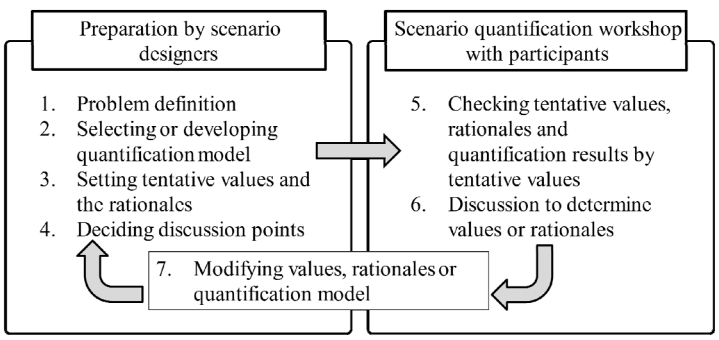

Fig. 1 Scenario quantification procedure using participatory backcasting (updated from Onozuka et al. (2021)).

Table 3 Examples of parameter values and their rationales established in the quantification workshop.

Parameter	Value (2020)	Value (BaU)	Tentative value set by scenario designers	After workshop	Unit	Rationales
Penetration rate of car sharing services	0%	0%	50%	50%	-	The same level as in Thailand. Reference: 45% in Bangkok, Thailand at 2050 (Sekine et al., 2020).
Users of car sharing services per shared car	-	-	50	10	-	The same level as in Japan (assumed by the scenario designers). Reference: Internet questionnaire.
						Considering time required, 50 is not realistic (comment by participants).
Annual car mileage	10000	10000	10000	5000	km / year	Reduced because of lifestyle change caused by COVID-19 (comment from workshop). In 2020, mileage was almost halved in Vietnam.

the BaU situation. In this case study, we assumed that the target product and region of concern were consumer cars in urban areas of Vietnam. This is because cars have not become widespread in Vietnam and controlling the production volume of cars could have a big influence on the country's CO_2 emissions.

4.2 Case Study of Narrative Scenario Quantification

The case study results are summarized as follows:

Phase 1. Workshop preparation by the scenario designers

1. The scenario designers decided to use a simple simulation model called "product circulation model," which was developed to evaluate the environmental impact of product lifecycles, considering consumer behaviors (Onozuka et al., 2021). This model was able to estimate environmental impact changes when various measures (e.g., sharing and remanufacturing) were considered.
2. The scenario designers set tentative input values and their rationales for the product circulation model. For example, the penetration rate of car-sharing services was set at 50% assuming that circumstances relating to car-sharing services would be similar to those in Bangkok, Thailand, referring to previous research done by other scholars. Table 3 gives some examples of input values and the rationales for them set by the scenario designers.
3. The scenario designers suggested a few discussion points, which focused mainly how parameter values would change from those in BaU scenarios. For example, they raised a discussion point about how to set the value of the parameter "Users of car-sharing services per shared car" because it was strongly related with the main measure (sharing services) of the narrative scenario.

Phase 2. Discussion by the workshop participants

The workshop participants discussed how to modify the input values based mainly on the discussion points proposed by the scenario designers. For example, "Users of car-sharing services per shared car" was modified from 50 to 10 through discussion by participants: "It is assumed in the narrative scenario that people will stop owning cars and use sharing services instead. However, this input parameter value refers to the current situation in a developed country, where people already own cars.

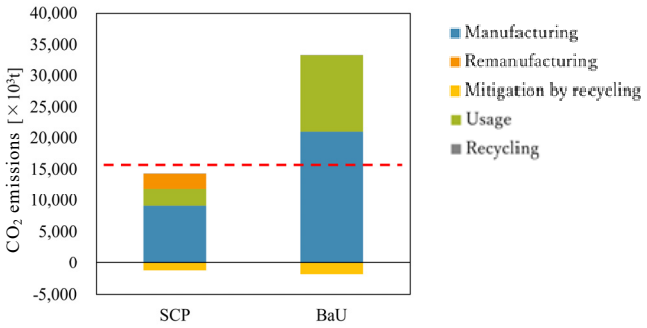

Fig. 2 Quantification result of case study.

Considering the time a sharing-service user would use the car in a day, 10 would be more appropriate than 50 to make the value more consistent with the storylines." Two other qualitative statements were also discussed. One was on lifestyle changes due to COVID-19 - "we can assume that the demand for mobility will decrease because remote work is being promoted to address the COVID-19 situation." This value was halved after considering a mobility report (Apple, 2020). The other was on renewable energy. One participant said "Renewable energy should also be taken into consideration because it has huge potential for reducing CO_2 emissions." In this narrative scenario, we assumed that renewable energy would be used at the level of the Sustainable Development scenario in the World Energy Outlook 2020 (International Energy Agency, 2020). Table 3 presents some of the input parameter values and rationales discussed at the workshop.

Phase 3. Review and modification

Based on the discussion by the participants, the scenario designers set input parameter values to estimate the CO_2 emissions and shared them with the workshop participants. Figure 2 shows the quantification results, which showed that CO_2 emissions would be reduced by 60% compared with the BaU scenario in 2050. Note that all the workshop participants agreed on the final quantification results in the second workshop.

5. Discussion

We have proposed a quantification method for narrative scenarios using participatory backcasting. Judging from the results of the case study, the proposed method worked well in obtaining quantitative scenarios

that achieve the predefined SCP goal (i.e., halving CO_2 emissions in 2050 from the BaU scenario). Although the focus of this paper was on SCP, the proposed method could be applied to any discussion on sustainability. We obtained some important insights into the quantification process when comparing the results of the experimental workshops.

First, the scenario designers' preparation of tentative input parameter values and rationales helped the experts determine the input parameter values for 2050. This is because it was smoother to start a discussion on whether suggested values were convincing or not, rather than determining input parameter values from scratch. Before running workshops, it is important to gather a sufficient amount of information related to various SCP measures described in the target scenario in a local context (e.g., in Southeast Asia) to facilitate discussions among the participants. The gathered information can be used in formulating rationales to decide input parameter values. Second, having the scenario designers raise the discussion points leads to reduced time required for quantification by guiding the discussion among the participants. Third, separating the roles of the scenario designers into facilitator and model operator (technical support staff) is helpful toward efficiently quantifying the narrative scenarios during two-hour workshops based on experts' discussions.

Table 4 compares three methods for quantifying narrative scenarios using a participatory backcasting approach. The originality of the proposed method is to provide a formal process for conducting workshop-based quantification aiming to obtain plausible sets of parameter values. When compared with the quantification processes by Vita et al. (2019) and Uwasu et al. (2020), our method focuses more on interactions with workshop participants to obtain direct feedback by asking them to give rationales for determining parameter values. One characteristic of the proposed method is to quantify narrative scenarios based on participants' discussions under workshops' strict time constraints (e.g., two hours per workshop).

In the proposed method, however, some problems remain to be further addressed. One problem is that the possible range of quantification (e.g., which parameters are considered at a workshop) is limited because the scenario designers choose the discussion points and pre-developed simulation models in advance of the workshops. To deal with this limitation, in Phase 1, the scenario designers need to choose discussion points carefully that are critical to achieving the predetermined goals. Another problem of how the proposed method would support policy design for SCP has not yet been examined. Therefore, engaging more real-world stakeholders (e.g., policy makers) in the scenario design process, including the quantification process, will be needed in further research. For example, combining participatory backcasting with a gamification approach shows a potential to motivate workshop participants' action towards visions created in a participatory backcasting process (Mandujano et al., 2021). The case study shown in this paper invited experts only, but it would be ideal to involve local stakeholders as well. One future task will be to have both researchers and stakeholders involved in testing the proposed methods.

6. Conclusions

We proposed a workshop-based method for quantifying narrative scenarios based on the concept of participatory backcasting. To develop the method, we conducted a literature review and held experimental workshops. To verify the effectiveness of our method, we quantified a narrative scenario in Vietnam using expert workshops. Through the experimental workshops and the case study, we gained the following insights:

- To reduce time spent on quantification workshops, it is important to establish discussion points in advance.
- Tentative input parameter values and rationales prepared by the scenario designers facilitate discussion during the workshop.
- Separating the role of scenario designer into facilitator and model operator assists smooth discussion.

Future work will include applying this process to other scenarios involving real-world stakeholders to further test the method.

Table 4 Comparison of quantification methods in participatory backcasting.

	Proposed method	Vita et al. (2019)	Uwasu et al. (2020)
Scenario title	Sustainable consumption and production in Southeast Asian countries in 2050	Sustainable lifestyles in European countries in 2030	Sustainable energy vision for a city in Japan in 2050
Goals to be achieved	To halve energy and resource consumption compared with that in the BaU scenario	To reduce footprints such as water or land.	To reduce CO_2 emissions by 70% in 2050 compared with those in 1990
Purpose of using workshops	To determine a plausible set of parameter values to achieve predefined goals based on narrative scenarios	To develop visions in narrative format	To develop visions and pathways in narrative format, To determine plausible input parameters to achieve predefined goals based on narrative scenarios
Quantification process	The quantification process was formalized as illustrated in Fig. 1. While the scenario designers chose discussion points and simulation models used, workshop participants (experts) determined the parameter values to achieve predefined goals based on their discussions.	With an input-output model, the research team performed quantification based on narrative visions which were developed at stakeholder workshops. No feedback was provided by the workshop participants to the quantification results.	Workshop participants (citizens) performed quantification, but the plausibility of the chosen parameter values was not discussed or confirmed during the workshop.
Participants	Scenario designers and experts	Scenario designers, experts, and stakeholders	Scenario designers and stakeholders

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The Influence of Regional and Local Characteristics on Sustainable Consumption and Production Patterns in Southeast Asia: Literature Review and Discussion

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Abstract

Sustainable consumption and production (SCP) patterns are inevitably based on human endeavors, including business models and lifestyles. Hence, regional and local characteristics are important factors in identifying SCP patterns and formulating SCP policies; however, SCP policies that originated in developed countries have tended to take a cosmopolitan or context-free position and neglect this aspect. In this study, we reviewed literature about cultural and geographical differences as well as the results of two workshops about SCP in Southeast Asia. We then discussed potential factors that affect SCP patterns and policies in Southeast Asia from a societal (context-dependent) approach. Factors identified include climate and nature, the existence and functions of business and infrastructure, economic growth and regional disparity, policy and regulation, religious rules, the relationship between government and industries, international trade, and people's cultural mindset (e.g., traditional versus secular, acceptance of inequality, self-expression and cultural context). We proposed a model structure to indicate how regional/local characteristics affect the constituents of consumption and production (CP) patterns (CP preferences and CP enablers) and SCP policies (policy needs and policy preferences). We then suggested CP-related regional/local characteristics and policy-related regional/local characteristics in Southeast Asia, presenting four general points regarding regional/local characteristics: that they are relative; that they are dynamic, historical and highly interrelated among each other; that culturalist approaches make meaningful generalizations difficult, necessitating a context-dependent societal approach; and that local characteristics can have a variety of influences on CP patterns.

Key words: cultural difference, policy design, policy transfer, sustainable consumption and production (SCP), Sustainable Development Goal 12 (SDG 12), sustainable lifestyles

1. Introduction

Since the Sustainable Development Goals (SDGs) were agreed upon at the UN General Assembly in 2015, ensuring sustainable consumption and production (SCP) patterns—the SDG 12 goal—has drawn global attention. Asia is a key region for this movement because its economies have been growing rapidly, and the resulting environmental pressures are large (c.f., IRP, 2019; PECoP-Asia, 2018). To ensure SCP in Asia, many efforts have been made. For example, Thailand (2017) developed its SCP roadmap for the period 2017–2036, and the SWITCH-ASIA program of the European Union has funded approximately 130 SCP projects across the region to date. However, according to the United Nations (UN ESCAP, 2019), progress on SDG 12 in Asia and the Pacific has lagged relative to the other SDGs in the region. Therefore, effective SCP policy implementation is needed.

SCP patterns are inevitably based on human endeavors, including business models and lifestyles. Hence, regional and local characteristics are important factors in identifying SCP patterns and also formulating SCP policies. According to Hantrais (2007), contextualization plays a central role in cross-national comparative research, and there are three research approaches: universalist (context-free), culturalist (context-bounded: the context cannot be changed and is the object of study), and societal (context-dependent: the context serves as an important explanatory variable and

an enabling tool). SCP policy has tended to take a universal or context-free position. For example, the United Nations Environment Assembly did not mention local or regional characteristics in its resolution on SCP (UNEA, 2019).

In the field of policy science, Dolowitz and Marsh (2000) discussed types of policy transfer and the reasons behind the increase of policy transfer. They also distinguished three types of failure in policy transfer: uninformed transfer, incomplete transfer, and inappropriate transfer. Failures caused by uninformed transfer are caused by biased/insufficient information about a transferred policy. Incomplete transfer occurs when important elements of a transferred policy are neglected. Inappropriate transfer results when not enough attention is paid to different values and contextual factors (cultural, political and/or economic) as well as the aims of policy targeted at a transferred area. Combinations of the three types of failure are also possible. Consideration of regional or local characteristics is therefore important to prevent failures in SCP policy, too. Minkman et al. (2018) constructed a detailed conceptual framework of policy transfer and identified groups of factors and subfactors related to policy transfer. These include the environment (circumstances of policy transfer) and adoptability, which consists of suitability (institutional fit and flexibility of policy), (adopting) capacity, (policy) resources, and ability to change policy course. However, concrete regional and local characteristics have yet to be considered in SCP policy transfer in the Asian context.

In this study, we therefore reviewed literature related to cultural and geographical (local/national/regional) differences and discussed important factors that could affect SCP patterns in Southeast Asia taking the societal approach. The structure of this article is as follows. In Chapter 2, we review literature about cultural and geographical differences. We also look at specific examples of regional, national or local characteristics (hereinafter, referred to collectively as "local characteristics") from workshops about consumption and production (CP) patterns in Southeast Asia (Tasaki et al., 2021). In Chapter 3, we discuss important localities that influence SCP patterns in Southeast Asia based on the insights from the previous two chapters. Chapter 4 is the conclusion.

2. Literature Review on Cultural and Geographical Differences

2.1 Cultural Differences

First, we reviewed studies about cultural differences. Cultural differences between different geographical areas have been pointed out by many practitioners and would appear to be the most important difference. The meaning of culture is, however, complex and its definition is diverse. For example, according to Kroeber and Kluckhohn (1952), who reviewed 164 definitions of culture and extracted the central idea, culture "consists of patterns, explicit or implicit, of and for behavior acquired and transmitted by symbols, constituting the distinctive achievement of human groups, including their embodiments in artifacts; the essential core of culture consists of traditional (i.e., historically derived and selected) ideas and especially their attached values." As the definitions made by scholars (c.f., Kluckhohn, 1951; Kroeber & Kluckhohn, 1952, Geertz, 1973; Kronenfeld, 2008; and Kronenfeld, 2018) denote, culture is a dynamically formulated pattern inherited and transmitted over a long time. The definition of culture is thus abstract, so we need to proceed to literature that more concretely explains cultural differences.

An early study that addressed cultural differences is Hall and Hall's *Understanding Cultural Difference* (1990). They compared three different cultural worlds based on their understanding that culture is communication, and identified common threads (categories): speed of messages (e.g., a headline is a fast message and a poem is a slow message), context in communication (high or low; how much information is enough to convey), space (e.g., wide or narrow personal space/territory), and time (monochronic or polychronic [doing many things at the same time]; past-, present-, or future-oriented). They also pointed out differences in terms of being fast or slow to respond to and interface with different cultures.

Research groups led by Ronald Inglehart and Geert Hofstede conducted intensive global surveys. The World Value Survey (WVS) founded by Inglehart has been investigating social, political, economic, religious and cultural values of people throughout the world since 1981. The latest (seventh) ongoing survey covers 80 countries. The famous "Inglehart–Welzel cultural map" has two major axes of cross-cultural variation—traditional values versus secular-rational values (the vertical axis) and survival values versus self-expression values (the horizontal axis). It is based on their concept of two major modernization processes: secularization of authority and emancipation of authority (Inglehart & Welzel, 2005). The latest map (WVS Association, 2020) shows that Asian countries are located around the center of the horizontal axis, between many Western countries on the right and orthodox European and African-Islamic countries on the left. A difference among Asian countries is that East Asian countries such as Japan and South Korea are located in secular areas, while other countries from the southeast to west are located in between secular and traditional. That is, Southeast Asian countries are characterized as having weak self-expression and a mixture of secular and traditional values.

Hofstede's cultural survey originated from a personnel survey at an international company, IBM, and was then extended. Hofstede et al. (2010) asserted six dimensions of national culture: power distance

(acceptance of unequal power distribution), individualism, masculinity, uncertainty avoidance, long-term orientation, and indulgence (against restraint). Table 1 shows index values for these six dimensions for Southeast Asian countries as compared to the world average. These countries tend to have notably higher power distance values, lower individualism values (i.e., stronger collectivism) and lower uncertainty avoidance values than the world average. The uncertainty avoidance and long-term orientation values, however, are relatively diverse.

Other researchers and practitioners have also made efforts to elucidate cultural differences. Meyer (2014) presented eight scales of cultural differences: communicating (low-context (simple and clear) vs. high-context (messages are between the lines)), evaluating (direct negative feedback vs. indirect negative feedback), persuading (principles-first vs. applications-first), leading (egalitarian vs. hierarchical), deciding (consensual vs. top-down), trusting (task-based vs. relationship-based), disagreeing (confrontational vs. avoiding confrontation), and scheduling (linear-time vs. flexible-time). For example, Americans, Australians and Netherlanders are low context while Japanese, Korean, and Indonesian are high context. Negative feedback tends to be direct for Russians, whereas it is indirect for Japanese, Thai and Indonesian people. Trust tends to be based on relationships in India, China, Thailand, and Japan. People in Indonesia, Japan, and Thailand tend to avoid confrontation while those in Singapore tend to be between confrontation and avoiding confrontation.

Kosaka (2008) explained differences between the West and the East. As shown in Table 2, practical, adjustable, holistic and less self-centered features of the East are described. Koren (1994) also pointed out differences between the modernized Western thinking and an Eastern way of thinking, a so-called *wabi-sabi* perspective. The differences respectively contrast logical and intuitive, absolute and relative, mass-produced and one-of-a-kind, faith in progress and no progress, control over nature and the uncontrollability of nature, adapting to machines and adapting to nature (in this group, the second element of each pair is a feature of the Eastern way).

The AsiaBarometer survey is the largest comparative survey in Asia and focuses on the daily lives of ordinary people based on the bottom-up principle (Inoguchi & Fujii, 2013). Inoguchi (2005) used principal component analysis on data from 10 countries and identified three major dimensions: (1) general trust, (2) trust in merit-based utility, and (3) trust in the social system. He asserted that the results were related to (1) a Confucian heritage, (2) English speaking, and (3) communist or

Table 1 Hofstede's six indices of national culture and their values in Southeast Asia.

	Index value (0 to 100)					
	Power distance	Individualism	Masculinity	Uncertainty avoidance	Long-term orientation	Indulgence
Indonesia	78	14	46	48	62	38
Malaysia	100	26	50	36	41	57
Philippines	94	32	64	44	27	42
Singapore	74	20	48	8	72	46
Thailand	64	20	34	64	32	45
Vietnam	70	20	40	30	57	35
Avg.	80	22	47	38	48	44
σ	±14	±6	±10	±19	±18	±8
Difference from world avg.	(21)	(−23)	(−2)	(−29)	(3)	(−2)
World average	59	45	49	67	45	45
Japan	54	46	95	92	88	42
China	80	20	66	30	87	24
South Korea	60	18	39	85	100	29

Data retrieved from Geerthofstede.com (2015), with averages calculated by the authors. East Asian countries are presented at the bottom for reference.

Table 2 Kosaka's dichotomization of Western and Eastern philosophy (Kosaka, 2008; summarized and translated by the authors).

	West	East
Philosophical motivation	Theoretical interests	Practical interests in life
Realism	Tendency to think metaphysically	Tendency to think intrinsically
Tendency to think separately	Reductionism	Holism
With and without	Thought of existence. The concept of "nothing" means to lack (something).	Thought of nothingness. "Nothing" can take any form and is not negative.
Positive and negative	Affirmation of human nature	Denial of human acts
Inner and outer	Nature should not be undeveloped	Humans should follow nature

former communist government, respectively. Furthermore, Inoguchi and Fujii (2013) categorized 28 Asian countries into five groups based on factor analyses. The three factors used for the categorization were: materialist (consisting of housing, standard of living, household income, education and job), post-materialist (friendship, marriage, neighbors, family life, leisure and spiritual life), and public-sphere (public safety, condition of the environment, social welfare system and democratic system). Cambodia, Laos, and Myanmar were in the group of countries whose primary factor was materialist and whose secondary factor was the public-sphere. The Philippines was the sole country whose primary factor was post-materialist and secondary factor was the public-sphere. In both of these two groups, the states exercise strong power and have the potential to influence SCP policy. Malaysia, Thailand, and Vietnam were categorized as countries with salient post-materialist features.

2.2 Other Regional/Local Differences

Some scholars have studied regional/local differences other than cultural ones. These include differences in demographics, family type, context, governance and other subjective factors as explained below.

Hoffmeyer-Zlotnik and Warner (2014) summarized demographic variables used to compare different countries. Suggested variables were sex, age, legal marital status, consensual union, ethnicity, education, employment, household size and household income. Esteve and Liu (2013) described a steady decline in household size in Asia from 1980. According to PRB (2020), household size was still relatively large at 4.1 persons/household in Southeast Asia in 2019, as compared to 2.4 and 2.6 persons/household in Europe and North America, respectively. Extended (large) families are more common in Southeast Asia. Macromill (2020a, b, c) elucidated differences between generations (age groups) in purchasing behavior in Thailand, Indonesia and Vietnam (Table 3). Although differences exist in people's ages in the generational categories, many commonalities can be seen among the members of the same generation.

Hantrais (2007) put forward the most frequently examined contexts in comparative research. These are political institutions, administrative structure, economic system, legal framework, social institutions and structures, social protection system, the physical environment and information technology in addition to cultural environment and socio-demographic variables. Kawabata (2005) asserted seven contexts in which to consider retail businesses in Southeast Asia. These were climate, race/population, religion, market distribution, history, policy and income.

Family systems form the basis of society. Todd (1999) categorized family structure in different countries into seven types based on two axes: liberal or authoritarian for the relationship between parents and children (and equal or unequal among siblings) and acceptance of internal marriage. More authoritarian (or high power distance from Table 1) is a family characteristic in Asia, and Todd classified families in Japan and Korea as stem families (authoritarian families with unequal siblings) and those in China and Vietnam as community families (authoritarian families with equal siblings). Families in Southeast Asian countries such as Indonesia, Cambodia, Thailand, Malaysia, Laos, the Philippines and Myanmar were categorized as anomic families, somewhere between liberal and authoritarian. Itao and Kaneko (2020) demonstrated through the use of a simulation model that countries with stem and community families corresponded to countries with social democracy and communism, respectively.

The World Bank publishes a set of governance indicators ranging from −2.5 to 2.5 (the world average is zero). Governance is related to policy adoptability, which is an important factor of policy transfer failure (Minkman et al., 2018). Table 4 shows six indicators for several Southeast Asian countries. The average of the voice and

Table 3 Differences in purchasing behavior of four generations in three Southeast Asian countries.

Generation	Thailand	Indonesia	Vietnam
1st	Baby boomers (founders of modern Thailand), born 1940–1964, prudent shoppers	Independence War generation, born 1945–1964, seek supplementary income, frugal	War era generation, born up to 1976, stable-minded and prudent
2nd	Generation X (political instability generation), born 1965–1979, strong consumer motivation and conspicuous consumers, open to buying online but prioritize the opinions of families/friends	Orde Bal era generation (Suharto System generation), born 1965–1974, not thrifty but spend conservatively, potentially high spending	Doi Moi era generation (Generation X), born 1976–1989, strong consumer motivation and conspicuous consumers, prefer multinational brands
3rd	Millennials, also known as Generation Y (technology generation), born 1980–1999, hybrid of Internet and real consumers	Millennials, born 1975–1998, use services rather than things, digitally friendly	Millennials (free trade era), born 1990–1999, preference for product functionality and green products
4th	Generation Z (uninterested generation), born after 2000, native digital consumers	Generation Z, born 1998–2002, self-centered and impulsive consumption behavior, technology savvy, digital natives	Post-Millennials (Generation Z), born after 2000, practical and technology savvy, driven by price and convenience

Retrieved from Macromill (2020a–c) and summarized by the authors.

Table 4 Governance indicators of Southeast Asian countries from 2017 to 2019.

Country	Worldwide Governance Indicators (−2.5 to +2.5)					
	Voice and accountability	Political stability and absence of violence/terrorism	Government effectiveness	Regulatory quality	Rule of law	Control of corruption
Singapore	−0.14	1.55	2.22	2.13	1.85	2.16
Brunei Darussalam	−0.91	1.19	1.24	0.68	0.63	0.77
Malaysia	−0.17	0.16	0.97	0.68	0.54	0.20
Thailand	−0.96	−0.69	0.36	0.12	0.06	−0.40
Indonesia	0.16	−0.51	0.13	−0.11	−0.33	−0.31
Philippines	0.05	−1.05	0.02	−0.01	−0.46	−0.53
Vietnam	−1.41	0.18	0.02	−0.34	0.02	−0.53
Lao PDR	−1.76	0.45	−0.61	−0.74	−0.89	−0.99
Myanmar	−0.86	−1.20	−1.09	−0.78	−1.01	−0.59
Avg.	−0.67	0.01	0.36	0.18	0.04	−0.03
Factor analysis						
Factor 1 (4.63)	0.16	0.88	0.94	0.92	0.96	0.92
Factor 2 (1.14)	0.92	−0.31	0.28	0.38	0.22	0.28
Japan	0.99	1.63	1.35	1.55	1.47	1.07
China	−1.52	0.47	−0.19	−0.25	−0.29	−0.25
Korea, Rep.	0.77	1.21	1.09	1.20	0.61	0.47

Data retrieved from World Bank (2020); three-year averages were calculated. The global average is zero. Values in parentheses next to the two factors indicate eigenvalues. East Asian countries are presented at the bottom as reference.

accountability indicator, which indicates participation in selecting the government, freedom of expression and association, and a free media, is notably low (−0.67). The authoritarian culture of Southeast Asia is reflected in this indicator. The other five indicators range from positive to negative and do not show a large general deviation from the world average. Our factor analysis showed these five indicators form a different factor from the voice and accountability indicator, and have strong correlations with each other (correlation coefficients of greater than 0.9, except for political stability, whose coefficients are 0.69–0.76).

2.3 Specific Groups of Local Characteristics Influencing CP patterns

The previous sections highlighted many points of view about general cultural, geographical and other differences. In this section, we review the results of two workshops showing specific groups of local characteristics that are directly linked to CP patterns. Tasaki et al. (2021) held two workshops to discuss SCP patterns in Southeast Asia and obtained 170 local characteristics that could affect SCP patterns of six activity domains: cooling, doing housework, eating, moving short distances, purchasing, travelling and working.

Table 5 presents 14 categories of local characteristics. The local characteristics in each category are more specific perceptions and attitudes than those reviewed in the previous sections. Culture and customs, industry, and infrastructure were the top three major categories of local characteristics, each accounting for more than 15% of the 170 local characteristics, followed by climate and nature. It would be difficult to identify cultural characteristics without extensive local knowledge. The same is true of local industry. Even if outsiders (non-local people) can observe the existence of industries directly linked to consumption and production, it would be difficult for them to identify the industries' functions in a society. In contrast, outsiders may be better able to identify some areas, for example, infrastructure, climate/nature and economic growth. These may be taken for granted by insiders (local people) and be relatively difficult for them to become aware of. Both views—internal and external—are required to gain a precise understanding of local characteristics.

3. Discussion on Local Characteristics Influencing SCP Policy

Based on the knowledge and insights gained from reviewing the literature and workshops, we discuss local characteristics in the context of SCP policy in this chapter. We can distinguish two different types of local characteristics. One influences CP patterns that are formed in certain countries/areas (targets of SCP policy), and the other influences the choice and implementation of SCP policy (hereafter referred to as "CP-related local characteristics" and "policy-related local characteristics," respectively). These local characteristics have complicated interrelationships. To structure this complexity and facilitate our understanding and discussion, we put forward a simple model of the

Table 5 Local/regional characteristics presented at the two workshops on SCP patterns in Southeast Asia.

Category*	Main identifier**	Examples	Main focus
Culture/custom (37%)	Insider (+6%)	Role of wife as "good cook, good housekeeper"; Relaxed (flexible) attitude about time; Easy going; Dangerous driving behavior; Set temperature of air conditioners too low (e.g., 18°C); Service mind ("Siam Smile"); Care about their social image; Buddhist spirits; Less walking; People value face-to-face communication; Cars as status symbol; Culture of eating-out, even for breakfast; Chili fish sauce	Actual behaviors and perceptions
Industry (21%)	Insider (+8%)	Traditional, no meal delivery system; Non-material consumption (massage etc.); All variety of foods available; Street food available 24 hours; Too many food stalls; Informal transport sector; High-value-added brand bicycles	Existence and non-existence of certain industries, including their functions in society
Infrastructure (18%)	Outsider (+11%)	Greener transport; Easy access to food and free Wi-Fi; 5G (telecommunication); High CO_2 intensity of electricity; Bad pavement conditions; Narrow roads; Comfortable public space (green space); Conventional well-ventilated houses; Traffic congestion; Power shortage; No parking spaces for bicycles on sidewalk	Quantity and quality of infrastructure
Climate/Nature (9%)	Outsider (+8%)	Hot weather; High humidity; Heat island effect; Existence of rainy season; Abundant tropical food	Climate conditions and their service functions
Public policy (8%)	Insider (+9%)	No license needed to become a housekeeper; No strict law enforcement; Plastic bags/containers not allowed in national parks	Existence and non-existence of certain policies as well as their effectiveness
Working (7%)		Immigrants and unregistered workforce; Working support services (co-working spaces, free Wi-Fi, childcare); Inflexible working rules; Commuting time	Working and non-working conditions
Commodity prices (6%)		Cheap street food for low-income people; Relatively low cost of living; Electricity cost	Low prices and low incomes
Economic growth (5%)	Outsider (+8%)	Increasing wealth; Increases in ownership of electronic equipment; Expansion of urban areas; Income gap	Growth itself and its consequences
Technology (4%)		Undergoing innovation; Improvement in automatic translation; Use of chemical substances; Adoption of new technologies	Existence and social acceptance
Human resources (4%)	Insider (+9%)	Lack of education; Digital literacy; Lack of knowledge about specific topics	Knowledge level and abilities of people and workers
Demography (4%)		Population; Population density; Increasing immigrant population; Many white-collar/high-income workers	Population and class changes
Pollution and safety (3%)		Emissions from fuel combustion (e.g., PM2.5); Air pollution from outdoor cooking; Cost considered over environment	State of pollution and control; people's attitudes
Politics and society (2%)		Trust among neighbors; Resistance from individuals to change; Communist government	Government and governance
Sanitation (2%)		Some street venders are not safe or clean; Food safety (diarrhea)	Protection against viruses and bacteria

* The percentages indicate frequency among all local characteristics raised at the two workshops (Tasaki et al., 2021).

** This column indicates the main group identifying the local characteristics. Insider and outsider refer to local and non-local people, respectively. The percentage values in parentheses indicate differences in the frequency rate between the two workshops in Thailand and Japan (no insiders attended the one in Japan); only differences >5% are shown.

relationships between CP patterns and SCP policy as shown in Fig. 1. It is based on two types of questions about *what* and *how*, with reference to the attitudes-facilitators-infrastructure (AFI) framework for SCP (Vergragt et al., 2014); five components of CP patterns (production, provision, consumption, products and services; Tasaki et al., 2021); and a policy cycle model (Cairney, 2012). This model shows the four constituent parts of CP patterns and SCP policy: CP preferences, CP enablers, policy needs and policy preferences.

3.1 CP-related Local/Regional Characteristics

CP preferences are influenced by local/regional characteristics. For example, family styles, such as extended (large) families and two-income families, allow family members to have different consumption patterns of eating (cooking or dining out) and purchasing (more or less). People's mindsets about satisfaction and materialistic/post-materialistic values also drive them to different consumption patterns. In Thailand, the former King, Bhumibol Adulyadej, advocated the idea of a "sufficiency economy" in which sufficiency meant a middle way—not too little and not too much—implying both self-reliance and frugality (Millet, 2011; Merle et al., 2017).

Climate and nature influence CP patterns. Southeast Asia has a hot, humid climate (the monthly average highest temperature is above 30°C all year), and it influences regional cuisine, for example, through the use of various spices, fish sources and aromatic ingredients even though food preservation technology and

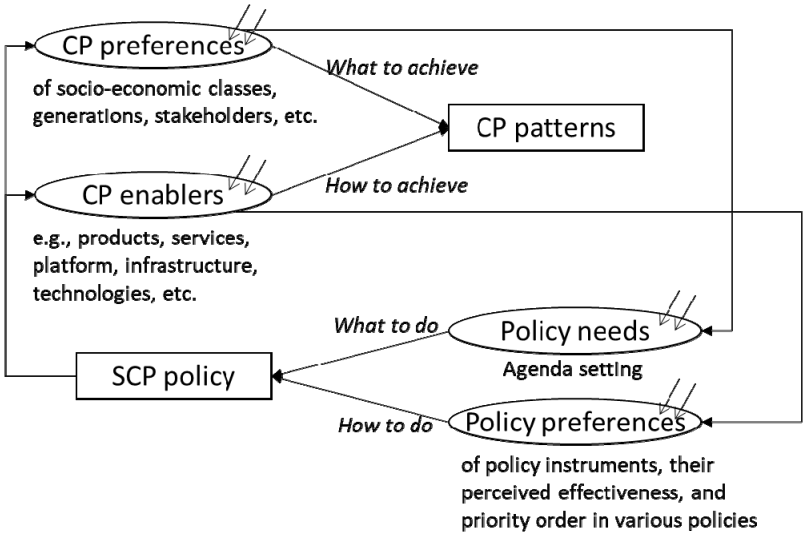

Fig. 1 Model of the relationships between CP (consumption and production) patterns and SCP (sustainable consumption and production) policy, including their constituents (in ovals). Local/regional characteristics influence all the constituents as shown by the double arrows.

globalization have made a variety of cuisines available. Climate also leads people to use more air-conditioning and energy, which is a concern of the IEA (2019). The use of air conditioners has spread to rural areas where traditional stilt houses can still be found, and even though people in rural areas tend to limit the time and period of use, younger generations tend to use air conditioners more than their elders (Yoshida et al., 2020). People in Southeast Asia regard cooling as a luxury and tend to set the temperature low. Kawabata (2005) explained features of markets in Southeast Asia as follows: there are no seasonal markets; clothing shops do not have to adjust their inventory as the seasons change (i.e., there are no winter clothes); people avoid walking even short distances (150 m is the average size of the trading area of convenience stores in Manila, whereas it is 500 m in Japan); and shopping centers with air conditioners are not just for shopping, but rather they are part of the urban space for daily life.

Businesses providing products/services and technology can be localized and regionalized; that is, they are directly influenced by local characteristics. For example, people living in rural areas in Southeast Asia have more contact with the soil in their daily life, and washing machines sold in rural areas have equipment for hand-washing clothing on the top (Watanabe et al., 2019). Street food venders enable people to eat out casually and support dual-earner families (c.f., Trafialek et al., 2017). Existing businesses' attitude towards competition or co-existence with new businesses is an important type of local/regional characteristic in forming a CP pattern. For example, conflicts between taxi businesses and new ride hailing/sharing services such as Uber and Grab and other mobility services prevent emergence of a new CP pattern (c.f., Ackaradejruangsri, 2015; Narupiti, 2019). Existence of an informal sector and relatively large secondhand and repair markets, a typical regional characteristic of developing countries, influences possible CP patterns there. Kobayashi and Fukushige (2018) proposed a "living-sphere approach" to incorporate region-specific satisfiers for basic needs into product design.

