Submitted: 24 May 2023

Published online in 'accepted manuscript' format: 24 October 2023

Manuscript title: Implementing ISO14001 in the engineering and construction sectors: a systematic review

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Accepted manuscript
doi: 10.1680/jensu.23.00038

Abstract

There is a need within society to manage our impacts on the environment. The ISO14001 tool, based on the original BS7750 standard, was created in 1996 and subsequently updated in 2004 and 2015, has become the most prevalent type of Environmental Management Systems (EMS) adopted worldwide. Engineering and construction organisations wanting to implement ISO14001 should be fully acquainted with the advantages and disadvantages of adopting an EMS. Using the SCOPUS academic database, this study uses the PRISMA-method to identify and select publications (since 1999) for systematic review. Examination of the chosen articles (n=46) reveals a limited number of works per annum, with a peak in 2011 (n=6). The most frequently reported benefits are 'enriching green corporate and public image', 'improved environmental performance' and 'regulation compliance'; whilst the barriers are 'costs', 'lack of experience, expertise or knowledge' and 'lack of training'. Further analysis, using VOSviewer, has shown the network relationships between article keywords, notably that sustainability is increasingly listed (since 2011) and links with most other keywords. This suggests the engineering and construction sectors may be seeing beyond the cost barrier and are realising the positive difference ISO14001 can contribute to their operations, their local/national communities, and to the SDGs.

1. Introduction

Management systems are used throughout many modern-day businesses as tools to monitor and improve operational performance (Brudan, 2010). The International Standards Organisation (ISO) are a major contributor to the production of these standards to which businesses can be certified. The ISO14001 standard is the most widely adopted global environmental management systems (EMSs) that allows the environmental impacts of an organisation to managed and monitored. However, the latest versions of the standards also support the economic, environmental, and social pillars of sustainable development.

The United Nations 2030 Agenda for Sustainable Development sets out 17 sustainable development goals (SDGs) and 169 sub-goals (UN, 2023). This work was aimed at integrating sustainability into organizations worldwide through addressing current and future stakeholder needs and contributing to the achievement of sustainable development for society and the planet. The SDGs were more ambitious than the Millennium Development Goals (MDGs). The SDG goals, extended the remit to cover the natural world, as well as the human-centric approach (Gusmao Caiado *et al.,* 2018). The goals were to engage all countries not just the developing nations. The additional issues considered included climate change, life on land, life below water, responsible production, responsible consumption, sustainable cities and communities. This work brought an increased focus within society on the need to protect the environment for future generations, as well as building upon many issues that had initially come to the fore in 1987 with the Brundtland Report, followed by the United Nations Conference on Environment and Development known as the “Earth Summit” in 1992. This has

been supported by documents such as the UK 25-year Environmental Plan (UK Gov, 2023), a new strategy for the Environment (OECD, 2023), the EU 8th Environmental Action Programme (EU, 2023) along with the ongoing work of the UN Environmental Programme (UNEP, 2023).

Greater environmental awareness and wider promotion of sustainability issues has meant EMSs have increased in use and popularity over the last 20 years and can be found operating in a variety of sectors. Adoption of the ISO14001 EMS has increased from ~15,000 certifications in 1999 to more than 346,000 in 2016 (ISO, 2023). Neumayer and Perkins (2004) examined the uptake of ISO14001 and noted certifications were 49.6% in Europe, 34.8% were in Asia, 7.3% in North America, 3.9% in Australia and New Zealand, 2.5% in Africa and 1.9% in Central and South America. In 2021 the number of valid certificates had reached 420,433 (ISO, 2023). These figures have not only increased but there is also a geographical change in terms of the highest number of certificates; China - 217,592; the UK - 17,378; Spain - 14,122; Japan - 21,976 and Italy - 18,135; America - 4,171; and Thailand - 4,381 certificates (ISO, 2023). Other researchers (Orcos and Palomas, 2019) have investigated the uneven application of ISO14001. This implies that there are differing factors that impact where engagement takes place and the areas which are finding most value in using the system. It is noteworthy that of the declared sectors (in 2021), the construction industries had the highest representation of all sectors with 68,551 certificates (ISO, 2023).

2. Purpose

The increase in awarding of EMS certificates, particularly in the construction sector, suggests a

value in the implementation of EMSs. It is possible that certain sectors are more proactive in engaging with sustainability (ISO 2023) and that this may be a driver for this uptake. The last 20-years, however, has seen much debate about the benefits and barriers of implementing ISO14001 and there is still a basic need to understand the reasoning for the uptake. A question remains as to the factors which influence engagement with EMS in the engineering and construction sectors. To enable this question to be answered this study aims to provide a systematic review of EMS publications linked to the engineering and construction sectors to identify the most widely reported benefits and barriers of using ISO14001 and to determine whether growth of sustainability in the sectors has influenced reporting.

