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Developing a new scale for measuring sustainability-oriented innovation

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ABSTRACT

Sustainability-oriented innovation is a developing area in the academic literature, and existing measurement models are either lacking in scope or they have not been validated. Following an extensive review of existing academic literature, this paper addresses this gap by developing a new sustainability-oriented innovation scale. The scale includes elements from the triple bottom line, which incorporates social, environmental, and financial considerations. Environmental considerations are further broken down into carbon footprint, pollution, and materials life cycle. Notably, we also separate capability (could we do it), evaluation (do we measure it), and performance (do we put it into practice in our products and services, and operations). As a holistic model we also include strategy, partnerships, and demand. The validity of the scale was tested first through a pilot study with 23 respondents, and second through a survey study with 202 respondents. Scale evaluation tests confirm the consistency, convergent, and discriminant validity of the new sustainability-oriented innovation scale. Both exploratory and confirmatory analysis results confirm that the theorised scale is a good fit for the data. The contribution of this paper is a comprehensive, validated survey instrument to measure the capability of organisations to deliver sustainable innovation.

1. Introduction

Sustainability is a critical consideration for humanity, as reflected in the UN Sustainable Development Goals which aim "to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity" (UNDP, 2015). In the widest sense, sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Since sustainability is critical for humanity, it is also critical for organisations of all types and sizes, in all sectors and geographies. Corporate sustainability integrates economic, environmental and social dimensions (Hansen et al., 2009; Jay and Gerard, 2015), which are often discussed together as the *triple bottom line* (Elkington, 1998; Norman and MacDonald, 2004). In order to achieve sustainability, innovation is essential (Luqmani et al., 2017; Kusi-Sarpong et al., 2019; Zhou et al., 2020), and both innovation and sustainability have grown significantly as research topics and have been studied together a great deal (Maier et al., 2020). Accordingly, the concept of *sustainability-oriented innovation* (SOI) integrates economic, social, and environmental considerations as core topics in the innovation process (Feniser et al., 2017). Further, sustainability-oriented innovation integrates ecological and social goals (De Medeiros et al., 2014) into the development of new products, processes, and organizational structures (Adams et al., 2016).

Sustainability-oriented innovation is clearly a topic of significant interest, but one with gaps. One extensive literature analysis of existing innovation indicators (Dziallas and Blind, 2018) showed that sustainability is not usually considered as a core element of product definition, but instead as a post-launch consideration. Indeed, the development of sustainability-oriented innovations is multidimensional (Souto, 2022), which makes it a complex and difficult task for companies (Buhl et al., 2019) that may include trade-off decisions (De et al., 2020). New capabilities are required, which may require transformation of the firm (Inigo and Albareda, 2019). A wide range of factors are important, and there is a significant body of work focusing on improving sustainability-oriented innovation through networks and external stakeholders (Goodman et al., 2017; Ghassim and Bogers, 2019), alliances and connections (Inigo et al., 2020), supply chain (Neutzling et al., 2018) and partnerships (Mariani et al., 2022). This focus on connections with external stakeholders reflects the context, that sustainability operates within a connected ecosystem (van de Wetering et al., 2017). External connections are also central to value creation, and to moving beyond incremental innovations focused on efficiency (Bos-Brouwers,

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2010). Sustainability-oriented innovation research to date has given the most attention to internal managerial aspects (Cillo et al., 2019) such as intentionality (Pinto, 2017) and top management support (Khurana et al., 2021), which might both be reflected in sustainability-rooted strategy (Klewitz and Hansen, 2014). However, there is also a behaviour gap (Luqmani et al., 2017) and so strategic sustainability behaviours are critical (Adams et al., 2016). Perhaps as a combined indicator of intentionality and action, culture is a critical success factor for sustainability oriented innovation (Geradts and Bocke, 2019).

Whilst the drivers of sustainability-oriented innovation have been discussed, to date (and to our knowledge) there is no comprehensive measurement scale. One extensive discussion of the prospects for a sustainability-oriented innovation assessment evaluates the challenges and benefits that may accrue and concluding that 'there is a need for practical methods that enable the integration of sustainability effects into innovation assessment' (Möller et al., 2014). One sustainability-oriented innovation scale was recently developed to analyse the most important contributors to sustainability in Indian SMEs (Khurana et al., 2019), and this was applied in a later empirical study investigating the influence of sustainability-oriented practices (Khurana et al., 2021). Their scale was developed with a specific focus on SMEs and so other factors might be important in organisations of different sizes. Another study evaluating the relationship between sustainability-oriented innovation and firm performance created a scale that included two main factors: process and product deployment, and competencies deployment (Maletič et al., 2016). With only two factors, this scale is not considered sufficient for an in-depth analysis of sustainability-oriented innovation.

The aim and contribution of this paper is the development and validation of a new scale for measuring sustainability-oriented innovation that is widely applicable. This scale could be applied in future studies to understand the relationships between firm characteristics and practices and sustainability performance, to evaluate product, industry, or geography effects, with the ultimate goal to improve the capability of a wide range of organisations to develop new innovations with positive effects on sustainability.

The paper proceeds as follows. Section 2 introduces the main sections of the new sustainability-oriented innovation scale, justifying the focus of each section with a targeted literature review. Section 3 includes all scale items developed following the literature review and the pilot study initial evaluation. Section 4 describes the scale testing process in detail. The paper concludes with section 5, a discussion of the main findings and contribution.

2. Developing a sustainability-oriented innovation scale

This section discusses each category in the sustainability-oriented innovation scale, building on the existing literature to justify the inclusion of various items beyond the well accepted triple bottom line (social, economic and environmental) including enactment, operations, strategy, partnerships and demand.

2.1. The triple bottom line: social, environmental and financial sustainability

The triple bottom line was developed as a way to assess the worth of a company in terms of its sustainability, with three constituent parts: social, environmental and financial (Elkington, 1998). Sustainability oriented innovation studies often reference the triple bottom line, whether directly (Hansen et al., 2009; Klewitz and Hansen, 2014; Khurana et al., 2019) or indirectly (e.g. Chen et al., 2014; Li and Bi, 2020). The triple bottom line concept has received substantial criticism (Norman and MacDonald, 2004) because, amongst other problems, there are no agreed-upon measures for either social or environmental performance. Innovation practitioners have also criticised the triple bottom line concept, arguing that it added complexity and that "Innovations can never create positive sustainability effects on all target dimensions" (Hansen et al., 2009). As a commonly discussed and wide-ranging concept, we include all three elements in our scale, and describe how we will evaluate each element in the following sections.