Availability of infrastructure can limit or expand the number of options that consumers and producers/providers can use. For example, in urban areas, public transportation infrastructure is very important. If public transportation is limited, citizens are likely to use automobiles and motorcycles, which may cause road congestion and increase carbon dioxide and other pollutant emissions. Without mass public transportation infrastructure, it is difficult to commute in an environmentally friendly manner in large urban areas. The same can be applied to electricity. Availability of environmentally friendly electricity is needed for a city to transform its SCP patterns. The percentage of energy-efficient housing stock in an area also determines the level of energy consumption in a city. Digital infrastructure can serve as an enabler for digitalized CP patterns such as servicizing and sharing, and digital connection quality is a determinant of such CP patterns. Participants in the workshops mentioned in Section 2.4 discussed not only conventional kinds of infrastructure (e.g., roads and waste collection systems) but also alternative types that would be able to support new SCP patterns and lifestyles. Examples were roads for specific purposes such as walking and bicycling, open public spaces, and digital infrastructure such as online platforms and digital currency. Infrastructure transformation is thus important for SCP.

Rapid economic growth and the resulting regional disparities constitute underlying regional characteristics in Southeast Asia. Compressed development, a term coined and characterized by Whittaker et al. (2010), resulted in

workforce shortages in urban areas and an increase in migrant workers (Rattanapan, 2015). Availability of a cheap labor force (i.e., migrant workers) both enables and impedes SCP patterns; for example, proper protection of migrant workers is often insufficient and long-term poverty is a possibility. Such disparities occur geographically. According to Kawabata (2005), regional disparities in Southeast Asia have formed a mosaic pattern rather than a monotonically changing pattern. Coexistence of different levels of development and their geographical distribution/pattern thus can be a local characteristic in Southeast Asia. Oizumi (2011) pointed out another example of local characteristics of government: increased taxation is a key to development in rural areas in Asia because funding is required, whereas decreased taxation is a key concept of development in urban areas because of market competition.

Religion is also a local/regional characteristic affecting CP patterns. For example, religion can trigger changes in people's behaviors. Several temples in Thailand are calling on believers to donate secondhand goods and recyclable waste. The collected secondhand goods and recycled resources are sold to dealers and recyclers. The revenue is then used for temple maintenance and other contributions to society, such as scholarships for the poor. The Indonesian Ulema Council, Indonesia's top Muslim clerical body, has organized a campaign to use reusable bags to reduce the number of single-use plastic bags in collaboration with Greenpeace and the Ministry of Forestry and Environment (Nugraha & Purwaningsih, 2018).

Various existing regulations can hinder or promote adoption of new SCP patterns. Ride hailing/sharing services such as Uber and Grab are not popular in Japan because it is difficult for new service providers to fulfill the requirements of the Road Transportation Act and the Passenger Vehicle Transportation Business Act. Collection and recycling of end-of-life vehicles are promoted by the automobile tax structure and the Automobile Recycling Act in Japan, whereas they are hindered in countries without similar regulations or laws. Other examples of regulations hindering or promoting adoption of new standards include the following: Halal standards set by the Malaysian government prohibit the reuse of packaging materials previously used on non-Halal products, and regulations for food contact containers in Thailand prevent bottle-to-bottle recycling of PET resin.

3.2 Policy-related Local/Regional Characteristics

People's mindsets affect their relationships with the government and public policy as well as people's compliance with public policy. As noted in Chapter 2, local characteristics in Southeast Asia include a mixture of traditional and secular, an acceptance of inequality (a high power distance), a relatively low level of self-expression, a high-context culture, relationship-based trust, low uncertainty avoidance, holism and a preference for real practices over transcendental theory/rules. By reflecting upon these tendencies, we came upon the following policy implications. First, the traditional authoritarian view places importance on the government. People therefore tend to follow what the government decides, and government officials tend to perceive a low need for public participation in policy decisions as compared to Western countries. SCP policy can thus be stringent; however, the goals of SCP policy can deviate from people's needs, and policy decisions may not fit stakeholders' situations. Second, people tend to neglect impractical rules and to use double standards. This is a tactic of respecting authority while practicing one's own life and business. Implementation of SCP policy in this sense can be problematic in Southeast Asia. In addition, a high-context culture does not help explain whether a person or institution will comply or not with any given policy. Third, insufficient institutionalization, which is typically observed in developing countries, increases a government's difficulty in putting policy decisions into force. The size and capabilities of municipalities in Southeast Asia are still small. It is therefore difficult to introduce the same municipal policy used in developed countries in these areas.

There is often a preference to adopt an ambitious policy agenda without considering its local feasibility. Aid receivers in the context of international cooperation can urge governments to accept a donor's preferred policy. In addition, rivalries between ministries and agencies tend to lead them to pursue new policy areas where the governing institution has yet to be determined.

Trust between industries and government can be weak in Southeast Asia. As noted previously, governments often make policy decisions without consulting industries. In addition, policy decisions are often not followed up with implementation. Moreover, some industries do not view the domestic market as important if it is small, and international cooperation influences policy decisions. Thailand is an example of a country where relationships with industries and inter-ministry coordination are relatively good.

Business enterprises are also important actors for SCP, and business activities have drawn more attention, especially since the SDGs were agreed upon. In a study about corporate environmental management in Japan, Thailand and Vietnam (Yagi & Kokubu, 2021), the most important stakeholders were buyers and investors in Japan, whereas they were the community and employees in Thailand and Vietnam. That is, community-oriented management was observed in these Southeast Asian countries. This characteristic is in line with the cultural position of Thailand and Vietnam on the Inglehart–Welzel's cultural map where its position is in between traditional values and secular-rational values. In

the late 1990s, Shimizu (1998) pointed out that Japanese corporate management that was originally based on humanism, collectivism and trust had shifted towards Anglo-Saxon management based on individualism and market competition, but that it would not become exactly the same as Anglo-Saxon management. Thailand and Vietnam are more oriented to community and traditional values than Japan. Therefore, their community-oriented management probably would not be shifted towards Anglo-Saxon management so easily.

Physical and perceptual distance between producers and consumers (i.e., the international market structure) may affect the process of finding SCP solutions. In economically large countries, the trade dependency rate (the ratio of exports and imports of products and services in gross domestic product) is usually low. For example, the trade dependency rates of Japan, China, India and Indonesia are around 40% (calculated from the World Bank's World Development Indicators database). On the other hand, the trade dependency rates of Singapore and Vietnam are 319% and 210% in 2019, respectively. The rates of Malaysia, Cambodia, and Thailand also exceed 100%. Producers tend to pay attention to the preferences of consumers in large markets, neglecting consumer preferences in small markets. This could be a barrier for consumers and governments in the promotion of SCP.

3.3 Local Characteristics Reconsidered

Figure 2 summarizes the relationships and patterns discussed in the previous sections. Several points are noteworthy here. First, local characteristics are relative. Some local characteristics mentioned in this study are truly local ones, but they also are common at the global level. An example is the 5G telecommunication infrastructure in Bangkok. This is unique to Bangkok when compared with the infrastructure in other cities and towns in Thailand, but not when compared with other leading capital cities in the world. That is, local characteristics are identifiable only when a reference is provided and can vary depending on the reference point. The reference point can be either the whole (e.g., "*A* is unique among...") or in comparison (e.g., "*A* is more...than that in..."). In other words, the criticism that "it is not a local characteristic" is not sufficient if the reference point is not mentioned.

Second, local characteristics are dynamic, historical and highly interrelated among each other. Some local characteristics have causal relationships. For example, people use air conditioners because of the humid and hot climate, and weak policy enforcement has resulted in a habit of breaking rules and the emergence of the informal sector. In addition, local characteristics have a dynamic nature. On-going change in a certain local characteristic brings about changes in other localities. Once a CP pattern

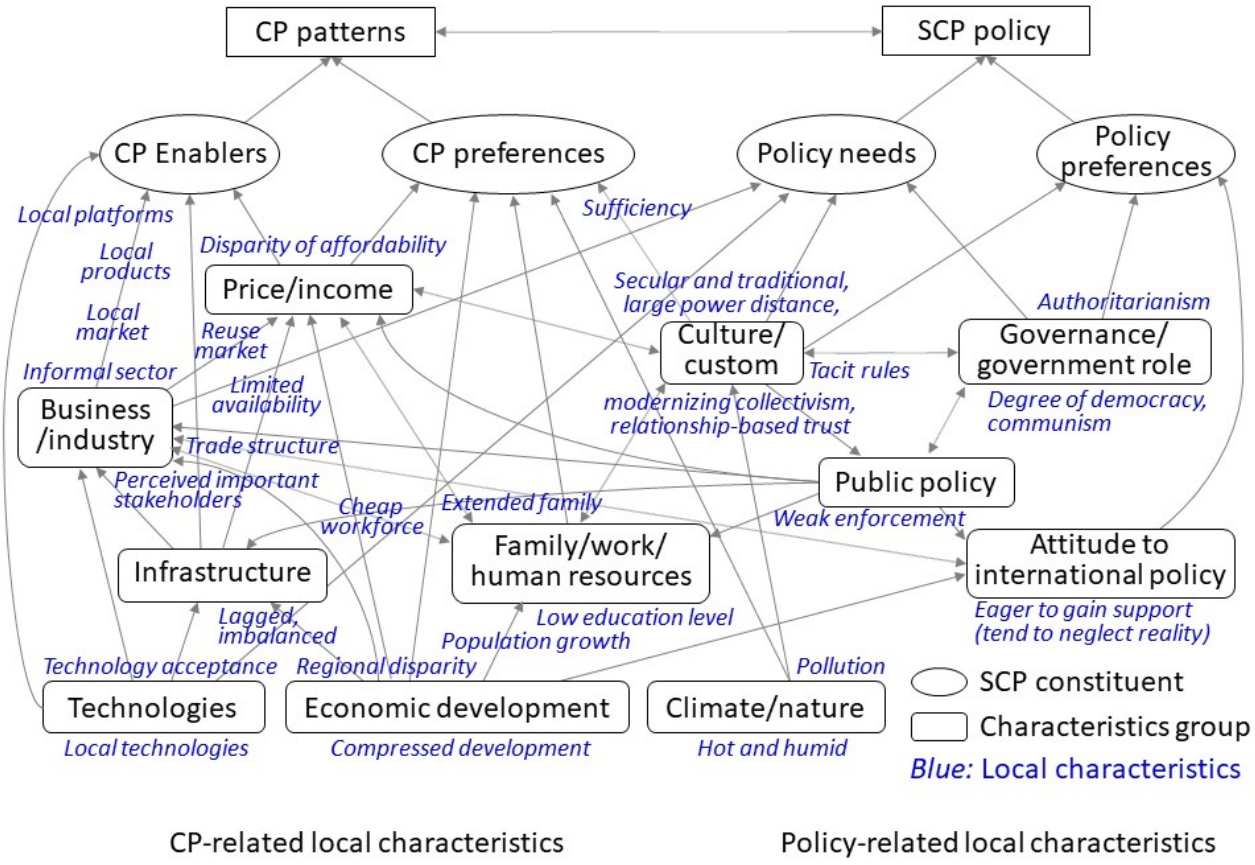

Fig. 2 Example of structured relationships between/among local characteristics and SCP constituents in Southeast Asia. The relationships between CP patterns, SCP policy and SCP constituents at the top are simplified. See Fig. 1 for the precise relationships.

or SCP policy is established, it influences culture, business and public policy. Therefore, localities cannot be clearly and precisely categorized.

Third, only local characteristics related to SCP patterns and policies are targeted by this study. As argued by Hantrais (2007), culturalist approaches make meaningful generalizations very difficult as they tend to illustrate diversity and divergence rather than similarity and convergence. In this study, we took a context-dependent societal approach and focused only on factors influencing SCP patterns and policy to guide SCP practitioners (including factors that would play an important role in the future). The SCP localities we discussed are thus not the same as the cultural/geographical differences discussed by culturists.

Fourth, local characteristics include both (1) those that act as a promoting/hindering factor influencing individual CP patterns and (2) those influencing whether a combination of multiple CP patterns can occur. For example, local regulation and local market conditions (including stakeholders' perceptions) can influence whether or not private cars, taxis, ride hailing/sharing, public buses and trains compete or coexist.

4. Conclusion

"Cultural difference" is a very convenient term to use. However, it prevents us from developing a deeper understanding of local characteristics and SCP policies. CP patterns are formed more or less in a regional and local context, and SCP policies have to be adjusted to these contexts to be effective and also to avoid policy transfer failure. This study reviewed literature about cultural and geographical differences and workshop results. We then discussed regional/local characteristics to be considered in SCP policy from a societal approach position. We proposed a model structure to indicate how regional/local characteristics affect the constituents of CP patterns (CP preferences and CP enablers) and SCP policies (policy needs and policy preferences). Our discussion based on CP-related regional/local characteristics and policy-related regional/local characteristics in Southeast Asia identified the following factors: climate and nature, existence and functions of business and infrastructure, economic growth and regional disparity, policy and regulation including religious rules, relationship between government and industries, international trade, people's cultural mindset characterized by a mixture of traditional and secular, high power distance (acceptance of inequality), relatively low self-expression, and high-context culture. These can be entry points for policymakers and practitioners to consider SCP policies and actions that are fitted to the local/regional context in Southeast Asia and that can enhance the effectiveness of SCP policies/actions.

Although these insights are informative for SCP practitioners in raising awareness about local characteristics and helping appropriate caution to be applied in policy transfer, we do not think they are sufficient as a rationale for taking specific actions. Every action has a specific context and has to take into account very specific elements of CP patterns and stakeholders. As discussed, local characteristics are relative and it is difficult for only insiders or only outsiders to be aware of all local characteristics. This can result in failure of SCP policy implementation. SCP practitioners need both to have a basic perspective and to make individual efforts to grasp regionalities/localities when designing and implementing SCP policies.

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A Framework for Locally-oriented Product Design Using Extended Function-structure Analysis and Mixed Prototyping

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Abstract

Ensuring sustainable consumption and production (SCP) patterns is an important task and is one of the United Nation's sustainable development goals. Each SCP pattern needs to be appropriate for its target region, so they differ according to regional or local characteristics, including culture, climate and customs. Therefore, product design should take into account these characteristics as appropriate. The purpose of this study is to propose a framework for locally-oriented product design using an extended function-structure map and a mixed prototyping environment. The former is applied to identify local specific information related to product function structure and to generate design ideas, and the latter is applied to evaluate design solutions in a reconfigured living environment comparable with an actual one. Combining these two elements in the design process allows local information to contribute to the design of locally-oriented products. The usefulness of the proposed framework is shown by applying it to the development of an improved washing machine design for use in the Vietnamese living environment.

Key words: locally-oriented product, satisfier, sufficiency, sustainable consumption and production (SCP), sustainable design

1. Introduction

Realizing a sustainable society is the most challenging issue facing humanity today. Ensuring sustainable consumption and production (SCP) patterns is one of the United Nation's sustainable development goals (SDGs; UNEP, 2010). Product companies have focused on improving the efficiency of production and products from the perspective of the environment. Eco-design guidelines and methodologies based on life-cycle thinking have been developed (Brezet & Hemel, 1997; Chiu & Chu, 2012; Kobayashi, 2005). They have contributed to improved eco-efficiency of products, and indices of product eco-efficiency have also been developed and applied (Kobayashi et al., 2005).

The appropriateness of SCP patterns varies according to factors such as the culture, climate, lifestyle and social norms of the target region. Indeed, studies have pointed out that general differences in human nature can be explained by culture (Hofstede et al. 2010; see also Tasaki & Kojima (2021) in this special issue.), 2010) and climate (Waztsuji, 1961), which affect individual personalities at a deeper level. This evidence suggests that regional differences have a broad effect on the human nature of ordinary people. To achieve an appropriate SCP pattern in each region, one study identified the importance of focusing on local characteristics in product design (Kobayashi, 2015). To recognize local characteristics and generate ideas for locally-oriented products, the same study proposed the concept of an extended function-structure analysis method that visualizes the relationship between local specific information and a product function-structure map (FSM) (Kobayashi, 2015). Another study later developed a visualization system for the extended function-structure map (EFSM) (Sugita et al., 2017).

In contrast, SCP focuses on not only more efficient production and products but also on reduced consumption while satisfying human needs, which is referred to as "sufficiency" (UNEP, 2010). However, sufficiency has been discussed mainly in the context of sustainable consumption and consumer behavior (Hertwitch, 2005; Jackson, 2005), and there are few studies in the field of product development. To improve sufficiency related to

industrial products in daily life, we proposed a framework based on the living-sphere approach (Kobayashi & Fukushige, 2018). An important aim of this approach is to realize satisfaction of basic human needs totally by products within the living sphere in order to design a locally-oriented sustainable product. An integrated framework of this approach consists of a universal human needs framework, as proposed by Max-Neef (Max-Neef, 1991), as well as the general concepts used in engineering design (Pahl & Beitz 1988). A key element of this needs matrix is the "satisfier," which refers to a quality which satisfies basic human needs that are expressed in the natural language (Kobayashi, et al., 2019). A mixed-prototyping (MP) environment was established and applied based on the living-sphere approach to evaluate new ideas of locally-oriented design (Kano, et al., 2019). However, the EFSM and MP system have not yet been applied systematically.

The objective of this paper is to propose a framework for designing locally-oriented products through use of EFSM and MP environments. The remainder of this paper is organized as follows. Related works are summarized in Chapter 2. In Chapter 3, a framework using EFSM and an MP environment is proposed. An applied example is described in Chapter 4, and its importance and remaining issues are discussed in Chapter 5. Chapter 6 concludes the paper.

2. Related Works

Practical application of product development approaches have been carried out that consider local culture, geography, climate, geopolitics, history and educational practices. A popular "market-in" approach is field observation, in which a skilled local observer or analyst identifies a gap in the market in terms of price, infrastructure, required performance or user education level. Because field observation is independent of other techniques, it can be easily applied to product development in an emerging or developing country, although it is relatively expensive. Field observation is a basic element of locally-oriented product design. For example, one study has reported on observation of cultural contexts (Spencer et al., 2015). However, the success of field observation depends on the person who analyzes the cultural contexts.

To determine specific preferences of a product user, personas are applied in product development (Pruitt & Grudin, 2003). Each persona has a gender, age, race, ethnic, family and socio-economic background. It is effective for establishing the right persona while considering appropriate regional characteristics. Cultural context, however, not only consists of the traits or behaviors of individuals but is also found in and through the everyday activities of the population as a whole (Lee, 2012). Thus, methods centered on the individual, including personas, carry the risk of overlooking invisible and implicit cultural values, thus providing incomplete and/or incorrect information to the designer. Co-design is regarded as a collaborative process between engineers and people in the local community. In a co-design approach, a workshop is held at each project milestone. A gatekeeper at each workshop plays the important role of connecting local residents with engineers (Sianipar et al., 2013). The quality of the design depends on the gatekeeper. A problem encountered in co-design is the difficulty of sharing information among project members, which can result in gaps in understanding.

Design evaluation is also an important process in product development. In terms of regional or cultural product design, most studies have applied a questionnaire approach (Hsu et al., 2013; Ghazali et al., 2018). Subjective evaluation using the semantic differential (SD) method (Osgood et al., 1957) is also applicable to cultural design. Principles for design in the developing world are useful in design review, but they are empirical and ad-hoc (Mattson & Wood, 2014). In past decades, various collaborative software applications based on virtual reality (VR) and augmented reality (AR) technologies have been developed to connect people and share design information in an immersive virtual environment (IVE) (Ong & Shen, 2009). Such VR- and AR-based applications for design review focus mainly on a target product designed with geometric modeling functions based on three-dimensional computer-aided design (3D-CAD) platforms (Feeman et al., 2018).

To review the design of industrial products, it is desirable to approximate the IVE to an actual space in which the designed products will be used. This enables experience with product-use cases in a variety of situations in their actual environment, and enables the designer to validate the functionality and visual harmony of the design with other products in the space. For this purpose, MP is an emerging approach in usability testing in a multimodal environment and is able to involve sight, hearing and touch in an IVE. This technology augments reality and the ability to analyze the inter-relationships between the physical form and behavior of industrial products (Bruno et al., 2010; Barbieri et al., 2013).

In summary, it would be desirable to have a holistic framework to collect and apply regional or local contextual information to facilitate the design and evaluation of locally-oriented products. However, such a framework has yet to be established.

3. Framework

The proposed framework for locally-oriented product design is shown in Fig. 1. In this study, the product design process comprises two processes: (1) problem recognition and ideation and (2) evaluation of design solutions. EFSM, MP environments and the SD method are applied to

support product design processes. Although they are useful independently, more effective utilization of local information can be realized by combining them. As local characteristics, function-structure mapping data on a local product, information related to that local product, the physical environment of the living-sphere and satisfiers of human needs are reflected in the FSM, EFSM, MP environment and SD method, respectively.

Before product design goes ahead, an EFSM and MP environment are developed by a design engineer, field observer, field expert and system developer. For development of the EFSM, an FSM of the reference product in the target region is compiled based on reverse engineering (Otto & Wood 1998) by a design engineer. The FSM comprises a method of describing a product and is widely used in functional analysis for clarifying the decomposed function and structure trees of a product and for visualizing the relationship between sub-functions and components (Pahl & Beitz, 1988). Reverse engineering initiates the redesign process in which a product is predicted, observed, disassembled, analyzed, tested, "experienced" and documented in terms of its functionality, form, physical principles, manufacturability and ease of assembly (Wood et al. 2001). Here, a design engineer collects information about not only the FSM but also data from actual experience.

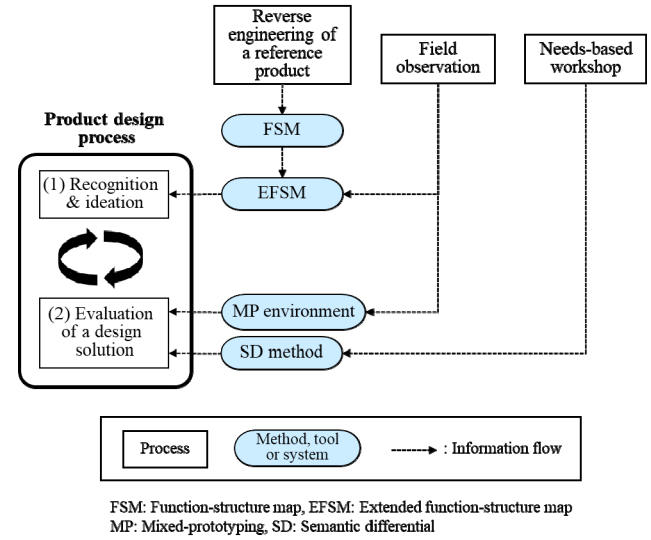

Fig. 1 Proposed framework for locally-oriented product design.

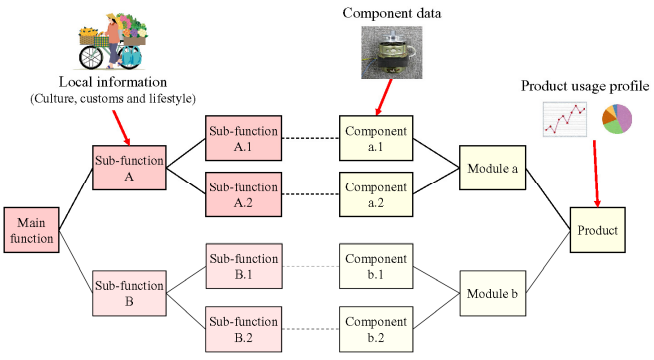

Fig. 2 Schematic of the extended function-structure map. (EFSM).

Then, related local information and a product usage profile are selected and linked to a product sub-function and component of the FSM by a design engineer (Fig. 2). This information link provides evidence for the function or structure of the reference product. The EFSM supports recognition and ideation, focusing on specific regional or local characteristics by visualizing the relationship between critical local information and the related function and/or component (Sugita et al., 2017). In other words, the EFSM is a tool for applying indigenous knowledge to product design based on engineering.

Local information is collected through field observations by a field expert before development of the EFSM and MP environment. In field observations, an observer collects local information, focusing on usage of all products in the living environment, including descriptions in natural language, interviews with locals and photography/video filming. Furthermore, satisfiers, as defined by Max-Neef, are identified in needs-based workshops held in the target area (Kobayashi, et al., 2019). Each satisfier is described in natural language and tends to satisfy fundamental human needs.

In the process of evaluating product design, evaluators experience product use cases in an MP environment, which involves subjective evaluation using the semantic differential (SD) method (Osgood et al., 1957). A living space where the target product is used in daily life is reproduced in the MP environment. This environment comprises tangible prototypes of real products and their virtual models to increase the evaluator's sense of agency. It allows for visual observation through a head-mounted display and also evaluation of the workload associated with the movement of the evaluator's body and tactile sensation while using the product.

Based on the local information obtained from field observations, a typical living space in the observed target region is reconstructed in a VR space created to the same scale as that of the real space. In addition, the evaluator's limbs are reproduced in the VR space, and their movement reflects the movement of the evaluator's actual hands and feet in the real space. In the real space, simplified physical prototypes that the evaluator can touch are placed in the same positions as those of the products created in the VR space. The virtual models are overlaid on the physical prototypes, and MP enables the evaluator to experience motion, load and a sense of touch that approximate reality.

After completing the experience, the evaluators rate the impression of their experience by assigning scores for pairs of evaluation criteria. The SD method measures the psychological attributions of an individual's attitude toward something. It focuses on the connotative meaning of objects, events and concepts, and is suitable for measuring emotional and behavioral aspects of an

individual's attitude (Klement et al., 2015). It consists of multiple sets of adjectives with opposite meanings such as "hot ↔ cold" that are divided into 5 or 7 levels and each is set as an evaluation criterion.

In this study, the evaluation criteria used in the SD method were extracted from satisfiers (Max-Neef, 1991) acquired from needs-based workshops in the target region. Requirements for the product are connected to the related satisfiers, and the connected satisfiers are converted into adjectives. Pairs of these bipolar adjectives (i.e., antonym pairs) are used as the evaluation criteria. The evaluation results are analyzed by comparing the score of each criterion for the target product before and after introducing design improvements.

The purpose of the proposed framework is appropriate application of local information with different properties to two product design processes. Namely, we apply 1) descriptive information on product use, lifestyle, climate and culture to create an EFSM, and on satisfiers to evaluate design solutions, and 2) spatial information from photos and videos to establish an MP environment. By using this framework, varied local information can be utilized to design locally-oriented products.

4. Example Application

4.1 Field Observation

In recent years, environmental issues have been surfacing due to population and economic growth in Southeast Asia (Kishita, et al., 2018). Although the gross domestic product (GDP) per capita in Vietnam is lower than that in high-income countries, its economic growth rate is the highest in Southeast Asia, so it is important to design locally-oriented products for Vietnamese consumers at reasonable prices. In this study, we focus on the washing machine as an example application of the proposed design framework.

Figure 3 shows a bathroom inside a traditional Vietnamese house. It consists of a washing machine and wash basin, a shower and a toilet. This configuration is typical in Vietnam. Here, clothes are washed by hand in the wash basin and/or washing machine. The custom of hand washing is popular because Vietnamese people commonly think that stains cannot be removed by available washing machines alone. Figure 4 shows wash basins for washing clothes and dishes outside the house.

4.2 Reverse Engineering

As an example application, we designed a new twin-tub washing machine for lower-middle-class Vietnamese people. In the same target user segment in other South Asian countries, such as Indonesia and the Philippines, twin-tub washing machines are relatively popular. However, in this study, we designed this type of washing machine for the Vietnamese market; we disassembled a single tub washing machine for sale in a Vietnamese market and used it as the base product. Figure 5 shows the reference product disassembled. This product consists of relatively few parts compared with those sold in high-income countries.

4.3 Recognition and Ideation using EFSM

Figure 6 shows a screenshot of the visualization system for the EFSM made by adding a component structure and related local information to the FSM of the base product. The window in the upper-left of the figure contains the following local information: "Residents believe that washing by hand and then putting the clothes in the washing machine is the best way to remove dirt, but because they are busy, they wash their clothes in the washing machine only," "washing machines are fast and convenient, but people believe that hand washing removes

Fig. 3 Bathroom in a traditional Vietnamese house.

Fig. 4 Wash basins for washing clothes and dishes.

Fig. 5 The local reference product disassembled.

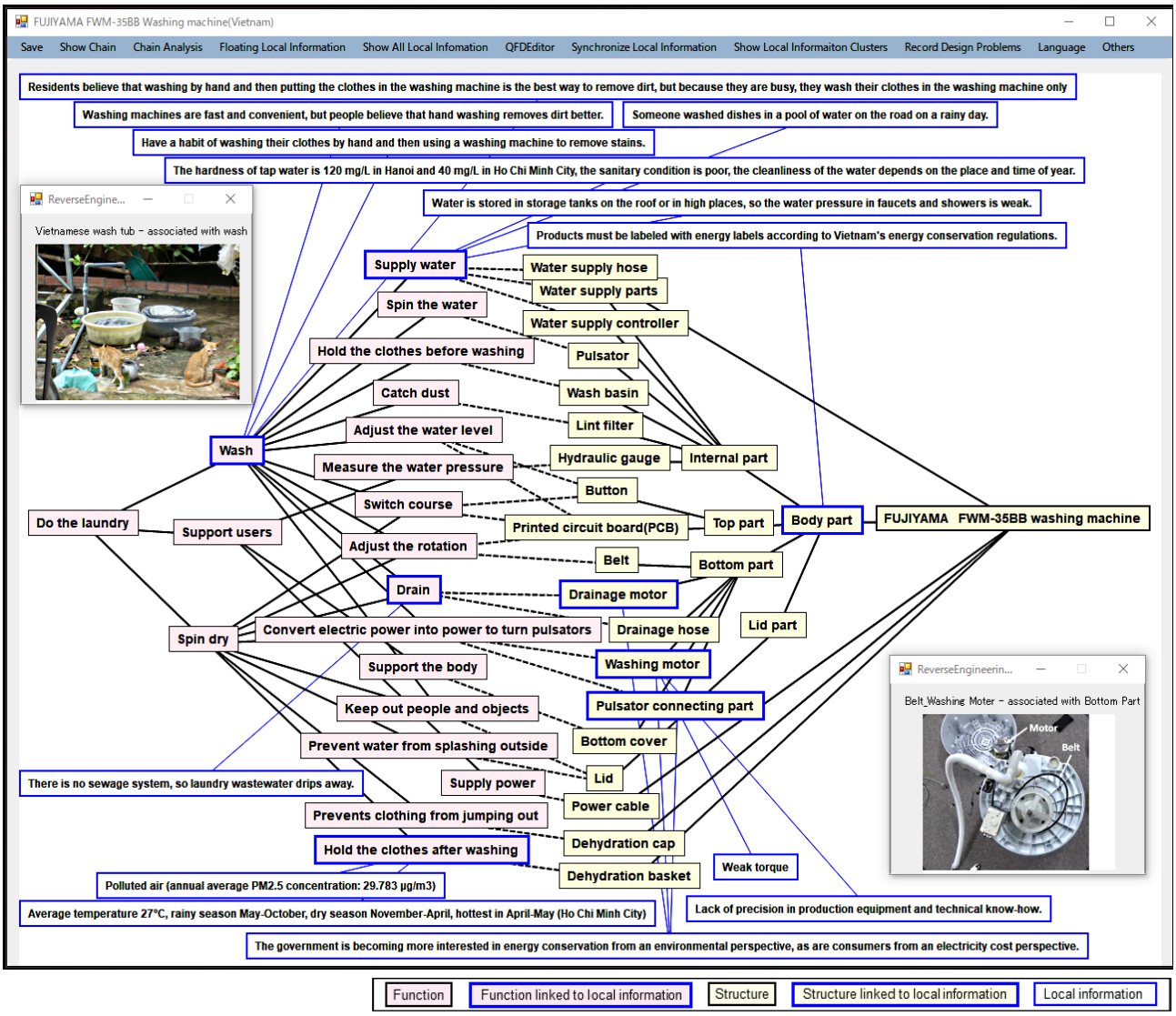

Fig. 6 A screenshot of the visualization system for the EFSM of a Vietnamese washing machine.

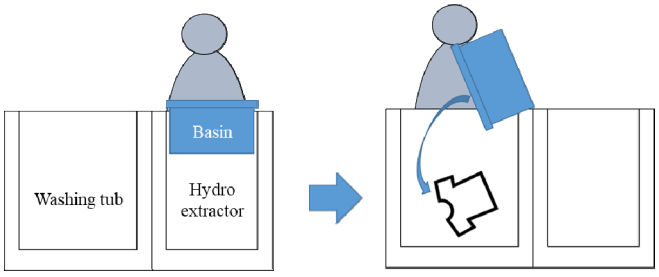

Fig. 7 A schematic of the design concept.

dirt better," and "Have a habit of washing their clothes by hand and then using a washing machine to remove stains." Also, the window in the lower-right area of the figure contains the following information: "Weak torque" and a photograph of the washing motor. A design engineer examined all the above information and came up with the idea of combining hand and machine washing in a single product.

From the results, we designed a combination of wash basin and twin-tub washing machine, as shown in Fig. 7. To facilitate the task of daily laundry, our new design solution introduces a wash basin attached to the drum opening of the hydroextractor, which enables manual washing on top of the machine while standing.

4.4 Design Solution Evaluation in an MP Environment Following the SD Method

We investigated replacing a fully automatic washing machine (reference product) with a locally-designed twin-tub washing machine including a wash basin in an MP duplication of the bathroom of a traditional Vietnamese house.

Before enlisting local people to experiment, we converted satisfiers gathered from workshops (Kobayashi, et al., 2019) held in Vietnam into 13 evaluation criteria based on the SD method as follows: calm ↔ restless, formed ↔ formless, healthy ↔ sick, comfortable ↔ uncomfortable, refreshed ↔ weary, free ↔ bound, cautious ↔ rash, accomplished ↔ awkward, clean ↔ dirty, delicate ↔ rough, satisfied ↔ dissatisfied, easy ↔ painful, and relaxed ↔ strained. In this experiment, the evaluation criteria were rated between 1 and 7, with a higher score indicating a more positive evaluation.

Furthermore, we constructed an MP environment

based on images of a bathroom that we visited during the field observation (Fig. 8). The hands and feet of the evaluators were reproduced in the virtual space, and these virtual models were linked to the evaluators' actual hands and feet in the real space. In addition, we placed simplified prototypes of the washing machine, washtub, water and laundry items in the real space, as shown in Fig. 9.

The two types of washing machines were installed in the MP environment of the same Vietnamese bathroom and were evaluated by three Vietnamese people (two men and one woman). These evaluators were immersed in the virtual bathroom including the physical prototypes and carried out the laundry process using the washing machines. First, they evaluated the fully automatic washing machine when carrying out the preliminary process of manual washing using the wash basin on the floor. Then, the fully automatic washing machine was replaced with the twin-tub washing machine, which involved manual washing in the wash basin attached to the top of the machine while standing.

The average values of the three evaluators for each criterion are shown in Fig. 10. The total average for all the criteria was 4.8 for the fully automatic washing machine and was slightly higher at 5.0 for the twin-tub washing machine. However, the score for "easy" decreased from 6.7 for the fully automatic washing machine to 5.3 for the twin-tub washing machine. Switching between the washing, rinsing and wringing processes and the work of transferring the clothes from the washing tank to the hydroextractor (i.e., the wringing and spinning tank) were found to lower the scores of the evaluation criteria for the twin-tub washing machine, but not necessarily for the fully automatic washing machine. These manual processes also resulted in lower scores for "calm," "pleasing," "refreshing" and "relaxed."