3. Methodology

This work was conducted using an interpretivist epistemology (i.e., taking a variety of different points of view or aspects of reality), applying an abductive reasoning approach (i.e., considering the different possibilities but with most effective explanation proposed), which was utilised to deliver on the aim of this study. A comprehensive review was conducted of the existing peer reviewed ISO14001 benefit and barriers literature following the PRISMA evidence–based process which is transparent and provides a complete reporting process. In this process articles are firstly identified, then screened, and finally checked for eligibility before being included in the systematic review (Liberati *et al.,* 2009). In this study the literature was restricted to peer–reviewed journal papers, due to the rigorous process and peer scrutiny undergone to ensure a higher validity of the findings than some other available materials.

The Scopus academic database was chosen as it covers a variety of different discipline

areas (such as engineering, business, social science). The search was limited to common phrases or keywords (such as environmental management, environmental management systems, ISO14001) within fields (such as architecture, engineering, construction) and the literature search was restricted to articles from 1999 to 2022 (years inclusive) and only works published in the English language; book chapters, documents and website articles were excluded due to the lack of peer review within these formats.

The typical code used to search the databases was: *TITLE-ABS-KEY ((“environmental management”) OR (“environmental management systems”) OR (“ISO14001”) AND (“architecture”) OR (“construction”) OR (“engineering”) OR LIMIT–TO (DOCTYPE, "re") OR LIMIT TO (DOCTYPE, "cp") OR LIMIT–TO (DOCTYPE, "ch")) AND (LIMIT–TO (SUBJAREA, "busi") OR LIMIT–TO (SUBJAREA, "engi") AND (LIMIT–TO (LANGUAGE, "English") AND (PUBYEAR AFT 1999)).*

This study aim will be supported through the production of a list of the benefits and barriers associated with the use of ISO14001 which have already been identified in existing literature. After all journal articles were screened and checked, the content analysis was performed as a means for selecting the publications which meet the inclusion criteria for this study and thereby can be included in the systematic review.

A scientometric analysis process was further applied to objectively measure and map the status of the current understanding and evolution of knowledge within the comprehension of the benefits and barriers to the use of ISO14001 within the engineering and construction sectors. VOSviewer software (version 1.6.17) was used to construct and visualise the

bibliometric networks, by the use of keywords and associations identified by the software and within this it was possible to visually demonstrate the distance between two nodes which could be utilised to indicate the relationships of the nodes (i.e., strongly related nodes are closely located and vice-versa). The nodes themselves are within a two-dimensional space within a given network and clusters, here colour has been used to highlight which node has been assigned and the size of the font has been used to show the recurrence of the term used (van Eck *et al.,* 2010; van Eck and Waltman, 2014).

4. Findings

The article searches conducted produced the following outcomes and the findings are presented in the sections which follow. This is presented in five sections: (i) identification and selection of articles; (ii) article sources; (iii) co-occurrence of countries; (iv) co-occurrence of keywords; and (v) classification of articles.

4.1 Identification and selection of articles

An initial literature search was conducted using Scopus generating, 176 articles. A screening process was then followed to remove any articles which were irrelevant or duplicated. Also, articles that were not relevant to the scope of the enquiry, or area of research were removed (Figure 1). This resulted in a final selection of (n = 46) articles which were included based on the chosen classification (Table 1). The number of publications which discuss ISO14001 appears to be consistent over the years with a slight increase post-2010 (n=24) which equates to 52% of articles within this study and all articles chosen for this study were published

post–1999 (Figure 2).

The papers were then classified to highlight year of publication, country of study, sector, methodology used, authors, and source type (all journal articles) (n=46).

Table 1: Details of the papers reviewed including the year of publication, country, sector, methodology used and the authors.

The publications reviewed (Figure 1) included 8 projects from China and Hong Kong and 7 from the USA, the remainder were conducted in a variety of countries including Australia, UK, Latvia, Italy, Nigeria, and Spain. The data shows that there was a noticeable increase in papers in 2011 which has since declined, although over the whole-time frame there are only minor fluctuations in the academic interest surrounding this topic. The analysis of the papers reviewed noted a variety of methods (Table 1) were used to ascertain the effectiveness of ISO14001, which are classified into 9 different types. The methodologies used are classified as action research, audit, case study, interview, literature review, literature review and case study, questionnaire, review, and structured interviews. The types listed in the methodology column are detailed in Table 1, showing that questionnaire is the most utilised method (59%) with case studies (17%) ranked second in popularity. Thus, questionnaires are by far the most popular method, possibly because of the time required and ease with which these can be conducted and produce large amounts of data.

4.2 Article sources

The selected articles are from a range of peer reviewed journals demonstrating the range of interest in this topic area across many subject specialisms (Table 2).

4.3 Co-occurrence countries

When considering the areas of the globe and over time where research into ISO14001 has been conducted (Table 2) there are a variety of countries where research into ISO14001 benefits and barriers has occurred. The country with the most publications is the USA (n = 7), however, this is a small number of papers, and many other countries have research interests including Australia, Bulgaria, China, Egypt, Finland, Germany, Hong Kong, Italy, Latvia, Malaysia, Nigeria, Singapore, Slovenia, South Africa, Spain, Turkey, UK, Vietnam. A wide variety of countries were found in the sample (n = 39). These articles were then reviewed with the aim of identifying key themes to ascertain the benefits and barriers to the uptake of ISO14001.