2.2. Economic sustainability

Economic sustainability is a key dimension, which alludes to ability to contribute to economic productivity to sustain livelihoods, communities and nations and hence is an integral aspect in all models of corporate sustainability (Basiago, 1998; Bos-Brouwers, 2010). However, economic sustainability is a difficult topic to address for a very wide range of organisation types (including private, public, and not-for-profit) since quite different metrics are used in these settings. As such our scale adopts a very broad view, addressing: economically beneficial products and services; the economic dimension of decision-making; and being 'economically excellent'.

2.3. Social sustainability

Social dimensions of sustainability have been developed and refined from von Geibler et al. (2006) to include health and safety, quality of working conditions, education and training, and social dialogue. We excluded some other elements that would be difficult for individual employees to know, or which were already included in other areas of our scale.

2.4. Environmental sustainability (eco-innovation)

Some previous sustainability-oriented innovation literature has adopted an eco-innovation perspective (Klewitz and Hansen, 2014), which focuses on how the firm and the focal innovation aim for and produce positive environmental benefits (Demirel and Kesidou, 2019). Previous eco-innovation scales have included the categories energy, materials and pollution (e.g. Mat Dahan and Yusof, 2020). Our scale includes carbon footprint, pollution, and materials life cycle in a matrix evaluation shown in Table 1. These categories are elaborated and justified in the following sections.

Organisations also experience a gap between knowledge and practice, referred to as the 'knowing-doing gap' (Pfeffer and Sutton, 2000), or the 'intention-performance gap' (Goossens et al., 2017). This is a particularly acute problem in complex problems relating to sustainability (Hulme, 2014). As such, and because what gets measured gets done (Giles-Corti et al., 2022), we have broken down our scale into three dimensions: *capability* (could we do it), *evaluation* (do we measure it) and *performance* (do we put eco-innovation into practice in our products and services/operations). In each of these behavioural dimensions we address three key elements of *eco-innovation*.

2.4.1. Eco-innovation: carbon footprint

Climate change will directly cause increased deaths, in a number of

Table 1
Matrix of eco-innovation indicators vs. organisational enactment.

Eco-innovation indicator	Organisational enactment
Carbon footprint	Capability
	Evaluation
	Performance (products and services)
	Performance (operations)
Pollution	Capability
	Evaluation
	Performance (products and services)
	Performance (operations)
Materials life cycle	Capability
	Evaluation
	Performance (products and services)
	Performance (operations)

ways. The 2021 European floods were reported to have occurred as a direct result of climate change. These floods are reported to have caused more than 200 deaths (Copernicus, 2021) and between €2–3 billion in insured losses (Cohn and Sims, 2021). A recent projection showed that increased temperatures of between 1.5 and 2 °C will cause almost 28, 000 additional heat-related deaths per year in China (Wang et al., 2019). Carbon dioxide is a major contributor to climate change (European Commission), though other contributors do have a meaningful impact, and in one model the total climate effect of other greenhouse gases is 57% of that from CO2 (Montzka et al., 2011). As such, international standards have been developed to include a single common metric that considers the global warming potential of a range of greenhouse gases using a CO2-equivalent measure, tCO_2e, (CCC, 2021). One measurement model, carbon accounting, has suffered from problems including the lack of consistent definitions and standards (Stechemesser and Guenther, 2012) but research is ongoing and is progressing alongside the development of global carbon institutions (He et al., 2021) and carbon trading (Zhang et al., 2020). Whilst this should ultimately include a wide range of gases and their global warming potential using an internationally recognised method for calculating tCO_2e, since our metric is not specifically a carbon accounting framework we are using the much narrower, incomplete but important measure of the contribution to climate change, *carbon footprint.*

2.4.2. Eco-innovation: pollution

The importance of pollution has been evaluated in a number of ways, but most striking is the increased death rate caused by air pollution. As an example both of how mitigation measures can make an important difference, and as an indicator of the very large early death rates, the acid rain reduction program started in 1990 in the USA and had a peak effect of over 23,000 avoided deaths in 2003 alone (Barreca et al., 2021). Globally, the effect of air pollution primarily caused by the burning of fossil fuels vastly outnumbers this, and is thought to cause 10 million excess deaths per year (Vohra et al., 2021). As a result of this we have included *pollution* in our eco-innovation scale. Given the potential variance in pollutants and metrics we do not propose any specific pollution measures but instead this is to be self-defined.

2.4.3. Eco-innovation: materials life cycle

The final element included in our eco-innovation scale is the materials life cycle. The contribution of materials production, use and disposal to human harm is less direct than greenhouse gases and pollution. Some materials are toxic or radioactive and can cause direct and significant harm at all stages of the life cycle. Some material types, such as plastics, can cause a serious but unknown amount of harm to people and the environment: "Plastic litter of all sizes has been acknowledged as a serious threat to biodiversity, especially in the marine environment" (Lavoie et al., 2021). One concept that encourages materials use in an ecologically non-damaging way is the circular economy, which the Ellen MacArthur Foundation defines as "an industrial economy that is restorative or regenerative by intention and design" (Ellen Macarthur Foundation, 2013). Materials are designed to be safely returned to the biosphere or reused. A truly circular materials cycle is not feasible: "All production processes lead to downgrading materials … Complete recycling is therefore a thermodynamic impossibility" (de Man and Friege, 2016). Even so, attention to materials and energy from a life-cycle or whole-life perspective is common in the sustainability-oriented innovation literature (e.g. Adams et al., 2016; Bocken et al., 2014; Luqmani et al., 2017). We therefore include *materials life cycle* in our eco-innovation scale.

2.5. Organisational enactment: capability

The specific capabilities required to develop sustainability-oriented innovations is rather varied, even within a single firm. Environmental knowledge is an important element required for creating eco-innovations (Bocken et al., 2014). Sustainability-oriented innovation is enhanced by environmental R&D (Demirel and Kesidou, 2019). Two important innovation inputs, R&D personnel and R&D expenditure, were both found in an major empirical study in China to have a significant impact on sustainability oriented innovation outputs (Li and Bi, 2020). Since our scale is intended to be applied to a wide range of organisation types, capability is used to address the capability to conduct eco-innovation *evaluation* across the three dimensions of carbon footprint, materials life cycle and pollution. Enactment (we have the capability to apply that knowledge) is considered to be embodied in the products and services. In addition, as an indicator of capability identified in the literature (e.g. Li and Bi, 2020) we also include R&D effort.