In contrast, the score for "free" increased because the quantity of water and washing time could be easily adjusted with the twin-tub machine. "Delicate" was connected to many requirements for laundry and is the only criterion connected to the requirement of "doesn't damage clothes." This score increased because the newly designed twin-tub washing machine allows manual clothes washing while standing with increased stability. Because none of the scores fell below 4.0, which is the middle value for each criterion, changes in the laundry processes were not considered to have negatively impacted the selected satisfiers.

Although the overall score slightly improved with use of the twin-tub washing machine, the evaluation results for some of the criteria, which were based on satisfiers, suggest that the design needs to be further improved. In particular, the functions and structure of the twin-tub washing machine need to be changed so that it makes transferring clothes from the washing tank to the wringing and spinning tank easier. A detailed design

Fig. 8 Virtual space of the MP environment.

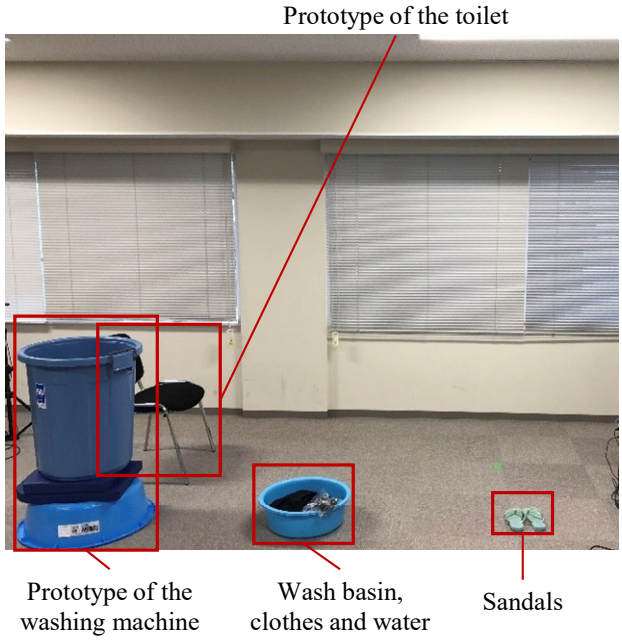

Fig. 9 Tangible prototypes in the MP environment.

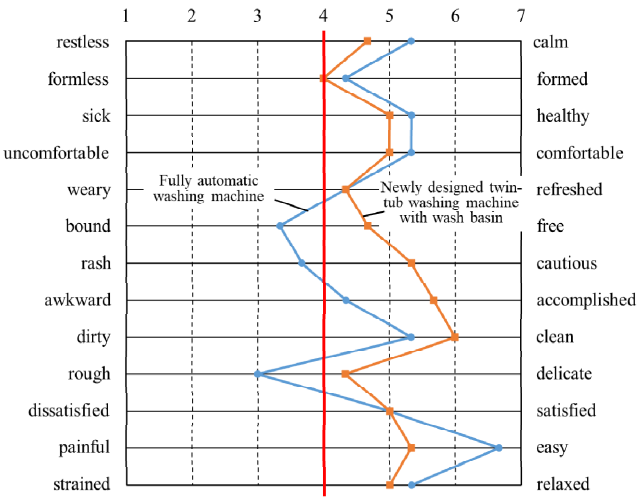

Fig. 10 Average scores of each criterion assigned by three evaluators for two types of washing machines.

review focusing on these features is subsequently required to identify functions that need to be improved.

5. Discussion

As described in Chapter 4, the design engineer is required to understand the relationship between local information and the FSM as well as recognize design issues. In this case, the EFSM itself is a concept visualization method in which local information expressed as free-format short sentences is linked to the FSM, which enables the design engineer to recognize design issues and generate design ideas. Thus, local information used in the EFSM should be appropriately arranged for product design. For example, three similar sentences are linked to the function node "Wash" in Fig. 6 because they were observed by different individuals in different field studies. Although we consider that this type of arrangement suggests that the nodes of local information are representative of the general population in the target region and are important, the local information should be analyzed in more detail in future work.

Next, we discuss our evaluation using an MP environment. By reproducing the living space and home equipment in the MP environment, the evaluators could evaluate the products and product use cases holistically within an environment approximating the realities of daily life. However, because differences in the importance of each satisfier and their mutual dependency were not considered in this study, further analysis of the satisfiers is needed. The effect of spatial and temporal discrepancy between virtual objects and tangible prototypes, such as time delays between tactile and visual senses, is another issue that needs to be further analyzed. The limitations of the MP environment in time and space restrict the scope of evaluation to only the in-use process of products within a limited interior space.

In general, the proposed framework can be applied during the early phase of product design. However, life-cycle thinking, including life-cycle planning (LCP), is necessary during the early phase of eco-design (Kobayashi, 2005). Therefore, we will consider a process that integrates the proposed framework and an eco-design framework such as LCP in future work.

6. Conclusion

In this study, we proposed a framework for designing locally-oriented products by using an EFSM and MP environment. This framework enables us to utilize different types of local information, namely, descriptive and spatial information for product design, while focusing on local characteristics as appropriate. We demonstrated the usefulness of the proposed framework by applying it to a novel Vietnamese washing machine design. We hope to apply the framework to more design cases using various types of products in different regions, especially in developing countries in Asia.

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Environmental Management Control Tools for Promoting Sustainable Consumption and Production in Thai and Vietnamese Companies

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Abstract

Sustainable consumption and production (SCP), as one of the sustainable development goals (SDGs) (Goal 12), plays an essential role in promoting environmentally conscious management practices. There are many environmental management tools that can affect the implementation of SCP and related environmental performance, such as environmental management systems, environmental management accounting (EMA), supply chain management and the use of environmental indicators. In addition, environmental management control systems (EMCS), a new concept, may also be useful because it is more comprehensive. In developing countries, identifying any of these tools as useful could promote SCP policy.

This study aimed to analyse how individual environmental management control tools promoted Thai and Vietnamese companies' SCP activities through multiple group structural equation modeling (MGSEM), based on our questionnaire survey data. The impact of SCP activities on environmental performance was also examined. Our results verify that it is appropriate to promote the adoption of SCP policy in companies in developing countries. Furthermore, when promoting SCP policy in developing countries, it is necessary to recognise that the effects of environmental management tools are not always uniform. Traditional management tools may work against new challenges, such as the implementation of SCP, so a more diverse menu of environmental management tools, including EMA, is required.

Key words: environmental management control systems, sustainable consumption and production, Thailand, Vietnam

1. Introduction

In 2015, the 2030 Agenda for Sustainable Development embraced a new set of sustainable development goals (SDGs) to transform the world over the next 15 years (United Nations, 2015). These goals are valid not only for developed countries but also for developing countries. Sustainable consumption and production (SCP), as one of the SDG goals (Goal 12), plays an essential role in promoting environmentally conscious management practices. On account of different economic conditions and socio-cultural factors, SCP requires a diverse focus in developed and developing economies (Wang et al., 2019).

There are many environmental management tools that can affect the implementation of SCP and related environmental performance, such as environmental management systems, environmental management accounting (EMA), eco-design, supply chain management and the use of environmental indicators. In addition to these tools, environmental management control systems (EMCS), as a package, could also be useful because they are more comprehensive. The EMCS concept started from that of management control systems (MCS). Malmi and Brown (2008), advocate an MCS package as a collection or set of relatively independent management control tools to maintain or alter patterns in organizational activities (Henri, 2006). One of the most frequently used MCS frameworks is Merchant and Van der Stedes' (2017) "object of control." The mechanism of EMCS as a form of MCS is designed to guide desirable organizational activities, especially in their environmental aspects (Nishitani et al., 2021). As the concept of EMCS is still under nascent development, a consensus on its definition,

conceptualization and operationalization remains absent and fragmented. Thus, in this paper, we define EMCS as a package based on the work of Merchant and Van der Stede (2017) that includes four important categories of environmental management control tools covering control over action (behaviour), results (outcomes), cultural factors and personnel. These topics have been investigated in the context of developed countries (Guenther et al., 2016) but not in developing countries. Identifying any of these tools or means of control as useful could promote SCP policy in developing countries.

Even though the number of studies analysing the relationship between EMCS and environmental performance is limited (Guenther et al., 2016; Nishitani et al., 2021), we have already examined the effectiveness of EMCS as a package for improving environmental performance in our previous studies in Thai and Vietnamese companies (Kokubu et al., 2019; Wu et al., 2021; Nishitani et al., 2021). However, if developing countries need to promote SCP policy for companies, it would be desirable to identify the individual tools or means of control that can contribute to the results. Therefore, in this study, we aimed to analyse how individual environmental management control tools impact the promotion of SCP activities in Thai and Vietnamese companies based on our questionnaire survey data. SCP activities' impact on environmental performance was also examined.

The remainder of this paper proceeds as follows. In Chapter 2, we introduce the source of the data used in the analysis and provide our analytical method. In Chapter 3, we present the results of multiple group structural equation modeling (MGSEM) and discuss factors related to EMCS. Finally, we provide concluding remarks and propose policy recommendations.

2. Data and Analytical Methods

2.1 Data

We designed a questionnaire, based on Guenther et al. (2016), to identify the major elements of EMCS and other environmental management tools.

The questionnaire survey was conducted in Thailand from October to December 2017 and in Vietnam from October to December 2018. The Thai stock market is broadly divided into the MAI market (a market for small and medium-sized enterprises, with an emphasis on future growth potential) and the SET market (a market for large enterprises). The questionnaire survey targeted 596 companies, excluding the financial sector. Of these, 130 companies were from the MAI market and 466 companies were from the SET market. The questionnaire had a valid response rate of 16.95% (SET: 78 companies; MAI: 23 companies). In Vietnam, we conducted the same questionnaire survey of 700 listed and unlisted companies, excluding the financial sector. Vietnam has three main stock markets: the Ho Chi Minh Stock Exchange (HOSE), the Hanoi Stock Exchange (HNX) and a market for unlisted public companies (UPCoM). Ultimately, 205 companies participated in the survey and the valid response rate was 27.14% (HNX: 34 companies; HOSE: 45 companies; UPCoM: 111 companies).

Guenther et al. (2016) point out that the systems of firms can distinguish between operating systems and management systems. In considering the continuum between these two systems, three different categories of environmental management can be classified: (1) the EMA approach, (2) EMCS, and (3) environmental management systems (EMS).

The EMA approach refers to the management of monetary, physical and qualitative information on the environmental impacts and financial consequences of environmentally relevant business activities—information that supports internal and external decision-making, reporting and accountability (Schaltegger et al., 2003). For example, environmental costing, material flow cost accounting and life cycle assessment for environmental issues are accounting-based instruments that have been suggested as loading the "EMA" factor in Table 1. Other means of control by the EMA approach are also assumed to include eco-product-related costing (Eco-products) and the use of environmental indicators (UEI).

The EMCS concept differentiates among action controls (e.g., monitoring activities and processes), results controls (focusing on the outcomes of employee behaviour), cultural controls (e.g., corporate culture and the incentive system) and personnel controls (e.g., employee selection and training) (Guenther et al., 2016). Action controls hold employees accountable for their actions, prescribe desired actions and reduce personal limitations. Results controls capture the classical cybernetic use of environmental performance measures via target-setting, collection of actual figures and measurement of the impact on incentives. Cultural controls capture and use a company's value, norms and degree of compliance. Personnel controls measure employee selection, training and promotion, which are important means of control for matching job requirements with applicants' skills.

EMS is defined as part of an organization's management system, used to develop and implement its environmental policies and manage its environmental aspects under ISO 14001 (ISO, 2004). At this time, EMS is considered to include two means of control: environmental decision making (EDM) and supply chain management (Suppliers). EDM captures the management of environmental aspects and the fulfilment of compliance obligations, while addressing risks and opportunities. Supply chain management consists mainly of environmental measures shared with suppliers.

In summary, "EMA," "Eco-products," "UEI," "Action controls," "Results controls," "Cultural controls,"

Table 1 Measurement constructs of environmental management control tools.

Focus	Categories of environmental management	Environmental management control tools (9 factors)
Operational level	Environmental management accounting	◦ environmental management accounting (EMA) ◦ the eco products-related costing (Eco-products) ◦ the use of environmental indicators (UEI)
	Environmental management control system	◦ Action controls ◦ Results controls ◦ Cultural controls ◦ Personnel controls
Strategic level	Environmental management system	◦ Environmental decision making (EDM) ◦ Supply chain management (Suppliers)

"Personnel controls," "EDM" and "suppliers" as mentioned above are included as nine separate environmental management control tools (factors) in the analytical model. The framework of the questionnaire was designed from these nine factors (see Table 1). The specific questions included for each factor were mainly cited from the following eight empirical studies: Ferreira et al. (2010), Goebel and Weissenberger (2017), Henri and Journeault (2010), Journeault (2016), Journeault et al. (2016), Perego and Hartmann (2009), Pondeville et al. (2013) and Widener (2007) on a five-point Likert scale (see Table 2).

Regarding the measurement of SCP, to represent the SCP variable, the questionnaire asked about the status of SCP, i.e., whether the company had incorporated or was planning to incorporate sustainable consumption and production into its business activity targets (1: yes, 2: no). We employed companies' self-evaluation on waste reduction as their environmental-performance-related SCP.

2.2 Analytical Methods

The analysis conducted in this study consisted of the following two steps.

In Step 1 we tested whether our data replicated the elements from EMCS and other environmental management tools. We then conducted exploratory factor analysis (EFA) to assess the elements of EMCS.

In Step 2, to investigate whether the elements of the EMCS and other environmental management tools verified in Step 1 could support the implementation of SCP and improve environmental performance, we employed MGSEM. Structural equation modeling (SEM) is a powerful statistical technique that combines a measurement model, or confirmatory factor analysis, and a structural model into a simultaneous statistical test (Hoe, 2008). It is particularly valuable in inferential data analysis and hypothesis testing where the pattern of inter-relationships among the study constructs are specified a priori and grounded in established theory. It has the flexibility to model relationships among multiple predictor and criterion variables, and statistically tests a priori theoretical assumptions against empirical data through CFA (Chin, 1998). In most cases, SEM is applied to the testing of causal relationships among variables (Hoe, 2008). It is also possible to estimate and compare models that come from two or more samples, called MGSEM (Sörbom, 1974). To compare Thai and Vietnamese companies, MGSEM was performed to examine the differences between the countries' models using AMOS (Ver. 27.0).

3. Results and Discussion

3.1 EFA Results

EFA (principal components with promax rotation) was performed on the questionnaire items. Hair et al. (1995) assumed the following multiple extraction rules with an eigenvalue ≥ 1.0, Kaiser-Meyer-Olkin (KMO) index > 0.5 (Cerny & Kaiser, 1977), and communality > 0.5 to determine factor extraction. The eigenvalue measures how much of the variance of the observed variables a factor explains. The value ≥1.0 explains more variance than a single observed variable. The KMO index ranges from 0 to 1, with 0.5 considered suitable for factor analysis. The communality is a definition of common variance that ranges between 0 and 1. Values closer to 1 suggest that the extracted factors explain more of the variance of an individual item. The acceptance of each item was decided based on a factor loading of 0.5 or more and a difference in cross-loadings of greater than 0.2 (Kaiser & Rice, 1974). As a result, eight factors were successfully extracted. Table 2 presents the final descriptive statistics for each item.

3.2 MGSEM Results

To clarify the impact of each EMCS element on SCP and the impact of SCP on environmental performance, MGSEM was performed with SCP and waste reduction as the dependent variable. The independent variables were the individual EMCS elements, Action controls, Results controls, Cultural controls, Personnel controls, EMA, supplier, EDM and UEI. The results are shown in Fig. 1. The model's fitting showed a sufficient value ($\chi^2 = 1.758$, $p < 0.001$, df = 1362, CFI = 0.928, RMSEA = 0.040).

Towards the implementation of SCP in Thailand, action controls are negatively significant and result controls are positively significant. There are no significant EMCA elements in Vietnam. Regarding the other elements, only EMA is significantly positive for SCP in

Table 2 EFA Results.

Items		Vietnam					Thailand				
		Min.	Max.	Mean	SD	λ	Min.	Max.	Mean	SD	λ
Action controls											
Q1	Superiors monitor and evaluate necessary steps regarding their subordinates' achievement of environmental performance goals.	1	5	4.19	0.911	0.783	1	5	3.88	0.963	0.724
Q2	Superiors define the most important work steps for routine environmental tasks.	1	5	4.17	0.883	0.791	1	5	3.88	0.900	0.846
Q3	Superiors provide subordinates with information on the most important steps regarding the achievement of environmental performance goals.	1	5	4.15	0.890	0.700	1	5	3.71	0.919	0.883
Q4	Policies and procedures manuals define the fundamental course of environmental activities.	1	5	4.10	0.959	0.779	1	5	3.98	1.029	0.624
Q5	Subordinates discuss the necessary work steps for achieving the environmental targets with superiors	1	5	4.17	0.911	0.891	1	5	3.95	0.932	0.612
Results controls											
Q7	Subordinates' achievement of environmental performance goals is controlled by their respective superiors.	1	5	4.07	0.952	0.872	1	5	3.85	0.914	0.821
Q8	Potential deviations from environmental performance goals have to be explained by the responsible subordinates.	1	5	4.06	0.962	0.904	1	5	3.72	1.013	0.855
Q9	Subordinates receive feedback from their superiors concerning the extent to which they achieved their environmental performance goals.	1	5	4.13	0.949	0.841	1	5	3.67	0.975	0.797
Personnel controls											
Q10	Our workforce is carefully selected whether it fits to our firm's environmental values and norms	1	5	3.91	0.970	0.906	1	5	3.53	0.979	0.653
Q11	Much effort has been put into establishing the best-suited recruiting process for an environmental job position	1	5	3.88	1.055	0.867	1	5	3.77	0.890	0.670
Q13	The environmental goal achievement is regarded as important condition for promotion	1	5	3.69	1.122	0.573	1	5	3.14	0.910	0.971
Cultural controls											
Q15	Our mission statement clearly communicates the firm's environment-related core values to our workforce.	1	5	4.17	0.911	0.745	1	5	3.92	0.961	0.679
Q16	Top managers communicate the firm's environment-related core values to our workforce.	1	5	4.27	0.893	0.613	1	5	4.00	1.029	0.667
Q17	Our workforce is aware of the firm's environment-related core values.	2	5	4.17	0.815	0.536	1	5	3.86	0.935	0.868
EMA											
Q29	Development and use of environment-related key performance indicators	1	5	3.52	3.52	0.672	1	5	3.59	1.192	0.651
Q30	Budgeting of environmental expenditures for operations	1	5	3.91	3.91	0.597	1	5	3.73	1.152	0.745
Q31	Life cycle assessment	1	5	3.37	3.37	0.971	1	5	3.06	1.182	0.605
Q32	Material-efficiency analysis in physical units	1	5	3.46	3.46	0.891	1	5	3.36	1.226	0.848
Q33	Material-efficiency analysis in monetary units	1	5	3.68	3.68	0.740	1	5	3.53	1.145	0.964
Suppliers											
Q38	Suppliers are selected according to their level of environment commitment.	1	5	4.19	0.959	0.774	1	5	3.63	1.006	0.808
Q39	Detailed information on environmental issues is regularly shared between major suppliers and our firm.	1	5	3.99	1.077	0.894	1	5	3.53	0.991	0.884
Q40	We commonly see targets for the suppliers for reducing the environmental burden.	1	5	4.01	1.028	0.975	1	5	3.29	1.115	0.914
Q41	The environmental policy involved with suppliers is stated.	1	5	4.03	1.009	0.962	1	5	3.38	1.170	0.856
Q42	The environmental burden in supply chains can be evaluated.	1	5	3.88	1.049	0.824	1	5	3.27	1.111	0.861
EDM											
Q19	Top management is actually involved in environmental management.	1	5	4.41	0.938	0.709	1	5	4.13	0.865	0.692
Q20	Environmental criteria are integrated in operational investment decisions.	2	5	4.45	0.810	0.920	2	5	3.86	0.856	0.630
Q21	All employees are encouraged to make suggestions in the field of the natural environment.	2	5	4.32	0.868	0.744	2	5	3.73	0.926	0.696
UEI											
Q34	To monitor internal compliance with environmental policies and regulations.	1	5	4.06	1.045	0.970	1	5	3.83	1.076	0.905
Q35	To provide data for internal decision-making.	1	5	3.91	0.993	0.901	1	5	3.76	0.981	0.923
Q36	To motivate continuous improvement.	1	5	3.80	1.075	0.811	1	5	3.67	1.068	0.834
Q37	To provide data for external reporting.	1	5	3.98	1.025	0.825	1	5	3.93	1.049	0.889

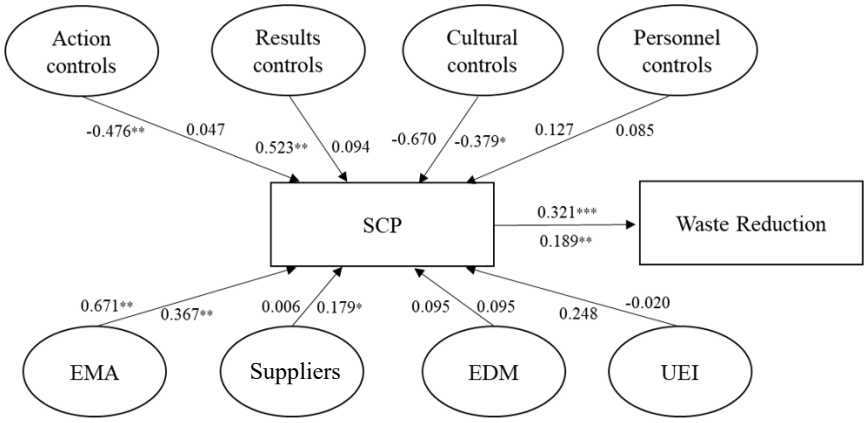
Notes: λ denotes the factor loading in EFA.

both countries. The implementation of SCP is significantly positively related to environmental performance (waste reduction) in both countries.

3.3 Discussion

The results of our analysis reveal four significant findings.

First, from the relationship between SCP and environmental performance (waste reduction), the results



$\chi^2 = 1.7580$, $p < 0.001$, df = 1362, CFI = 0.928, RMSEA = 0.040, SRMR = 0.0755 Note: *$p < 0.05$, **$p < 0.01$

Fig. 1 Multiple group structural equation modeling with environmental performance.
Figures to left of arrows: Thailand ($N = 86$), Figures to right of arrows: Vietnam ($N = 158$)

indicate that the implementation of SCP can improve environmental performance. Hence, it is appropriate to promote SCP policies at the corporate level.

Second, the results show that the role of EMA is positively significant for the implementation of SCP in developing countries. Following the EFA results, the companies undertaking budgeting of environmental expenditures for operations, life cycle assessment and material-efficiency analysis in physical and monetary units, particularly the use of environment-related key performance indicators, can drive the implementation of SCP policy. When companies implement SCP policy, these aspects provide hints for effective policies, using specific EMA instruments to advance environmental management.

Third, when discussing the impact of each element of the EMCS on SCP, the analysis does not show the same results in Thailand as in Vietnam. Statistical significance was observed for action controls and result controls in Thailand but not in Vietnam. This result indicates that in Vietnamese companies EMCS has not been developed to the same degree as in Thai companies.

Fourth, regarding Thai companies, it would be reasonable to assume that action controls negatively impact SCP implementation because these controls are very traditional and rigorous to some extent, such as the use of manuals and behaviour monitoring. It can be considered that since SCP is quite a new concept, certain traditional and rigorous management tools would not be effective for its purpose. In contrast, result controls address the use of environmental performance measures through target-setting, collecting actual figures, variance analysis and the impact on incentives as a process. As they allow for more flexible management than action controls, this may help them work effectively when companies introduce new business activities such as SCP policy.

4. Conclusions

In this study, we used data from Thai and Vietnamese companies with MGSEM to examine effective environmental management tools for promoting SCP and improving related environmental performance. We obtained positive results for the use of EMA in implementing SCP and the use of SCP in environmental performance in both countries. In addition, we confirmed positive results from result controls and the negative results from action controls with regard to the implementation of SCP in Thai companies, although neither are statistically significant in Vietnamese companies.

Since the analytical results for both countries show a positive impact of SCP on environmental performance, it is appropriate to promote companies' adoption of SCP policy. In Thai companies, more flexible environmental management tools would be more effective for SCP implementation than rigorous traditional tools. These findings suggest that when promoting SCP policy in developing companies, it is necessary to recognise that the effects of environmental management tools are not always the same. Since the level of environmental management in developing countries generally lags behind that in developed countries, it is advisable to encourage companies' use of basic manual environmental management tools. However, traditional management tools may work against new challenges, such as the implementation of SCP, so a more diverse menu of environmental management tools, including EMA, may be required.

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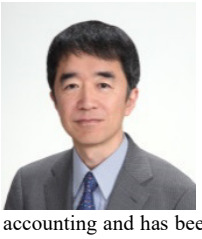

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Effect of Life Cycle Thinking-based Information on Environmental Attitudes and Behaviors in Bangkok, Thailand

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Abstract

The concept of life cycle thinking (LCT) is essential for sustainable consumption and product development. A thorough evaluation of its impacts on people's environmental consciousness and behavior is still lacking, however, as is people's understanding of the LCT concept. The present study aims to evaluate the effect of LCT on people's attitudes and behaviors, using an information-provision strategy, and to compare the effects of LCT-based information with other types of information provision. LCT-based and alternative information were created for promoting two pro-environmental behaviors: waste separation and refill product purchase. Designed information was distributed through a web-based survey conducted in Bangkok, Thailand and its vicinity. The LCT-based information about both waste separation and refill products had significant impacts on improving the respondents' attitudes toward the target behaviors, but its effects on behavior improvement in both cases were insignificant. Compared with the alternative information provided, the LCT-based information was significantly more useful in relation to both target behaviors. The results of the present study suggest the possibility and opportunity for using the LCT concept for both promotion of and education on sustainable consumption.

Key words: information provision, life cycle thinking, pro-environmental behavior, refill products, waste separation

1. Introduction

Pro-environmental behavior (PEB), also known as environmentally-conscious, green or sustainable behavior, plays an important role in transitioning to a sustainable society. Toward that end, environmental education and dissemination of environmental information can be key to inducing consciousness and changed behavior among people.

Information provision has shown its efficacy in fostering behavioral change; it helps people understand details on how to engage in new behaviors and the effectiveness of behavioral changes (Schultz, 2002; Kaiser & Fuhrer, 2003). Information and knowledge can be categorized into four types: procedural, declarative, impact and social-norm (Kaiser & Fuhrer, 2003). Procedural knowledge refers to information about how to perform or achieve a particular behavior, e.g., how to recycle (Schultz, 2002). Declarative knowledge is the ability to provide facts on something, e.g., what climate change is. Impact or effectiveness knowledge refers to that on consequences of actions, e.g., the environmental impact of using bottled water (Bolderdijk et al., 2013). Lastly, knowledge of social norms, particularly descriptive norms, includes information about what others do, e.g., how many people use their own cup or tumbler at cafes (Lee et al., 2015).

Reports on the efficacy of information provision on behavioral change vary depending on information type and target behavior. Procedural knowledge has been widely provided to promote recycling behavior. It can increase the level of people's knowledge on recycling and raise their recycling rates even from low levels. Lack of this type of knowledge is, however, seen as a barrier to recycling (Schultz, 1999, 2002).

Social descriptive norms have been reported as a

strong predictor of recycling (Schultz, 2002), and both descriptive and injunctive social norms affect reduction of littering in public places (Cialdini et al., 1990). Lee et al. (2015) found that just providing declarative information by itself about an existing environmental program could increase people's intention to engage in purchasing the products proposed by the program.

In addition to the above information types, life cycle thinking (LCT) in information dissemination is being more commonly included. To implement sustainable consumption and production and a shift toward a circular economy, LCT is a vital concept (Lewandowska et al., 2018). This concept provides an opportunity to expand one's focus from the narrow specific stages of one product's life cycle to consider its entire life cycle and its consequences for the environment (UNEP, 2012). The entire life cycle includes extraction of materials from nature, manufacturing, shipping and transporting, and the use and disposal of a product. Along this chain, natural resources are utilized and disposed of accompanied by the generation of pollutants. A thorough consideration of all the impacts throughout the entire life cycle would help avoid unawareness of the problem shifting from one to another stage of the cycle. In the academic field, the concept of LCT has been applied to environmental impact assessment of products and services, and calculating the impact of life-cycle assessment (LCA) helps inform and guide consumers in making environmentally-friendly daily purchasing decisions.

Tsuda et al. (2013) examined the literature on the utility of LCT-based information and found that it has been disseminated to consumers in various forms such as numeric data (e.g., a product's carbon footprint), supply chain map visualization and documentary films. They found that although some LCT-based information was available and disseminated in the literature, an evaluation of its effect on environmental consciousness and behavior was still lacking.

Relevant studies on the effect of LCT-based information on consumers' preferences and perceptions include Upham et al. (2011) and Kikuchi-Uehara et al. (2016a, 2016b). Upham et al. (2011) found that although the respondents favored carbon labeling, they showed confused, questioning and misunderstanding responses to the labeled samples. Additional information was needed to improve understanding. Providing LCT-based information is also important in addition to providing a final figure based on LCA calculations like carbon footprints. Kikuchi-Uehara et al. (2016 b) applied the LCT concept to create information on environmental impacts for reusable and disposal shopping bags and determined the effectiveness of the information on respondents' environmental awareness. They found that LCT-based information was effective at improving environmental awareness of respondents with lower LCT skills.

The present study aims to evaluate the effect of LCT-based information on people's attitudes and behaviors, and compare the effect of LCT-based information with other types of information provision. We aim to expand knowledge into the context of developing societies, where environmental deterioration has emerged at an alarming rate but little research on PEBs exists. Southeast Asia, one of the most dynamic regions in the world, had the most rapid rate of carbon dioxide emissions during 1990–2010. In fact, about 90% of emissions arise from developing countries, namely Indonesia, Malaysia, the Philippines, Vietnam and Thailand (Asian Development Bank, 2015). As one of the fastest-growing cities and a major contributor to the region's emissions, Bangkok, the capital of Thailand was selected as the study area.

In Thailand, the concept of LCT had been chiefly employed for quantifying the environmental impact of products and services, i.e., LCA and footprints (Gheewala & Mungcharoen, 2017). Ecolabels, namely green labels (Type 1), SCG eco value (Type 2), carbon reduction labels (Type 3) and energy labels (other types), have been used to inform consumers for over a decade (Mungkung et al., 2021). Nonetheless, no studies focusing on the effect of LCT-based information had been accomplished yet in Thai society.

2. Materials and Methods

2.1 Target PEBs

Two target behaviors were selected from the results of our previous study in Bangkok (Phuphisith et al., 2017) investigating people's practice rates of 49 PEBs, reasons for conducting or not conducting each behavior, and perceptions toward the environment and PEBs. The two selected target behaviors were 'waste separation' and 'refill product purchase.' For 'waste separation,' our previous study showed that it was perceived as the most environmentally-friendly action (29.0%), but practiced less often by the respondents (50.7% respondents 'always' or 'often' practiced it). In contrast, 'refill product purchase' was conducted by many respondents (79.0%), but less perceived as an environmentally-friendly action (2.5%).

2.2 Information Design and Treatment Groups

To determine the effects of LCT-based information, three groups were established for each behavior according to the information types provided and codes shown in Table 1. The information types provided were: no information (WC and RC), information based on LCT (WL and RL) and alternative information such as descriptive norms for waste separation (WA) and product information on refill products (RA). Previous studies have demonstrated the importance of social norms to recycling (e.g., Schultz, 2002; Iyer & Kashyap, 2007); thus, one of the social norms — the descriptive norm — was adopted

for alternative information on waste separation (WA).

For 'refill product purchase,' information about the availability of products is considered essential for engaging in this behavior. This issue relates to the factor of perceived behavioral control (PBC), which refers to one's perceptions about difficulties and controllability over behavioral performance. According to the Theory of Planned Behavior (Ajzen, 1991), PBC is one of the key determinants for predicting the intention to perform a behavior. Therefore, product availability information was provided to the RA group.

The details of the LCT-based information for waste separation (WL) were on how waste separation could reduce environmental impacts from the life-cycle viewpoint, using illustrations on process chains and a textual explanation (Fig. 1). The information included an explanation that waste separation could decrease the amount of garbage going to landfills and, thereby reduce greenhouse gas (GHG) emissions from landfills. In addition, recycled waste, such as from plastic bottles and aluminum cans could be substituted for virgin materials and thus contribute to environmental impact reduction. The WA information was about descriptive norms; the number of people carrying out waste separation in Bangkok was presented together with the corresponding numbers for Seoul and Tokyo (Fig. 2). The number of people carrying out waste separation in Bangkok was taken from our previous results (Phuphisith et al., 2017), and the numbers for Seoul and Tokyo were cited from Lee et al. (2013).

The LCT-based information for purchasing refill products (RL) showed how much the environmental load could be reduced by using refill products instead of single-use products (Fig. 3). The environmental impact was presented as the percentage of total GHG reduction throughout the life cycle based on the estimations by Shimpo et al. (2012). Instead of showing the exact GHG values, the approximate impact reduction from switching from single-use bottles to a refillable bottle was shown. For RA information, available refill products were shown with brand examples in each category (Fig. 4). Here, 12 product categories were presented: body soap, hand soap, dishwashing liquid, liquid detergent, softener, spray starch, bleach, kitchen cleaner, bathroom cleaner, floor cleaner, car/air freshener and instant drink powder.

2.3 Questionnaire Surveys

2.3.1 Questionnaire Survey on Attitude Changes and Intentions

The designed information was presented through an online questionnaire, consisting of five parts: (1) socio-demographics; (2) attitudes before receiving the information and current practices; (3) information provision; (4) comprehensibility, usefulness and prior knowledge about the information provided; and (5) attitudes and intentions after receiving the information.

Table 1 Information provision groups.

Information provided		Waste separation (W)	Refill products (R)
(C) Control group—no information		WC	RC
(L) LCT information		WL	RL
(A) Alternative information		WA	-
(A) Alternative information	Descriptive norm	WA	-
	Product availability	-	RA

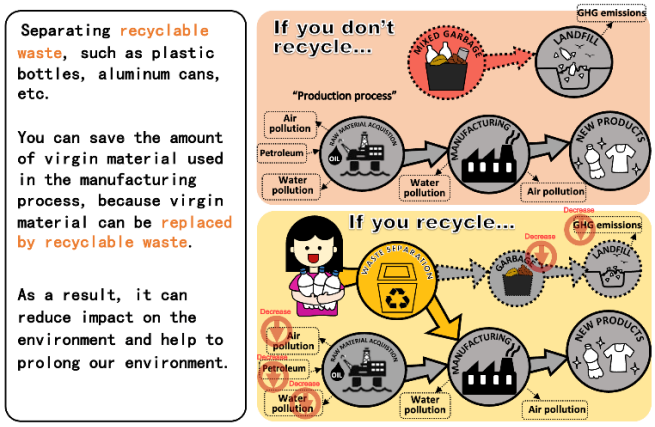

Fig. 1 LCT-based information about waste separation presented to Group WL.

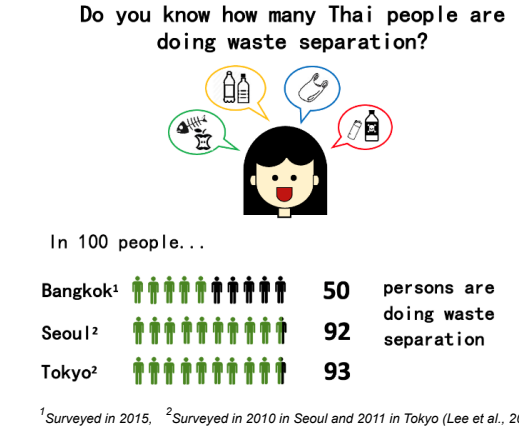

Fig. 2 Descriptive norm information about waste separation presented to Group WA.