4.4 Co-occurrence of keywords

Keywords are used to provide a concise description of the subject of the papers. This information has enabled the production of a network of keywords to demonstrate the knowledge provided by researchers (Su and Lee, 2010). By use of a software system, VOSviewer, “Author Keywords” and “Full Counting” filtered to keywords appearing 5 or more times in the papers. The software system then looked for those words which appear most frequently as keywords in this literature review (Hosseini *et al.,* 2018).

The size of the node in Figure 3 and the lines connecting to other keywords which occur in the article on ISO14001 are presented in a variety of colours and these colours demonstrate the links between the recurring keywords within the journal articles on ISO14001. The clusters are in different colours, and then keywords within the same cluster which are linked strongly

are shown in the same colour. As expected, environmental management and environmental performance are clearly shown but also is industry (Figures 3). It is interesting, however, to note that sustainability appears at a lower level in the density and lower still is sustainable development (Figures 3), which may reflect a change in attitude towards the use of ISO14001, for more than just environmental management in the purest sense. It is noted that sustainability as a keyword has not been used as much as environmental, but this has been slowly changing in papers from 2011 onward which supports the idea of a shift in attitude to organisations being more sustainable rather than just environmentally aware.

4.5 Classification of articles

This review focusses on the benefits and barriers to the use of ISO14001 in the engineering and construction sectors using literature within this area to support on the aim of the research. From the literature review (Table 1) the articles were analysed to produce a list of the benefits and barriers that have been identified through previous research into environmental management, ISO14001, and environmental management systems. These benefits and barriers associated with the use of ISO14001 were then sorted into key themes (Tables 3–10) namely: Public Relations (PR), Economics, Environmental, Legal, Community (only benefits found), Operational, Human Resources (HR) and Sector Specific (only barriers found).

Those most frequently cited benefits in the literature reviews are (i) enriching green corporate and public image (appearing in 44% of the articles), (ii) improved environmental performance (39%) (iii) compliance with regulations (39%), cost savings (37%) and long-term competitive advantage (35%). While in respect to the barriers to implementation, the highest

reported barriers are (i) cost (61%), (ii) lack of expertise (30%), (iii) lack of training (28%), (iv) lack of stakeholder support (26%), (v) not a legal requirement, lack of government pressure, time, and documentation (22%). Tables 3–10 show the benefits and barriers and the number of times these are mentioned in the literature that has been reviewed.

For reporting purposes and to present those considered to be widely appropriate, it was decided to record and present only those benefits or barriers that are mentioned a minimum of five times in separate articles.

4.5.1 Public relations benefits and barriers

The benefits (Table 3) which relate to PR shows that by far the most reported benefit is *"to enrich green corporate and public image"*. In relation to barriers within the PR category there were very low reporting of barriers, suggesting that ISO 14001 is positive in respect of improving public image.

4.5.2 Economic benefits and barriers

When considering the benefits and barriers in respect of economics (Table 4), it is evident that the top reported factor was *"cost"* which was seen as a barrier to engagement. However, when reviewing the benefits, the most reported factor was that of *"cost saving"*, so it appears that cost-benefit is an important factor when deciding on whether to engage with ISO14001 and if the potential savings are more than the cost of implementing the standard, a positive net-balance may be sufficient to encourage engagement.

4.5.3 Environmental benefits and barriers

Table 5 details the reported benefits and barriers in relation to Environmental factors, here the most reported factors are *"improved environmental performance"*, followed by that of *"protecting the environment"*. These are factors which are a requirement of ISO14001 so would be expected to be found as being a benefit. The barriers noted are low in number of times they are reported.

4.5.4 Legal benefits and barriers

The legal impacts of implementing ISO14001 in Table 6 list the most reported benefit as *"compliance with legislation"* and again the barriers reported are not significant in the number of times that they are reported. Here again legal compliance is an expected outcome of the implementation of an EMS.

4.5.5 Community benefits and barriers

In relation to the community benefits (Table 7) these are only mentioned in a small number of papers (n=9), and none of the community related barriers reach a reporting number which is deemed significant to report.

4.5.6 Operational benefits and barriers

In respect of operational factors (Table 8), it is interesting to note that the benefits are not significant enough to reach the number required for reporting, but here more barriers are reported in respect of *"lack of stakeholder support"* and *"documentation*". This is worth

noting as it has been reported in other studies that stakeholders can be the reason for implementing ISO14001. This value placed on stakeholders could be to in respect of the ability to enable engagement with tenders, but this may of course be also influenced by the the nature of the stakeholders who are being discussed in this literature. A potential barrier which is reported is that the supply chain is not able to deliver on ISO14001. Another barrier is in relation to documentation. The required documents can be challenging for smaller companies to manage.

4.5.7 Human resource benefits and barriers

In the category of Human Resources (HR) (Table 9) there are issues pertaining to the knowledge of the staff who would be required to engage with the system, with expertise being highlighted as a barrier along with the lack of training on the system. Time is also noted in this category as a barrier to the implementation. The main reported benefit is that of the environmental awareness of the staff.

4.5.8 Sector specific benefits

In relation to the sector benefits none are noted in the literature reviewed in relation to the implementation of ISO14001 within the sector-specific category (Table 10). There are, however, barriers with the one cited most as being *"lack of government pressure."* This lack of pressure would suggest that it appears that a legal requirement is needed for some organisations to engage with environmental management systems and that the lack of this requirement is resulting in many not engaging.