2.6. Products and services vs operations

The selection of specific criteria is highly dependent on the focal innovation (Hansen et al., 2009). Our scale therefore differentiates between products and services and operations, to allow for a differential focus depending on the relative impact of those phases. Some very high contributors to CO2 production include aviation, which causes 3.5% of global warming[1] and generates 99.9% of its total life-cycle impact during the use phase (Howe et al., 2013). Conversely, concrete contributes 8% of global CO2 emissions (Nature editorial, 2021) but this is largely generated during the production phase (Josa et al., 2004). To account for these differences, we separate the evaluation of eco-innovation in products and services from operations.

2.7. Sustainability strategy

A sustainability-oriented innovation scale developed to analyse the most important contributors to sustainability in Indian SMEs (Khurana et al., 2019) showed that three elements were most important in the implementation of sustainability-oriented practices: Top management support, government initiatives and financial resources (Khurana et al., 2021). Since management support is a major driver of sustainability-oriented innovation, we have elected to include strategy in our scale. This is because the depth of support by the organisation to sustainability as an objective can be evaluated in terms of its sustainability strategy, which can be considered on a scale from incremental and reactive to radical and sustainability-rooted (Klewitz and Hansen, 2014). Belief structures are also thought to be meaningful in sustainability orientation (Garay et al., 2019), but can be considered as an embodied feature in the strategy. Culture is a particularly important topic for existing large firms seeking new approaches to sustainability oriented innovation (Geradts and Bocke, 2019) that require the alignment of individual and corporate purpose. However, we focus on the stated strategy of the firm, with respect to the degree of innovation sought (e.g. radical, well beyond legislation) and the degree to which the sustainability goals operate within a wider ecosystem.

2.8. Organisational partnerships for sustainability

A critical element of achieving meaningful sustainability-oriented innovation is the orientation towards partnerships (Mariani et al., 2022), or engagement with external stakeholders (Ghassim and Bogers, 2019). Sustainability often requires a connected network of organisations working across the life cycle, and sometimes requires new technologies or infrastructure that are beyond the scope of any single firm. As such organisations must understand systems change that expands beyond the firm as part of a connected ecology (Adams et al., 2016). Creating and engaging in such networks requires an active approach to alliances (Inigo et al., 2020).

[1] https://ourworldindata.org/co2-emissions-from-aviation.

2.9. Demand

Demand for products and services is argued to be a major driver of sustainability. Demand for products, services and systems that do not yet exist cause a dilemma for innovators: if you do not innovate then you risk becoming obsolete, but if you do innovate in uncertain areas you risk producing expensive failures (Christensen, 1997). The problem with assessing future demand in markets that do not yet exist is that market predictions are inaccurate and largely used to demonstrate mimetic conformance, or a ceremonial role (Kirsch et al., 2009). Our scale therefore includes consideration for future demand in a wide way that includes changes in demand patterns, the emergence of new business models (Evans et al., 2017), or new service systems (Roy, 2000; Manzini and Vezzoli, 2003). The strength of environmental regulation is also known to play a major role in driving eco-innovation: "regions with high green technology innovation performance tend to be those with high environmental regulation intensity" (Li and Bi, 2020). As such, our scale includes the future effect of new regulatory systems.

2.10. Control variables

Control variables were adopted from Atinc and Simmering (2021) and include country, industry, turnover, employees, and sector. This is because these characteristics can fundamentally change the internal context within an organisation, leading to changes in the level of variables measured at organisational level. For future analysis of its importance or impact we also ask whether the organisation follows an environmental management system such as ISO14001.

3. Proposed sustainable innovation scale

In the previous section, we began the process of scale development, following the paradigm first suggested by Churchill (1979) and since widely adopted in scale development studies in business and management (e.g. Papadas et al., 2017), by specifying the domain using the existing literature to show that the new scale of sustainable innovation is necessary and distinctive from existing measures of similar constructs. In this section, we describe the next step in the process of scale development which is to build on that literature to generate a selection of items that capture this construct. Several of the scales build directly on the matrix of eco-innovation indicators shown in Table 1, logically building out each aspect of the matrix (capability, evaluation, products and services, and operations). The remaining scales (control variables, strategy, partnerships, economic, social, demand) are intended to directly reflect the literature discussed in section 2.

The final version of the sustainability-oriented innovation (SOI) survey scale is shown in Table 2.

4. Scale testing and evaluation

In this section we present the data and analysis we conducted to evaluate the reliability and validity of the sustainability-oriented innovation scale. Since the aim of this paper is to develop and validate the sustainability-oriented innovation scale rather than to advance the methods and develop software, we chose well known, robust and replicable approaches and techniques, e.g. reliability analysis, then exploratory factor analysis, and then confirmatory factor analysis. Similarly, we used software tools that are widely available to the academic research community, namely SPSS and Amos SPSS. Other examples of scale development studies applying the same steps, techniques and software applications can be found in, for example, Byrne (2001) or Thakkar and Thakkar (2020). This section describes the pilot study, survey data gathering, reliability evaluation, exploratory and confirmatory factor analysis.

Table 2
Edited sustainability-oriented innovation scale following the pilot test All scale variables use the following seven-point Likert Scale: Almost never true/usually not true/rarely true/occasionally true/often true/usually true/almost always true.

Topic	Question text	Response type
Control variables		
Role	What is your role/profession (e.g. project manager, innovation director, legal assistant, administrator)	Free text
Country	What is your country of residence?	Free text
Industry	What Industry is your organisation operating in?	Free text
Turnover	Approximate annual turnover of your organisation?	Free text
Employees	Approximate number of employees	Free text
Sector	Is your organisation private, public sector or not-for-profit?	Option selection
ISO14001	Does your organisation follow an environmental management system such as ISO14001?	Yes/No
Sustainability-oriented innovation scale variables		
Capability 1	Understanding the capability of your organisation - We have the capabilities required to fully understand the future pollution effects of our new products	Likert scale
Capability 2	Understanding the capability of your organisation - We have the capabilities required to fully understand the future materials life cycle of our new products	Likert scale
Capability 3	Understanding the capability of your organisation - We have the capabilities required to fully understand the future carbon footprint of our products and services in use	Likert scale
Capability 4	Understanding the capability of your organisation - We conduct environmental research and development (R&D)	Likert scale
Evaluation 1	Sustainability evaluation that your organisation carries out - We evaluate the future pollution effects of our new products in use	Likert scale
Evaluation 2	Sustainability evaluation that your organisation carries out - We evaluate the future materials life cycle of our products and services in use	Likert scale
Evaluation 3	Sustainability evaluation that your organisation carries out - We evaluate the future carbon footprint of our products and services in use	Likert scale
Evaluation 4	Sustainability evaluation that your organisation carries out - We evaluate the current pollution contribution of our day-to-day operations	Likert scale
Evaluation 5	Sustainability evaluation that your organisation carries out - We evaluate the current materials life cycle of our day-to-day operations	Likert scale
Evaluation 6	Sustainability evaluation that your organisation carries out - We evaluate the current carbon footprint of our day-to-day operations	Likert scale
Products and services 1	The sustainability performance of your new products and services - Our new products and services will produce zero pollution	Likert scale
Products and services 2	The sustainability performance of your new products and services - The materials life cycle of our new products and services will be a closed loop with no landfill	Likert scale
Products and services 3	The sustainability performance of your new products and services - Our new products and services will have a zero or negative carbon footprint	Likert scale
Products and services 4	The sustainability performance of your new products and services - Our new products and services are sustainable	Likert scale