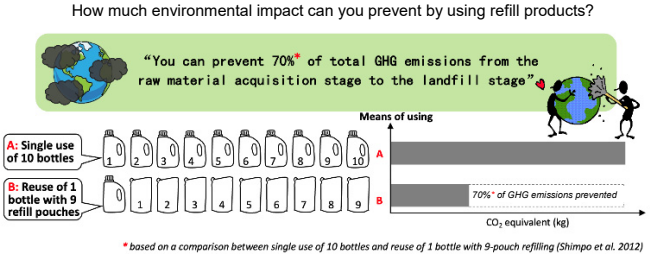

Fig. 3 LCT-based information about refill products presented to Group RL.

All items were provided in the form of closed questions.

First, the respondents were asked about their socio-demographics, including gender, age, education level, family size and house type. Then they were asked about their attitudes toward waste separation or purchase of refill products. The questions were adapted from the studies of De Young (1990) and Kikuchi-Uehara et al.

Fig. 4 Product information about refill product categories presented to Group RA.

(2016 a). Two questions were used: "How important is waste separation/purchasing refill products to preserving the environment and conserving our natural resources?" ($A1_{before}$) and "How important is waste separation/purchasing refill products to environmental management?" ($A2_{before}$). The respondents were requested to indicate their degree of agreement on a six-point scale ranging from 'strongly agree' to 'strongly disagree.' Then, they were asked about their current waste separation or refill product purchase practices. The practices were measured on a six-point scale ranging from 'always' to 'never.' In addition, the respondents of the W-group were asked to select waste types they separated from among the choices provided, which included wet waste, newspapers and paper, aluminum cans, glass, milk cartons, plastic bottles, lamps, batteries and spray bottles, and other. Respondents of the R-group were asked to select categories of refill products they purchased from among the choices provided, which included body and hand soap, dishwashing liquid, liquid detergent, household cleaners, car/air freshener, instant drink powder and other.

After responding to the above questions, the respondents were presented one type of information according to their assigned group as described in Table 1. Then the respondents were asked about their perceptions of the comprehensibility and usefulness of the information provided, using a six-point scale ranging from 'strongly agree' to 'strongly disagree.' They were also asked about their prior knowledge concerning the information provided. The WA respondents were asked whether they had ever thought about the differences in practices between Bangkok, Tokyo and Seoul (K_{WA}). The answer choices were: "The size of differences is 'larger,' 'a bit larger,' 'similar,' 'a bit smaller,' 'smaller' than/to what I thought," and "I've never thought about this before." The WL respondents were asked whether they had been aware of (i.e., had knowledge of) the mechanism of environmental-load reduction by waste separation (K_{WL}). The answer choices were: I was aware of it 'very much,' 'much,' 'fairly much,' 'slightly,' 'seldom' and 'never.' The RL respondents were asked whether they had been aware of GHG reduction resulting from use of refill products instead of single-use products (K_{RL}) with the same answer choices as provided to the WL group. The RA respondents were asked to select the product categories they had never been aware of before from the choices provided (K_{RA}). One more choice was also prepared for the respondents who were aware of all the categories: "I am aware of all the categories listed here."

The respondents were then asked about their attitudes and intentions to perform the target behaviors. Question A1 was asked again after information provision ($A1_{after}$), and an additional question about attitude was also asked: "Do your daily activities have impacts on environmental problems due to resource use, product manufacturing, product transportation or disposal?" ($A3_{after}$). The respondents were requested to indicate their agreement using a six-point scale ranging from 'strongly agree' to 'strongly disagree.' For intentions, the respondents were asked how much they would try to perform or keep performing the target behaviors in the following one month, using a six-point scale ranging from 'absolutely' to 'never.'

No information was provided to the control groups (WC and RC); therefore, they were promptly asked question $A3_{after}$ followed by the above-described question on their intention to perform the target behavior.

The questionnaire was initially developed in English and then translated into Thai. To avoid misunderstanding of the questions and to check for any difficulties in answering, the Thai version was preliminarily tested with 10 Thai members of the University of Tokyo (nine students and one faculty member) during 19–23 September 2016, and was revised reflecting their comments. The questionnaire was distributed through a web-based survey by Intage Inc. (Japan) during 12–24 October 2016, and there was a total of 2,446 respondents. All respondents were Thai citizens living in Bangkok and its vicinity, aged 20–59 years.

2.3.2 Questionnaire Survey for Follow-up Practice

One month later, another survey was conducted to follow up on the respondents' actual practices. The follow-up questionnaire was sent to all respondents who had participated in the previous survey. The questionnaire consisted of two parts: (1) target behavior practice rates and (2) reasons for not performing the behavior.

The W-group were asked whether they had performed waste separation in the previous one month or not, using a six-point scale ranging from 'always' to

'never.' If they selected 'never,' 'rarely,' or 'seldom,' they were asked to select one reason from the following list: 'forgot,' 'bothersome,' 'time consuming,' 'inconvenient,' 'no one does it,' 'no rule,' 'no consideration,' 'cost,' 'no chance to do,' 'not environmentally-friendly,' 'not cool,' 'not necessary to do' and 'other.'

The R-group were asked whether they had tried to increase their refill product purchasing in the previous one month. The respondents were asked to choose an answer from this list: 'increased greatly,' 'increased to some extent,' 'did not change my behavior,' and 'never used refill products.' The respondents who selected 'did not change my behavior' or 'never used refill products' were asked to select one reason from the list shown above.

The follow-up survey was conducted using the same company as for the previous survey (Intage Inc., Japan) during 10–17 November 2016. A total of 1,093 respondents replied, representing 45% of the respondents who had replied to the previous questionnaire.

3. Results

3.1 Prior Knowledge, Comprehensibility and Usefulness of Information Provided

The socio-demographic characteristics of all the subgroups were similar. The ratio of males to females was 50% and most respondents were in their 20s or 30s, had an undergraduate degree and lived in detached houses with a family size of 3–5 people.

Concerning previous knowledge, most of the WA respondents thought that the differences between performing waste separation in Bangkok compared to Tokyo and Seoul were larger or a bit larger than what they had imagined (K_{WA}). One-third of the WL respondents said they had been fairly aware (30.9%) and another one-third had been well aware (29.4%) of the mechanism of environmental-load reduction through waste separation (K_{WL}). The respondents who had never, seldom or slightly been aware of the mechanism accounted for 15%. One-third of the RL respondents said they had been fairly aware (30.3%) of environmental-load reduction through use of refills instead of single-use products (K_{RL}). Another third of respondents had never (8.6%), seldom (5.9%), or slightly (14.2%) been aware of it. Among the RA respondents, 32% said that they had been aware of all categories presented in the information provided, and 36% had not been aware of one category. The least known category was car and air refill products (36.3%), followed by instant drink products (19.5%).

Concerning the respondents' degree of understanding of the information, scores of 1–6 were provided from 'strongly disagree' to 'strongly agree.' Between the two types of information, LCT-based information showed slightly higher average scores (WL, 5.48; RL, 5.56) than alternative information types (WA, 5.45; RA, 5.53), but the differences were not significant (*t*-test, $p>0.05$).

The average scores on usefulness are presented in Table 2. Between two significantly different scores on usefulness, LCT-based information showed higher average scores than the alternative information types (*t*-test, $p<0.05$).

3.2 Effects on Attitudes and Intentions

The same questions about attitude were asked of the respondents before and after they received the information, and the differences in scores between $A1_{before}$ and $A1_{after}$ were analyzed by paired *t*-test to determine the effects of information on attitude change. The differences between $A1_{before}$ and $A1_{after}$ were small for waste separation cases (WA and WL) and not significantly different (Table 3). However, RL and RA groups showed significantly higher scores for $A1_{after}$ than $A1_{before}$ (*t*-test, $p<0.05$). The RL showed a higher average score of change than the RA, but the difference was not significant ($t = 1.08$, $df = 812$, $p=0.28$). In addition, Cohen's *d* effect size was calculated for determining the size of each information type's effect on attitude. A relatively minor effect was observed in the W groups ($d < 0.2$, Fritz et al., 2012) while a small ($d = 0.2$) to medium ($d = 0.5$) level was observed in the R groups. It should be noted that the score of $A1_{before}$ was already high and there was limited room for improvement as measured by the six-point scale. The average scores of $A1_{before}$ for waste separation were higher than those for refill products. De Young (1990) also found that a high antecedent attitude toward recycling (4.40 out of a maximum of 5) was a possible reason for unimproved attitude (4.21 of 5) after an education program.

To deal with this issue, additional analyses were carried out; the respondents were divided into two groups:

Table 2 Mean scores on usefulness of information types.

Group	N	Mean	S.D.	t-test
WL	411	5.55	0.59	**p=0.025**
WA	407	5.45	0.71	
RL	409	5.61	0.64	**p=0.001**
RA	405	5.46	0.63	

Measuring question: 'Do you think this information is helpful?' using a six-point scale.

Table 3 Mean scores of attitudes after and before.

Group	Attitude (after)		Attitude (before)		Effect size (Cohen's *d*)	Paired t-test (two-tailed)
	Mean	S.D.	Mean	S.D.		
WL	5.66	0.56	5.66	0.61	0.01	p=0.866
WA	5.70	0.59	5.69	0.56	0.02	p=0.749
RL	5.56	0.66	5.33	0.72	0.32	**p<0.005**
RA	5.45	0.68	5.28	0.76	0.23	**p<0.005**

Measuring question: "How important is waste separation (WL, WA) /purchasing refill products (RL, RA) to preserving the environment and conserving our natural resources?" using a six-point scale.

low and high $A1_{before}$ levels. The cut-off point was set based on the proportion of respondents' answers. Respondents who had rated $A1_{before}$ at '6' were counted as the high baseline group (WA_{high} and WL_{high}), whereas the respondents who had rated at '5' or lower were counted as the low baseline group (WA_{low} and WL_{low}). The results showed that the average scores of changes were larger in the low baseline groups for both information types, 0.50 for WA_{low} (n = 109) and 0.49 for WL_{low} (n = 112), than those in the whole sample groups, 0.01 for WA (n = 407) and 0.00 for WL (n = 411), and these increases were also significant (*t*-test, $p<0.01$). The almost equal size of attitude changes between WA_{low} (0.50) and WL_{low} (0.49) indicated slightly different effects of information types on changes in attitude among the low baseline groups.

Most respondents in both high baseline groups, 87% for WA_{high} (n = 298) and 83% for WL_{high} (n = 299), showed no change after receiving information. The average scores were slightly negative (WA_{high}, −0.17; WL_{high}, −0.18), with no significant effect of information types (*t*-test, $p>0.05$).

The effects of information provision were also investigated for differences between baseline practices and intentions. The scores on practice rate asked before and intention to do asked after information provision were compared. It is important to note, however, that the questions themselves were different (current practice rate and intention to do) and different measuring scales were used: 'always,' 'often,' 'sometimes,' 'seldom,' 'rarely,' and 'never' for practice; but 'absolutely,' 'certainly,' 'possibly,' 'moderately,' 'may not,' and 'never' for the intention scale. Therefore, with careful interpretation, the differences between practice and intention could be compared only among the same behavior: waste separation or refill product purchase.

The average scores on differences between baseline practice and intention to perform waste separation are shown in Table 4. The scores were calculated from the intention score minus the baseline practice score. The score of the WA group was higher than that of WL group. The scores of both treatment groups were lower than the control group score, but there were no significant differences between the scores of the control and treatment groups (*t*-test, $p>0.05$). In short, there were no differences between the respondents with and without the information in terms of changes between baseline practices and intention to peform waste separation.

For refill products (Table 4), both treatment groups had significantly higher scores than the control group (*t*-test, $p<0.05$), with the score of the RL group non-significantly higher than that of RA group.

3.3 Effects on Follow-up Practice

One month later, another survey was carried out to follow up on changes in behaviors of all the respondents that participated in the first survey. The response rate range was 41.7% – 48.3% for all subgroups. The numbers of females were higher than males in all subgroups, but the other major characteristics were similar to those in the first survey.

The average scores on state of practice during the month are shown in Table 5; the scores were calculated from 'never' = 1 to 'always' = 6. The scores of the treatment groups (WA, WL) were lower than those of the control group (WC), but the differences were not significant (*t*-test, $p>0.05$). That is, there was no significant difference in follow-up practices between the respondents with and without information provision. Although follow-up practices were asked about using the same scale as for the baseline practice rates—a six-point scale—no direct comparison was possible because the questions differed slightly. The follow-up survey used the words 'previous month,' but no specific period had been indicated in the previous survey. The difference in the wording could have some impact on the respondents' perceptions or feelings in their reports about their practices.

For refill-product behavior, the respondents were asked about their practices using a four-point scale, and the average scores were calculated from 'never or not used' = 1 to 'increased greatly' = 4. Both treatment groups (RL, RA) had higher scores than the control (RC), but the differences were not significant (*t*-test, $p>0.05$; Table 5).

In addition to the practice rates, the respondents who selected 'never,' 'rarely' or 'seldom' for the previous-month target behaviors were asked to choose one reason for not doing so. The three waste separation groups (WC, WL and WA) showed similarities in major reasons for not

Table 4 Mean scores of baseline practices and intentions by groups.

Group	Mean change	S.D.	t-test	
			Comparison	p-value
WC	0.51	0.99		
WL	0.47	1.07	WC vs WL	p=0.532
WA	0.50	1.06	WC vs WA	p=0.823
RC	0.41	0.93	RC vs RL	**p=0.001**
RL	0.64	1.08	RC vs RA	**p=0.039**
RA	0.56	1.20	RL vs RA	p=0.348

Measuring questions for baseline practice: 'How often do you do waste separation?' (WC, WL, WA); 'How often do you buy refill products?' (RC, RL, RA). Measuring questions for intention: 'How much will you try to do or keep doing waste separation within this month?' (WC, WL, WA); 'How much will you try to buy or keep buying refill products within this month?' (RC, RL, RA). All responses were measured using a six-point scale.

Table 5 Follow-up scores of practices by groups.

Group	N	Mean	S.D.	t-test	
				Comparison	p-value
WC	186	4.52	1.36		
WL	176	4.36	1.44	WC vs WL	p=0.283
WA	176	4.51	1.29	WC vs WA	p=0.910
RC	198	2.75	0.90		
RL	188	2.86	0.89	RC vs RL	p=0.257
RA	169	2.76	0.95	RC vs RA	p=0.912

Measuring questions for baseline practice: 'Last month, did you do waste separation?' (WC, WL, WA); 'Last month, did you try to increase your purchase of refill products?' (RC, RL, RA). All responses were measured using a six-point scale.

doing so. Most of the respondents did not practice waste separation for the following reasons: 'forgot,' 'bothersome,' 'inconvenient,' and 'no chance to do.' For purchasing refill products, a variety of reasons for not purchasing were observed across the three groups (RC, RL and RA). The most common reasons were 'inconvenient,' 'forgot,' 'cost' and 'no chance to do.'

4. Discussion

Our results showed that LCT-based information was highly useful for introducing the LCT concept to the general public and significantly more useful than alternative information for both target behaviors. The LCT-based information provided was also understandable. These findings provide support for the use of the LCT concept through information provision, as well as educating the public. The average scores on previous knowledge of the LCT information provided were 4.59 and 4.10 (of 6.00) for waste separation and purchasing refill products, respectively. A lower level of previous knowledge was observed for information on specific details—in this case the 'calculated quantity' of GHG reduction from using refill products. Thus, such quantitative data together with some explanation based on LCT could be more useful toward encouraging public knowledge.

Our results showed that information provision had positive impacts on respondents' attitudes and intentions toward both target behaviors, but non-significant impacts on behavior improvement. These findings are similar to others in the literature showing that information provision did improve respondents' knowledge (Schultz, 1999; Bolderdijk et al., 2013) and intentions (Lee et al., 2015), but was unsuccessful in improving their behaviors (Schultz, 1999; Lee et al., 2015). Regarding behavioral theories, internal variables such as attitudes, knowledge and intentions are important determinants for engaging in PEBs (Ajzen & Fishbein, 1977). Performing PEBs is, however, also a function of external variables (Guagnano et al., 1995; Olander & Thogersen, 1995; Kollmuss & Agyeman, 2002). Information provision can influence such internal variables, but improvement of internal variables alone cannot change behaviors without considering external factors. Considering the results of refill-product purchasing, both of the provided information types increased people's attitudes and intentions toward refill-product use. Nevertheless, some respondents could not increase their behavior practice rate for the following reasons: 'inconvenient,' 'forgot,' 'cost,' and 'no chance to do.' The reason of cost indicates that prices of the existing refill products are perceived as not consumer-friendly. The reason of inconvenience implies that the respondents want to perform the action, but cannot or are not yet ready for it. In the case of purchasing refill products, this may be due to the availability of preferred products or brands. The reason of no chance to buy indicates much stronger external influences: it is assumed that people want to perform the action or they are ready to, but there is no way or chance for them to purchase the products. This was supported by the characteristics of the respondents who selected 'no chance to do;' most of whom were in their 20s and lived in family groups of 3–5 members. Young people have fewer chances to purchase household products when they live with other family members.

The effects of information type differed between the two target behaviors. The LCT-based information on refill products had a greater effect than the alternative information on changes in attitudes, intentions and behaviors; whereas the results were opposite for waste separation. Although the differences between LCT-based and alternative information were not statistically significant for either target behavior, the impacts observed in the study and the high level of usefulness of the LCT-based information indicated its benefits and potential for use as another valuable type of information to enhance people's attitudes and behaviors. Additionally, the LCT concept would be useful in school education to encourage children's awareness of possible connections between their daily behaviors and the environmental consequences, which may help in long-term development of understanding and attitudes toward environmentally-friendly society and behaviors.

Other pragmatic interventions should also be introduced and implemented along with information-intensive campaigns and environmental education for achieving behavioral change. Examples of behavior-changing tools include gaining commitment, developing community norms, improving infrastructure and using prompts (McKenzie-Mohr, 2000). For instance, to promote purchasing refill products, marketing price campaigns, a variety of product brands and quick reminders presented on the product shelf may be used together to remove cost barriers, inconvenience and the problem of forgetting to purchase refill products.

5. Conclusions

The present study has applied the concept of LCT to the designing of information provided to foster the PEBs of waste separation and purchase of refill products. The effects of LCT-based information were investigated regarding changes in people's attitudes, intentions and behaviors, and compared with those of other information types.

The results showed that the average score of knowledge about the mechanism of environmental-load reduction through waste separation was higher than that of information about GHG reduction through use of refill products. The LCT-based information about both behaviors was significantly more useful than the alternative information provided.

The effects of LCT-based information on changes in

attitudes, intentions and behaviors differed depending on the target behavior. The LCT-based information about refill products had significant effects on changes in attitudes and intentions, but not on follow-up practices. However, LCT-based information about waste separation had a significant effect on attitude change, particularly in respondents with a low baseline attitude level, but had no significant effect on intention and follow-up practices. The results indicate that information based on LCT can improve people's attitudes toward target behaviors, but additional support is needed to facilitate behavioral change.

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Estimating the Potential Material-saving Effects of Automotive Parts Remanufacturing in Southeast Asia

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Abstract

Remanufacturing is an important element in enhancing the resource efficiency of economies. Automotive parts are a representative target of remanufacturing. This study has attempted to estimate the potential contribution of automotive parts remanufacturing toward reductions in material resource consumption in the Southeast Asian region. Material consumption for automobiles and automotive spare parts in the region in 2030 is estimated at 5.2 million tons and 314,000 tons, respectively. Of the materials, steel is expected to comprise 3.5 million tons and 213,000 tons, accounting for 2.7% and 0.16%, respectively, of steel use in the region. The material-saving effects of remanufacturing are then considered. The results indicate the potential contribution of automotive parts remanufacturing to the reduction of material consumption in the region in 2030 to be an estimated 251,000 tons of materials and 170,000 tons of steel, accounting for 0.13% of steel use in the region. This article also presents a discussion on potential market barriers to remanufacturing in the region. The major barriers include: 1) manufacturers' hesitation to undertake remanufacturing, and 2) consumers' non-acceptance of remanufactured products. The implications of a web-questionnaire survey the study conducted in four countries in the region to assess consumers' acceptance of remanufactured products are discussed along with items needing further study.

Key words: automotive parts, consumer perception, remanufacturing, resource efficiency, Southeast Asia, sustainable consumption and production

1. Introduction

Reducing material resource consumption is an essential requirement for realizing a sustainable society. Overconsumption of material resources has been widely warned about since as early as the 1970s. Still, global consumption has continued to increase over time, and it is expected to increase further in the future. The global annual consumption of metal materials has reached 8 billion tons today, and it is predicted to reach 20 billion tons in 2060 (OECD, 2019). The current study focuses on the Southeast Asian region. The region's economic development is remarkable, and the consumption of material and energy is also increasing rapidly. Today, the region has a population of 662 million, accounting for 8.5% of the global population, and substantially larger than that of Japan, the US or the EU (Table 1). On the other hand, the number of cars owned in the region is 58 million, 4.5% of the global total, and the annual consumption of steel there is 93 million tons, 4.9% of the global total (Table 1), representing the potential for car ownership growth. These factors indicate that the region's material and energy consumption is most likely to increase significantly in the following decades. Measures are necessary to mitigate the increase.

Remanufacturing is an industrial process in which used products are restored to their original as-new condition/ performance or better (UNEP-IRP, 2018). Remanufacturing has the effect of reducing material demand because it prolongs the usage of the components of a product and thus reduces the demand for new component manufacturing. Remanufacturing is even

Table 1 Basic economic indicators, automobiles and steel use in Southeast Asia and other regions.

	Population in 2020 (millions) [a]	GDP per capita in 2019 (USD current prices) [b]	Sales of new vehicles in 2019 (thousand units) [c]	Vehicles in use in 2015 (thousand units) [d]	Vehicles in use per 1000 inhabitants in 2015 [d]	Steel use in 2019 (thousand metric tons, crude steel equivalent) [e]	Steel use per capita in 2019 (kg crude steel equivalent) [e]
Indonesia	271.7	4,200	1,030	22,513	87	19,140	71
Malaysia	32.8	11,210	604	13,309	439	10,706	335
Philippines	109.6	3,510	410	3,823	38	11,697	108
Singapore	5.8	65,640	91	813	145	2,899	499
Thailand	66.5	7,820	1,008	15,491	228	21,416	308
Vietnam	96.2	3,420	277	2,170	23	27,318	283
ASEAN10 [f]	662.0	4,940	3,471	58,118	88	93,176	140
(global ratio)	(8.5%)		(3.8%)	(4.5%)		(4.9%)	
Japan	126.0	40,800	5,195	77,404	609	69,782	550
China	1410.6	10,240	25,797	162,845	118	947,519	659
US	329.9	65,250	17,037	264,194	821	108,500	330
EU27+UK	447.0	46,590	17,896	294,213	581	172,437	336
Global	7773	11,540	90,424	1,282,270	182	1,888,890	245

[a] Source: Population Reference Bureau https://www.prb.org/2020-world-population-data-sheet/
[b] Source: International Monetary Fund https://www.imf.org/external/datamapper/datasets/WEO
[c] Source: (OICA, 2021a) [d] Source: (OICA, 2021b) [e] Source: (World Steel Association, 2020)
[f] ASEAN (Association of Southeast Asian Nations) comprises 10 member countries – Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, Brunei, Cambodia, Laos, and Myanmar. In this paper, "ASEAN10" and "Southeast Asia" are used interchangeably.

more essential, even compared with recycling, because it can be more economically viable, more resource-efficient and less energy-intensive than recycling.

Although remanufacturing has attracted attention in recent years in academia, industry and government, it is not clear how much of an impact remanufacturing will have on material saving at the societal or macro level. The market impacts of remanufacturing have become gradually clearer in the last decade. The production of remanufactured goods in the US in 2011 was estimated at 43.0 billion USD (USITC, 2012), and in Europe, at 29.8 billion EUR (ERN, 2015), but again, the material-saving effects are not known. This study has attempted to estimate the potential contribution of automotive parts remanufacturing in Southeast Asia.

The automobile industry in Southeast Asia, typically in Thailand, has developed through the attraction of foreign automobile manufacturers since the 1960s. Foreign automobile manufacturers have set up local factories, followed by which, foreign automotive parts manufacturers have also set up local factories. In recent years, local parts manufacturers have been growing. The number of parts manufacturers is largest in Thailand, followed by Indonesia and Malaysia (DBJ, 2015). This region has local parts manufacturers and potential for growth of the parts remanufacturing industry.

The automotive parts sector is where remanufacturing is most actively conducted globally. This study has attempted to address whether the potential impact is on the order of 1%, or 0.1%, or 0.01% material saving in the Southeast Asian region. Clarifying the scale of impacts is the first step in arguing for the priority of measures and policies.

The rest of the paper is organized as follows. Chapter 2 presents our estimation of the potential material-saving effects of automotive parts remanufacturing in Southeast Asia. The methods, assumptions, data and results of this estimation are presented. Chapter 3 discusses the market barriers to remanufacturing in the region. These barriers may include consumers' non-acceptance of remanufactured products and companies' hesitation to undertake remanufacturing. The final chapter discusses the results and concludes the study.

2. Potential Material-saving Effects of Automotive Parts Remanufacturing in Southeast Asia

2.1 Estimation Method

We estimated the potential material-saving effects of automotive parts remanufacturing in Southeast Asia in the year 2030 using the following procedures:

1) The materials breakdown of an automobile was estimated.
2) The amounts of flow (annual sales) and stock (products in use) of automobiles in the region in 2030 were estimated. Based on that and the materials breakdown per automobile estimated in (1), the material usage for automobiles in the region in 2030 was estimated.
3) The demand for spare parts stock per car, and the materials breakdown of spare parts were estimated. Based on those estimations and car stock estimated in (2), the material use for spare parts was estimated.
4) The material-saving effects of automotive parts remanufacturing at the product level were estimated,

and the share of remanufactured parts in the spare parts market was estimated. Based on these estimations and the material use for spare parts estimated in (3), the potential material-saving effects of automotive parts remanufacturing were estimated.

5) The CO_2-saving effect was also estimated. Based on estimates of CO_2-saving effects of automotive parts remanufacturing at the product level, and the amount of remanufactured automotive parts estimated in (4), the potential CO_2-saving effects of automotive parts remanufacturing were estimated.

The estimations in these processes involved uncertainties; therefore some of them can be regarded as assumptions rather than estimates. The processes are described in further detail in the following sections.

2.2 Flow and Stock of Automobiles

Material resources are used in developing all types of artifacts including, buildings, urban infrastructure, transportation infrastructure and all kinds of products. Automobiles are one of the prominent consumers of material resources. Today, 90 million cars are sold annually (flow), and 1.3 billion cars are in use globally (stock) (Table 1). The stock has increased for over a century and its trend shows it is not likely to reach saturation in the near future. Southeast Asia comprises 4.5% of the global stock (Table 1). It has sales of 3.5 million cars (flow) and 58 million cars in use (stock) (Table 1). While the number of cars per 1000 inhabitants is around 600 in Europe and Japan, and 821 in the US, it is 88 in Southeast Asia, and the figure varies highly country-wise in the region, from 439 in Malaysia to 23 in Vietnam (Table 1). These figures and trends indicate that both the flow and stock in Southeast Asia are likely to increase significantly in the coming decades.

2.3 Material Use for Automobiles

An automobile typically weighs 1.0 to 1.5 tons. Of the curb weight, approximately 70% is steel (ferrous metals), 10% is non-ferrous metals (Al, Cu, etc.), 10% (or less) is plastics and 10% (or more) is other materials (glass, rubber, fluids, etc.). Several studies have investigated bills of automobile materials (e.g. Mayyas et al., 2017; Bobba et al., 2021; Tahara et al., 2001). We used the figures shown in Table 2 for the weight of an automobile and its materials breakdown.

Assuming the figures in Table 2 represent the average figures for automobiles in Southeast Asia, we estimated the amounts of materials in vehicles sold in 2015 and 2030 in the region. Table 3 shows the results, where, in 2015, the vehicles (3.1 million units) are made up of 3.59 million tons of materials, of which 2.86 million tons are metals, of which 2.40 million tons are steel (Table 3). The amount of steel (2.40 million tons) accounts for 2.8% of the total steel used in the region (Table 3).

In our estimation for the year 2030, we first estimated the car sales and steel use in the region in the year 2030. They were estimated in both cases by extrapolating the linear approximations of their trends in the years 2010–2019. The car sales in 2030 were estimated at 4.5 million units, and the steel use, at 130 million tons (Table 3).

We assumed that the influence of increased numbers of electric vehicles (EVs) and other factors would be limited. Globally, more than 6.8 million battery EVs (BEVs) were on the road in 2020 (IEA, 2021), whereas in Thailand, only 7,250 BEVs were on road yet as of April 2021 (EVAT, 2021). EVs (total of BEVs and plug-in hybrid EVs (PHEVs)) are predicted to account for 7% of the car stock worldwide by 2030 (IEA, 2021). The ratio is expected to be lower in Southeast Asia. This study did not take the influences of car electrification into account.

The materials, metal and steel used in vehicles in the region in the year 2030 were estimated at 5.19, 4.14, and 3.47 million tons, respectively, and the steel for cars was estimated to comprise 2.7% of the total steel used in 2030 (Table 3).

The estimated fractions of steel used in automobiles in the region (2.8% and 2.7%) are smaller than those globally. According to Allwood and Cullen (2015), the steel used in cars and trucks in 2008 globally was 108 million tons, comprising 10.0% of total steel used globally that year.

2.4 Material Use in Spare Parts

We then estimated the amount of materials used in

Table 2 Materials breakdown and weight of an automobile.

	Weight (kg)	Portion (%)
Steel	773	67.0
Non-ferrous metal (Al, Cu, etc.)	147	12.7
Plastics	89	7.7
Others (rubber, glass, fluids)	145	12.6
Total weight	1153	100.0

Note: We referred to the data collected in the study by Tahara et al. (2001). Although not all the details on the data used in that study were indicated in the literature, we used those data in our study. The total weight (1,153 kg) does not include the weight of gasoline, although the 'curb weight' generally includes the weight of gasoline.

Table 3 Materials used in automobiles.

	2015	2030
Automobile sales in SEA (units) (a)	3.11 M [1)]	4.50 M [3)]
Weight (=a*1.153) (tons)	3.59 M	5.19 M
Metal weight (=a*0.920) (tons)	2.86 M	4.14 M
Steel* weight (=a*0.773) (tons) (b)	2.40 M	3.47 M
Steel use in SEA (tons) (c)	84.8 M [2)]	130 M [4)]
Steel use fraction (=b/c) (%)	2.8%	2.7%

Note: SEA stands for 'Southeast Asia'.
[1)] Source: (OICA, 2021a)
[2)] Source: (World Steel Association, 2020)
[3), 4)] Source: Authors' estimation (or assumption).

automobile spare parts. To estimate this, we estimated the materials breakdown of spare parts, and the quantities of spare parts traded in markets. Table 4 shows 11 types of automotive parts that are commonly traded as spare parts in markets. When an automotive part is broken, the driver can make a choice of repairing the part (repair), replacing the part with a brand-new one (new), replacing it with a remanufactured part (remanufacturing) or replacing it with a reused part (reuse). The 11 types of parts also represent the parts that are commonly remanufactured today in regions such as the US (Frost & Sullivan, 2011), EU (Bobba et al., 2021) and Japan (the authors' study). The table shows the parts' weight, parts' steel content weight, and our estimates of the ratio of spare part demands (units) to car stock amounts (units).

These estimated ratios indicate spare engine demand units, for example, in year Y, and are calculated as follows:

(car stock number in year Y) * (0.5%)

The weight of material used in these engines (total weight of the engines), and the weight of the steel used in the engines are calculated as follows, respectively:

(car stock number in year Y) * (0.5%) * 135.0 (kg),
(car stock number in year Y) * (0.5%) * 73.6 (kg)

We estimated the ratio (e.g., 0.5% for the engine) by referring to the estimated units of remanufactured parts sold in the EU (Bobba et al., 2021), the corresponding estimation in the US (Frost & Sullivan, 2011), and the authors' interviews with personnel in the industry in Japan. In the EU, for example, 3.22 million units of remanufactured alternators (spare parts) were sold in 2012 (Bobba et al., 2021). The ratio to the car stock number in the EU that year (260.5 million) was 1.2%. We presumed the potential ratios would be larger in Southeast Asia because the average age of the cars in the region was higher than in the EU, US or Japan. We assumed the ratio would be higher by up to 70% in Southeast Asia. For alternators, we hypothetically estimated the ratio at 2% (Table 4).

The car stocks in the years 2015 and 2030 in Southeast Asia were/will be 58.1 million (Table 1) and 90.0 million (authors' estimate), respectively. The potential demand figures for spare parts shown in Table 4 (11 types of parts) were calculated at 7.0 million and 10.8 million units, respectively. These have total weights of 101,000 tons and 157,000 tons, respectively.

In addition to the 11 types of parts in Table 4, we also took other parts into account. The parts considered additionally were mainly exterior automotive parts such as doors, bonnets, lights, mirrors and so on. These parts are more like to be reused than remanufactured today. We include these parts in our account because the potential demand for remanufactured parts of these types does exist. We assumed that the total weight of demand for these parts would be the same as that for the 11 types of parts.

Our results show the total weight of the demand for these spare parts to be 203,000 tons in 2015, and 314,000 tons in 2030. Of these amounts, steel accounts for 137,000 tons in 2015, and 213,000 tons in 2030. Figure 1 presents our estimates of the flow and stock of automobiles, spare parts and related materials for the year 2030.

The demand for spare parts, or the 'spare part demand per car in stock' in Table 4, can vary from market

Table 4 Top remanufactured automotive parts, their weight, steel content and demand per car in stock.

	Weight (kg)	Steel (kg)	Spare part demand per car in stock*
Engines	135.0	73.6	0.5%
Alternators	4.5	2.7	2%
Starters	2.5	1.5	2%
AC compressors	5.8	2.4	2%
Transmissions	102.5	82.0	0.5%
Driveshafts	7.6	6.9	2%
Electronic units	5	3	0.5%
Clutches	6	6	0.5%
Brake calipers	5	5	1%
Steering gears	6.6	6.6	0.5%
Water pumps	1.9	1.2	0.5%

*Note: Estimated ratio of the annual demand for spare parts (units) to the number of automobiles-in-use (cars in stock). For example, "2%" indicates that when there are 100,000 cars in use, there will be demand for 2,000 units of spare parts per year.
For the parts' total weight and steel weight, we referred to data collected in the study by Tahara et al. (2001).