5. Discussion

This section sets out to review the findings of the literature review in respect of the engineering and construction sectors to establish the practical implications of the most reported benefits and barriers to the use of ISO14001 within organisations.

5.1 Benefits of ISO14001

Those most frequently noted by the literature review are (i) Enriching green corporate and public image, (ii) Improved environmental performance and compliance with regulations, (iv) cost savings and (v) Long-term competitive advantage. Improved environmental performance and compliance with regulations are a requirement of ISO 14001, therefore this discussion will focus on the other leading benefits; enriching green and public image, cost savings and long-term competitive advantage (Ofori *et al.,* 2000; Shen and Tam, 2002; Valdez and Chini. 2002; Adetunji *el al.,* 2003; Swaffield and Johnson, 2005; Turk, 2009; Terio and Kahkonen, 2011: Bailey *at al.,* 2020, Horry *et al.,* 2022).

It is, however, interesting to note that enriching green corporate and public image is highlighted more frequently than improved environmental performance which is one of the requirements of the system. It is possibly more beneficial to an organisation to improve their public image rather than their environmental performance in terms of improved economic prosperity. There is a risk, however, that this could result in the EMS becoming a badge rather than bringing about positive actions, but this is not reflected in the literature. Compliance with regulations is seen as being a notable benefit but again this is about legal requirements and not

something out of the ordinary. This, however, could be linked back to economic benefits due to the reduced risk of liability and hefty fines for non-compliance (Arimura *et al.,* 2008; Chan, 2008). Cost savings again, are an economic advantage and as such may well be judged against the costs of implementation to ascertain if this is an economically viable or even a beneficial action for a company to take. The last benefit which was seen as significant was the one of long-term competitive advantage (Chavan, 2005) which may well link to the ability to compete for tenders (Turk, 2009). Certain organisations have witnessed increased export opportunities due to having a recognised management system and thus, organisations experience additional positive PR. The use of ISO14001 can also be beneficial to companies looking to expand their environmental work to have a more sustainability focussed strategy and to enable engagement with the SDGs (Horry *et al.,* 2022). It is possible to use the system as a means of mapping how their work contributes to the delivery of the SDGs (Horry *et al.*, 2022).

5.2 Barriers of ISO14001

The most frequently cited barriers in the literature reviewed are cost, lack of stakeholder support and lack of experience, exoertise or knowledge (Ofori *et al.,* 2000; Ofori *et al.,* 2002; Shen and Tam, 2002; Zutshi and Sohal, 2004; Turk, 2009; Turk, 2012; Owolana and Booth, 2016; Bailey *et al.,* 2020; Horry *et al.,* 2022a).

The leading barrier to the implementation of ISO14001 is cost. Shen and Tam (2002) noted this in their research in Hong Kong and cost as a barrier has continued to be a major factor in the uptake of environmental management systems. It must also, however, be remembered that cost savings are seen as a benefit. There is a balance to be achieved

between the costs and the savings to be made which will majorly influence the decisions as to whether to adopt an environmental management system or not. The next major factors in relation to barriers, is that of lack of experience, expertise and knowledge closely followed by lack of training. As these barriers are similar, they will be examined together.

There are issues as seen from the literature review in relation to the lack of knowledge and the sectors inability to increase that knowledge, which is a major factor in the uptake of the system approach. Whether the stakeholders are committed to the system is another factor that has been highlighted in the past. It has been noted more recently, however in Horry *et al.* (2022) that more companies are highlighting the requirement of having an EMS to ISO14001 standard as a prerequisite for engagement with the tender process. So, while lack of stakeholder commitment is listed as a barrier, there is a growing stakeholder requirement within the tender process. Furthermore, documentation has also been noted as a challenge by previous researchers (Owolana and Booth, 2016; Schmidt and Osebold, 2017) in relation to environmental management systems, and this is particularly relevant for SMEs who may not have the staff time available to manage the requirements. Finally, time is identified as a barrier (Bailey *et al.*, 2020; Horry *et al.,* 2022) as this is an extra task on top of an organisation's daily routine.

6. Originality

The benefits and barriers of ISO14001 have been well documented over the years. As opinions and public awareness change in relation to issues such as climate change, there is an increasing focus on not just environmental management but also sustainability. The engineering and

construction sectors are having to adapt to the new world and the changing expectations of societies and their governments in respect of environmental protection. The use of ISO14001, however, is still very much focused on short-term economic factors, and HR challenges of staff awareness and training. It is vital that as a society, there is a move to encourage more environmentally aware staff, to ensure not only the survival of engineering and construction organisations but also the sustainability of their operations in relation to their impact on the planet. The uptake of ISO14001 has been consistently increasing since it was introduced in 1996, and the benefits and barriers have for the most part been consistent over time. One factor which seems to be changing is the inclusion of sustainability in the keywords as opposed to purely environmental management.