(continued on next page)

Table 2 (*continued*)

Topic	Question text	Response type
Products and services 5	The sustainability performance of your new products and services - Our new products and services will be socially beneficial	Likert scale
Operations 1	The sustainability performance of your organisation's operations - Our day-to-day operations produce zero pollution	Likert scale
Operations 2	The sustainability performance of your organisation's operations - The materials life cycle of our day-to-day operations is a closed loop; there is no landfill	Likert scale
Operations 3	The sustainability performance of your organisation's operations - Our day-to-day operations have a zero or negative carbon footprint	Likert scale
Operations 4	The sustainability performance of your organisation's operations - Our day-to-day operations are sustainable	Likert scale
Strategy 1	Your sustainability strategy - We strive to meet exceptionally high environmental goals	Likert scale
Strategy 2	Your sustainability strategy - Our top management are fully committed to sustainability	Likert scale
Strategy 3	Your sustainability strategy - Our sustainability strategy is proactive, and goes well beyond current regulations	Likert scale
Strategy 4	Your sustainability strategy - Our sustainability strategy is radical, and aims higher than others in our industry	Likert scale
Partnerships 1	Organisational partnerships for sustainability - Our innovations could not be delivered by our organisation alone	Likert scale
Partnerships 2	Organisational partnerships for sustainability - We collaborate with a wide range of external actors and stakeholders	Likert scale
Partnerships 3	Organisational partnerships for sustainability - Our sustainability goals are informed by a wide range of external views	Likert scale
Partnerships 4	Organisational partnerships for sustainability - We are willing to make new partnerships in order to meet our sustainability goals	Likert scale
Economic 1	Economic sustainability - My organisation will produce economically beneficial products and services	Likert scale
Economic 2	Economic sustainability - Our innovation decisions include finance as a central consideration (e.g. costs, revenues)	Likert scale
Economic 3	Economic sustainability - My organisation is economically excellent	Likert scale
Social 1	Social dimensions of sustainability - My organisation has excellent health and safety	Likert scale
Social 2	Social dimensions of sustainability - My organisation has excellent working conditions	Likert scale
Social 3	Social dimensions of sustainability - My organisation has excellent stakeholder and social dialogue	Likert scale
Social 4	Social dimensions of sustainability - My organisation improves the education and training of its workers	Likert scale
Demand 1	Demand patterns - We are considering how our new products and services might change demand patterns	Likert scale
Demand 2	Demand patterns - We are considering how our new products and services could be delivered through new business models	Likert scale
Demand 3	Demand patterns - We are considering how our new products and services could be delivered through new service systems	Likert scale
Demand 4	Demand patterns - We are considering the future effect of new regulatory systems	Likert scale

4.1. Pilot study

We began the evaluation of the scale with a pilot study, which involved 23 respondents recruited from a sustainable aerospace design project in the United Kingdom. Since we were developing a scale focusing on sustainability-oriented innovation, and all respondents were working on a sustainability-oriented innovation project, they were an ideal sample group for scale evaluation. We subjected the subscales to Cronbach alpha coefficient and item-total correlation analyses. All subscales yielded Cronbach alpha values ranging from adequate ($\geq$0.6) to satisfactory ($\geq$0.7), except the *Individual* subscale, which yielded a value of 0.2. Therefore, we discarded the individual subscale. Similarly, there were nine items, which when deleted from the subscale, the alpha value increased, indicating the subscale would be more reliable without that item. This suggested that when editing the scale, we should discard the nine items or refine them so that they would be more consistent with other items on the same subscale.

4.2. Data gathering

We gathered data from paid survey service platform Prolific (https://www.prolific.co/), which provides the facility to pay respondents a small fee for taking part in research. Prolific operates on the same model as Amazon Mechanical Turk, but it has panels of respondents in several countries outside of the United States, including the United Kingdom (UK). We exclusively targeted UK respondents. Our sample was deliberately broad, since our survey should be suitable for organisations of a range of types and sizes. We therefore selected for *employed* persons in companies of *any size*, with tenure of *1 year or more* in order to ensure some knowledge of the company's stated and actual practices relating to sustainability.

Research has demonstrated that online paid survey platforms produce data of comparable in quality to direct-contact methods, whilst offering the advantages of speed and ease of use (Paolacci et al., 2010; Rand, 2012; Goodman et al., 2013; Buhrmester et al., 2015).

We restricted the data collection to the UK to control for the potential variance of the scale across countries. A growing body of research indicates that there may exist distinct sustainability values and cultures in organisations, which influence the realised sustainability strategies of organisations (Assoratgoon and Kantabutra, 2023; Leiserowitz et al., 2005; Linnenluecke and Griffiths, 2010). Organisational-level cultures themselves have long been considered to nest within wider national cultures, whose dominant characteristics they osmose (Hofstede, 1980; House et al., 2004). Thus there may be variance in the sustainability innovation scale across countries (e.g., Brancu et al., 2022; Leitgöb et al., 2023).

We gathered 202 responses from Prolific over two weeks in October 2022. Respondents worked in diverse industry sectors; the largest were education, healthcare, retail, and manufacturing, which, respectively contributed 28 (14%), 23 (11%), 13 (6%) and 11 (5%) respondents. 102 (51%) were private sector organisations; 75 (37%) and 25 (25%) of the remainder were respectively, public sector and third sector organisations. Just over half, i.e. 108 (53%) of the respondents' organisations had more than 250 employees, whereas 57 (28%) had more than 10 and up to 250 employees can be regarded as Small and medium-sized enterprises (SMEs) and the remainder, i.e. 37 (18%), had 10 or fewer employees and can be classified as 'Micro'. 81 (40%) of the respondents stated that their organisation followed an environmental management system such as ISO14001.