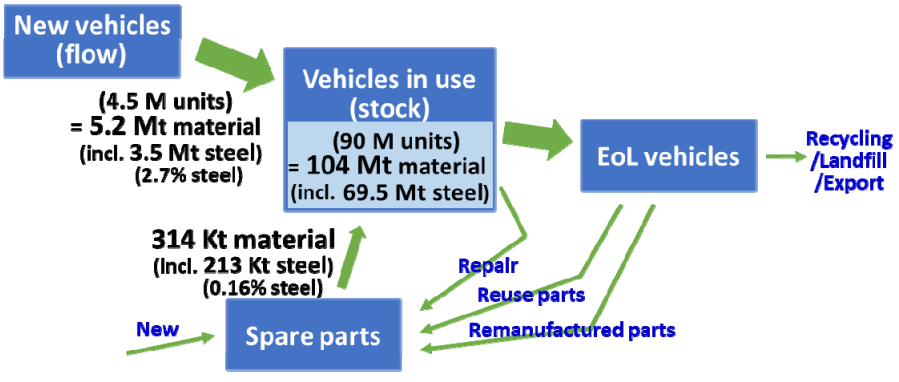

Fig. 1 Estimated flow and stock of automobiles, potential spare parts and related materials in Southeast Asia in 2030.

to market depending on the conditions under which cars are used. The factors can include: the average age of the car stock in the market, road conditions, climate conditions (temperature, humidity, etc.), quality of original components and so on. The available data for spare parts are limited. For reference, Table 5 shows the result of the authors' survey (web questionnaire survey) on drivers' experiences with repairing or replacing alternators or starters in six countries. The percentage of drivers who had experienced the need for repair or replacement was relatively high in the four Southeast Asian countries (50.2% in Malaysia to 74.8% in Vietnam), and it was also high in the US (55.6%) and low in Japan (11.3%). Although demand for spare parts may differ and change depending on conditions in the future (either increasing or decreasing), the estimates in Fig. 1 present a potential.

2.5 Automotive Parts Remanufacturing in Southeast Asia

Globally, the automotive parts remanufacturing industry is one of the largest remanufacturing sectors. It is the second-largest sector in the EU after the aerospace sector (ERN, 2015) and is the third-largest in the US after the aerospace and heavy-duty & off-road (HDOR) equipment sectors (USITC, 2012). In the aftermarket for automotive alternators and starters, for example, remanufactured parts comprise 90% in the US (Frost & Sullivan, 2011) and EU (Bobba et al., 2021), and about 50% in Japan (Matsumoto et al., 2018).

In Southeast Asia, reuse (or direct reuse) and repair are much more common than remanufacturing today. Generally, repair is more artisanal and labor-intensive than remanufacturing. In a long-term trend, as the country's economy develops and income and wage levels of the country rise, repairs are more likely to be replaced by remanufacturing (Matsumoto et al., 2018). The growth levels of automotive parts remanufacturing industries vary from country to country in Southeast Asia. The industry in Malaysia is growing (Yusop et al., 2016), whereas Vietnam does not have an identified remanufacturing industry yet (Guidat et al., 2017). The Malaysian government is also active in supporting the development of a promising remanufacturing sector within a local hub for remanufacturing (Yusop et al., 2016; Matsumoto et al., 2021). In Indonesia, the industry is still in a very early stage of development. Fatimah et al. (2013) describe remanufacturers as not very effective at producing remanufactured parts. The Indonesian government strictly restricts the import of used capital goods, which could partially limit the growth of the industry in that country (Matsumoto et al., 2021). Overall, in Southeast Asia, automotive parts remanufacturing is most likely to continue to grow in the coming decades, and the governments and industry should also support its growth to enhance the circularity of products.

Table 5 Drivers' experiences with repairs/replacements of alternators or starters.

		Have you ever repaired or replaced an alternator or starter (A/S) in your car, including the A/S of your current car and/or your previous cars?		
		Yes	No	I don't know
Indonesia	N=500	66.2%	33.8%	-
Malaysia	N=500	50.2%	39.6%	10.2%
Thailand	N=500	64.8%	35.2%	-
Vietnam	N=500	74.8%	20.4%	4.8%
Japan	N=600	11.3%	61.7%	27.0%
US	N=500	55.6%	38.8%	5.6%

Source: Authors' web-questionnaire survey of car owners in these six countries.

Notes: The survey in the US was conducted in November 2014. The surveys in the other five countries were conducted in January 2017. In the surveys in Indonesia and Thailand, the authors overlooked inclusion of the answer option of "I don't know".

2.6 Potential Material Saving Effects of Automotive Parts Remanufacturing

In remanufacturing, 65% to 95% of subcomponents on a weight basis are reused (Kim et al., 2008; Fatimah et al., 2013; UNEP-IRP, 2018; Bobba et al., 2020), This indicates that remanufacturing has 65% to 95% material-saving effects compared with brand-new parts manufacturing (manufacture of parts using only new subcomponents). Conservatively assuming that remanufacturing has an 80% material-saving effect, the potential contribution of automotive parts remanufacturing in saving materials overall and steel itself would be 162,000 tons and 110,000 tons, respectively in 2015, and 251,000 tons and 170,000 tons, respectively, in 2030. These amounts of steel correspond to 0.13% of the steel used in Southeast Asia in 2015, and 0.13% of the steel to be used in the region in 2030.

2.7 Potential CO_2-Saving Effects

We also estimated the potential effects of remanufacturing on reducing CO_2 emissions. First, the CO_2 emissions from manufacturing 203,000 tons of new spare parts (in 2015) and 314,000 tons of new spare parts (in 2030; Fig. 1) were estimated. The emissions were calculated at 629,000 tons of CO_2, and 974,000 tons of CO_2, respectively. The inventory data from the previous study (Tahara et al., 2001) was used in the calculation. Second, the CO_2 saving effects of remanufacturing were considered. Extant studies indicate that remanufacturing saves 85% of energy use (Kim et al., 2008), and 66–78% of global warming potential (GWP) (Bobba et al., 2020) when compared with new parts manufacturing. Assuming remanufacturing saves 75% of CO_2 emissions compared to new parts manufacturing, using 203,000 tons of remanufactured spare parts in 2015 and 314,000 tons in 2030 (Fig. 1) instead of using brand-new spare parts would save emissions of 472,000 tons of CO_2 and 731,000 tons of CO_2, respectively. The ratios of these

figures to the total CO_2 emissions of Southeast Asia in 2015 (1.3 billion tons CO_2) are 0.036% and 0.056%, respectively.

2.8 Discussion

This section has provided estimates of materials used in automobiles and spare parts in Southeast Asia. It was estimated that 3.6 million tons of materials were used in automobiles in 2015 and for spare parts, 137,000 tons. Suppose about 20% of sub-components need to be replaced in remanufacturing with new sub-components. In that case, 80% of the material used in spare parts represents potential material-saving effects through automotive parts remanufacturing. For spare parts, reused parts and repaired parts are commonly used in the region today. However, as the economy grows in the area, brand-new spare parts may become more common (Matsumoto et al., 2018). It is vital to make the use of remanufactured spare parts widespread instead of encouraging use of brand-new spare parts.

The material for spare parts (293,000 tons) accounts for about 5% of the total amount of materials in automobiles and spare parts. It should be seen that it is of great significance that 5% of materials used in a sector can be circulated through remanufacturing. The estimated results also indicate that the effects of using automobiles for a long time are also significant. A simplified calculation shows that if the average life of a car increases by 10% (used for 1.5–2 years longer), the demand for new vehicles will be reduced by 10%, which corresponds to 360,000 tons of materials. Automotive parts remanufacturing can also affect the long-term use of vehicles because availability of inexpensive and reliable remanufactured spare parts gives drivers an incentive to maintain and repair their cars, which leads to long-term use rather than replacement with new cars.

There are several important issues regarding material use in the automotive sector. First, as it is often argued, there can be trade-offs between material saving and CO_2 reduction. Prolonged use of cars can eliminate opportunities to replace CO_2-inefficient cars with the latest CO_2-efficient vehicles. Both the material and CO_2 aspects should be adequately considered. Second, there can also be trade-offs between material saving and car safety. The average weight of a car has increased over the decades in the US (Mayyas et al., 2017) and in Europe (Allwood & Cullen, 2015). There are several reasons for this trend, one of which is that car weights have increased to improve the safety of cars. If it is challenging to save materials on account of safety issues in automobiles, long-term use and circulation are even more critical. Third, promoting the use of secondary materials in automobiles may have a significant material-saving effect. In the automobile sector, there is plenty of room for material recycling. Forth, as a long-term trend, internal combustion engine (ICE) vehicles will be replaced by EVs. Adopting remanufacturing and circulation for EVs and EV spare parts will be a significant challenge.

3. Discussion: Market Barriers for Automotive Parts Remanufacturing

3.1 Barriers to Remanufacturing

The barriers to remanufacturing are mainly derived from the difficulty of integrating products issued from a circular manufacturing process into a business ecosystem dedicated to maximizing the number of products from traditional linear systems in the market. Figure 2 presents the perceived barriers to remanufacturing from the point of view of a manufacturing company (Widera & Seliger, 2015). Typically, there are four categories of barriers to remanufacturing (Fig. 2; UNEP-IRP, 2018). They include: (1) core acquisition barriers, (2) technological barriers, (3) market barriers (product sales barriers (Fig. 2)), and (4) regulatory barriers.

The technological barriers include a lack of technical solutions for optimizing material and information flows. The market barriers refer to a range of obstacles, the major ones of which include: 1) original equipment manufacturers' (OEMs') hesitation to undertake remanufacturing, and 2) consumers' non-acceptance of

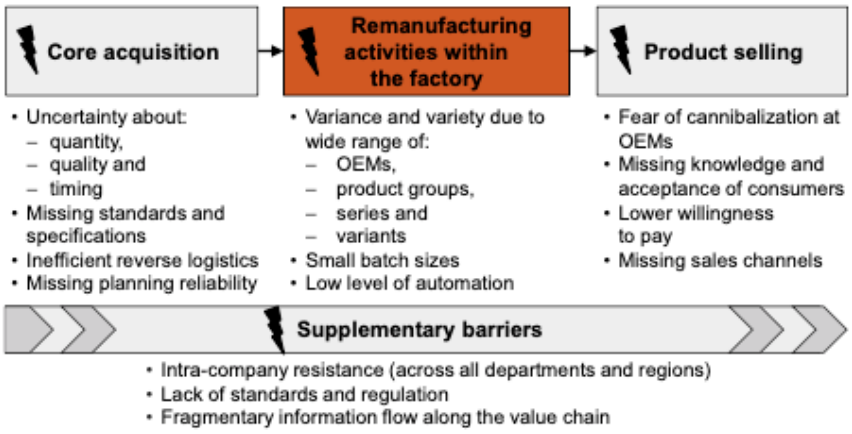

Fig. 2 Barriers to remanufacturing. Source: Widera and Seliger, 2015

remanufactured products. A market barrier specific to OEMs is the fear of cannibalization (Fig. 2), which shows that remanufactured products are considered as replacing the sales of new and more profitable product ranges with their potential to tap new markets or customer segments. The obstacles in this context in the region are discussed below, where the discussion of OEMs is based on a literature review.

3.2 Market Barriers on the Supply Side

In the spare parts market in Southeast Asian countries, as well as in other countries, including the US, EU and Japan, independent remanufacturers rather than OEMs are the main actors in supplying remanufactured automotive parts today. From a long-term perspective, OEMs are expected to play a significant role in the remanufactured automotive parts market. A market barrier specific to OEMs is the fear of cannibalization. Many OEMs offering remanufactured products encounter internal resistance from departments in charge of new products over the perception of competition, resulting in fewer financial and sales channels specific to the remanufactured products markets. Especially in North American and European automotive parts markets, OEMs have launched remanufactured product lines only to face competition from independent remanufacturers. This reaction causes most producers in this field not to consider remanufacturing part of their long-term development strategy. Therefore, it can be assumed that the relative lack of independent remanufacturers in Southeast Asia, combined with the small market size, can explain the lack of application by OEMs of remanufacturing in such countries. As imports of used products are increasingly restricted, the option to offer imported remanufactured parts may also not be seen as an economically attractive solution.

Further consideration of business models for automotive parts is needed. In general, remanufacturing works best when the cost savings compared to new parts benefit the OEM in the case of product-service systems where use of the product is sold without transfer of ownership. As per example in the case of copy machines leased as "pay per use" on customer premises, these models are widely accepted within the providing companies, and customers focus solely on the reliability of the product instead of its production origin.

3.3 Market Barriers on the Demand Side

The spread of remanufacturing largely depends on consumers' acceptance of remanufactured products. Consumers are often unfamiliar with remanufactured products, and even if they know about them, they may have concerns about the quality of remanufactured products. These hinder their acceptance of remanufactured products (Matsumoto et al., 2018). A web questionnaire survey to investigate consumers' knowledge, purchase experiences, and purchase intentions regarding remanufactured automotive parts was conducted in a total of six countries, including four Southeast Asian countries – Indonesia, Malaysia, Thailand and Vietnam. The survey targeted consumers who owned and drove cars. Table 6 shows the question items and the results, which show that consumers in the four countries have a relatively high acquaintance with remanufactured auto parts. While in Japan, only 22.2% of consumers have heard of remanufactured auto parts, many more consumers in those four countries know about the products. Also, many consumers in the four countries answered they had experienced purchasing of remanufactured auto parts, while in Japan, only 16.3% of consumers answered that way. The average intention to purchase remanufactured auto parts is also high in the four countries compared to among consumers in Japan. These results indicate that the four countries in Southeast Asia are in favorably suited in terms of consumers' level of knowledge, familiarity and intention to purchase remanufactured auto parts. The industries and governments in these countries should make efforts to maintain that level.

Although the four Southeast Asian countries in which the survey was conducted comprise the majority of the region, having 92% of the car stock in 2015 and 71% of population in 2020, the other six countries in that region

Table 6 Consumers' knowledge, purchase experience and purchase intention of remanufactured automotive parts.

		[Knowledge] Q: Have you ever heard of remanufactured auto parts?		[Purchase experience] Q: Have you ever bought remanufactured auto parts?		[Purchase intention] Q: If I need to repair an alternator or starter (A/S), I am willing to buy remanufactured A/S. 7-point Likert scale ("1: strongly disagree" to "7: strongly agree")
		Yes	No	Yes	No	Average (middle=4.0)
Indonesia	(N=500)	80.8%	19.2%	51.4%	48.6%	4.43
Malaysia	(N=500)	73.0%	27.0%	42.0%	58.0%	3.98
Thailand	(N=500)	69.2%	30.8%	48.8%	51.2%	4.44
Vietnam	(N=500)	95.2%	4.8%	66.8%	33.2%	4.93
Japan	(N=600)	22.2%	77.8%	16.3%	83.7%	3.28
US	(N=500)	70.8%	29.2%	41.8%	58.2%	4.25

Source: Author's web-questionnaire survey to car owners in the six countries.

Notes: The survey in the US was conducted in November 2014. Surveys in the other five countries were conducted in January 2017.

have different economic properties. Those six countries include more wealthy nations such as Singapore and Brunei, and also countries less developed than the four countries surveyed. Consumer behaviors could differ in those countries, and future research should include a market study in these six countries.

4. Conclusions

This article has presented estimates of the potential material-saving effects of automotive parts remanufacturing in Southeast Asia. The potential for the year 2015 is estimated at 162,000 tons of material, 110,000 tons of steel and 0.13% of the steel used in the region. The potential for the year 2030 is estimated at 251,000 tons of material, 170,000 tons of steel and 0.13% of the steel used in the region. For steel use, the automotive sector (automobiles and spare parts) uses about 3.0% of the steel in the region, and spare parts remanufacturing has the potential for saving 5% of the sector's steel use.

There are other sectors that consume large amounts of steel. Globally, 42% is used in buildings, 14% in infrastructure and 13% in mechanical equipment, among others. (Allwood & Cullen, 2015). Each sector should promote material saving through long-term use, maintenance and remanufacturing. In addition to the market barriers discussed in the previous chapter, auto parts remanufacturers face core acquisition, technological and regulatory barriers. Governments are expected to help industries overcome these barriers and support the realization of a circular economy.

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Household Survey on Air Conditioner Use and Energy Consumption in Vietnam

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Abstract

Demand for electricity is rapidly increasing in Vietnam due to increased use of air conditioners (ACs) and other electrical appliances. Therefore, effective measures are needed for reducing Vietnamese electricity consumption to reduce potential future demand. In 2016, we conducted a survey of 30 households in urban and rural areas of Hanoi and Long An in northern and southern Vietnam, respectively, to examine differences in electricity consumption and the use of ACs and other electrical appliances between different locations and socioeconomic classes. We found that ACs were mainly used in the summer (May–October in Hanoi; March–August in Long An). Households with higher incomes tended to use ACs for most or all of the year. Many households tended to use ACs while sleeping. Younger respondents tended to use ACs for a longer period of time compared with their parents. Respondents in Long An seemed less dependent on ACs compared with those in Hanoi because of regional characteristics and their custom of cold-water bathing. Although increased income is a major factor underlying the use of ACs, other factors such as the structure of modern housing, health awareness, the inability to open windows and local customs were also found. Together, the present results suggest that both hard-type (e.g., improving the thermal performance of residential buildings) and soft-type (e.g., publication of basic tips for energy-saving AC use) policy approaches will be important for reducing future energy consumption in Vietnam.

Key words: air conditioning, consumer behavior, lifestyle, sustainable consumption

1. Introduction

In 1986, the government of Vietnam initiated a set of economic reforms (collectively referred to as the Đổi Mới Policy) with the aim of transitioning the Vietnamese economy to a socialist-oriented market economy. The success of these reforms meant that in only 20 years Vietnam went from being one of the poorest countries in the world with a per capita GDP of about 200 USD in 1990 to being a middle-income country with a per capita GDP that exceeded 1000 USD in 2008. During this period, the Vietnamese economy grew at an average annual economic growth rate of 7%, second only to that of China. While this rapid economic growth has brought about material affluence, various social problems have also emerged. For example, social inequality has increased, with the gaps between the rich and poor, and urban and rural areas becoming increasingly apparent (Taylor, 2004). Along with this economic growth, a new urban, educated middle class has formed (Nguyen-Marshall et al., 2012). This new middle class, made up of people generally in their 30s with a college degree work at companies with foreign affiliations, are relatively free from old perspectives, have rational values and drive mass-consumption trends in the country (King et al., 2008). The parents of this new middle class, the so-called Bao Cấp generation, had a tough time during their adolescence in the "subsidy period" before the Đổi Mới (1975–1986) (Teekantikun, 2014) and some were educated in the former Soviet Union or in Eastern European countries. The grandparents of this new middle class were born before the country achieved independence, experienced extreme poverty under a protracted period of war (First Indochina War, 1946–1954; and Second Indochina War, 1965–1975); and were middle-aged as the country transitioned to a socialist state. This intergenerational gap, together with the current socioeconomic disparities, greatly divided society because,

in a sense, the social wisdom of the ancestors hardly worked.

Due to its high economic growth, Vietnam's final energy demand increased by an average of 4.1% annually between 2006 and 2015, and if this trend continues, Vietnam's final energy demand is projected to grow by 2.5 times between 2015 and 2035 (Danish Energy Agency, 2017). According to a 2016 Vietnamese household living standard survey, ownership rates of major household appliances were 92% for a color television, 69% for a refrigerator, 35% for a washing machine, 27% for a water heater and 19% for an air conditioner (AC) (GSO of Vietnam, 2018). Compared to the ownership level of 2006, AC ownership increased by a factor of six, whereas those of other electric appliances increased by factors ranging from one to four. If this proliferation continues, energy demand in the country will further increase, leading to greater impacts on the global environment (Sahakian, 2014). Therefore, it is important to find a way to reduce the energy used for ACs and other household electric appliances.

Many studies have been conducted on the indoor thermal environment of houses in Southeast Asia, mainly in the field of building environmental engineering (Kubota et al., 2011; Uno et al., 2003). Kubota and Ahmad (2006) and Kubota (2007) examined how residents used ACs or opened windows to cool their living space. Several studies on household energy use have also been conducted in Vietnam (Kim et al., 2000; Le et al., 2009; Le & Yoshino, 2010; Nagasaki et al., 2011; Sawashima & Matsubara, 2017; Le & Pitts, 2019). Kim et al. (2000) measured the indoor thermal environment (temperature and humidity) of traditional housing in Hanoi, but because this study was conducted in the 2000s, a time when ACs were not in widespread use, the impact of AC use was not examined. Le et al. (2009), Le & Yoshino (2010) analyzed questionnaire survey data to investigate the relationship between electronic appliance ownership and energy consumption. Nagasaki et al. (2011) surveyed energy consumption in six houses in Ho Chi Minh City, the largest city in Vietnam, investigating the hours and temperature setting of AC use. Sawashima & Matsubara (2017) surveyed four houses in Haiphong, northern Vietnam, and investigated the hours and temperature setting of AC use. Le & Pitts (2019) studied the energy usage patterns of 60 households in Tuy Hoa City on the south-central coast of Vietnam. Despite these many studies, there are no studies that have focused on AC use by different income groups in Vietnam.

Here, we collected basic data on AC use and household energy consumption from households in different socioeconomic classes in urban and rural areas of Vietnam. Using this data, we then considered the following research questions: 1) When and how are electric appliances used in urban and rural areas of Vietnam? 2) How has the spread of electric appliances differed from that in other Asian countries, such as Japan? 3) What are the drivers and barriers to owning new electric appliances, especially cooling appliances such as ACs? 4) To what extent are people aware of energy saving?

2. Methods

2.1 Survey Area

Vietnam is a large country with a north–south orientation. Vietnam's climate can be divided into two zones: a tropical monsoon zone and a warm–dry winter zone. The southern part of Vietnam, especially Ho Chi Minh City and the surrounding Mekong Delta, has a tropical savanna climate, with annual average temperature ranging from 22°C to 27°C all year round. The northern part, including Hanoi, has four seasons, and the temperature typically varies from 14°C to 33°C. We accounted for the two different climates by conducting our interview survey once in northern Vietnam (Hanoi in March) and once in southern Vietnam (Long An Province in August). Both surveys were conducted in 2016.

Hanoi is the capital of Vietnam and the second most populated municipality. Its population exceeds seven million and the main industry there is the service industry (GSO, 2020). Long An (population 2 million) is a mid-sized province that adjoins Ho Chi Minh City and is located at the entrance to the Mekong Delta. Since 2002 improvements in transportation access have resulted in many factories relocating from Ho Chi Minh City to industrial zones in Long An, which together comprise 28 industrial parks (Runckel, 2006; VOV World, 2016). The major industry in Long An is manufacturing, which accounts for half of the gross regional product, although the production of raw materials in rural areas accounts for approximately 20% of the gross regional product (GSO, 2020).

Fifteen households were selected in each region with consideration given to ensuring a selection of households that would represent the diversity in Vietnam with respect to household size, monthly income and occupations of family members. Local officials helped us select households from each income class. Monthly incomes in urban areas of Hanoi and Long An were classified as low, <10 million VND (457 USD; 1 USD = 21,887 VND); middle, 10–30 million VND (457–1,371 USD); and high, >31 million VND (1,416 USD); in rural areas of Hanoi as low, <5 million VND (226 USD); middle 5–10 million VND (226–457 USD); and high, >10 million VND (457 USD) ; and in rural areas of Long An as low, <5 million VND (226 USD) ; middle, 10–25 million VND (457–1,142 USD); and high, >25 million VND (1,142 USD). In Hanoi, nine households were selected from the central districts of Hanoi City (i.e., Ba Dinh District, Dong Da District and Hai Ba Trung District) and the fast-developing new urban district Thanh Xuan; and six

households were selected from a rural area (Dong Anh District) (Fig. 1). In Long An, three households were selected from Tan An City, the provincial capital, and the remaining 12 households were selected from Thanh Hoa District, which has a town area (six households) as well as rural areas that are characterized by a mix of Melaleuca tree plantations and other agricultural activities (six households).

2.2 Household Interviews

We conducted face-to-face interviews based on a questionnaire that comprised items similar to those used in our previous work in Chiang Rai, Thailand (Yoshida et al., 2020). The questions were asked and then answered in Vietnamese by the head of each household or their family members. These responses were translated immediately into English by an attending interpreter. The survey consisted of six parts: household attributes, ownership of electric appliances, use of ACs, knowledge and intention to save electricity, information related to the purchase of electric appliances, and future purchasing and lifestyle prospects. The basic specifications of the household electrical appliances, including the manufacturer's name, model, year of manufacture and power consumption, were identified by inspection of the product labels or by observation of the product's appearance. The layout of each residence was recorded through photographs and hand drawings. The residential floor space was measured in all households in Long An, but only three households in Hanoi due to time constraints or the respondents' refusing permission. From 10 households in Hanoi and 11 households in Long An, monthly electricity bills (from one to six months) were also obtained. Each household visit took 1–1.5 hours.

3. Results

3.1 Respondent Characteristics

Tables 1 and 2 present summaries of the households that were visited. In Hanoi, there were six three-generation households (40.0%), four couples or single parents with child(ren) (26.7%), three elderly couples (20.0%), one single-person household (6.7%), and one other (6.7%). In Long An, there were six couples or single parents with child(ren) (40.0%), two three-generation households (13.3%), two elderly couples (13.3%), one single-person household (6.7%), and four others (26.7%). The "other" category was large in Long An because there many more households in which the respondents were living with a brother/sister or other relatives. The average number of household members was 4.4 in Hanoi and 5.1 in Long An.

In Hanoi, there were three high-income households, four middle-income households and two low-income households in the urban area and two high-income households, three middle-income households and one low-income household in the rural areas. In Long An, there were two high-income households, four middle-income households and three low-income households in the urban areas and two high-income households, two middle-income households and two low-income households in the rural areas.

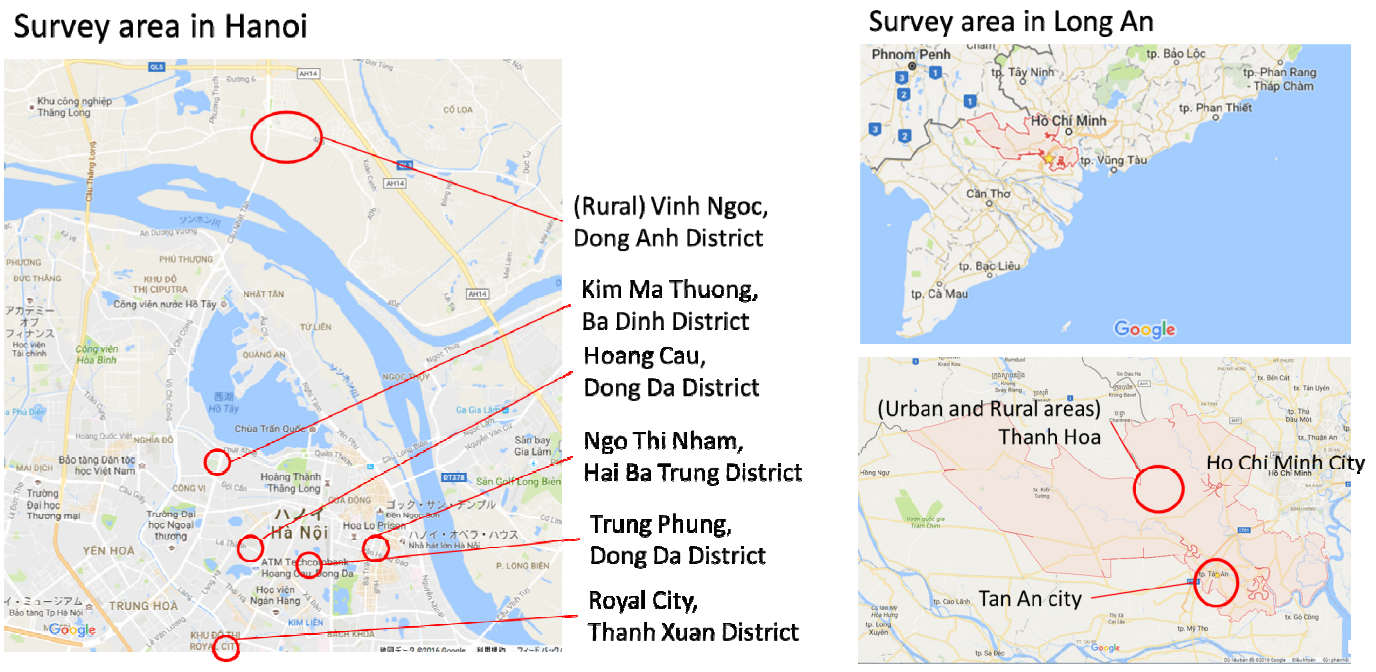

Fig. 1 Study areas in Hanoi (left) and Long An (right).

Table 1 Summary of the study households in Hanoi.

ID	House		Respondent		Household		Main income earner in household		Electrical appliances in household				
	Location	Type	Gender	Age	Monthly income (1000 VND)	Other members (age)	Academic level	Occupation	TV	AC	Electric fan	Fridge	Rice cooker
1	Urban	Three-story town house	F	68	26,000	Husband (77), son (44), daughter-in-law (41), grandchild (12)	College/ university	Engineer, businessperson	3	3	5	1	2
2	Urban	Three-story town house	F	45	17,000	Husband (47), daughter (21), daughter (6), father-in-law (77), mother-in-law (71)	Upper secondary	State enterprise employee	3	2	4	1	1
3	Urban	Three-story town house	M	68	7,500	Wife (67)	Vocational school	Retired, dancing teacher	3	2	5	2	2
4	Urban	Flat, apartment	F	29	8,500	Husband (33), son (4), son (<1)	College/ university	Electrical technician	1	0	2	1	1
5	Urban	Four-story town house	F	78	15,000	Son (46), daughter-in-law (41), grandchildren (14, 8)	Vocational school	Train conductor/ supervisor	2	2	3	1	1
6	Urban	Five-story town house	F	41	100,000	Husband (41), son (16), son (9), mother (67), sister (34)	Graduate school	Director, businessperson	3	8	13	1	1
7	Urban	Condominium	M	41	50,000	Wife (40), son (13), daughter (<1)	College/ university	Manager, businessperson	1	2	1	1	1
8	Urban	Two-story town house	F	51	10,000	Daughter (24), daughter (19)	Lower secondary	Street food vendor	1	1	2	2	1
9	Urban	Four-story town house	M	62	30,000	Wife (62)	Graduate school	Engineer	3	4	13	2	2
10	Rural	Two-story detached house	F	59	15,000	Husband (60), son (34), daughter-in-law (24), grandchildren (9, <1)	Lower secondary	Famer, mechanic	3	1	8	1	2
11	Rural	Two-story detached house	F	61	6,500	Husband (66), son (33), daughter-in-law (32), grandchildren (12, 9)	Lower secondary	Famer, taxi driver	1	1	3	1	3
12	Rural	Three-story detached house + coop	M	38	9,500	Wife (38), son (18), son (13)	Lower secondary	Farmer, speaker rental service	2	0	4	2	1
13	Rural	Single-story detached house + coop	M	61	600	None	No formal education	Farmer, scrap buyer	1	0	2	0	0
14	Rural	Three-story detached house + coop	M	47	12,000	Wife (44), son (23), son (20)	Lower secondary	Farmer, construction worker	2	0	5	1	1
15	Rural	Single-story detached house + two coop	M	54	10,000	Wife (48), daughter (26), daughter (20)	College/ university	Accountant	1	0	2	1	1

Note: 1 USD = 21,887 VND (average exchange rate during March – August 2016; Resona Bank).

Table 2 Summary of the study households in Long An.

ID	House		Respondent		Household		Main income earner in household		Electrical appliances in household				
	Location	Type	Gender	Age	Monthly income (1000 VND)	Other members (age)	Academic level	Occupation	TV	AC	Electric fan	Fridge	Rice cooker
1	Rural	Single-story detached house	M	43	25,000	Wife (41), children (17, 11, 7)	Lower secondary	Farmer	1	0	7	1	1
2	Rural	Single-story detached house	M	39	11,000	Wife (38), children (20, 16, 11)	Lower secondary	Farmer, embankment construction business	1	0	3	1	1
3	Rural	Single-story detached house	M	41	16,000	Wife (33), children (15, 13, 5)	Elementary	Commune committee member, farmer	1	0	5	1	1
4	Rural	Single-story detached house	M	31	27,000	Wife (30), children (5, <1), brother (24), sister-in-law (24)	Lower secondary	Truck driver	2	1	4	1	1
5	Urban	Single-story detached house	M	81	1,000	Wife (65)	Upper secondary	Lottery ticket seller	1	0	4	1	2
6	Urban	Three-story detached house	M	67	60,000	Wife (64), son (41), daughter-in-law (41), daughter (38), son-in-law (42), grandchildren (18, 16, 13, 9, 11, 8)	Upper secondary	Home appliances shop owner, forest owner	6	5	20	1	1
7	Urban	Single-story detached house	F	39	2,000	Son (14), daughter (6)	Elementary	Freelance worker	1	0	3	0	1
8	Rural	Single-story detached house	F	70	600,000	None	Lower secondary	Farmer, cashew shell peeler	1	0	1	0	1
9	Rural	Single-story detached house	M	48	3,500	Wife (48), daughter (24)	Lower secondary	Farmer, cashew shell peeler	1	0	2	1	1
10	Urban	Single-story detached house	F	41	15,000	Husband (44), son (16), son (11)	Lower secondary	Nail and hair salon owner	1	2	5	1	1
11	Urban	Single-story detached house	M	31	10,000	Wife (37)	College/university	School teacher	1	1	3	1	1
12	Urban	Single-story detached house	M	66	20,000	Wife (64), son (40), daughter-in-law (37), grandchildren (16, 13, 7)	Lower secondary	Food store and restaurant owner, forest owner	2	0	10	1	3
13	Urban	Single-story detached house	F	25	20,000	Husband (28), uncle (41), aunt (41), uncle's children (13, 11, 9)	College/university	Accountant company employee	1	3	8	1	1
14	Urban	Single-story detached house	F	54	213,000	Husband (60), brother (55), son (29), daughter-in-law (25), son (22) grandchildren (8, 3)	College/university	Trade and investment company owner	3	5	10	1	1
15	Urban	One-story detached house	M	40	7,000	Wife (40), son (11), mother (81)	Lower secondary	Street food seller	1	0	4	0	1

Note: 1 USD = 21,887 VND (average exchange rate during March – August 2016; Resona Bank).

3.2 Housing Characteristics

In the urban areas of Hanoi, the traditional residences are row houses (aka shop houses or pencil houses) (Shinozaki et al., 2005), which have a narrow facade, long depth, and multiple stories (Fig. 2). The walls are made of brick, and the floor is either tiled or made of concrete without any insulation. Except for at the ends of the row house complex, sunlight cannot penetrate deep inside the houses, which means the room temperature rarely goes above 30°C (Thao & Nam, 2018). In the urban areas of Hanoi, the total floor area of a three-story house was 81.74 m^2 (Household 3) and that of a four-story house was 191.18 m^2 (Household 9). In contrast, a typical household in a rural area (Household 15) was situated on a large plot of land (150 m^2) and the total floor area of the main building and annex was 48.46 m^2. The rural houses also usually had ponds/wells, gardens and livestock huts.

In Long An, most of the residences were single-story buildings, and the houses were relatively new compared with the houses in Hanoi. Several households were rebuilding their house with brick and concrete instead of the traditional palm-leaf thatching. On average, the houses were 14–17 years old in Hanoi and 8–9 years old in Long An. All the residential buildings that we visited, except for one apartment in Hanoi, were detached houses or row houses. The average housing unit had a floor area of about 60–80 m^2 and 2–3 bedrooms.

3.3 Ownership of Electronic Appliances

Televisions (TVs), rice cookers and electric fans were items owned by most households regardless of whether they were located in an urban or rural area. In urban areas of Hanoi, ACs were very popular and many households owned two or more units; even some low-income households owned an AC unit. Refrigerators, washing machines and electric water heaters were also owned by low-income households. Many households in urban areas used gas for cooking, but several had switched from gas to electricity for safety concerns. In Hanoi, due to the cold weather in winter, some ACs had both a cooling and heating function, and electric water heaters were used to heat water for bathing. Several high-income households also had a halogen heater in their bathrooms and a stand-up, hanging-type electric clothes dryer.

In rural areas of Hanoi, ACs were not widely used and only high-income households owned one, but most rural households said they would like to have one in the future. We also found that refrigerators, washing machines and water heaters were owned mainly by middle- and high-income households. Several households used both wood and gas for cooking.