7. Conclusions

This work has presented a systematic literature review, which has examined the benefits and barriers to the use of ISO14001 over the last twenty-plus years. The main finding of this research is the generation of a comprehensive list of major benefits and barriers to the use of the system within the engineering and construction sectors. Those most often noted by the literature review are: (i) enriching green corporate and public image (44%), (ii) improved environmental performance (39%) (iii) compliance with regulations (39%), cost savings (37%) and long-term competitive advantage (35%). While in respect to the barriers to implementation, the highest reported barriers are: (i) Cost (59%), (ii) Lack of experience, expertise, or knowledge (35%), (iii) Lack of training 28%, (iv) Lack of stakeholder support (26%) and (v) Time and Lack of Government pressure (22%). Most of the articles included in this review used

questionnaires as their data collection instrument which provides a view of the participant completing the questionnaire and are reliant on the validity of the questions being asked. It must also be noted that the answers to the questions will be dependent on the maturity of the system and the demands of the supply chain within which these organisations sit. Further, in-depth phenomenological research would be required to ascertain the reasons behind the selection of each of the benefits and barriers. Since cost has featured as both a benefit and a barrier, it would be worthwhile investigating to ascertain what dictates whether it is one or the other.

The uptake of ISO14001 demonstrates the benefits for many organisations related to improving their PR, reducing their environmental impacts, ensuring compliance, reducing costs, and improving long-term competitive advantage, rather than driving their sustainability objectives. The driving force appears to be economic benefits to the organisation. Therefore, more research is required to ascertain the following:

- Examine the impact of tender requirements in relation to the uptake of ISO14001 from a pool of suitable professionals within the engineering and construction industry.
- Clarification of the challenges faced by organisation in relation to the knowledge, skills and expertise and the training available to remedy the skills gap within the sectors.
- Establish whether the focus for an organisation is on environmental management or whether the focus is more about sustainability and environmentally social governance. This could be done by using case studies of organisations who are engaged with

delivering on the SDGs via their environmental management system.

Throughout this study, it has been highlighted that whilst the engineering and construction sectors use ISO14001, they may not be using it to the extent of what is possible in line with prescriptions in the document. It is currently restricted by the narrow focus on economics and staff experience. By examining more details about the opportunities and case studies demonstrating how sustainability has been brought within the bounds of ISO14001, other companies may be encouraged to see the art of the possible. Through this approach they could begin to use the system not just to save money, but to make a positive difference in relation to the sustainability of their operations but also to the sustainability of the sector. Using the ISO14001 system to examine how their organisation could deliver on the SDGs and improve the local and national community would be a useful starting point to engaging with the delivery of the broader opportunities in respect of sustainability.

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Table 1. Details of the papers reviewed including the year of publication, country, sector, methodology used and the authors

ID	Year	Country	Sector	Method	Authors
1	2022	UK	Construction	Questionnaire	Horry *et al.*
2	2020	UK	Construction	Questionnaire	Bailey *et al.*
3	2020	Various	Construction	Interview	Johnstone
4	2019	Italy	Construction	Questionnaire	Chiarini *et al.*
5	2018	South Africa	Construction	Questionnaire	Ololade and Ramestse
6	2017	Germany	Construction	Questionnaire	Schmidt and Osebold
7	2016	Various	Construction	Literature Review	Campos *et al.*
8	2016	Australia	Construction	Audit	Dejkoski
9	2016	China	Engineering	Questionnaire	Feng *et al.*
10	2016	Nigeria	Construction	Questionnaire	Owolana and Booth
11	2015	Bulgaria	Construction	Questionnaire	Harizanova
12	2015	Vietnam	Engineering	Questionnaire	Nguyen and Hens

13	2015	Malaysia	Construction	Case Study	Yusoff *et al.*
14	2012	Italy	Engineering	Questionnaire	Arena *et al.*
15	2012	Turkey	Construction	Questionnaire	Turk
16	2011	USA	Engineering	Questionnaire	Frachetti
17	2011	Spain	Construction	Case Study	Gangolells *et al.*
18	2011	Hong Kong	Construction	Questionnaire	Lam *et al.*
19	2011	Spain	Construction	Questionnaire	Rodriguez *et al.*
20	2011	Finland	Construction	Action Research	Terio and Kahkonen
21	2011	China	Engineering	Questionnaire	Zeng *et al.*
22	2010	Malaysia	Engineering	Questionnaire	Abdullah and Fuong
23	2010	Egypt	Construction	Questionnaire	Sakr *et al.*
24	2010	Latvia	Construction	Case Study	Tambovceva
25	2009	Turkey	Construction	Questionnaire	Turk
26	2008	Germany	Engineering	Questionnaire	Frondel *et al.*
27	2007	Spain	Construction	Questionnaire	Rodriguez *et al.*

28	2007	Slovenia	Construction	Questionnaire	Selih
29	2005	USA	Engineering	Interviews	Curkovic *et al.*
30	2005	Various	Construction	Literature review and Case Study	Swaffield and Johnson
31	2004	China	Construction	Literature Review	Chen *et al.*
32	2004	USA	Construction	Case Study	Christini et al.
33	2004	Australia	Engineering and Construction	Questionnaire and Interviews	Zuchi and Sohal
34	2003	UK	Construction	Questionnaire	Adetunji *et al.*
35	2003	USA	Engineering	Questionnaire	Babakri *et al.*
36	2002	USA	Construction	Review	Ball
37	2002	Singapore	Construction	Questionnaire	Ofori *et al.*
38	2002	Hong Kong	Construction	Questionnaire	Shen and Tam
39	2002	USA	Construction	Literature Review and Case Study	Valdez and Chini
40	2001	Hong Kong	Construction	Review	Pun *et al.*