4.3. Reliability evaluation

We subjected the 202 survey responses to the Reliability Analysis procedure in IBM SPSS 29, setting the model to Alpha. The reliability procedure calculated the initial Cronbach's Coefficient Alpha for each scale, which assessed the level of agreement across the items of the scores of the 202 respondents on each subscale by comparing the variance of the summated score for the items in the subscale against the sum of the variances of individual items, whilst weighting for the number of items in the subscale (see: Cronbach, 1951). Larger values of Coefficient

Alpha indicate greater agreement and, following Nunnally (1978), values greater than 0.7 are considered to indicate reliable scales.

To check how well scores on each individual item agree with the scores of the other items on the subscale and the individual contribution of each item to the reliability of the subscale, we run two additional tests. The first is the item-total correlation, which is the product-moment correlation coefficient of the scores of the 202 respondents on each individual item with the correlation of the mean of their scores on other items on the same subscale. Larger values of the item correlation indicate greater agreement of the item with its counterpart items on the subscale.

The second is the alpha-without test, which is a repetition of the Cronbach Alpha calculation whilst deleting each item from the subscale. A smaller alpha-without value than the initial alpha value confirms that the sub-item adds to the overall reliability of the subscale, whereas a larger value suggests the item makes the scale less reliable.

Table 3 shows the initial alpha values for each scale, item-total correlation, and alpha-without values upon deletion of each item from its respective subscale. The final column indicates whether we deleted an item from the subscale.

The sustainability-oriented innovation scale showed good internal consistency. All nine subscales yielded Cronbach alpha values greater than 0.8, the minimum being 0.80 for the economic subscale and the maximum being 0.96 for the evaluation subscale. However, not all items contributed to reliability. Deleting the following items from their respective subscales improved reliability: Capability_4, ProductService_5, and Partnerships_1. Therefore, we deleted these items before proceeding with further scale evaluation procedures.

The subscales demonstrate good internal consistency, with all final alpha values all exceeded 0.7, the threshold value specified by Nunnally's rule.

Table 3
Scale Reliability: alpha values and item-total correlations.

Subscale/ Initial alpha	Item	Correlation of item with mean of rest of the items	Cronbach Alpha Value when item deleted	Item deleted (Y/N)
Capability Initial Cronbach Alpha Value for scale: 0.908	Capability_1	0.839	0.865	N
	Capability_2	0.855	0.859	N
	Capability_3	0.844	0.863	N
	Capability_4	0.642	0.933	Y
Evaluation Initial Cronbach Alpha Value for scale: 0.962	Evaluation_1	0.871	0.956	N
	Evaluation_2	0.888	0.954	N
	Evaluation_3	0.904	0.952	N
	Evaluation_4	0.896	0.953	N
	Evaluation_5	0.857	0.957	N
	Evaluation_6	0.858	0.957	N
Products and Services Initial Cronbach Alpha Value for scale: 0.912	ProductService_1	0.812	0.883	N
	ProductService_2	0.794	0.887	N
	ProductService_3	0.843	0.876	N
	ProductService_4	0.822	0.881	N
	ProductService_5	0.606	0.925	Y
Operations Initial Cronbach Alpha Value for scale: 0.931	Operations_1	0.799	0.900	N
	Operations_2	0.830	0.894	N
	Operations_3	0.842	0.892	N
	Operations_4	0.856	0.889	N
Strategy Initial Cronbach Alpha Value for scale: 0.945	Strategy_1	0.850	0.934	N
	Strategy_2	0.846	0.935	N
	Strategy_3	0.918	0.913	N
	Strategy_4	0.859	0.931	N
Partnerships Initial Cronbach Alpha Value for scale: 0.881	Partnerships_1	0.652	0.881	Y
	Partnerships_2	0.738	0.849	N
	Partnerships_3	0.809	0.821	N
	Partnerships_4	0.771	0.836	N
Economic Initial Cronbach Alpha Value for scale: 0.802	Economic_1	0.675	0.699	N
	Economic_2	0.628	0.749	N
	Economic_3	0.638	0.739	N
Social Initial Cronbach Alpha Value for scale: 0.872	Social_1	0.716	0.840	N
	Social_2	0.783	0.813	N
	Social_3	0.690	0.850	N
	Social_4	0.715	0.840	N
Demand Initial Cronbach Alpha Value for scale: 0.943	Demand_1	0.817	0.941	N
	Demand_2	0.910	0.912	N
	Demand_3	0.892	0.918	N
	Demand_4	0.841	0.933	N

4.4. Exploratory factor analysis

To work out whether the scale was reflecting the expected nine subscale structure, we conducted an Exploratory Factor Analysis (EFA) of the Sustainable Innovation Scale, excluding the items deleted after the reliability analysis. The EFA applied the principal components factor extraction method, with the Equamax method of rotation, which attempts to simplify both the factors and the loadings of each indicator variable. The detailed results of the EFA are shown in Table E in the appendix.

The EFA model fitted the data very well. Kaiser-Meyer-Olkin Measure of Sampling Adequacy was high at 0.927, close to 1, which is ideal. Bartlett's test of Sphericity was statistically significant, with $\chi 2 = 7518$ ($df = 595, p < 0.001$), indicating that the indicator variables are related and relationships among them can be represented by a factor structure.

Table E shows the rotated factor structure: all indicator variables had high loadings on their assigned subscales. The nine factors explained a total of 84% of the variance in the data. All eigenvalues were greater than 0.7, conforming with Jolliffe's rule (see e.g. Rea and Rea, 2016) to extract factors with eigenvalues at least 0.7.

4.5. Confirmatory factor analysis

Next, we subjected the scale to a Confirmatory Factor Analysis (CFA). Figure C (in the appendix) is an SPSS Amos graphic of the factor structure: For the subscales to be constituents of the same scale, a necessary condition is that they should all be significantly correlated with each other. Thus the CFA modelled each subscale as correlated with every other subscale.

The CFA results confirmed the factor structure. Although the model Chi-square was significant with $\chi 2 = 282.1$ ($df = 106, p < 0.001$), the other fit statistics were indicative of a very good fit for the data: the Root Mean square Residual (RMR) = 0.128, was small and close to zero. Likewise the Goodness of Fit Index (GFI) = 0.991 was greater than 0.95 and close to 1; the Bentler-Bonett Normed Fit Index (NFI) = 0.989 was also close to 1 and greater than 0.9. Both latter results are indicative of a very good fit for the data.