In Long An, high-income and several middle-income households in the urban areas owned ACs. One high-income household in a rural area had a plan to install an AC, but most households said that they preferred fans and the natural breeze over ACs, which is in contrast to the rural households in Hanoi. Several households in urban areas of Long An were planning to install ACs in their bedrooms. The main reason for purchasing an AC was to provide greater comfort and a healthy environment for their children while they are studying or sleeping. Most people, excluding old people and infants, used cold water to shower throughout the year. In general, the older generations are comfortable with bathing with cold water from a nearby river, as they have done from an early age. However, wealthy, white-collar workers who are accustomed to spending their whole day in an air-conditioned office said that they preferred taking a warm shower and that this had become a habit for most of them.

3.4 AC Usage

In Hanoi, the main period in which ACs are used for cooling lasts three months (June–August) in light-use households and seven months (April–October) in heavy-use households. Heating was mainly used by high-income households from December to February.

Fig. 2 Front view of representative housing units in urban (left) and rural (right) areas of Hanoi (a) (b) and Long An (c) (d).

Members of households lacking ACs with a heating function warmed themselves using electric blankets and/or oil heaters. In Long An, the corresponding period of AC use in light-use households was two to six months (March–August), but heavy-use households used their AC all year round. Also, the period of use tended to be longer in households with higher incomes.

To understand more about the daily use of ACs, we asked each household to tell us who switched the AC on or off and how many hours they used the AC in each room. In Hanoi, eight households said that they used the AC while they slept (10 pm to 6 am). In Hanoi, children/grandchildren tended to use ACs for longer hours than did their parents (Fig. 3); the average daily usage time for children/grandchildren was 8.1 h, whereas that for their parents it was 5.3 h. In Long An, four out of six households also said that they used the AC while they slept and the period of usage was one to two hours earlier than that in Hanoi (i.e., 8 pm to 5 am).

Regarding the temperature setting, 12 households said that they used a setting of 25°C–26°C, but some households used a setting 2°C–3°C higher or lower. It should be noted that older family members (grandparents) reported simply turning off the AC rather than adjusting the temperature because they could not read the English on the remote control for the AC unit, whereas the younger family members (parents in their 30s and 40s and their children) reported being able to read the English and understand how to control the AC.

In response to the multiple-choice question, "What do you usually do to reduce electricity consumption when using the AC unit to cool a room?" most people in Hanoi chose "close windows/doors" followed by "limit the time/hours of use," "clean the filter" and "do not turn on/off frequently" (Fig. 4). In Long An, most people chose "clean the filter" and "close windows/doors." No one in either location chose "set air flow direction to horizontal." Only one respondent in Long An chose "do other things," which was to use an energy-saving mode.

Regarding simultaneous use of a fan and AC, more households in Hanoi than in Long An said that they used both at the same time.

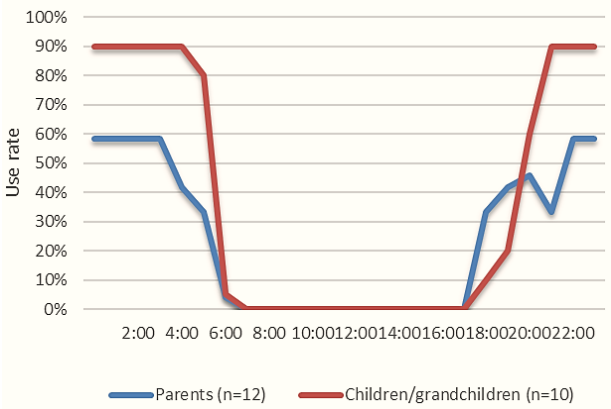

Fig. 3 Daily usage patterns of air conditioning for cooling by households in Hanoi.

3.5 Alternative Methods of Cooling

Regarding alternative methods of cooling, in Hanoi most people chose "open a window and let the wind in" and "do other things" (e.g., use a hand fan), followed by "have a cold drink," "take a shower" and "go to a public space, shopping mall, cafe, etc." (Fig. 5). In Long An, most people chose "have a cold drink," "take a shower," "open a window and let the wind in" and "sprinkle water," meaning sprinkling water over the roads and pavement to lower the temperature via evaporation. No one chose "go to a public space, shopping mall, cafe, etc."

3.6 Energy Saving

Due to the increased ownership of electric home appliances, electricity consumption by low-income households in urban areas and high- and middle-income households in rural areas of Hanoi had reached about 160–280 kWh per month (300–500 thousand VND; 14–23 USD). Electricity consumption of high- and middle-income households in urban areas and high-income households in rural areas in Hanoi had reached 330–670 kWh per month (600–1200 thousand VND; 27–55 USD), approximately twice that of the other groups.

In Hanoi, monthly electricity consumption data were obtained from monthly electricity bills provided by several respondents. The electricity consumption of the households with ACs was highest in summer (May–October) followed by spring (March–April) and winter (January–February); autumn (November–December) was the lowest season. In contrast, the electricity consumption of the households without ACs remained almost the same throughout the year. In rural areas of Hanoi, electricity consumption was highest in summer followed by winter and spring. Electricity consumption in rural areas of Hanoi was highest in winter when they turned heaters on for their livestock.

In Long An, the electricity consumption of the low- and middle-income households without ACs in urban areas and low- and middle-income households in rural areas without ACs was a maximum of 140 kWh per month (250,000 VND; 11 USD). In contrast, the electricity consumption of middle-income households with ACs in urban areas and high-income households with ACs in rural areas was about 200 kWh per month (400,000 VND; 18 USD). The electricity consumption of high-income households with ACs in urban areas reached 1,000 kWh per month (2 million VND; 91 USD).

In response to a question about the household's intention to save energy, 80% of the respondents in Hanoi and 100% of the respondents in Long An said that they tried to save energy, and almost all of these respondents chose "economic reasons" as the trigger for wanting to save energy. With regard to energy-saving labels on electric appliances, the majority of respondents said that they did not remember seeing the labels, which suggests

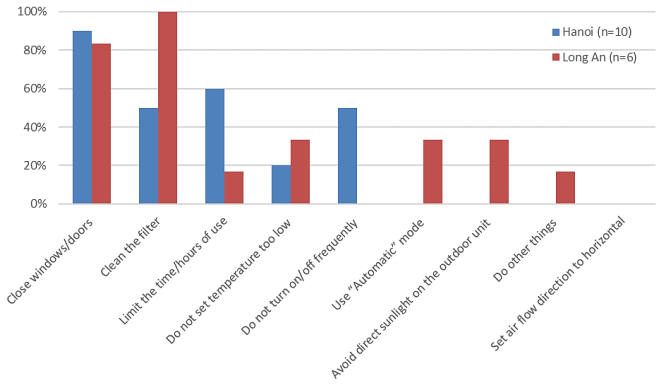

Fig. 4 Responses to the question "What do you usually do to reduce electricity consumption when using the air conditioning unit to cool a room?"

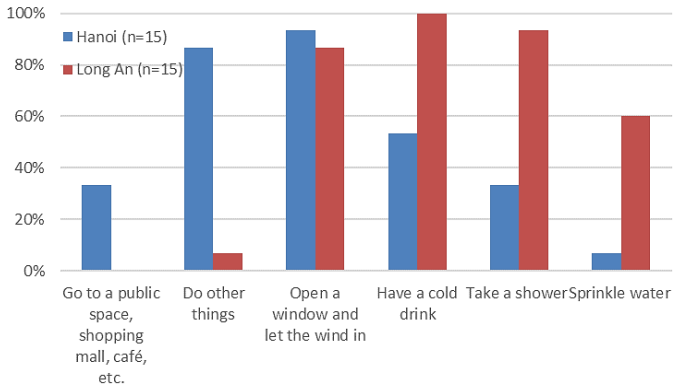

Fig. 5 Methods of cooling besides using air conditioning units or fans (multiple responses were possible).

that the government's publicity and advertising of the meaning of energy labels may not have been successful at leading consumers to purchase products with high energy efficiency.

3.7 Future Prospects

Regarding electric appliances that the respondents planned to buy in the future, the demand for ACs was highest in Hanoi. In Long An, the demand for LEDs (light-emitting diodes) or smart TVs was largest, with ACs third after electric fans. Most households responded that "money" was the main barrier to buying new products; very few households selected "space" or "electric capacity."

Although most of the respondents in Hanoi were unsure about what their ideal lifestyle would be, they tended to choose "healthy" or "convenient & comfortable" instead of "environmentally friendly" as their ideal lifestyle. In Long An, because it had been difficult to obtain clear responses to the question about ideal lifestyles in Hanoi, we changed the question to ask about the changes in their living environment in the past 10 years, as well as future changes that they expected to see in the local area over the next 10/20/30 years. Many people said that they had seen an improvement in infrastructure, manifested in the construction of roads, and that they had been able to purchase household appliances and motorbikes in the past 10 years. They said that they hoped for more improvements in the future.

Thus, from these responses, we can infer that Vietnamese households will likely be demanding more convenient and comfortable lifestyles in the future.

4. Discussion and Conclusion

How does the spread of electric appliances in Vietnam differ from that in Japan in the past? In Japan in the late 1950s, with the rapid growth of the Japanese economy, refrigerators, washing machines and black-and-white TVs were informally referred to as the "three sacred treasures." Like the Imperial Regalia, which represent the three virtues of valor, wisdom and benevolence, these electrical goods were said to be symbols of affluence, longing and convenience. In the mid-1960s, the "sacred treasures" changed to cars, ACs, and color TVs; and in the 1990s to digital cameras, DVD players, and flat-screen TVs. Thus, the items most coveted by people have shifted from home appliances related to daily life to digital home appliances related to entertainment and hobbies.

In contrast, in Vietnam in the 1990s, TVs, video players and motorcycles were the "sacred treasures" for the Vietnamese people (Minagawa, 1997). In fact, data from the Vietnam Household Living Standards Survey (GSO, 2006, 2018) have indicated that the penetration rate of these three items was higher than that of all other items until the first half of the 2000s. It is interesting to note that the penetration rate of video players was higher than that of appliances useful in daily life such as refrigerators and washing machines (Trinh, 2014). Since 2006, the penetration of telephones (including mobile phones) has increased rapidly, whereas that of video/DVD players has decreased, such that mobile phones are now considered to have replaced video players as one of the "sacred treasures" (GSO, 2006, 2018; Trinh, 2014).

In our survey, the penetration rate of ACs was clearly higher among the higher income groups and many households said they would possess more ACs if they had enough money. One obvious factor in owning and using an AC was "increased income." As incomes rose, more people came to live in modern houses and use more electric appliances including ACs. Although the airtightness of houses in Vietnam had somewhat improved (Kim et al., 2000), most respondents reported being dissatisfied with the indoor thermal environment because it was not suitable for Vietnam's hot, humid climate. The thermal environment can be improved by using electric fans and opening windows to increase air flow; however, several respondents pointed out that in reality the windows cannot be opened due to noise or heat caused by

urbanization or because they felt it was unsafe to have a window open at night. Global warming appears to be an additional reason windows cannot be opened. Together, we conclude that these are the major factors leading Vietnamese people to purchase and use ACs (Fig. 6).

Although the Vietnamese government has promoted the use of products with high energy efficiency since 2003 (Nong et al., 2020), few households recognize the energy labels on electric appliances. Koning et al. (2015) found that although awareness and knowledge of sustainable consumption is generally low among the urban middle-class in Vietnam, motivation to live healthy lifestyles and protect the planet for future generations is high. Our study shows that the habit of showering with cold water has been changed by the introduction and use of ACs. As the number of people who spend more hours in air-conditioned rooms increases, it is likely that more people will opt to use ACs for longer hours and to take hot showers. This represents a major shift in the daily behavior of Vietnamese people. However, this also suggests that promoting energy-saving lifestyles among young people (e.g., TV commercials encouraging people to dress in lighter clothes in the office or adopt traditional habits such as bathing with cold water) may help to avoid the overuse of ACs in the future.

Previous studies have suggested improving the indoor thermal environment by improving the thermal performance of residential buildings and promoting the use of high-efficiency ACs (Sawashima & Matsubara, 2017; Le & Pitts, 2019). We found that people's awareness of energy saving is still low, so these hard-type measures are still needed. As the number of households installing ACs increases in both urban and rural areas, however, new measures drawing on a broader perspective are also needed. We need to place equal importance on soft-type policy approaches, such as publication of basic energy-saving tips for AC use and promotion of environmentally friendly lifestyles.

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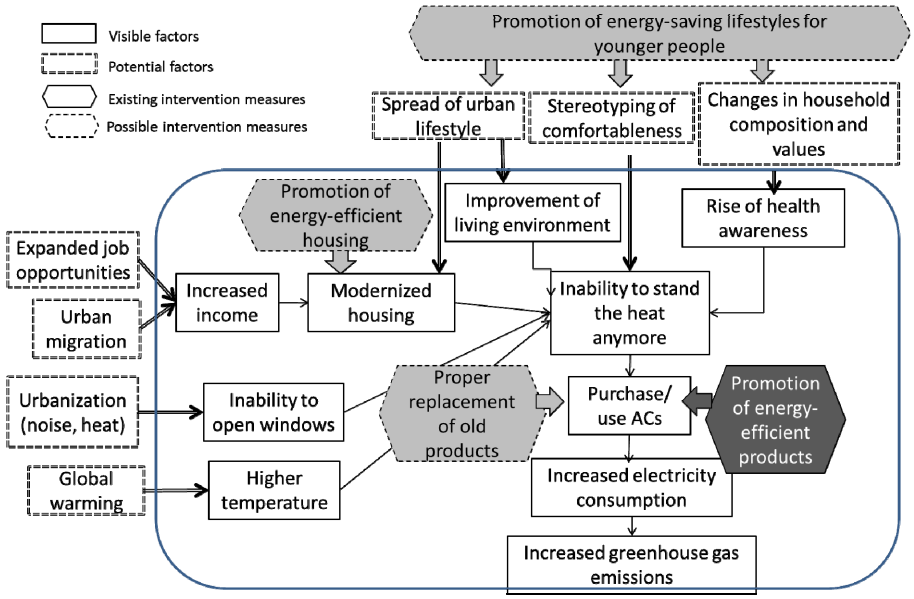

Fig. 6 Motivation for owning and using air condition units, and expected measures to mitigate environmental impacts.

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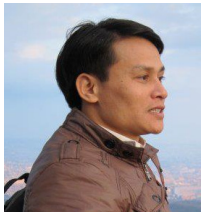

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Estimating Material Flows of Two-wheelers in Cambodia Imported from Asian Countries as Used Products

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Abstract

The increase in the demand for two-wheelers in Cambodia has led to a significant increase in the import of used two-wheelers from Asian countries. The practical lifespan of two-wheelers newly reused in Cambodia is therefore quite short, resulting in the quick and significant generation of end-of-life vehicles. While there has been an increase in the number of studies based on developing waste estimation models, scenarios in which reused products are imported to a given country have not been given significant attention. A model is needed that would account for two-wheelers imported for reuse by second and third owners in Cambodia, considering differences in lifespan among two-wheelers. In a scenario analysis for estimating the number of obsolete two-wheelers, both local production and import for reuse in Cambodia were considered during the period of 2010–2040. A population balance model modified for both cases was used in the scenario analysis. Through these analyses, it was estimated that the number of discarded two-wheelers in Cambodia in 2040 will be in the range of 754,000 to 986,000 units, which is 6.2–8.5 times more than in 2020. Strategies for waste mitigation and effective treatment for resource recycling using discarded two-wheelers in Cambodia are discussed to provide guidelines for avoiding environmental pollution and resource dissipation.

Key words: ELV, environmental dumping, motorcycle, recycling, Weibull distribution

1. Introduction

The demand for various types of products has increased significantly in developing countries in recent years as a result of rapid urbanization, increased population and changing lifestyles (Takahashi, et al. 2017).

The incremental demand for products in developing countries has resulted in an increase in the import and export of used products (Yoshida & Terazono, 2010). Developed countries export large quantities of used products to developing countries for the purpose of reuse (Yoshida & Terazono, 2010).

Exporting large quantities of used products to developing countries for further consumption contributes to extension of the overall lifespan of products and to improved affordability in developing countries (Curran & Williams, 2010). Among waste management approaches, reuse performs well in terms of materials and energy recovery (Lu et al., 2018).

In addition to the positive aspects of exporting used products from developed countries to developing countries, there are some notable drawbacks. Because the used products have already been used for a number of years in another country, the practical lifespan of these newly reused commodities in the developing country is inevitably shorter than that of a new product. The expected consequence of this is a rapid increase in the number of obsolete products in developing countries in a relatively short time frame.

It should be noted that because the current capacity of recycling facilities in developing countries is not sufficient to enable the proper treatment of obsolete products, the disposal of used products in these countries inevitably leads to environmental pollution and resource dissipation (Hoang et al., 2019). Since sustainable

management policies for obsolete products are developed on the basis of estimated waste volume (Kumar et al., 2017), it is important that the waste volumes in developing countries be estimated and that projections be made for the future.

While the demand for various types of products has increased, the global increase in road transportation has led to a massive demand for on-road vehicles. Along with the increase in demand for road transportation, the number of end-of-life vehicles (ELVs), including cars and motorcycles, is expected to increase continuously.

The number of ELVs generated in a number of countries has been estimated, with studies published for China (Hu and Kurasaka 2013), Japan (Tasaki et al., 2001), Belgium (Inghels et al., 2016), and Taiwan (Lin et al., 2018). Collecting data for ELVs is relatively easy in developed countries because the number of ELVs is rigorously managed by vehicle registration systems (Yano et al., 2014). On the other hand, in many developing countries, ELVs are not properly managed due to inadequate registration systems, which makes it challenging to monitor the number of ELVs (Duc et al., 2013). Given that the demand for vehicles is expected to increase and appropriate recycling systems and strategies have yet to be well established, estimating the number of ELVs is important in developing countries. Kurogi et al. (2021) focused on the case in Vietnam, although their study did not estimate the number of ELVs considering that the on-road vehicles had been already used for some years in their country of origin.

Particularly in Asian developing countries such as Cambodia, the penetration rate of two-wheelers is extremely high for a number of types of vehicles (Truong & Ngoc, 2020). In this study, "two-wheelers" are defined as two-wheeled vehicles powered by a motor with no pedals. Cambodia is known to have started importing used products like second-hand two-wheelers and engines a few decades ago (Chanthy & Vilas, 2011). According to BMI Research, from January to June 2020, Cambodia imported 180,590 two-wheelers worth $99 million (B2B CAMBODIA, 2020). Because the two-wheelers had already been used for some years in their country of origin, the practical lifespans of these newly reused two-wheelers in Cambodia were considerably shorter than those of new two-wheelers. Therefore, it is of interest to the authors to estimate the number of obsolete two-wheelers in Cambodia by considering their second and third owners.

Thus, the objective of this study was to estimate the number of obsolete two-wheelers in Cambodia during the period 2010–2040 and design an appropriate management plan for obsolete two-wheelers generated in Cambodia. This study is structured as follows: In Chapter 2, the methodology is presented for analyzing the lifespan of two-wheelers domestically produced in Cambodia and imported from other countries and estimating the number of two-wheelers discarded among obsolete two-wheelers in Cambodia. Chapter 3 focuses on the number of obsolete two-wheelers for the period 2010–2040 in Cambodia, based on three scenarios. The appropriate treatment of obsolete two-wheelers in Cambodia from the perspective of intermediate treatment and final recycling is discussed in Chapter 4. Finally, this study is concluded in Chapter 5.

2. Methodology

2.1 Flow of Two-wheelers to Cambodia from Other Countries in Southeast Asia

It is necessary to grasp the flow of two-wheelers used in other countries and exported to Cambodia as used products. In this study, data on the number of two-wheelers imported to Cambodia were taken from UN Comtrade (United Nations International, n.d.). UN Comtrade is an official repository of international trade statistics. The flow of two-wheelers registered in UN Comtrade covers both new and used two-wheelers with no distinction made between them. This study used data on their import to Cambodia from other countries in Southeast Asia from 2000 to 2019.

2.2 Lifespan Estimation

2.2.1 Definitions

The definition of product lifespan varies in the literature depending on the system employed in the research (Oguchi et al., 2010). Murakami et al. (2010) summarized product lifespan using different terminologies.

This study applied two terminologies relevant to product lifespan. The first terminology is "domestic service lifespan" for both two-wheelers produced domestically in Cambodia and new imported two-wheelers. The domestic service lifespan was defined as the duration of time from the point when the owner is first in possession of the two-wheeler until the moment it is discarded by its final owner and is channeled for treatment and recycling. The second terminology is "extended service lifespan." This is used to refer to two-wheelers imported from other countries. The extended service lifespan is defined as the duration from the point when the 2nd owner or 3rd owner is first in possession in Cambodia until the moment when it is discarded by the final owner and is channeled for treatment and recycling.

According to Tasaki, these definitions are effective for predicting the number of obsolete products and developing an appropriate management strategy for waste (Tasaki, 2006). The concept of a domestic service lifespan has often been used in earlier studies to estimate the number of obsolete products (e.g., Nguyen et al., 2009; Nguyen et al., 2017).

2.2.2 Lifespans of Two-wheelers in Cambodia

It is necessary to consider the lifespans of two-wheelers domestically produced and imported from other countries separately.

The lifespan of two-wheelers domestically produced in Cambodia follows the definition of domestic service lifespan. This study applied the domestic service lifespan of two-wheelers in Vietnam, which had been reported to be 20.3 years, to the case of Cambodia (Kurogi et al., 2021). Cambodia and Vietnam are both Southeast Asian countries and they share a border. Although they differ politically, they have experienced a similar process of economic development with stable price movement (Asian Development Bank, 2011). It was therefore considered reasonable to apply the 20.3 years that had been determined as the domestic lifespan of two-wheelers in Vietnam to the case of Cambodia.

To determine the lifespan of two-wheelers imported to Cambodia, their extended service lifespan needed to be considered. In this study, we focused on import data from five countries: Vietnam, Thailand, India, China and Japan. These five countries account for the majority of two-wheelers imported to Cambodia, representing more than 90%.

Another assumption made in this study was that the duration of use by each owner in Cambodia would be identical to those in Vietnam, China, Thailand and India. The potential applicability of the case in Cambodia to Vietnam was mentioned in Section 2.2.1. It is, however, reasonable that the lifespan of a motorcycle would be different in each country. As such, an assumption was established for each country based on the lifespan reported in the existing literature for that specific country. The study by Kurogi et al. (2021) appears to be the only study which includes a detailed discussion on the lifespan of motorcycles for each generation of owners in Vietnam and Japan. Since the lifespan of a commodity varies depending on GDP per capita (Kosai et al., 2020), this study assumed that Vietnam, China, Thailand and India fell under the same category as developing countries, while Japan is considered to belong to a different category. In practice, as seen in the similar ownership rate of two-wheelers in Thailand and Vietnam (Bach Duong, 2016), the trend of two-wheeler use in developing countries appears to be similar. Meanwhile, the ownership of two-wheelers in Japan differed significantly from that in developing countries (Kurogi et al., 2021). As such, this study employed the domestic service lifespan (or duration of each owner) of two-wheelers in Vietnam identified in the previous study (Kurogi et al., 2021) to the case of Cambodia, China, Thailand and India.

Table 1 Average duration of each owner's two-wheeler use in Vietnam and Japan based on Kurogi et al. (2021).

Country	First owner [years]	Second owner [years]	Third owner [years]
Cambodia, Vietnam, Thailand, India, China	12.1	4.28	2.14
Japan	4.8	2.9	

The average durations of ownership by each owner in Cambodia, Vietnam, India, China, Thailand and Japan are presented in Table 1. Despite the uncertainty under the qualitative assumption, this study at least differentiates among categories of associated countries to some extent.

2.2.3 Estimation of Lifespan Distribution

To estimate the lifespan distribution, this study employed the Weibull distribution function, which is considered to be the most suitable simulation model for product lifespan (Wang et al., 2013). In particular, this study also estimated the number of obsolete two-wheelers considering second and third owners in Cambodia.

The Weibull distribution function for two-wheelers in Cambodia is described in the next chapter. This model differs slightly from existing models, in that our study uses a modified version of the Weibull distribution function based on the extended service lifespan of two-wheelers in Cambodia.

The Weibull distribution function for the two-wheelers domestically produced and imported from other countries is indicated by the following equation:

$$F_t^{\alpha}(y) = 1 - \exp\left[-\left(\frac{y+\sum_{i=1}^{\alpha} X_{\alpha}}{\bar{y}}\right)^{\beta} \cdot \left\{\Gamma\left(1+\frac{1}{\beta}\right)\right\}^{\beta}\right] \quad (3)$$

$$= 1 - R(y) \quad (4)$$

where $F_t^{\alpha}(y)$ is the accumulated obsoletion rate of age y where the product reaches its end of life under ownership generation α, y is the duration of use from the point when the two-wheeler is imported to Cambodia from another country, X_{α} is the duration of ownership generation α in other countries, i.e., X_0 is used when there is no use of the two wheeler in another country (corresponding to a new two-wheeler imported from another country to Cambodia) and X_1 refers to the duration of the first ownership in another country (corresponding to a used two-wheeler imported from another country for a second ownership in Cambodia), $\bar{y}$ is the average lifespan of two-wheelers in Cambodia, β is a shape parameter estimated by confirming how well the curve matches the accumulated distribution percentage of obsolete two-wheelers. Γ is a gamma function. $R(y)$ is the survival rate of two-wheelers in Cambodia in year y.

2.3 Predicting the Number of Obsolete Two-wheelers

The population balance model (PBM) designed by Tasaki was used in many similar studies to predict the number of two-wheelers (Tasaki et al., 2004). This model has been widely used to calculate the number of obsolete products, and it is used to explain scenarios for ELVs in many countries (Yano et al., 2016; Tsasaki et al., 2001; Lin et al., 2018; Yano et al., 2014; Xu et al., 2019). This study also applied the PBM, as it describes the

relationship between the number of possessions, demand and disposals.

The PBM is a model for estimating the flow of obsolete products by considering only the first owner. In this study, the existing PBM was modified to account for the different generations of owners.

2.3.1 New Two-wheelers Domestically Produced in Cambodia

The PBM for two-wheelers domestically produced in Cambodia is indicated by the following equation:

$$N'_t - N'_{t-1} = E_t - W'_t \quad (5)$$

where E_t is the number of two-wheelers which are domestically produced as a new product for which demand existed in Cambodia in year t. N'_t is the number of new domestically produced two-wheelers owned in Cambodia in year t, and W'_t is the number of new domestically produced two-wheelers which are discarded in Cambodia in year t. In this study, data from 2000 to 2019 obtained from research published by Honda (Wedge Holdings, 2017) were used for calculating the number of new two-wheelers domestically produced, representing demand in Cambodia in year t.

W'_t is calculated by the following equation:

$$W'_t = \sum_{i=0}^{t-2000} \{E_{t-i} \times f'_t(i)\} \quad (6)$$

$$f'_t(i) = R'_t(i-1) - R'_t(i) \quad (7)$$

where $f'_t(i)$ is the obsoletion rate of age i in which the end of life of a two-wheeler domestically produced in year t is reached, and $R'_t(i)$ is the survival rate in year i after the two-wheeler produced domestically is shipped. $R'_t(i)$ is calculated in Equation 4 in Section 2.2.3. Based on the data on W'_t and E_t, N'_t is calculated from 2000 to 2019 using the PBM.

This study assumed that the N'_t of Cambodia after 2020 would be on the same upward trend as that of Vietnam. Cambodia and Vietnam are in Southeast Asia and they have experienced a similar process of economic development with stable price movement (Asian Development Bank, 2011). Since the outline of Vietnam's N'_t up to 2004 matches the outline of that of Cambodia up to 2019, N'_t is calculated by multiplying the N'_t of Cambodia up to 2019 by the rate of increase in Vietnam since 2004. The rate of increase in N'_t in Vietnam was estimated by Kurogi et al. (2021). E_t after 2020 is calculated using the PBM based on the N'_t, and N'_t, obtained.

2.3.2 Two-wheelers Imported to Cambodia

The PBM for two-wheelers imported to Cambodia is indicated by the following equation:

$$N"^{\alpha}_t - N"^{\alpha}_{t-1} = F_t{}^{\alpha} - W"^{\alpha}_t \quad (8)$$

where $F_t{}^{\alpha}$ is the number of two-wheelers imported as ownership generation α which represents the demand in year t, $N"^{\alpha}_t$ is the number of two-wheelers imported as ownership generation α and owned in Cambodia in year t. $W"^{\alpha}_t$ is the number of two-wheelers, which are imported as ownership generation α and discarded in Cambodia in year t.

The number of two-wheelers imported from other countries which are discarded in Cambodia in year t is calculated by the following equation:

$$W"_t = \sum_{i=0}^{t-2000} \{F^{\alpha}_{t-i} \times f"_t(i)\} \quad (9)$$

$$f"_t(i) = R"_t(i-1) - R"_t(i) \quad (10)$$

where $f"_t(i)$ is the obsoletion rate of age i in which the end of life of two-wheelers imported in year t is reached, and $R"_t(i)$ is the survival rate in year i after the imported two-wheeler is shipped. $R"_t(i)$ is calculated in Equation 4 in Section 2.2.3. Based on the data on $W"_t$ and $F_t{}^{\alpha}$, $N"_t$ from 2000 to 2019 is calculated using the PBM.

As pointed out above regarding domestically produced two-wheelers, for $N"_t$ after 2019, it is assumed that the number of two-wheelers imported from other countries and owned in Cambodia will increase in the same way as the number of two-wheelers owned in Vietnam. F^{α}_{t-i} after 2019 is calculated using the PBM based on the $N"_t$, and $W"_t$ obtained.

2.3.3 Total Number of Discarded Two-wheelers in Cambodia

The total number of two-wheelers discarded in year t is calculated by the following equation:

$$W_t = W'_t + W"^{\alpha}_t \quad (11)$$

Finally, this study estimated the number of obsolete two-wheelers to be generated in Cambodia by 2040.

3. Results

The number of obsolete two-wheelers in Cambodia was estimated. The results are presented in Fig. 1. This study considered three scenarios where all two-wheelers imported to Cambodia from other countries would be used by first, second and third owners, in turn. That is, a random mixture of ownership generations was not considered here. For instance, the scenario description "Import (1st)+Domestic production" indicates estimation of the total number of obsolete two-wheelers that had been imported to Cambodia from other countries as new products as well as those produced domestically in Cambodia.

To generalize, it is estimated that the number of obsolete two-wheelers in Cambodia will increase year by year in all three scenarios. The estimated number of obsolete two-wheelers drastically increases after 2020. This is because there was an abundance of two-wheelers imported in 2016, which have a great influence on the increase after 2020.

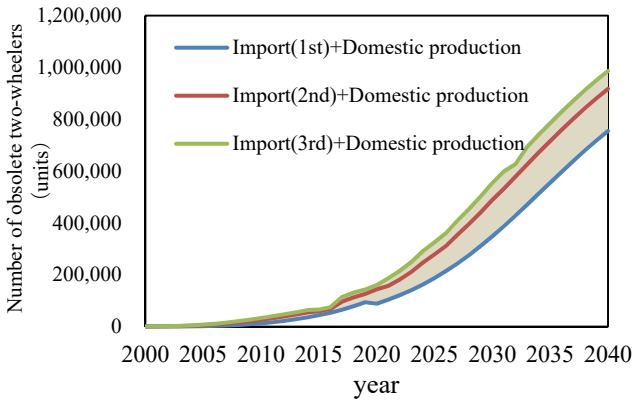

Fig. 1 Estimation of the number of obsolete two-wheelers in Cambodia.

This study demonstrates the features of this trend, using the scenario "Import(2nd)+Domestic production." Here, all two-wheelers imported into Cambodia are considered used products which are used by second owners in Cambodia. The number of two-wheelers discarded in 2030 (approximately 0.49 million units) and 2040 (approximately 0.91 million units) is expected to be 3.4 times and 6.4 times higher, respectively, than that in 2020 (approximately 0.14 million units). The number of two-wheelers owned in Cambodia in the year 2040 is expected to be 16,000,000 units, and the average number of two-wheelers per capita in 2040, 0.87 units.

Based on these three scenarios, it can be said that the conceivable number of obsolete two-wheelers in Cambodia is within the gray range in Fig. 1, with an error range of ± 10% in the reliability of this result. Meanwhile, this error range indicates that different ownership generations for imported two-wheelers result in a significant difference in the estimate. This suggests that the shorter lifespan of two-wheelers imported from other countries shortens the disposal cycle. For instance, it was found that the number of discarded two-wheelers in Cambodia under the scenario of "Import (3rd) + Domestic production" in 2040 (986,000 units) would have increased by a factor of 1.31 compared to that under the scenario of "Import (1st) + Domestic production" (754,000 units).

In this way, the real number of obsolete two-wheelers in Cambodia may be greater than the estimated number of obsolete two-wheelers in Cambodia based on the existing PBM, which does not consider different ownership generations. This is a clear indication that Cambodia urgently needs treatment measures for discarded two-wheelers.

4. Discussion

In the previous chapter, the estimated number of obsolete two-wheelers in Cambodia during the period up to 2040 was presented. To address the issue of treating significant quantities of obsolete two-wheelers in Cambodia, it will be important to develop an appropriate management strategy for two-wheelers in Cambodia.

Appropriate treatment of obsolete two-wheelers needs to be executed in two steps: intermediate treatment and final recycling. At intermediate treatment facilities, obsolete two-wheelers would be manually disassembled and crushed using a machine so that the waste could be processed smoothly. At the final recycling facilities, the waste would be recycled according to how it was classified as a resource in the intermediate treatment facilities. From the perspectives of intermediate treatment and final recycling, we considered what would be required to ensure that obsolete two-wheelers in Cambodia are treated appropriately.

4.1 Intermediate Treatment

The current capacity for intermediate treatment in Cambodia is not sufficient to meet the requirements for the proper treatment of the waste from obsolete two-wheelers (JICA, KOA SHOJI, FORVAL 2016). Therefore, we investigated the possibility of installing an intermediate treatment facility in Cambodia.

Regarding the number of obsolete two-wheelers to be processed, the scenario "Import (3rd) + Domestic production" provided in Chapter 3 was used to represent the worst case scenario in Cambodia.

To suggest the systems required for appropriate intermediate treatment of two-wheelers in Cambodia, a field survey was conducted at one of the formal intermediate facilities in Japan as a representative case. In the case of the disassembling process, a facility covering approximately 1,000 m^2 of land deals with approximately 2,000 units per person per year, with 24 laborers working fulltime. This means that 24 workers are capable of manually disassembling 48,000 motorcycles in one year at a single intermediate treatment facility. Assuming that installations with equivalent capacity to that in Japan were established in Cambodia, a total of 21 intermediate treatment facilities equivalent in capacity to one Japanese intermediate treatment facility would be required by 2040 in order to disassemble the projected number of obsolete two-wheelers in Cambodia.

Crushing machines and backhoes are used in the crushing process. The number of crushing machines required to deal with the estimated number of obsolete two-wheelers in Cambodia in 2040 was estimated. It was assumed that a general crushing machine with a maximum processing capacity of three tons per hour was installed. If this crushing machine is operated for eight hours per day on 250 days per year, 6,000 tons of obsolete two-wheelers could be crushed by this single crushing machine annually. Considering that the weight of the typical two-wheeler is 73 kg, the amount of waste from two-wheelers in Cambodia in 2040 was estimated at 72,000 tons. Based on these data, 12 crushing machines will be required by 2040 in Cambodia. Considering that 21 intermediate treatment facilities will be required by

2040 under the perspective of the disassembly process, the installation of a single crushing machine at each intermediate treatment facility would be sufficient in Cambodia.