41	2001	Hong Kong	Construction	Case Study	Tse
42	2000	China	Construction	Case Study	Chen *et al.*
43	2000	Singapore	Construction	Questionnaire	Ofori *et al.*
44	2000	USA	Construction	Case Study	Quinn
45	2000	Australia	Construction	Case Study	Walker
46	1999	Singapore	Construction	Questionnaire	Kein *et al.*

Table 2. Source Journals and time frame of publications for IS014001 research papers between 1999 and 2022

Journal Names	1999	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011	2012	2015	2016	2017	2018	2019	2020	2022	Grand Total
Architectural Engineering and Design Management							1														1
Asian Social											1										1
Automation in Construction						1															1
Building and Environment				2								1									3
Building Strategy and Environment																	1	1			2
Construction Management and Economics	1	1										1									3
Ecological Economics									1												1

Economic Engineering in Agriculture and Rural Development														1								1
Economics and Management											1											1
Environment, Development and Sustainability																					1	1
Environmental Management													1									1
Environmental Practice				1																		1
ICE Management, Procurement and Law																			1			1
International Journal of Business Management													1									1
International Journal of Project Management				1																		1
Issues in Social and														1								1

Environmental Accounting																						
Journal of Civil Engineering and Management								1								1						2
Journal of Cleaner Production			1		1						1	2		1	2					1		9
Journal of Construction Engineering and Management		1				1																2
Journal of Environmental Assessment and Policy			1																			1
Journal of Environmental Engineering and Landscape Management															1							1
Journal of Environmental Management												2										2
Pollution Engineering		1																				1
Proceedings of the Decision							1															1

Science Institute																						
Proceedings of the Institute of Civil Engineers – Engineering Sustainability					1																	1
Resources, Conservation and Recycling								1														1
Technovation						1																1
The TQM Magazine		1																				1
Total Quality Management and Business Excellence										1												1
Waste Management																1						1
Grand Total	1	4	2	4	2	3	2	2	1	1	3	6	2	3	4	1	1	1	2	1		46

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doi: 10.1680/jensu.23.00038

Table 3. Classification of PR Benefits and barriers highlighted in literature

		Benefits							Barriers		
Year	**Authors**	**Enrich green corporate and public image**	**Future proofing for the defacto standard**	**Company strategy**	**Better environmental communication and dialogue**	**Reduced complaints**	**Market differentiation**	**Investor confidence**	**Negative publicity**	**Open to public scrutiny**	**Just a badge (superficial adoption)**
2022	Horry *et al.,*	X			X	X	X	X	X	X	X
2020	Bailey *et al.,*	X				X					
2018	Ololade and Ramestse	X									
2016	Owolana and Booth	X				X	X				
2016	Dejkovski										X
2015	Harizanova	X									
2015	Nguyen and Hens				X						
2015	Harizanova *et al.,*	X									
2012	Arena *et al.,*	X									
2012	Turk	X				X					
2011	Terio and Kahkonen	X							X		
2010	Haslinda and Chan	X									
2010	Sakr *et al.,*	X									
2009	Turk	X				X					
2008	Frondel *et al.,*	X									
2007	Selih			X							
2005	Curkovic *et al.,*										X
2005	Swaffield and Johnson	X									
2004	Christini *et al.,*				X						
2004	Zutshi and Sohal									X	
2003	Adetunji *et al.,*	X	X					X			

2002	Ofori *et al.*,	X									
2002	Shen and Tam	X									
2002	Valdez and Chini	X									
2001	Tse						X				
2000	Ofori *et al.*,	X									
2000	Walker	X									
		20	1	1	3	5	3	2	2	2	3

Accepted manuscript
doi: 10.1680/jensu.23.00038

Table 4. Classification of Economic Benefits and Barriers highlighted in literature

		Benefits																		Barriers					
Year	**Authors**	**Long-term Competitive advantage**	**Higher profits**	**Market based pressures**	**Stakeholder Pressures, confidence and improved relationships**	**New market opportunities**	**Tender requirement**	**Pressure from competitors**	**Removal of trade barriers**	**Exports**	**Improved customer satisfaction and perception**	**Benchmark with competitors**	**Investor confidence**	**Cost savings**	**Waste management savings**	**Save costs related to water use**	**Energy Efficiency - reduced costs**	**Reduced operating costs**	**Cost savings through process improvements**	**Lower insurance costs**	**Cost**	**Capital costs/investment**	**Costs may be higher than benefits**	**High investment**	**Audit costs**	**Doesn't add value**	**Increased costs**
2022	Horry *et al.*,	X	X	X	X	X	X	X	X		X			X		X	X		X	X	X		X			X	
2020	Bailey *et al.*,	X					X							X	X						X	X	X				
2020	Johnstone														X		X										
2018	Ololade and Ramestse										X			X									X			X	
2017	Schmidt and Osebold	X																			X						
2016	Feng *et al.*,	X	X																		X						
2016	Owolana and Booth													X							X	X					X
2016	Dejkovski																									X	
2016	Campos *et al.*,																				X	X		X			