To estimate the extent of Common Method Bias (CMB) in the data, we run two additional CFA models: a model with an unmeasured latent factor and a Harman one-factor model where all items loaded onto a single factor. The results indicated CMB was not likely to be a significant issue: The model with the unmeasured latent factor did not differ significantly from the baseline model (ΔCFI = 0.01). By contrast, the Harman one-factor model was significantly worse (ΔCFI = - 0.394).

Table V (in the appendix) shows the factor loadings of the indicator variables and the Average Variance Explained (AVE) and the Composite Reliability (CR) for each subscale. All indicator variables loaded strongly on their assigned subscale: all factor loadings exceeded 0.7 and were significant with $p < 0.001$. The Average Variance Explained (AVE) by each subscale exceeded the acceptable threshold of 0.5. Likewise, the CR values for each scale exceed 0.7, the required minimum under Nunnally's rule. Thus, we can conclude the Sustainable Innovation scale demonstrates **convergent validity**.

Table S (in the appendix) shows the estimated subscale inter-construct correlations and the comparison of correlation within each construct against inter-construct correlation to apply Fornell and Larcker's (1981) criteria for discriminant validity. The inter-construct coefficients ranged from moderate to strong and were all significant at the 0.05 p-value level. This confirms the significant covariance of the subscales as constituents of the same scale. On the other hand, all within-construct correlation values, i.e. square root of AVE, exceeded the inter-construct correlation value of each subscale with the other subscales. This demonstrates that the subscales are distinct from each other, and the Sustainable Innovation Scale demonstrates discriminant validity under Fornell and Larcker (1981) criteria.

5. Discussion

5.1. Main findings

This paper develops and validates a new scale for measuring sustainability-oriented innovation, a developing concept that is extremely far-reaching, influencing an organisation's values, products and services, and practices (Adams et al., 2016). Having conducted a literature review to identify the key aspects, the scale includes sustainability dimensions of capability, evaluation, products and services, operation, strategy, partnerships, economic, social, and demand.

In order to evaluate the new scale we first ran a pilot test with 23 respondents, and subsequently modified the scale. We then tested the scale by analysing 202 survey responses. The scale evaluation tests confirm the consistency, convergent, and discriminant validity of the sustainability-oriented innovation scale. Both exploratory and confirmatory analysis results confirm that the theorised scale is a good fit for the data.

5.2. Contribution

This paper presents an important step forward in developing the wider understanding and organisational adoption of sustainability-oriented innovation (SOI). In the wider research topic of innovation indicators, sustainability has received limited attention (Dziallas and Blind, 2018). A number of systematic literature reviews have been carried out addressing SOI (Adams et al., 2016; Cillo et al., 2019; Maier et al., 2020), all of them noting the recent development and the relevant immaturity of this topic. One systematic review noted that (as of 2016) "… little attention has been paid to SOI, and what exists is only partial" (Adams et al., 2016). Another noted that of the three perspectives they identified in the SOI literature (internal managerial, external relational, and performance evaluation) the first perspective is the most considered, and the others remain underdeveloped (Cillo et al., 2019). A bibliometric study revealed that during the period 2010–2020 there was a marked growth in the research literature addressing sustainability and innovation, and the authors noted the emergence of 'sustainable innovation' as a new concept (Maier et al., 2020).

Whilst a great deal of work has been done in the area of sustainability-oriented innovation, we were not able to find an existing, validated framework that could be widely applied in a range of settings. Some of the existing models have addressed specific areas such as SMEs (Bos-Brouwers, 2010), and so exclude large firms, environmentally sustainable product innovation (De Medeiros et al., 2014), and so exclude services, manufacturing SMEs (Chen et al., 2014; Khurana et al., 2019, 2021), eco-process innovation focusing on manufacturing processes (Mat Dahan and Yusof, 2020), manufacturing supply chains (Kusi-Sarpong et al., 2019), or the strategic sustainability behaviours of SMEs (Klewitz and Hansen, 2014). Many of these focused analyses do consider a wide range of factors, but their intended application areas are quite specific.

A number of frameworks have been proposed that are comprehensive but not empirically validated. The 'sustainability innovation cube' considers a range of dimensions in the target areas of need, life cycle and target (Hansen et al., 2009), and whilst it does include a qualitative expert review, it does not include a survey scale or a quantitative validation. Another extensive review presents SOI according to three main dimensions: the sustainability orientation, types, and degrees (Jay and Gerard, 2015). This comprehensive framework did not include a measurement scale, was not validated, and was not peer reviewed. There is also some early empirical work into the success factors of sustainability-oriented innovation in single case studies, which include "adopting an existing route to market, partnering with an NGO, and learning from mistakes in a safe failure space" (Luqmani et al., 2017).

As such, our contribution to the academic literature is a widely applicable sustainability-oriented innovation scale that consolidates the existing work and which is empirically validated. Our assessment framework includes eco-innovation capability, evaluation, products and operations, strategy, partnerships, economic sustainability, social sustainability, and consideration for future demand.

5.3. Strengths and limitations

We have proposed a wide-ranging survey scale that can be used in a variety of organisational settings. The advantages of this include the ability to make comparisons across sectors and geographies. The disadvantages of this approach include the omission of critical variables that are sector-specific. A power generation plant might need to measure the release of PM2.5 airborne particulates, whereas a steel manufacturing plant might need to consider specific water contaminants.

Since our validation sample was UK only, which enabled control for variance related to national culture differences across countries, the scale may need to be validated prior to applying it in other countries whose dominant national culture values and practices differ significantly from the United Kingdom, e.g. China (Gupta et al., 2002). On the other hand, the scale is likely to be invariant in countries which are culturally very similar to the UK, i.e. so-called Anglo-Saxon culture cluster countries such as United the States (Gupta et al., 2002).

The scale attempts to include all the elements that according to the literature are pertinent to measuring sustainability-oriented innovation. As such, it is composition is bounded by what is currently known to be relevant either theoretically or from empirical findings. As the research advances in this area, the scale may be extended to include new elements and/or simplified to delete elements that become less relevant.

5.4. Future research

Future work can apply the validated scale in a number of ways. First, the relationships between the scale dimensions can be evaluated, including the most influential dimensions and the strength of their relationships. Large-scale surveys could study the sustainability-oriented innovation performance within and between sectors and geographies, including across countries to determine invariance. Future studies could also analyse whether the sustainable innovation scale predicts expected outcomes, including successful innovations with demonstrable sustainability impact.