4.2 Final Recycling Facility

Landfilling is a major waste treatment method in Cambodia (Singh, et al. 2018). At present, the appropriate recycling systems have yet to be established. It is not considered likely that the necessary number of treatment facilities can be established with the capacity to properly treat all the obsolete two-wheelers domestically in Cambodia by 2040. Thus, the possibility of engaging neighboring countries for cooperation in dealing with the large quantity of obsolete two-wheelers must be considered as a course of immediate action.

To consider the requirements for final recycling facilities, we estimated the amount of waste materials contained in the two-wheelers in Cambodia. The amount of each material contained in an obsolete two-wheeler in Cambodia was estimated by using the estimated number of obsolete two-wheelers in Cambodia, which was calculated as indicated in Chapter 3, based on the data for the composition of two-wheelers. The scenario "Import (3rd) + Domestic production", as provided in Chapter 3, was used to demonstrate the features of the worst case scenario in Cambodia. The amounts of each material contained in a two-wheeler were estimated by Kurogi et al. (Kurogi, et al. 2021).

Based on these data, the amounts of waste materials contained in a two-wheeler in Cambodia were estimated, as shown in Fig. 2. There is more steel than any other metal contained in a two-wheeler: the amount of steel discarded from obsolete two-wheelers in Cambodia in 2040 is predicted to be approximately 30,000 tons. After steel, the metal contained in the largest quantity in two-wheelers is the aluminum alloy, ADC12. Approximately 19,000 tons of waste ACD12 can be expected to be generated from obsolete two-wheelers in Cambodia in 2040. It is important to collect and recycle these metals efficiently from obsolete two-wheelers.

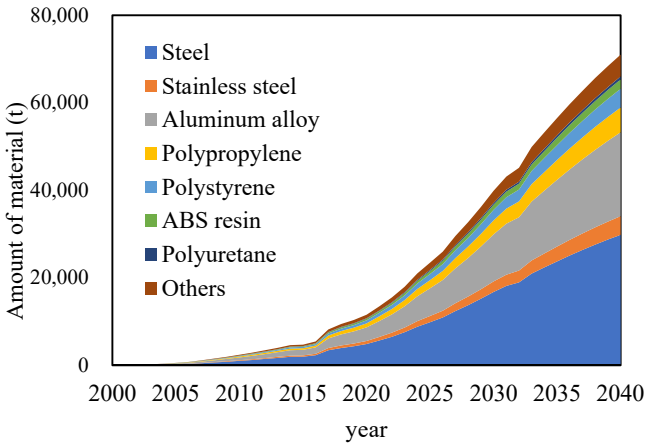

Fig. 2 Estimation of the amounts of waste materials contained in two-wheelers in Cambodia under the Scenario "Import (3rd) + Domestic production."

Since there is more steel than any other metal contained in a two-wheeler, we considered the case of steel in more depth. It is important to ensure that the steel from obsolete two-wheelers is efficiently recycled. The capacities of final recycling facilities for iron scrap in 2019 in neighboring countries, such as Vietnam and Laos have been confirmed (Cravioto, et al. 2021). These capacities were compared with the amount of iron scrap waste generated from obsolete two-wheelers in Cambodia.

The capacity of final recycling facilities to process iron scrap wastes in Vietnam is reported to be approximately 1,148,000 tons, and that in Laos, about 0.15 tons (Cravioto, et al. 2021). Considering there are 30,000 tons of iron scrap contained in the obsolete two-wheelers in Cambodia, the capacities of final recycling facilities in neighboring countries would be capable of handling the amount of iron scrap waste from Cambodia's obsolete two-wheelers. That is, it will be possible for the iron scrap wastes generated from the obsolete two-wheelers in Cambodia to be properly treated if they are delivered to the appropriate treatment facilities in Vietnam.

As mentioned above, used products are imported into Cambodia from neighboring countries like Thailand and Vietnam. It should be stressed that these exporting countries also need to take responsibility for dealing with the materials in obsolete used products like two-wheelers. An agreement will need to be made between Cambodia and neighboring countries arranging for all of the iron scrap waste to be delivered to the appropriate treatment facilities to ensure that these valuable materials are not wasted. In addition, an optimal transportation system connecting peripheral countries in the ASEAN region should be considered as part of the responsibility for dealing with the materials of obsolete used products like two-wheelers.

4.3 Limitations

In this study, we estimated the number of obsolete two-wheelers to be generated in Cambodia during the period 2010–2040. Several limitations, however, must be acknowledged. It should be noted that this study assumed that the trends in the ownership rates in Cambodia and Vietnam will be the same. The two-wheeler ownership rate may decrease with the growing number of privately owned cars and the development of infrastructure in Cambodia, such as railways, subways and a bus system. If the ownership rate in Cambodia decreases, it is possible that the number of obsolete two-wheelers will actually decrease.

In addition, this study assumed the lifespan of two-wheelers to be constant, whereas the practical lifespan will inevitably change with economic development (Kosai et al., 2020). According to a study by Kosai et al. (2020), the lifespan of two-wheelers in

Cambodia is expected to become shorter in the near future. It is necessary to develop a policy to provide an incentive for extending the lifespan of Cambodia's two-wheelers.

Although this study differentiates among associated countries in rough categories in terms of lifespan, it would be reasonable to expect that the average duration of each ownership in Cambodia, Vietnam, India, China and Thailand would actually differ. Further analysis to determine the lifespan of two-wheelers more accurately for each of the associated countries will also be necessary. Moreover, though this study employed data from gasoline-fueled two-wheelers, it is reasonable to expect that the share of electric two-wheelers will increase in the future. It will be necessary to consider changes in the waste materials contained in two-wheelers in Cambodia from this perspective. These perspectives will be addressed in a future study.

5. Conclusion

In this study, the flow of two-wheelers to Cambodia from other countries in Southeast Asia was estimated using UN Comtrade data. Then, the lifespans of two-wheelers domestically produced in Cambodia and imported from other countries were analyzed, and lifespan distributions were determined using the Weibull distribution for each case. The existing population balance model was modified to account for the different generations of owners. The number of obsolete two-wheelers in Cambodia was estimated during the period 2010–2040 using the population balance model modified accordingly to consider the reuse of two-wheelers imported from other countries and used by second and third owners in Cambodia. Finally, the requirement to ensure the appropriate treatment of obsolete two-wheelers in Cambodia was considered from the perspective of intermediate treatment and final recycling.

We found that the number of discarded two-wheelers in Cambodia in 2040 will be in the range of 754,000 to 986,000 units. Since this is between 6.2 and 8.5 times higher than that of 2020, ensuring that obsolete two-wheelers can be appropriately handled must be considered a top priority issue.

Acknowledgement

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Sustainable Consumption in Terms of Subjective Well-being in Asia

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Abstract

This study presents an overview of our research on the association between consumption and subjective well-being (SWB) to suggest implications for sustaining SWB within the context of environmentally sustainable consumption. Future environmental burdens, such as reaching planetary boundaries, require us to suppress overconsumption. For developed countries, where the population consumes disproportionately more resources, considering how to sustain SWB even if people reduce their consumption levels is necessary. For developing countries, where people are increasing consumption as their economies develop, considering how to realize high SWB while considering future environmental restraints is imperative. Therefore, for both developed and developing countries, improving SWB-per-unit consumption is important. We conducted five surveys in rural and urban Vietnam and Japan from 2016 to 2021. Our estimation results suggest the following: (1) Paying attention to relational consumption rather than material consumption is important; (2) for material consumption, a sharing economy based on strong social capital is efficient; and (3) for material consumption, individuals who take better care of their possessions exhibit increased SWB-per-unit material consumption. We conclude that having individuals develop an attachment to material goods and value social capital is requisite for improving SWB through material and relational consumption.

Key words: material consumption, relational consumption, subjective well-being, sustainable consumption

1. Introduction

If developing countries could emulate the current consumption patterns of developed countries, the entire world would be on equal footing regarding consumer behavior. However, this scenario could exacerbate the increasing global environmental burden. Furthermore, if consumption levels in developed countries are not reduced, existing problems will only be aggravated. To realize sustainable global consumption (as advocated in the ongoing discourse on planetary boundaries), developed countries' current consumption levels and developing countries' expected future consumption levels must be reduced.

In this study, we investigated whether a lifestyle providing optimal and sustainable utility to consumers would be feasible for developed and developing countries. If such a lifestyle can be clearly defined, a viable consensus on sustainable consumption may be realized. Moreover, establishing that an increase in consumption is not necessarily correlated with an increase in subjective well-being (SWB) may suppress rampant consumption.

2. Method

Given the limit on the absolute level of material consumption implied by planetary boundaries, individuals in developed countries must consider how to decrease their absolute level of material consumption. As shown in Fig. 1, if the current relationship between consumption and SWB in developed countries corresponds to Path B, a decrease in consumption could lead to significant

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decrease in their SWB. Therefore, a move from Path B to Path A is required, as indicated by the arrow in Fig. 1. Conversely, in developing countries, individuals expect SWB improvements to accompany economic growth. To suppress overconsumption and keep consumption levels below planetary boundaries, we need to improve individuals' SWB-per-unit consumption. This could be achieved by changing from Path B to Path A. This would enable consumption within planetary boundaries to avert deterioration in SWB when consumption levels increase along with economic growth. Therefore, a move from Path B to Path A is also needed for developing countries. Thus, to realize Path A, increasing SWB-per-unit consumption is necessary, as represented by the arrow in Fig. 1.

To this end, one important task is classifying consumption. If individuals experience a higher degree of SWB by consuming one product rather than another at the same cost, they will achieve greater SWB. Studies have reported that social capital exerts a significantly positive influence on SWB. Further, Bjørnskov (2003) reports that social capital affects happiness to a greater degree compared to income at least in developed countries. Thus, relational goods or consumption may exert a significant influence on SWB. Essentially, by engaging in consumption involving social interaction, the consumer may simultaneously experience greater satisfaction related to social capital and a corresponding increase in SWB.

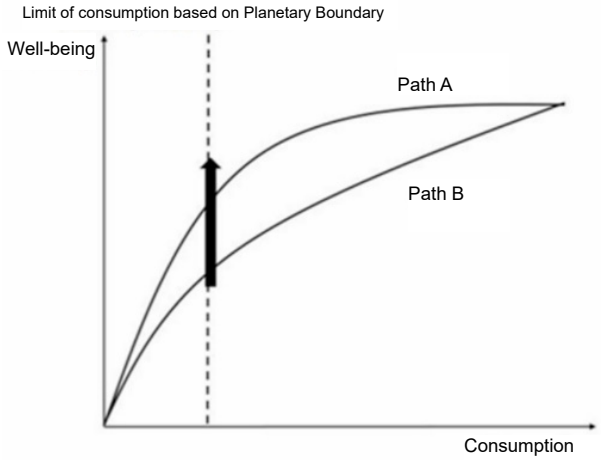

Fig. 1 Effect of decreasing or increasing consumption levels on SWB based on planetary boundaries. Source: Tsurumi et al. (2021a).

Because the environmental load from relational consumption is not necessarily insubstantial, we must be careful not to equate an increase in consumption with a decrease in environmental load. However, if the correlation between the completely solitary consumption of goods and an increase in SWB can at least be affirmed as difficult to establish, we can begin investigating whether such goods should be unwelcome in the future. We have focused not only on the total amount of consumption expenditure and types of consumption (i.e., material and relational consumption) but also on individuals' various ways of thinking and beliefs, which include the principle that it is best to lead a simple life with minimal material possessions, belief in the Confucian teaching that "a contented mind is a perpetual feast," Maslow's hierarchy of needs (Love), environmental ethics, and attachment to material goods. These beliefs can affect the relationship between consumption and SWB and whether high SWB can be achieved through reduced consumption.

To examine the relationship between consumption and SWB, we present the following equation:

$$SWB_i^k = \varphi_1 + f\left(consumption_i\right) + \sum_j \alpha_j X_{ij} + \varepsilon \quad \cdots (1)$$

where i represents the individual and k represents the SWB indicator of type k, with k being any of the following five types: the Cantril Ladder, life satisfaction, subjective happiness, affect balance and *eudaimonia*. φ_1 is a constant. The main independent variable, $consumption_i$, represents consumption of i (total consumption or both material and relational consumption). X_{ij} represents control variables used in prior SWB studies (i.e., age, gender, level of subjective health, education, marriage and having children). Furthermore, as consumption expenditure is reported per household, we also control for the number of people in the household. Finally, α_j represents coefficients, and ε is the uncorrelated error term. To identify the different functional forms of consumption clearly, we utilized nonparametric functions for consumption. Regarding the other explanatory variables, we accounted for parametric functions and applied a semiparametric regression. Five surveys were conducted from 2017 to 2021, as shown in Table 1.

Table 1 Our original surveys.

	Survey period	Methods	Country/region	Observations
Survey 1	March 2017	Internet survey	Japan (nationwide)	N = 13,690 (valid responses: 9,635)
Survey 2	March 2018	Internet survey	Vietnam (urban area)	N = 2,218 (valid responses: 1,370)
Survey 3	March 2019	Face-to-face survey	Vietnam (rural area: Thieu Ngoc)	N = 2,052 (valid responses: 1,921)
Survey 4	March 2020 (follow-up survey of survey 3)	Face-to-face survey	Vietnam (rural area: Thieu Ngoc and Darsal)	Thieu Ngoc: N = 1,824 (valid responses 1,250), Darsal: N = 3,043 (valid responses 2,435)
Survey 5	November 2020, March 2021 (follow-up survey to Survey 1)	Internet survey	Japan (nationwide)	November 2020 (N = 2,500; valid responses: 1,639), March 2021 (N = 3,214; valid responses: 2,748)

Table 2 Main survey questions.

		Survey question
SWB	*Cantril ladder*	Please imagine a ladder with steps numbered from 0 at the bottom to 10 at the top. The top of the ladder represents the best possible life for you, while the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say that you stand at this time? Responses are given on an integer scale from 0 to 10.
	Life satisfaction	Overall, how satisfied are you with your life? Responses are given on an integer scale from 1 ("not at all satisfied") to 5 ("completely satisfied").
	Subjective happiness	Overall, how happy are you with your life? Responses are given on an integer scale from 1 ("unhappy") to 5 ("very happy").
	Eudaimonia	Overall, to what extent do you feel that the things you do in your life are worthwhile? Responses are given on an integer scale from 0 ("not at all worthwhile") to 10 ("completely worthwhile").
	Affect balance (within a week)	How often have you felt or experienced the following feelings or actions? Please answer in terms of a week. Positive affect: pleasure, enjoyment, smile. Negative affect: anger, sadness. Four-step evaluation; 4 = "often," 3 = "sometimes," 2 = "rarely," and 1 = "not at all." A balance of five affect categories derived from the average values of positive affect categories minus those of negative affect categories.
Household income (US$)		Please tell us your yearly household income.
Total consumption (US$)		Approximately, how much does your household spend monthly on consumption?
Material consumption (US$)		What is the average monthly amount spent in your household to purchase "goods" (electrical appliances, furniture, clothes, shoes, publications and other sundries, excluding expenditure related to housing, cars and bikes)?
Relational consumption (US$)		What is the average monthly amount spent in your household on "consumption relating to interactions with your family, relatives, friends and acquaintances" (e.g., travel, gifts, dining with them in your own home or outside, excluding expenditure related to housing, cars and bikes)?

Table 3 Our five analyses

	Theme	Data	Publication
Analysis 1	Relationship between consumption and SWB in Japan	Survey 1	Tsurumi et al. (2020b)
Analysis 2	Effects of "way of thinking and belief" on the relationship between consumption and SWB in Japan	Survey 1	Tsurumi et al. (2020a)
Analysis 3	Relationship between consumption and SWB in urban and rural Vietnam	Surveys 2, 3, and 4	Tsurumi et al. (2021b)
Analysis 4	Effects of attachment to material goods on the relationship between consumption and SWB: Evidence from rural Vietnam	Survey 4	Tsurumi et al. (2020c)
Analysis 5	Relationship between consumption and SWB in Japan: Comparison of before and during the COVID-19 pandemic	Surveys 1 and 5	Tsurumi et al. (2021a; 2021c)

Table 2 presents the main survey questions. We conducted five types of analyses, which are summarized in Table 3. We present an overview of their results in the next chapter.

3. Results

3.1 Analysis 1: Relationship between Consumption and SWB in Japan (Tsurumi et al., 2020b)

Figure 2 presents simplified estimation results for the relationship between monthly household total consumption expenditure and SWB. We found that total consumption contributed to life evaluation (life satisfaction and the Cantril ladder), while emotional well-being (affect balance) had a certain threshold. The definitions of total monthly household consumption expenditure and SWB are presented in Table 2. Figure 2 implies that increasing total consumption could improve individuals' life evaluation, which makes mitigating rampant consumption difficult.

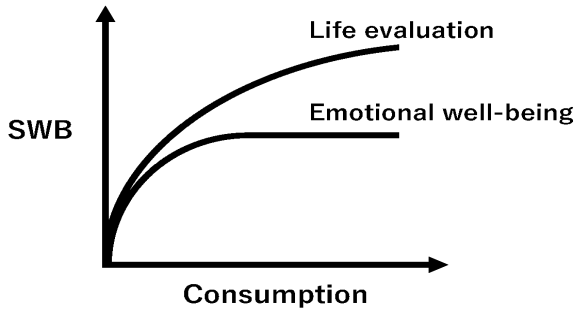

Fig. 2 Consumption and SWB (Japan). Based on the results of Tsurumi et al. (2020b).
Note: Vertical line corresponds to life evaluation (life satisfaction and the Cantril ladder) and emotional well-being (affect balance).

Figure 3 shows simplified estimation results of the relationship between material consumption and SWB, and that between relational consumption and SWB. The definitions of both material consumption and relational

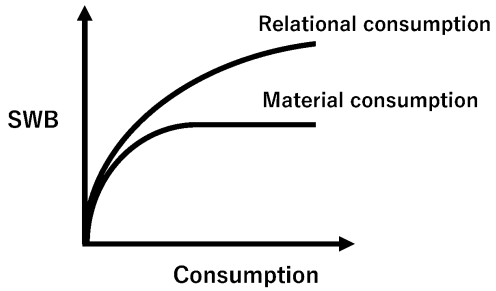

Fig. 3 Relational and material consumption and SWB (Japan). Based on the results of Tsurumi et al. (2020b).
Note: Vertical line corresponds to both life evaluation and emotional well-being.

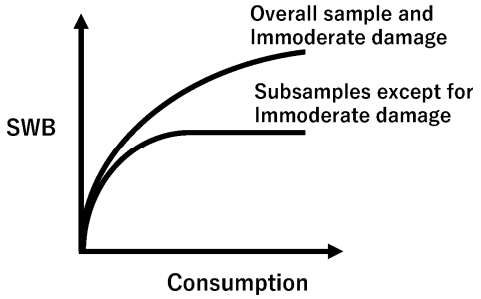

Fig. 4 Consumption and SWB in Japan (Overall sample and subsamples). Based on the results of Tsurumi et al. (2020a).
Note: Vertical line corresponds to life evaluation (life satisfaction).

Table 4 Definitions of subsamples.

Subsample	Definitions
Subsample A	Which of the following statements best describes your "ideal life"? Please select all options (as many as you wish) describing your ideal life (sample selection "Living a simple life with minimal material possessions": N = 2752).
Subsample B	Question: "A contented mind is a perpetual feast" is a Confucian teaching. Basically, "Human desires are endless, but a person who is satisfied living within his means and does not crave for more is happy and rich. A person who is pleased with today and has no complaints about the present is blessed with a life of contentment." Do you believe in this teaching? (sample selection "I believe in it": N = 3,541)
Subsample C	Regarding Maslow's hierarchy of needs, how satisfied are your needs at stage 3 (Love)? (sample selection: "Satisfied")
Subsample D-1, D-2, D-3, and D-4	Please tell us whether you agree with the following: D-1. Irreversibility: Once destroyed, the natural environment can never be restored to its prior state (sample selection "Agree": N = 3,027). D-2. Intergenerational equity: We must pass on to future generations the natural and cultural legacy we have received from prior generations (sample selection "Agree": N = 2,967). D-3. Intergenerational equity (with the cost of sacrifices): Even at the cost of sacrifices from our generation, we must leave behind a natural environment in good shape for future generations (sample selection "Agree": N=1,836). D-4. Immoderate damage: If things go on this way, there will be enormous environmental destruction and disasters in the future (sample selection "Agree": N = 3,438). Sources: Ekins et al. (2003) and Ekins (2014)

consumption are shown in Table 2. We found that relational consumption contributed to all measures of SWB without clear upper bounds. In contrast, material consumption contributed to all measures of SWB only up to certain thresholds.

3.2 Analysis 2: Effects of "Way of Thinking and Belief" on Relationship between Consumption and SWB in Japan (Tsurumi et al., 2020a)

In Analysis 2, we investigated the relationship between consumption and SWB using the subsamples shown in Table 4. This study aimed to investigate whether belief or environmental ethics affect the relationship between consumption and SWB.

Figure 4 presents simplified estimation results. The results show that, although there are no SWB (life satisfaction) satiation thresholds for total consumption among people in Japan on average, there are satiation thresholds among some subsamples. A simplified SWB (life satisfaction) satiation point for these subsamples, exclusive of "Subsample D-4: Immoderate damage," is illustrated in Fig. 4. The implication is that those subsamples have no incentive for increasing their total consumption after a certain threshold, which may suppress overconsumption.

No satiation threshold exists for individuals who have environmental ethics concerns, such as fear of causing "immoderate damage." Thus, we need to acknowledge that, even if we merely recognize the gravity of environmental problems (i.e., "immoderate damage"), changing our relationship between consumption and SWB is difficult. Additionally, our estimation results imply that individuals who professed to fulfill Maslow's hierarchy of needs (Love) may be connected with those who place great importance on future generations' wellbeing. Thus, the concepts of irreversibility and intergenerational equity could be similar to the concept of granting great importance to social capital or future generations, which may also suppress overconsumption.

3.3 Analysis 3: Relationship between Consumption and SWB in Urban and Rural Vietnam (Tsurumi et al., 2021c)

Analyses 1 and 2 suggest that (1) in Japan, total consumption contributes to better life evaluations without clear upper bounds; (2) however, a SWB saturation point

for total consumption among individuals who have "certain ways of thinking and belief" exclusive of belief in "immoderate damage" is evident in Fig. 4; (3) relational consumption contributes to all SWB measures with no clear upper bounds, while material consumption contributes to all SWB measures only up to certain thresholds.

The above results, however, may be specific to developed countries. Therefore, Analysis 3 reveals the relationship between material and relational consumption and SWB in rural and urban Vietnam. The simplified estimation results for urban Vietnam shown in Fig. 5 suggest that neither the relationship between material consumption and SWB nor the relationship between relational consumption and SWB has any statistically significant correlation. This may imply that SWB saturation exists concerning material consumption even in developing countries. Moreover, it may imply that people in urban Vietnam place little importance on social capital. Conversely, the simplified estimation results in rural Vietnam shown in Fig. 6, suggest that relational consumption contributes to SWB without clear bounds. This finding implies that people in rural Vietnam place greater importance on social capital.

We also found a negative correlation between material consumption and SWB. Our additional analysis shows that individuals who exhibited a high frequency of bartering have relatively high SWB. Overall, our estimation results imply that SWB saturation vis-à-vis material consumption can be observed even in developing countries' rural areas. Additionally, our results show that relational consumption and material consumption can significantly increase individuals' SWB if they have strong connections with their neighbors or if they engage in bartering. Our findings imply that a sharing economy with strong social capital could be key to sustainable consumption.

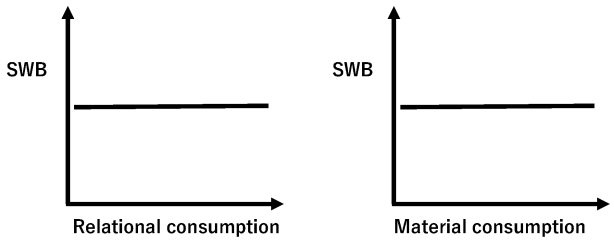

Fig. 5 Relational and material consumption and SWB (urban area in Vietnam). Based on the results of Tsurumi et al. (2021a).
Note: Vertical line corresponds to life evaluation and emotional well-being.

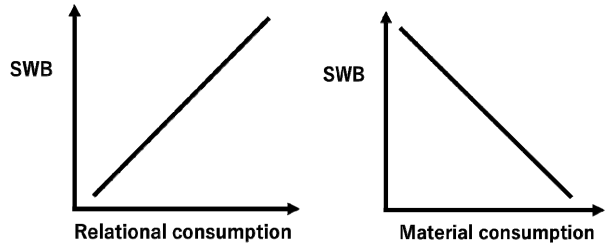

Fig. 6 Relational and material consumption and SWB (rural area in Vietnam). Based on the results of Tsurumi et al. (2021a).
Note: Vertical line corresponds to life evaluation and emotional well-being.

3.4 Analysis 4: Effects of Attachment to Material Goods on Relationship between Consumption and SWB: Evidence from Rural Vietnam (Tsurumi et al., 2020c)

In Analysis 3, we found that increased material consumption was not associated with increased SWB in rural Vietnam. If an increase in material consumption diminishes SWB (as with economic development), economic growth could have a negative effect on SWB. Thus, considering how to increase SWB through material consumption is necessary. Some individuals tend to use the same material goods more extensively than others. These particular individuals consume fewer material inputs, other things being equal. In Analysis 4, we investigate whether these individuals are happier. To examine individuals' characteristics, we asked the following: "Please select all applicable items. – I want to utilize "goods" and look after them for as long as possible (attachment dummy = 1: applicable; attachment dummy = 0: not applicable)." We then divided our sample into Group A (with attachment) and Group B (without attachment). Group A corresponded to "attachment dummy=1" and Group B corresponded to "attachment dummy=0."

Figure 7 shows simplified estimation results. We found that for Group A (individuals who take better care of their possessions), increased consumption is linked to increased SWB (life satisfaction), whereas for Group B (individuals who do not take good care of their possessions), increased consumption is linked to decreased SWB. This implies that a lifestyle wherein individuals take better care of their possessions increases SWB-per-unit consumption. This finding also has a useful policy implication for developing countries, who can improve their SWB by promoting economic growth alongside responsible consumption.

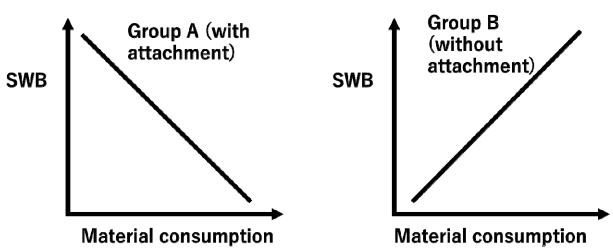

Fig. 7 Material consumption and SWB (rural area in Vietnam). Based on the results of Tsurumi et al. (2020c).
Note: Vertical line corresponds to life satisfaction.

3.5 Analysis 5: Relationship between Consumption and SWB in Japan: Comparison of Before and During the COVID-19 Pandemic (Tsurumi et al., 2021b; Tsurumi et al., 2021c)

The COVID-19 pandemic may have had a great impact on relational consumption because people have been required to spend more time indoors. Analysis 5 investigated the pandemic's impact on SWB.

Figure 8 shows descriptive statistics on SWB (life satisfaction and affect balance) and consumption (material and relational consumption) (see Table 2 for definitions) before and during the COVID-19 pandemic in Japan. Both life evaluation (life satisfaction) and emotional well-being (affect balance) significantly decreased from November 2019 to November 2020. Regarding consumption, although material consumption exhibited little change, relational consumption dramatically decreased. Further, we investigated the determinants of SWB change before and during the COVID-19 pandemic. We utilized two-period datasets: dataset A corresponded to Survey 5, which covered 2019 and 2020 for the same respondents, whereas dataset B corresponded to surveys 1 and 5 for the same respondents, comprising both March 2016 and 2020. The first-differences estimations were applied in the regression. We obtained similar estimation results between Dataset A and Dataset B. The results show that, for both life evaluation and emotional well-being, approximately 50% of the decrease in SWB can be explained by a decrease in relational consumption after controlling for the effect of concerns surrounding infection rates in individuals' residential area. This implies that relational consumption is the main determinant of SWB and that the COVID-19 pandemic had negative effects on SWB mainly by decreasing relational consumption.

4. Conclusions

This study presents an overview of our research regarding the relationship between consumption and SWB. Analyses 1 to 5 suggest that the key factors to improving SWB-per-unit consumption under the constraint of planetary boundaries are as follows: (1) paying attention to relational consumption, rather than material consumption is important; (2) for material consumption, having a sharing economy based on strong social capital is efficient; and (3) for material consumption, individuals who take better care of their possessions exhibit increased SWB-per-unit material consumption. Significantly, relational consumption did not contribute to SWB in urban Vietnam. Our survey data suggest that people in urban Vietnam place relatively less importance on social capital than people in rural Vietnam and Japan. For people in rural Vietnam, where strong social capital exists, and for people in Japan, where people tend to recognize the importance of social capital after experiencing social capital losses related to urbanization, relational consumption is key to improving SWB-per-unit consumption. People in urban areas in developing countries need to place greater importance on social capital to improve their SWB-per-unit consumption. Additionally, improving SWB through material consumption requires placing greater importance on attachment to material goods once again, so they are

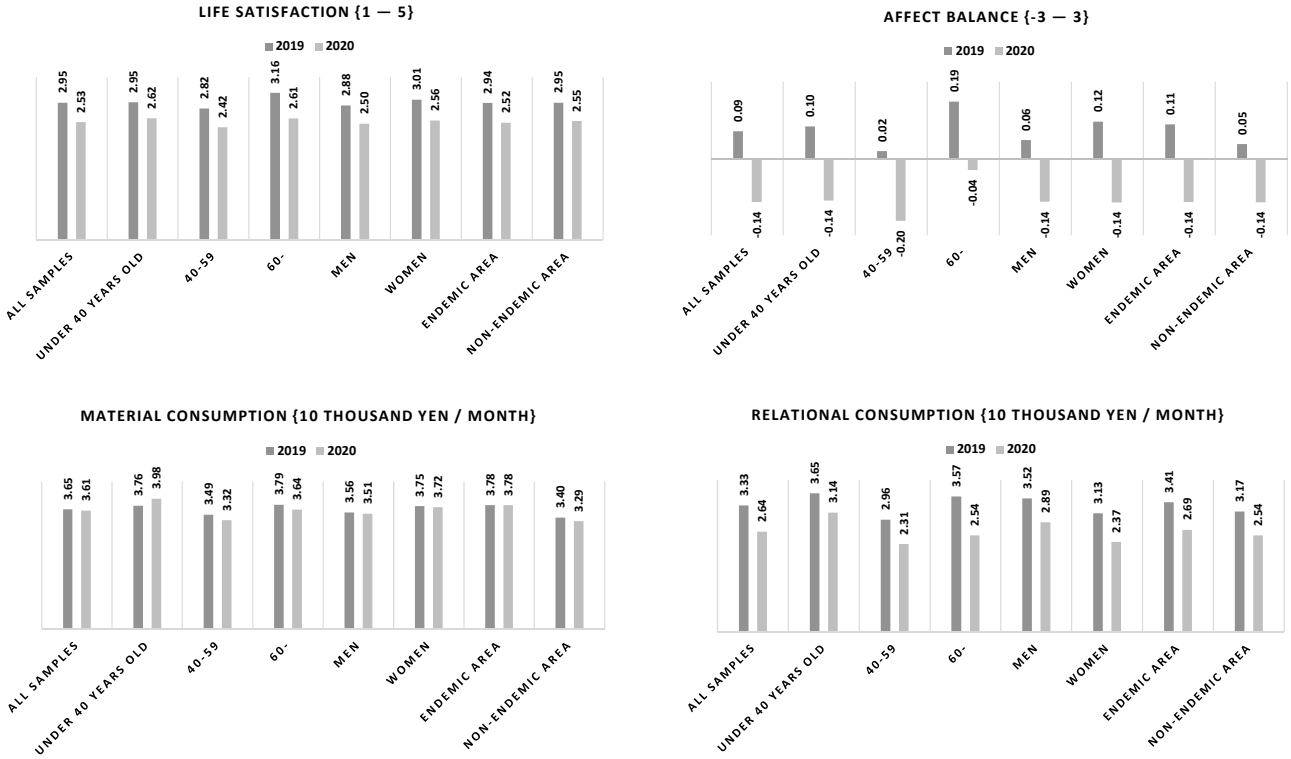

Fig. 8 Consumption and SWB before and during the COVID-19 pandemic (Japan). Source: Tsurumi et al. (2021b).

preserved longer rather than being quickly discarded. Thus, reestablishing individuals' attachment to social capital and material goods is necessary.

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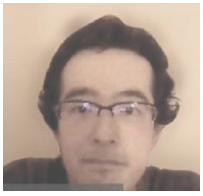

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The Sustainable Development Goals as a Tool for Analysis: SCP Linkages with Economic, Social, and Environmental Agendas

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Abstract

The 17 Sustainable Development Goals (SDGs) and their 169 targets are not independent of each other but have mutual impacts. These connections are referred to as interlinkages or cohesive actions. To achieve the SDGs, integrated solutions across sectors are needed with them in mind. Sustainable consumption and production (SCP) is a key to connect multiple goals and targets of the SDGs. The objectives of this article are twofold. The first is to identify approaches for visualizing and analyzing the interrelationship between corporate activities and the SDGs based on the results of joint research with Ryohin Keikaku Co., Ltd, especially regarding SCP. The second is to consider the interlinkages in three thematic areas: housing, energy and agriculture, suggesting policy approaches to manage the interlinkages within each theme in Asia. First, as a case study on corporate activities, this article demonstrates how the activities of Ryohin Keikaku Co., Ltd., a Japanese company famous for its MUJI brand, are connected with the SDGs, particularly focusing on SCP. The results indicate a potential for linking corporate activities with a broad range of SDG targets. Second, this article examines the three thematic areas of housing, energy and agriculture. These three thematic areas were chosen for analysis, as they are key areas in the management of SCP. This part of the article illustrates the interlinkages within each theme and suggests policy approaches as to how to manage them within each theme. To address the challenges of SCP, the article concludes that as there are potentials in linking not only specific goals of the SDGs but also the broader goals and targets, it is essential to have cohesive actions to address the challenges.

Key words: energy, food and agriculture, housing, sustainable consumption and production (SCP), Sustainable Development Goals (SDGs)

1. Background and Purpose

At the United Nations Summit held at the UN Headquarters in New York in September 2015, the Sustainable Development Goals (SDGs) were adopted through the consensus of all 193 member countries as shared global goals to be achieved by 2030. The SDGs include 17 goals, but they are not to be considered isolated as if in silos. Tasaki and Endo (2017) discussed various aspects, such as how promoting energy efficiency increases the consumption of rare earth metal resources, recognized the interconnections among multiple sectors, and examined the nexus concept, which advances initiatives in multiple sectors in integrated ways.

When multiple components are linked to one another, one can imagine the contrasting impacts of synergies and trade-offs. Understanding these synergies and trade-offs is crucial in order to minimize the trade-offs, maximize the synergies, avoid resource depletion and secure equitable partnerships (Hegre, 2020). The 2030 Agenda itself emphasizes the importance of considering the 17 goals and 169 targets as one package, describing the 17 Sustainable Development Goals as "169 associated targets which are integrated and indivisible" (para. 18).

The SDGs and sustainable consumption and production (SCP) are intimately linked as well. Hotta &

Kanie (2019) point out that poverty and inequality are increasing as consumerism rises along with mass production, and that environmental degradation issues are arising as a result of increased waste. They describes SCP as a policy concept that aims to address these issues by focusing on the relationship between consumption and production.