2015	Harizanova										X		X									
2012	Arena *et al.,*				X						X		X						X			
2012	Turk			X							X											
2011	Frachetti													X								
2011	Lam *et al.,*																		X			
2011	Rodriguez *et al.,*					X																
2011	Terio and Kahkonen	X											X						X			
2011	Zeng *et al.,*		X																			
2010	Haslinda and Chan			X					X	X						X			X		X	
2010	Sakr *et al.,*	X		X				X											X			
2009	Turk	X		X	X	X	X	X	X	X			X	X			X		X			
2008	Frondel *et al.,*												X									
2007	Rodriguez *et al.,*																		X			
2007	Selih										X		X						X			
2005	Curkovic *et al.,*	X												X					X		X	
2005	Swaffield and Johnson	X											X	X		X			X	X		
2004	Chen *et al.,*																		X			

2004	Christini *et al.*,	X									X			X							X						X
2004	Zutshi and Sohal																				X				X			
2003	Adetunji *et al.*,	X			X	X	X	X	X			X	X	X			X											
2003	Babakri *et al.*,																				X							
2002	Ofori et al.,	X								X	X								X		X		X				X	
2002	Shen and Tam	X												X			X				X		X					
2002	Valdez and Chini	X												X					X		X							
2001	Tse	X												X	X		X			X	X	X						
2000	Chen *et al.*,																				X							
2000	Ofori *et al.*,	X												X							X		X					
2000	Quinn															X	X											
2000	Walker					X					X																	
1999	Kein *et al.*,			X							X										X							
		16	2	3	6	5	5	3	4	3	12	1	1	17	7	2	7	1	4	2	27	5	8	1	1	3	3	

Accepted manuscript
doi: 10.1680/jensu.23.00038

Table 5. Classification of Environmental benefits and barriers highlighted in literature

Year	Authors	Benefits																		Barriers						
		Reduced carbon footprint	Continuous improvement	Reduce resources used	Monitor and measure supplier performance	Environmental impact reversal awareness	Improved environmental performance	Pollution prevention	Increase public awareness of environmental issues	Reduced environmental impact	Reduced environmental risks	Protect the environment	Reduce waste generation at source	Increased recycling	Environmental awareness	Desire for certification	Reduce emissions	Commitment to environmental responsibility	Reduce environmental incidents	Identification of environmental aspects and impacts	Identification of environmental impact	Little improvement in environmental performance	Lack of link to EIA	Lack of public concern over environmental issues	No environmental improvement
2022	Horry *et al.,*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
2020	Bailey *et al.,*			X			X	X				X	X	X					X							
2020	Johnstone	X		X			X					X	X	X								X				
2019	Chiarini *et al.,*														X											
2018	Ololade and Ramestse						X					X			X											
2017	Schmidt and Osebold		X																					X		
2016	Owolana and Booth						X	X				X														

Accepted manuscript
doi: 10.1680/jensu.23.00038

2016	Dejkovski																	X
2015	Harizanova	X			X	X			X									
2015	Nguyen and Hens				X	X					X		X					
2015	Yusoff *et al.,*				X													
2012	Arena *et al.,*				X													
2012	Turk				X			X	X		X							
2011	Frachetti	X								X								
2011	Gangolells *et al.,*				X													
2011	Terio and Kahkonen									X								
2010	Haslinda and Chan										X					X	X	
2009	Turk	X	X	X	X	X	X	X		X	X	X	X	X	X			
2008	Frondel *et al.,*					X												
2007	Rodriguez *et al.,*									X								
2005	Curkovic *et al.,*									X								
2005	Swaffield and	X																

	Johnson																									
2004	Chen *et al.*,						X																	X	X	
2004	Christini *et al.*,						X			X	X															
2003	Adetunji *et al.*,			X			X																			
2002	Ball						X			X																
2002	Ofori *et al.*,						X					x	X										X			X
2002	Shen and Tam					X			X	X		X														
2002	Valdez and Chini									X																X
2001	Pun *et al.*,											X														
2000	Ofori *et al.*,			X								X														
2000	Chen *et al.*,																								X	
2000	Quinn			X			X			X			X													
1999	Kein *et al.*,																			X			X			
		2	2	10	2	3	18	7	2	7	4	11	10	3	7	2	3	2	3	3	1	5	2	4	3	