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CRediT authorship contribution statement

David Baxter: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization, Resources, Funding acquisition, Project administration. **Maxwell Chipulu:** Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – review & editing, Visualization, Software.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendices.

Table E
Exploratory Factor Analysis: Rotated factor loadings and Variance Explained

Indicator Variable	Rotated Factor Loadings								
	1	2	3	4	5	6	7	8	9
Capability_1	0.238	0.093	0.063	0.830	0.144	0.208	0.191	0.169	0.049
Capability_2	0.257	0.050	0.031	0.846	0.131	0.177	0.143	0.156	0.138
Capability_3	0.349	0.201	0.105	0.738	0.056	0.230	0.133	0.176	0.143
Evaluation_1	0.614	0.144	0.031	0.409	0.132	0.330	−0.002	0.329	0.187
Evaluation_2	0.667	0.142	0.026	0.364	0.113	0.323	0.009	0.337	0.152
Evaluation_3	0.696	0.224	0.038	0.375	0.155	0.327	0.015	0.197	0.179
Evaluation_4	0.767	0.239	0.040	0.316	0.109	0.237	0.071	0.207	0.133
Evaluation_5	0.712	0.231	0.191	0.317	0.066	0.252	0.139	0.218	0.112
Evaluation_6	0.688	0.284	0.090	0.329	0.208	0.240	0.138	0.193	0.121
ProductService_1	0.058	0.080	0.361	0.060	0.797	0.156	0.084	0.026	0.187
ProductService_2	0.088	0.069	0.386	0.179	0.778	0.065	0.074	0.066	0.173
ProductService_3	0.186	0.100	0.379	0.025	0.766	0.244	0.121	0.143	0.122
ProductService_4	0.057	0.135	0.325	0.218	0.641	0.203	0.187	0.219	0.282
Operations_1	0.028	0.019	0.862	−0.025	0.279	0.143	0.080	−0.003	0.138
Operations_2	0.028	0.028	0.783	0.126	0.385	0.092	0.080	0.103	0.144
Operations_3	0.132	0.104	0.823	0.053	0.333	0.167	0.093	0.029	0.140
Operations_4	0.008	0.144	0.716	0.119	0.366	0.165	0.161	0.158	0.224
Strategy_1	0.217	0.179	0.198	0.275	0.257	0.656	0.142	0.263	0.239
Strategy_2	0.191	0.237	0.160	0.251	0.235	0.660	0.289	0.262	0.145
Strategy_3	0.315	0.179	0.193	0.254	0.195	0.699	0.207	0.253	0.180
Strategy_4	0.308	0.139	0.234	0.229	0.150	0.687	0.135	0.279	0.202
Partnerships_2	0.118	0.141	0.026	0.055	0.028	0.063	0.191	0.850	0.122
Partnerships_3	0.172	0.176	0.068	0.194	0.087	0.315	0.076	0.774	0.204
Partnerships_4	0.196	0.262	0.067	0.274	0.184	0.314	0.127	0.693	0.147
Economic_1	0.028	0.222	0.166	0.091	0.190	0.259	0.113	0.123	0.732
Economic_2	0.090	0.245	0.012	0.157	0.182	−0.127	0.193	0.265	0.752
Economic_3	0.137	0.112	0.261	−0.030	0.093	0.250	0.298	0.032	0.711
Social_1	−0.126	0.086	0.117	0.192	0.108	0.113	0.765	0.076	0.245
Social_2	−0.071	0.073	0.182	0.194	0.114	0.083	0.794	0.108	0.292
Social_3	0.187	0.263	0.075	−0.013	0.092	0.077	0.713	0.261	0.202
Social_4	0.197	0.301	−0.017	0.084	0.065	0.202	0.787	0.089	0.018
Demand_1	0.182	0.749	0.136	0.093	0.082	0.146	0.147	0.221	0.287
Demand_2	0.138	0.835	0.054	0.118	0.123	0.163	0.209	0.202	0.224
Demand_3	0.162	0.840	0.069	0.093	0.101	0.157	0.194	0.160	0.218
Demand_4	0.197	0.768	0.043	0.165	0.084	0.162	0.263	0.208	0.172
% of Variance explained	10.9	10.0	9.9	9.6	9.3	9.1	8.9	8.6	7.6
Subscale label	Evaluation	Demand	Operations	Capability	Products and Services	Strategy	Social	Partnerships	Economic