Links among the SDG goals facilitate mainstreaming of dimensions which previously suffered from not having strong sectoral anchoring in the development arena, especially considering the existence of many links between SDG 12 on SCP and other goals. SCP is an essential requirement for sustainable development, as recognized in Johannesburg at the 2002 World Summit on Sustainable Development, and in Rio de Janeiro, at the 2012 UN Conference on Sustainable Development (Rio+20). However, until recently, SCP has suffered from being weakly integrated with other areas of work. A publication by Le Blanc in 2015 illustrates the interactions between SCP and social and environmental agendas (Le Blanc, 2015). According to this illustration, SCP is connected to the agendas through linkages such as hunger, poverty, health, education, climate change, energy and infrastructure development.

Agenda 2030 itself emphasizes that the achievement of SCP is an integral part of the SDGs. The text adopted by the United Nations focusing on the SDGs covers SCP in paragraph 28 as follows: "We commit to making fundamental changes in the way that our societies produce and consume goods and services. Governments, international organizations, the business sector and other non-state actors and individuals must contribute to changing unsustainable consumption and production patterns, including through the mobilization, from all sources, of financial and technical assistance to strengthen developing countries' scientific, technological and innovative capacities to move toward more sustainable patterns of consumption and production. We encourage the implementation of the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns. All countries should take action, with developed countries taking the lead, taking into account the development and capabilities of developing countries." (UN, 2015).

Indeed, there are strong connections between SCP and each target under SDG 12 (responsible consumption and production). The UN (2020) warns that the current global consumption of natural resources is unsustainable. For example, the global material footprint increased from 73.2 billion tons in 2010 to 85.9 billion tons in 2017. As implied in the popular "Build Back Better" concept often mentioned in the context of recovery from the COVID-19 pandemic that has affected the world since 2020, the world needs to develop plans to enable the realization of SCP. Meanwhile, there are linkages with not only SDG 12 but also several other goals and targets. In other words, when considering issues related to SCP, strategies and solutions must be considered with an awareness of the interlinkages between the broad range of challenges represented in the goals of the 17 SDGs.

Against this background, this article examines several approaches that can be used to visualize and analyze how corporate activities and the SDGs, including SCP, are closely connected with each other. In this article, we focus on four case studies in different countries and try to draw lessons from these case studies on effective approaches for realizing SCP.

Case studies are chosen based on our group of scientists' capacity and network. Therefore, this study is a first step towards more comprehensive research. Still, we believe that these case studies can verify our approach to examining these matters. Based on a case study with a retail company, Ryohin Keikaku Co., Ltd., this article first analyzes how corporate activities relate to SCP, indicating a potential to link corporate activities with a broad range of SDG targets. Next, the article examines the three thematic areas of housing, energy and agriculture in Asia. These three thematic areas are chosen for analysis, as they are highly dependent on natural resources and thus have higher merit to be aligned with SCP. Chapter 2 of our article illustrates the interlinkages among the SDGs within each theme and suggests policy approaches as to how to manage them in Asia.

2. Interlinkages among the SDGs within Each Theme

2.1 Linkages between Corporate Activities and the SDGs in the Context of SCP

Despite the publication of a number of corporate guidelines such as the "SDG Compass," jointly developed by the Global Reporting Initiative (GRI), UN Global Compact (UNGC) and World Business Council for Sustainable Development (WBCSD); the "SDGs Guide for Management" by Japan's Ministry of Economy, Trade and Industry (METI); and "Guidelines for All Companies to Develop Sustainably" by the Ministry of the Environment (MOE), which all indicate steps or procedures to take in the pursuit of implementing the SDGs, these publications do not clarify in detail what kinds of corporate activities would help achieve the SDGs. In fact, during the past several years, SDG initiatives have spread rapidly among Japanese companies. The Japan Federation of Economic Organizations revised its *Keidanren Charter of Corporate Behavior* in 2017 to emphasize delivering on the SDGs through the realization of "Society 5.0." This charter was one factor that accelerated SDG-related initiatives by major corporations in Japan.

Thus, while consideration of the SDGs is evident among major corporations, 99.7% of companies in Japan are small- or medium-sized enterprises. Among

companies responding to a 2018 survey by the Kanto Bureau of Economy, Trade and Industry, more than 80% replied, “We know nothing about the SDGs,” while only 2% replied “We are already taking action” or “We are considering taking action.” Regarding “Topics for action on the SDGs,” 30.2% of small- and medium-sized enterprise respondents answered, “We have no idea where to start.”

Conscious of these issues, the xSDG Consortium: Financial Assessment Platform Working Group (2020) developed and published the “SDGs Action List for Companies, Version 1.0” (referred to below as the “SDGs Action List”), which summarizes examples and key considerations regarding concrete initiatives by companies tackling the SDGs. By concretely presenting corporate actions that can be taken to achieve the SDGs, they enable connections to be made to provide yardsticks or criteria for actors, including financial institutions and investors that evaluate corporate actions on the SDGs.

The SDGs Action List presents corporate actions, referred to as the “SDGs Actions,” to contribute to achieving the 169 targets of the SDGs. These SDGs Actions are then provided in combination with a list of “Specific Examples of Actions” applicable by companies at the functional level. According to the SDGs Action List for Companies, Version 1 User’s Guide, three points must be kept in mind with respect to the Specific Examples of Actions. First, the examples do not cover actions that are already required by laws and regulations. Second, the examples do not cover corporate social responsibility (CSR) since CSR in recent years has tended to be applied in the context of corporate information disclosure and social contribution activities. Finally, what the examples do cover is corporate actions that contribute to the achievement of the SDGs through a company’s core business (xSDG Consortium: Financial Assessment Platform Working Group, 2020).

For each division or department in a company to identify its own roles and to facilitate initiatives in the SDGs Actions, tags have been assigned in the four categories of “management,” “labor and human rights,” “environmental management” and “climate action.” In addition, each SDGs Action comes with an indication of which stage of the supply chain process is involved, whether it be procurement, distribution, production, sales or crosscutting.

For example, Target 12.5 of SDG 12 (Responsible Consumption and Production) says: “By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.” For this target, the SDGs Actions include “Practice the 4Rs (Reduce, Reuse, Recycle, Refuse) throughout the life cycle.” Brought to the practical level in a company, some of the proposed specific examples of actions include reducing the use of shopping bags; recovering used products, parts and containers; and using direct-to-consumer sales from producers. Actions such as these are tagged as “environmental management” functions within the company. Next, from the supply chain perspective, the actions are tagged as “crosscutting” since they can be considered at all stages, as shown above.

The first half of this article attempts to examine approaches to visualizing and analyzing the interrelationships between corporate activities and the SDGs, including SCP, based on the SDGs Action List. Kosaka (2020) analyzed how the international certification programs and Fairtrade Standards will contribute to achieving the SDG targets. However, the study focuses only on whether a particular initiative conforms to the wording indicated in the SDGs in order to determine whether or not the initiative follows the SDGs. Determining which corporate activities contribute to the SDG targets is highly challenging for private companies because it requires specialized knowledge.

2.2 The Case of Corporate Activities

As explained above, we now know that company actions are closely related to contributing to the attainment of the SDGs. Therefore, this study uses the SDGs Action List as a tool to provide clear standards on whether specific actions of private companies contribute to the SDGs. This article focuses on the efforts of Ryohin Keikaku Co., Ltd. as a case study to identify clearly the linkages between corporate activities and the SDGs, using the SDGs Action List.

From 2018 to 2020, utilizing this SDGs Action List, the xSDG Laboratory conducted a joint research project with Ryohin Keikaku Co., Ltd. to analyze the relationships between corporate activities and the SDGs and consider how to visualize the content. Ryohin Keikaku Co., Ltd is a Japanese company that plans, manufactures and sells “MUJI” brand products including apparel, household goods and food items. It has stores in Japan and abroad. The company is particularly appropriate as a case study for this research, as it is involved in various business activities at each stage of the supply chain, from the procurement of raw materials to the disposal of products, including the collection of products for recycling.

The SDGs Action List breaks down the various corporate activities into the components of practical SDG actions. Within all of that, many SCP-related actions become evident. For example, the SDGs Action List contains the action “Practice the 4Rs (Reduce, Reuse, Recycle, Refuse) throughout the life cycle.” Ryohin Keikaku dubbed these SDGs actions as “100 Good Things,” and was already spreading word about them inside and outside the company. For example, the “100 Good Things” include actions like recycling textile products and wool, and these also apply to the “Practice the 4Rs” action in the SDGs Action List. However, the “100 Good Things” did not specify exactly which of the

SDG targets were being helped toward completion by which actions. Issues like these could probably be identified in many companies.

Any of these individual actions are also connected to the SCP action to "use recycled materials in company products." This action is not only connected to Target 12.5, with which an interlinkage was confirmed above. When analyzed using the SDGs Action List, it is also linked with the action of "adopt business methods that prioritize the environment and production efficiency," under Target 9.4. In this way, the SDGs Action List for Companies (Version 1.0) is useful as a basis for determining whether or not corporate actions are contributing to SDG targets and if so, to which ones.

Even companies that have not gone as far as Ryohin Keikaku in terms of summarizing their own actions in "100 Good Things" can use the SDGs Action List for Companies to summarize and analyze their actions that contribute to the achievement of the SDGs. In other words, the SDG actions in the SDGs Action List can be used as a common standard that can be applied by many companies (Fig. 1).

Further, in the joint research with Ryohin Keikaku, a web tool was developed to visualize the interlinkages between the "100 Good Things" and each of the SDG targets and to show the linkages with components of each of the SDGs (Fig. 2). This specific example is in a format that reflects the "100 Good Things" of Ryohin Keikaku, but using the SDG actions in the SDGs Action List, it would also be possible to apply the format more generally.

An example of something similar to the SDGs Action List discussed above is the "new framework (support model) to support local small- and medium-sized companies in their SDGs initiatives" (referred to below as the "Support Model"), introduced by the Kanto Bureau of Economy Trade and Industry under METI (2019). A major difference between the two is that whereas the SDGs Action List shows concrete initiatives that contribute to achieving the targets one by one, the Support Model indicates multiple SDG targets to which the examples contribute. With the Support Model, one can see that, for example, "conducting proper waste management and working to reduce waste" under "basic items expected by the market and society from the SDGs perspective" contributes to the achievement of not only Targets 12.3, 12.4 and 12.5 under SDG 12 but also of Targets 11.6 and 14.1.

It is essential to understand the economic, social and environmental impacts of corporate activities using the framework of the SDGs and promote business development in ways that create a sustainable future, including the realization of SCP. For this to occur, collaboration and partnership will be essential throughout the entire supply chain, as indicated in the SDGs Action List.

This section has described an analysis of interlinkages between corporate activities and targets of the SDGs in a concrete manner as a case study of the MUJI brand.

2.3 Housing Sector

2.3.1 The Case of the Housing Sector

Any failure to properly manage and develop housing could constitute a significant threat to achieving the SDGs through direct or indirect impacts on issues such as climate change, ecosystems, energy security, urban management and mobility. Some of the links between achieving adequate, safe and affordable housing (Target 11.1) and several other SDGs are clear (e.g., SDG 1 on poverty or access to basic services, SDG 3 on health, SDG 4 on education, SDG 6 on clean water and sanitation, SDG 7 on affordable and clean energy, SDG 8 on decent work, SDG 10 on reducing inequality, SDG 16 on good governance and SDG 17 on partnerships and means of implementation). Other targets—such as those linked to climate change, financing, sustainable production and consumption, gender equality, food security and nutrition, and migration—are also inextricably linked to adequate housing.

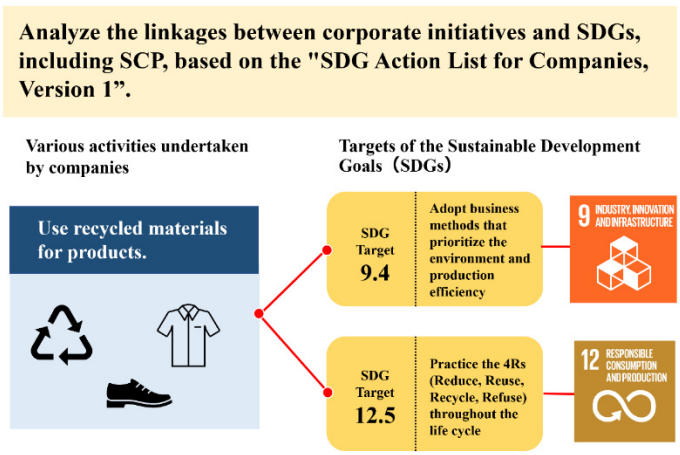
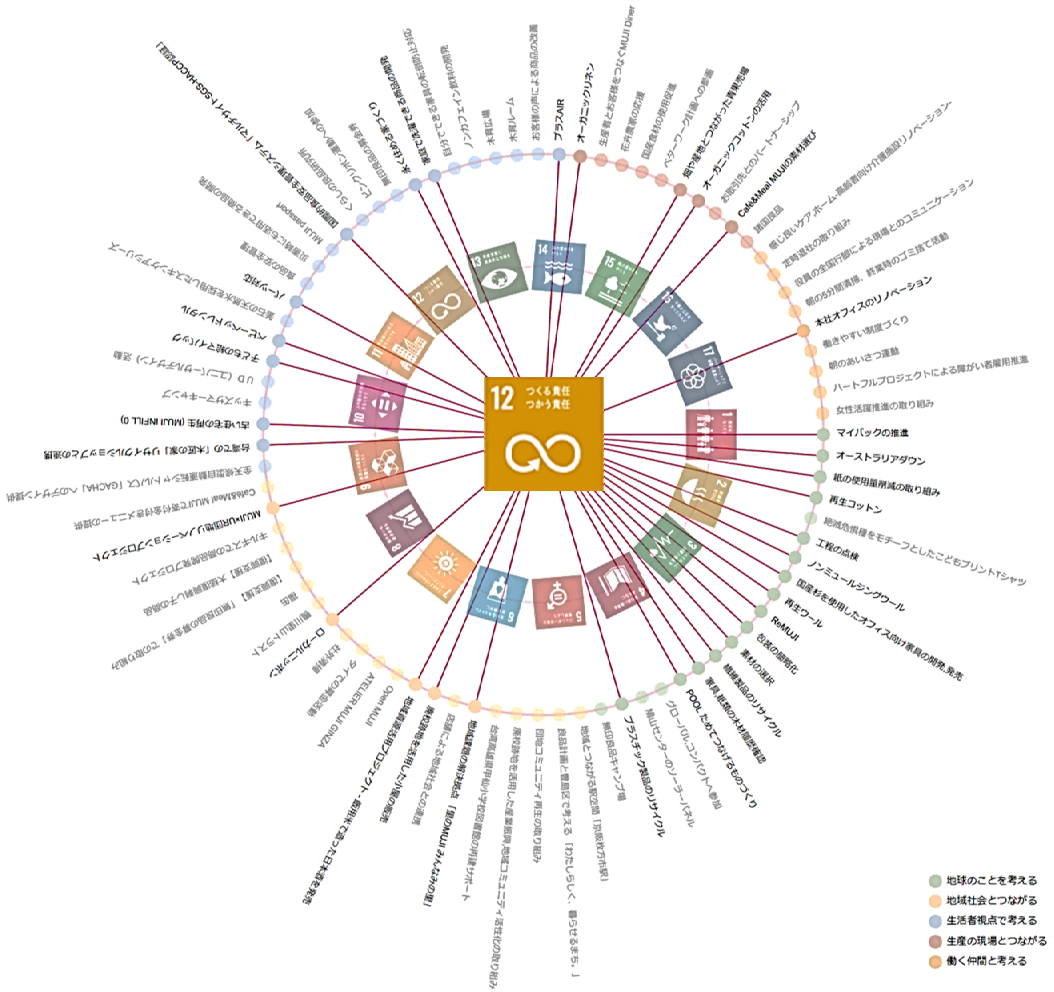


Fig. 1 Detail from the analysis (excerpt from joint research with Ryohin Keikaku Co., Ltd.).

Ryohin Keikaku's "100 Good Things" are placed on the periphery of the circle. These are corporate actions that contribute to the SDGs, such as "Use recycled materials in company products". The table clearly shows that corporate initiatives are contributing to the achievement of multiple SDGs.



This text explains the goals of the SDGs and how corporate activities are related to those goals.

つくる責任つかう責任

SDGsのゴール12は、「持続可能な消費・生産形態を確実にする」ことを目標に掲げています。
その実現に向けて設定されたターゲットは全部で11。大量生産・大量消費・大量廃棄から脱却するライフスタイルの実現に向けて、企業ができることはとても多くあります。
例えば、ターゲット12.1「先進国主導のもと、開発途上国の開発状況や能力を考慮しつつ、すべての国々が行動を起こし、「持続可能な消費と生産に関する 10 年計画枠組み（10YFP）」を実施する」ことについて、企業が取組むことができることも多くあります。例えば、「持続可能な生産方法の検討と実践」、「指針や計画の実施」「SDGsに関するトップコミットメントの公表」といった取り組みを通じて、持続可能な生産に関する長期計画や指針の策定・実施を推進することができます。
良品計画では、１００の良いことのうち「ノンミュールジングワール」、「オーストラリアダウン」といった各種取り組みを通じて、地域のことを考え直すことで、ターゲット12.1の達成に貢献しています。
また、ターゲット12.5「2030 年までに、廃棄物の発生を、予防、削減（リデュース）、再生利用（リサイクル）や再利用（リユース）により大幅に減らす」も企業の取り組みが活発と言えるでしょう。その取り組みとしては、「レジ袋の削減」「食品ロスを削減する仕組み」「使用済製品、部品、容器の回収」「生産者による直接販売の実施」「再生材の利用」といった数多くの取り組みが例として挙げられます。
製品のライフサイクルにおける4R（リデュース、リユース、リサイクル、リフューズ）の実践は、企業の取り組みとして欠かせない配慮のひとつと言えるはずです。
良品計画でも、100の良いことの中で、「廃校跡地を活用した小屋の販売」「包装の簡略化」「POOL ためてつなげるものづくり」「MUJI×UR団地リノベーションプロジェクト」といった様々な取り組みを通じて、製品の再利用や工程の点検などを行うことで、ターゲット12.5の達成に貢献しています。

「企業のためのSDG行動リスト ver.1」の該当項目 ＊一部追記

カテゴリ	具体的行動	SDGs的行動の要素	ターゲット
環境マネジメント	・持続可能な生産方法の検討と実践 ・指針や計画の実施 ・SDGsに関するトップコミットメントの公表	持続可能な生産に関する長期計画や指針の策定・実施	12.1
環境マネジメント	・廃棄物の削減目標を掲げる ・化学物質や廃棄物の削減に関する取り組み	工場などにおける化学物質・廃棄物の削減	12.4
環境マネジメント	・レジ袋の削減 ・(飲食店などでの)割り箸削減 ・簡易包装 ・折り畳みコンテナの使用 ・食品ロスを削減する仕組み ・使用済製品・部品、容器の回収 ・注文生産の実施 ・生産者による直接販売の実施 ・再生材の利用	ライフサイクルにおける4R（リデュース、リユース、リサイクル、リフューズ）の実践	12.5
環境マネジメント	・サステイナビリティ報告書や統合報告書などの定期報告	持続可能性に関する情報の定期的な報告	12.6

Based on the SDG Action List for Companies (Version 1.0), it shows the corporate actions that contribute to the achievement of the SDG goals shown in the center of the circle. By reviewing this table, the reader can understand what targets of the SDGs the company's actions are related to.

Fig. 2 Visualization of interlinkages between corporate activities and SDG 12 (excerpt from joint research with Ryohin Keikaku Co., Ltd.)

SDG 1 is closely linked to housing issues, as trends indicate that with humanity becoming increasingly urban, poverty is becoming increasingly urban as well and is often represented by a rise in numbers of slum dwellers in cities who lack access to basic services and adequate housing. It also covers land tenure security, which is critical in housing provision and basic services. Housing security also offers a foundation for access to primary means of economic production. SDG 3 on good health and wellbeing is extensively interlinked with housing, as health is often affected by the place of residence. Housing quality plays a decisive role in the health status of residents. Many health problems are either directly or indirectly related to housing quality due to factors such as construction materials used, equipment installed and the individual dwellings' size or design (Bonnefoy, 2007). Adequate, safe, and affordable housing equipped with access to basic services can help reduce communicable diseases and limit environmental hazards such as water and waste pollution, contributing to better health.

Housing located accessibly to education facilities helps to achieve SDG 4. In turn, attaining SDG 4 can contribute to making cities inclusive and sustainable (SDG 11). Vulnerable groups such as slum dwellers often face difficulties in accessing education. Education may help these groups obtain adequate skills and decent jobs, which is critical in achieving SDG 8 on decent work and economic growth. In many cases, such as in Mumbai, when educational facilities are available in slum areas, they are often limited to primary education (ODI, 2016). Children who need to travel far for their education face financial disadvantages. Moreover, primarily through housing choices, poverty eradication (SDG 1), education (SDG 4) and drinking water (SDG 6) targets are not independent endeavors.

Housing and basic services are inextricably linked. Achieving SDG 6 promotes the availability and sustainable management of water, and sanitation for all will help promote better housing and slum upgrading (Target 11.1). Housing accounts for much of human waste and some urban solid waste, both of which are directly linked to several other targets under SDG 6 and SDG 11. Housing equipped with effective waste management systems is crucial to ensuring access to safe drinking water, sanitation and hygiene and to improving water resources' quality and sustainability. Along with water, food and other ecosystem services, the sustainable provisioning of energy is a precondition for sustainable cities (TWI2050, 2018).

SDG 7 promotes access to affordable, reliable, sustainable and modern energy for all. Given the role of energy in addressing the economic, social and environmental dimensions of livelihood, SDG 7 is interlinked with housing and, more broadly, with SDG 11 from various angles. Access to energy in housing—by enabling people to heat or cool their homes and to use lighting and cooking facilities—interacts positively with health targets that unfold over multiple years (Nilsson et al., 2018). In turn, SDG 11, through access to more sustainable housing as one component of urban infrastructure, creates the conditions for achieving SDG 7. If the costs of new energy policies for housing fall disproportionately on the poor, poverty eradication could be impaired (Sovacool et al., 2016). Direct energy consumption and embedded energy in housing and services in urban areas have various environmental impacts. Thus, unsustainable consumption patterns for energy could hamper the achievement of SDG 12 and SDG 13. Conversely, better housing and waste management could contribute to a circular economy (SDG 12).

2.3.2 Management of Interlinkages in the Housing Sector

Housing is increasingly developed, financed and managed by a mix of public agencies, markets, third sector organizations and cooperative or community actors, leading to various hybrid forms of governance (Van Bortel et al., 2019). The development of housing requires synergies among all parties and sectors involved throughout the building life cycle in order to achieve the desired outcomes. The concept of "green" development, including energy efficiency, needs to be implemented throughout the housing life cycle so that multi-agent and multi-sector synergies can be extended to all aspects of housing production, from policy development to planning and design, construction and transportation, operation and maintenance, as well as demolition and disposal (Zhang et al., 2018).

Housing is a complex construct and requires complex approaches. Given the variety of synergies and trade-offs across numerous goals and targets, it is necessary to approach housing in a cross-sectoral and multidisciplinary way. Any research on housing, therefore, needs to embrace a holistic concept of housing. The impacts of housing factors such as energy provision and basic services need to be evaluated against actual housing conditions and the broader urban environment. Interlinkages between housing frameworks and other frameworks need to be considered; for example, housing and health issues should be considered within a public health framework. To reorient the relevant policies, normative and governance frameworks need to be adjusted to enable concrete actions by governments to attend to housing as a priority.

2.4 Energy Sector

2.4.1 The Case of the Energy Sector

Energy is a central component of the United Nations' 2030 Agenda and the Sustainable Development Goals (SDGs) (Lu, Nakicenovic et al., 2015). SDG 7 (Energy for All) aims to "ensure access to affordable, reliable, sustainable, and modern energy for all" (UN, 2015).

According to the 2021 Tracking SDG 7 Report, the number of people without access to electricity dropped from 1.2 billion to 759 million between 2010 and 2019 (IEA, 2021). Increasing access to electricity and raising the share of renewable energy is central to world development. The ways energy is produced and consumed will impact the prospects for other development issues (social, economic, political and environmental). Moreover, the provision of sustainable, low-carbon energy and an increase in energy efficiency, can contribute to sustainable consumption and production (SDG 12).

First, progress toward the achievement of SDG 7 can help achieve crucial progress on welfare and wellbeing. Energy plays a vital role in poverty eradication (Practical Action, 2014), with many studies showing that the provision of modern energy services (SDG 7. Target 1) to rural communities can increase economic productivity and contribute to improved household income (SDG 8), which can help reduce poverty (SDG 1) (Barnes et al., 2015; Eggoh et al., 2011). Increasing energy access can also contribute to improvement in living standards through positive impacts on basic services such as healthcare (SDG 3), education (SDG 4) and water and sanitation (SDG 6). For example, increased electrification rates in homes and schools can help with education for all (SDG 4), particularly target 4.2, which aims to ensure that all girls and boys have access to good quality education (Daka & Ballet, 2011; UNDESA, 2014).

Second, there are numerous interlinkages between SDG 7 and infrastructure (both agricultural and industrial). Indeed, energy is a core component in enhancing the resilience of urban infrastructure, which means making cities safe and sustainable (SDG 11). In rural areas, using clean energy to upgrade cooking facilities can generate positive impacts on living standards. For instance, increasing the global share of renewable energy (SDG 7 and Target 7.2) can eliminate associated health problems (SDG 3) arising from the use of traditional sources of energy (biomass, coal, charcoal, kerosene) that release indoor air pollution (Torres-Duque et al., 2008). Similarly, the provision of energy is essential for the operation and maintenance of food systems (SDG 2), medical facilities (SDG 3) and water treatment facilities (SDG 6) (Mushtaq et al., 2009). Improvements in energy infrastructure to power these systems cannot be achieved without access to financial tools and international cooperation (SDG 9 and SDG 17). Reliable energy systems are also important for resilient and sustainable industrialization (SDG 9). In contrast, the reconfiguration of energy systems and the use of natural resources is closely linked to sustainable consumption and production patterns (SDG 12) and, notably, the sustainable management and efficient use of natural resources (Target 12.2) (Howells et al., 2013). Indeed, efforts to improve resource efficiency require more effective use of natural resources by, for example, the deployment of renewable energy and other energy-efficient technologies to replace fossil fuels. Such efforts can positively influence consumption patterns, resulting in responsible production and a reduction in energy-associated waste.

Finally, the implementation of SDG 7 is closely related to and complementary with climate action (SDG 13), as increasing the share of renewable energy in the energy mix and enhancing end-use energy efficiency (Targets 7.2, 7.3, 7.A) are seen as vital pathways to combat global warming (Target 13.2) (IEA, International Renewable Energy Agency, United Nations Statistics Division, The World Bank, & World Health Organization, 2019). Indeed, increasing the share of low-carbon energy systems will be crucial to staying within the target of limiting warming to 1.5 to 2 degrees Celsius based on the 2015 Paris Agreement on climate change. Achieving SDG 7 can also slow deforestation caused by the use of fuelwood and thus contribute positively to life on land (SDG 15) (Odihi, 2003). Sustainable access to energy services is imperative to avoid further ecosystem loss and degradation.

2.4.2 Management of Interlinkages in the Energy Sector

At the institutional level, the promotion of low-carbon and efficient energy resources faces challenges relating to governance as a result of interactions among multiple levels of government (Ahlborg, 2017). Efforts to optimize interlinkages with other SDGs can add multiple layers of complexity to existing governance modes. Policymakers need to design energy policies based on an understanding of the pathways and directions of SDG interactions, which can differ depending on contexts, resources and capabilities. It is also imperative for policymakers to design energy policies that utilize a systematic approach in coordination with different agencies (responsible for education, agriculture, forestry health, etc.) that can simultaneously advance the implementation of other development targets.

Efforts to advance energy targets also need to be aligned with climate action targets. To achieve the temperature targets of the Paris Agreement, countries need to decarbonize their energy systems by increasing energy efficiency and the share of renewables. Policymakers should start from the pledged Nationally Determined Contributions (NDCs) and make steady improvements at different stages of related policy processes. Additionally, policymakers need to design integrated policies that promote the sustainable management of natural resources (e.g., the food-energy-water nexus). The nexus approach can help planners at the national and local level to conceptualize and quantify trade-offs and synergies in order to make informed decisions. It can also help prioritize certain actions (relating to SDG targets) that connect policy processes across multiple levels, including local, national and global.

2.5 Agriculture Sector

2.5.1 The Case of the Agriculture Sector

Sustainable agricultural development is the management and conservation of the natural resource base and the orientation of technological change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations (FAO, 1988). Historically, agriculture has been associated with food, a point also recognized in the 2030 Agenda through ending poverty (SDG 1), ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture (SDG 2). Apart from its direct impact on hunger and malnutrition, the food system is also linked to other development-related challenges addressed in the SDGs, including poverty, water and energy use, climate change and unsustainable production and consumption. Reaching the SDG targets will not be possible without a strong and sustainable agricultural sector.

Major improvements in agricultural productivity have sometimes come with social and environmental costs, including water scarcity, soil degradation, ecosystem stress, biodiversity loss, decreased fish stocks and forest cover, and higher levels of greenhouse gas emissions. Therefore, sustainable production and consumption of resources (SDG 12) in the agricultural sector is important to guarantee the achievement of global goals as a whole. This means that the focus should not be solely on the end goal but also on the means used to achieve it.

With respect to achieving zero hunger (SDG 2) and ending poverty (SDG 1), the role of agricultural development in poverty reduction is well established in the economic literature. As most of the poor in developing countries depend heavily on agriculture, ending poverty is linked to increasing returns from agriculture. Much of the world's agricultural production takes place on small farms; currently, 90% of 570 million farms worldwide are small and cultivated by 1.5 billion of the world's poor (Rapsomanikis, 2015).

With respect to water (SDG 6) and energy (SDG 7), water is a vital resource and a key input for agriculture. Also, agriculture is considered the largest water-consuming sector and, at the same time, a major water polluter. Global projections indicate that demand for freshwater, energy and food will significantly increase over the coming decades, mainly due to the increased pressures of population growth and mobility, economic development, international trade, urbanization, diversifying diets, cultural and technological changes, and climate change (Hoff, 2011). Climate change and its impacts on water resources and crop production are major forces the agricultural sector will have to cope with in the twenty-first century.

Efforts to address food loss (SDG 12) and waste reduction in agriculture are seen as a means toward achieving other SDGs, including improving food security and nutrition (SDG 2), reducing greenhouse gas emissions (SDG 13), and lowering pressure on water and land resources (SDG 6 and SDG 15), and can increase productivity and economic growth (SDG 1 and SDG 8). Factors influencing food loss in the food supply chain include poor infrastructure and logistics; lack of technology; insufficient skills, knowledge and management capacity of supply chain actors; and lack of timely access to markets after harvest (Gustavsson et al., 2011). Considerable food loss occurs in low-income countries due to the lack of proper harvesting, storage capacity, poor storage conditions and lack of capacity to transport produce to processing plants or markets immediately after harvesting (Gustavsson et al., 2011). In developing countries, the lack of packaging and marketing systems (Gustavsson et al., 2011) causes food loss immediately after harvesting. This problem can be tackled by strengthening the food supply chain, by encouraging supermarkets to procure products directly from farmers. With the expansion of multibrand retail outlets in India, some cooperative retail chains and private supermarket chains have begun to source some of their fruit and vegetables from farmers via collection centers (Nuthalapati et al., 2020). However, these collection centers are limited to areas near large cities.

2.5.2 Management of Interlinkages in the Agriculture Sector

A fundamental requirement for delivering sustainable food and agriculture, thus boosting their synergies with other goals, is the creation of an enabling policy environment. Sectoral ministries also need to change the way they work and coordinate policies across government. The transition to more sustainable agriculture and food systems calls for actions to build political alliances and coalitions with other multi-stakeholder partners beyond food and agriculture. Multi-stakeholder mechanisms and new forms of participatory governance structures may bolster policy ownership and at the same time help to mobilize capacities, information, technologies and access to financial and production resources (FAO, 2018).

Addressing climate change and sustainable agriculture is a governance challenge that requires multidimensional approaches involving all stakeholders. Different tiers of government need to work together toward this common goal, aligning their policies to address the challenges. The continuous involvement of non-state actors such as the private sector and communities is also required. As the issues that affect climate change and sustainable development are deeply interconnected at all levels, one-size-fits-all policies will not be effective in addressing these issues.

Innovation and the adoption of suitable agricultural practices are necessary in order to meet the critical challenges of climate change and sustainable development in agriculture. Certain factors both enable and facilitate

innovation in the field of agriculture. Top motivating factors are related to production and economic character (i.e., higher production results and, respectively, higher economic effects), while social and particularly ecological factors are secondary (Anastasova-Chopeva et al., 2015). Factors that constrain the adoption of suitable agricultural practices include a lack of resources, incompatibility and complexity of new technology, and socio-economic and cultural constraints. Inadequacies in extension intervention, technical training and information are the main constraints that affect information and knowledge-sharing networks (Silva & Broekel, 2016). As an example of how to address such constraints, investment in rural market infrastructure could allow small land holders to commercialize and enhance the supply of perishable products, thereby increasing their profits and income. The linking of small farms to urban food value chains could also provide promising new avenues for small farmers and help in rural poverty reduction. It is also important to link factors that enable innovations with production and economic needs in ways that encourage climate-friendly innovations, at the same time as reducing barriers to adoption such as a lack of resources and complexity of new technologies.

3. Conclusion

This article suggests that to resolve the challenges of SCP, it will be necessary to have integrated approaches to addressing the goals and targets broadly. The MUJI brand case suggests the necessity of considering initiatives with an awareness of synergies and trade-offs, as many corporate actions are related to multiple goals and targets of the SDGs. The cases from the three thematic areas show that cross-sectoral approaches need to be taken at various levels of governance to integrate SCP issues further in each area.

In addition, it is crucial to seek linkages among a broad range of stakeholders through the entire supply chain, because reflecting a variety of perspectives will enhance sustainability of the products. In Policy Design and Evaluation to Ensure Sustainable Consumption and Production Patterns in the Asian Region (PECoP-Asia), Hirao et al. (2021) have proposed 13 opportunities for accelerated achievement of SCP for policy-making in Asia and the Pacific in line with the 2030 Agenda for Sustainable Development, and the above-mentioned point fits well with Opportunity 11 (enhancing collaboration).

The first half of this article analyzed how the private companies' activities could be linked to SCP and the SDGs. By using the SDGs as a tool for analysis, companies are able to discover spaces for improving sustainability, and thereby contribute to the SDGs as well as differentiate actions in terms of sustainability. The latter function is likely to be an appealing merit for companies as society must move towards sustainability. The second half of this article discussed interlinkages in broader areas including the housing, energy and agriculture sectors. Our findings indicate that efforts as well as activities from both policymakers and private companies will be required in order to realize SCP and the SDGs. As private companies' activities are deeply involved in policy-making processes towards SCP, it is necessary for private companies to incorporate SCP-conscious strategies at earlier stages of developing their products and services.

One issue raised was how to increase the number of companies targeted for analysis. By conducting case studies featuring a broad range of sectors, further evidence could be gathered regarding the remaining issues.

This article also stressed that multi-stakeholder involvement would be essential for development and implementation of policies for achieving the SDGs, through sharing of knowledge and promotion of partnerships. To achieve the SDGs and create a sustainable future, government policymakers and corporate strategists need fully to understand the complexities and integration of the SDGs through a cross-sectoral approach.

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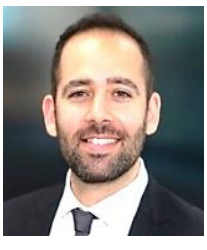

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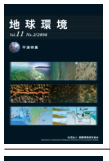	Vol. 11 No. 2／2006年 干潟特集 樋口 広芳
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