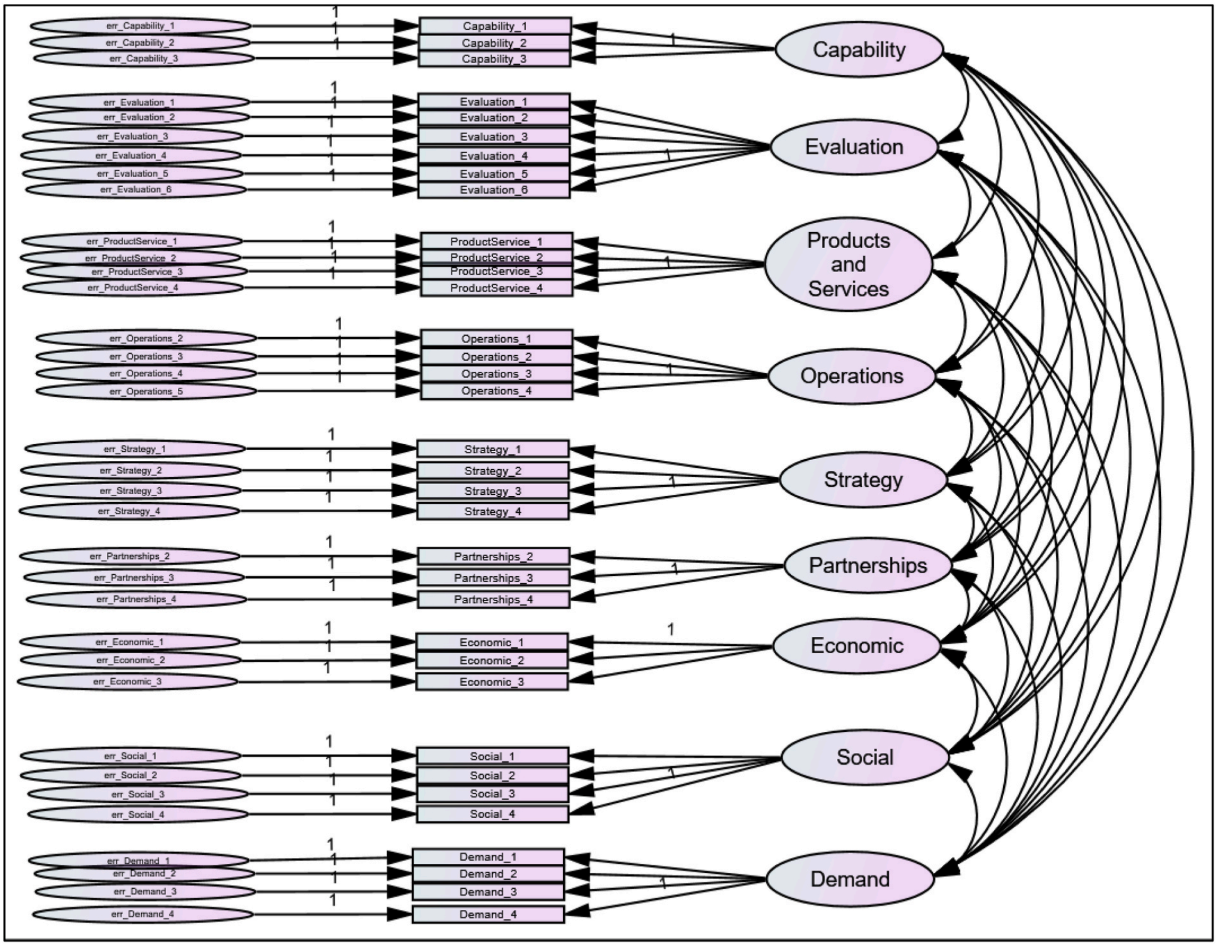

Fig. C. Hypothesized Confirmatory Factor Structure of the Sustainable Innovation Scale.

Table V
Convergent Validity: AVE, CR and Confirmatory Factor Loadings

Subscale AVE & CR	Indicator		Subscale	Standardised Estimated Loading
AVE = 0.821	Capability_3	<—	Capability	.962
CR = 0.932	Capability_2	<—	Capability	.868
	Capability_1	<—	Capability	.886
AVE = 0.809	Evaluation_6	<—	Evaluation	0.919
CR = 0.962	Evaluation_5	<—	Evaluation	0.898
	Evaluation_4	<—	Evaluation	0.877
	Evaluation_3	<—	Evaluation	0.915
	Evaluation_2	<—	Evaluation	0.888
	Evaluation_1	<—	Evaluation	0.900
AVE = 0.753	ProductService_4	<—	Products and Services	0.956
CR = 0.924	ProductService_3	<—	Products and Services	0.905
	ProductService_1	<—	Products and Services	0.789
	ProductService_2	<—	Products and Services	0.81
AVE = 0.770	Operations_1	<—	Operations	0.756
CR = 0.93	Operations_2	<—	Operations	0.856
	Operations_3	<—	Operations	0.907
	Operations_4	<—	Operations	0.976
AVE = 0.812	Strategy_1	<—	Strategy	0.899
CR = 0.945	Strategy_2	<—	Strategy	0.896
	Strategy_3	<—	Strategy	0.927
	Strategy_4	<—	Strategy	0.882
AVE = 0.731	Partnerships_2	<—	Partnerships	0.66
CR = 0.904	Partnerships_3	<—	Partnerships	0.891
	Partnerships_4	<—	Partnerships	0.981
AVE = 0.576	Economic_1	<—	Economic	0.798
CR = 0.802	Economic_2	<—	Economic	0.714
	Economic_3	<—	Economic	0.761

(*continued on next page*)

Table V (*continued*)

Subscale AVE & CR	Indicator		Subscale	Standardised Estimated Loading
AVE = 0.629	Social_1	<—	Social	0.709
CR = 0.871	Social_2	<—	Social	0.796
	Social_3	<—	Social	0.855
	Social_4	<—	Social	0.806
AVE = 0.807	Demand_1	<—	Demand	0.889
CR = 0.944	Demand_2	<—	Demand	0.915
	Demand_3	<—	Demand	0.881
	Demand_4	<—	Demand	0.908

Table S
Inter- Construct correlations and comparisons with within construct correlations

Subscale 1	Subscale 2	Inter-Construct Correlation Coefficient	Within-construct correlation (SQRT AVE)	Is SQRT AVE > Inter-construct Correlation?
Capability				
Capability	Demand	0.457	0.906	Yes
Capability	Economic	0.438	0.906	Yes
Capability	Operations	0.308	0.906	Yes
Capability	Partnerships	0.578	0.906	Yes
Capability	Products and Services	0.432	0.906	Yes
Capability	Social	0.453	0.906	Yes
Capability	Strategy	0.692	0.906	Yes
Economic				
Economic	Demand	0.664	0.76	Yes
Economic	Social	0.659	0.76	Yes
Evaluation				
Evaluation	Capability	0.782	0.899	Yes
Evaluation	Demand	0.601	0.899	Yes
Evaluation	Economic	0.5	0.899	Yes
Evaluation	Operations	0.337	0.899	Yes
Evaluation	Partnerships	0.684	0.899	Yes
Evaluation	Products and Services	0.468	0.899	Yes
Evaluation	Social	0.388	0.899	Yes
Evaluation	Strategy	0.792	0.899	Yes
Operations				
Operations	Demand	0.335	0.877	Yes
Operations	Economic	0.549	0.877	Yes
Operations	Partnerships	0.328	0.877	Yes
Operations	Social	0.382	0.877	Yes
Operations	Strategy	0.558	0.877	Yes
Partnerships				
Partnerships	Demand	0.612	0.855	Yes
Partnerships	Economic	0.57	0.855	Yes
Partnerships	Social	0.496	0.855	Yes
Products and Services				
Products and Services	Demand	0.42	0.868	Yes
Products and Services	Economic	0.618	0.868	Yes
Products and Services	Operations	0.829	0.868	Yes
Products and Services	Partnerships	0.451	0.868	Yes
Products and Services	Social	0.436	0.868	Yes
Products and Services	Strategy	0.642	0.868	Yes
Social				
Social	Demand	0.602	0.793	Yes
Strategy				
Strategy	Demand	0.61	0.901	Yes
Strategy	Economic	0.645	0.901	Yes
Strategy	Partnerships	0.74	0.901	Yes
Strategy	Social	0.573	0.901	Yes

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