Table 6. Classification of Legal Benefits and Barriers highlighted in literature

		Benefits								Barriers			
Year	**Authors**	**International standards**	**Compliance with regulations**	**Liability threats**	**Reduction in fines**	**Lower risk of liabilities or due diligence**	**Cost of non-compliance**	**May become mandatory**	**Improved relations with regulators**	**Legal ramifications**	**Legal issues resulting**	**Legal compliance**	**No mechanical control**
2022	Horry *et al.,*		X	X	X	X	X		X	X	X	X	X
2020	Bailey *et al.,*	X			X								
2020	Johnstone		X										
2018	Ololade and Ramestse		X										
2017	Schmidt and Osebold		X										
2016	Owolana and Booth					X							
2016	Dejkovski		X										
2015	Nguyen and Hens		X										
2015	Harizanova		X			X							
2011	Terio and Kahkonen									X	X		
2010	Haslinda and Chan								X			X	
2009	Turk		X					X					
2008	Frondel *et al.,*		X										
2007	Rodriguez *et al.,*		X										
2007	Selih		X										
2004	Chen *et al.,*		X										
2004	Christini *et al.,*		X										
2003	Adetunji *et al.,*		X		X	X	X						
2002	Ball												X
2002	Ofori *et al.,*			X				X					
2002	Shen and Tam		X		X								
2002	Valdez and Chini								X				
2001	Pun *et al.,*		X										
2000	Ofori *et al.,*		X										

1999	Kein *et al.*,			X									X	
				1										
		1	8	2	4	4	2	2	3	2	2	3	2	

Table 7. Classification of Community Benefits highlighted in literature

		Benefits					
Year	**Authors**	**Improved community relations**	**Social Pressure (Community and activists)**	**Social legitimacy and responsibility**	**Community participation**	**To improve industry and government relations**	**Government support and incentives**
2022	Horry *et al.,*	X	X	X	X	X	X
2018	Ololade and Ramestse			X			
2012	Arena *et al.,*	X				X	
2012	Turk			X			
2011	Zeng *et al.,*		X				
2009	Turk			X			
2007	Selih						X
2003	Adetunji *et al.,*		X			X	X
2002	Shen and Tam				X		
		2	3	4	2	3	3

Table 8. Classification of Operational benefits and barriers highlighted in literature

		Benefits														
Year	**Authors**	**Increase knowledge about operations**	**Efficient operations**	**Improved quality in products or services**	**Improved organisational system**	**Head office instruction**	**Increase in efficiency and productivity**	**Management open to research and or criticism**	**Standardised processes**	**Improved risk management (H&S)**	**Corporate management**	**improved efficiency**	**Conformity**	**Flexible**	**Parent company pressure**
2022	Horry *et al.,*		X	X	X		X	X	X	X	X		X	X	
2020	Bailey *et al.,*									X					
2020	Johnstone		X												
2019	Chiarini *et al.,*	X													
2018	Ololade and Ramestse								X						
2017	Schmidt and Osebold														
2016	Campos *et al.,*														
2016	Feng *et al.,*														
2016	Owolana and Booth									X					
2015	Nguyen and Hens		X												

2015	Yusoff *et al.,*														
2012	Arena *et al.,*			X											
2012	Turk								X						
2011	Lam *et al.,*														
2011	Rodriguez *et al.,*														
2011	Terio and Kahkonen		X		X										
2010	Haslinda and Chan														
2010	Sakr *et al.,*														
2010	Tambovceva														
2009	Turk		X		X			X	X		X		X		
2008	Frondel *et al.,*					X									X
2007	Selih														
2005	Curkovic *et al.,*					X									X
2005	Swaffield and Johnson		X												
2004	Christini *et al.,*	X			X	X				X				X	
2004	Zutshi and Sohal														
2003	Adetunji *et al.,*					X									
2003	Babakri *et al.,*														
2002	Ball				X										
2002	Ofori et al.,						X		X						
2002	Shen and Tam														

2002	Valdez and Chini														
2001	Pun *et al.,*											X			
2001	Tse														
2000	Ofori *et al.,*		X				X		X	X					
2000	Quinn					X									
1999	Kein *et al.,*														
		2	7	2	5	5	3	2	6	5	2	1	2	2	2

Year	Authors	Barriers																																						
		Setting up management structures	Lack of stakeholder support	Lack of supplier support	Lack of client requirement	Separate design and build	Lack of stakeholder demand or pressure	Difficult to engage subcontractors	Lack of rigour	Focus on process not results	Audits	Documentation	Can use ISO 9000 to deliver the objectives	Risk low	Decreased competitiveness	Existing subcontractor system	Management see no benefits	Top management commitment towards implementation	Only as good as the management commitment	Unsuitable standard	Following procedures	Change of existing practice	Not required for export	Incompatible subcontracting systems	Lack of technical information and support	Lack of resources (inc human)	Disruption to work flow	Onerous	Increased complicated documents	Bureaucratic	Lack of materials and technology	Configuration of current operations	Complexity of standards	Lack of knowledge about ISO 14001	Lack of support	Uncertainty of benefits	Lack of rewards	Lack of incentives	Need for tailor made training	Lack of experienced consultants	Lack of experience, expertise or knowledge	Lack of training
2022	Horry *et al.,*	X	X			X	X	X	X	X	X	X	X	X	X	X		X		X		X	X	X		X	X			X	X		X	X	X	X		X	X	X	X	X
2020	Bailey *et al.,*		X	X				X								X						X		X	X				X									X	X		X	X
2020	Johnstone		X	X												X																										
2019	Chiarini *et al.,*																																									
2018	Ololade and Ramestse																	X																X							X	X
2017	Schmidt and Osebold											X																						X							X	X
2016	Campos *et al.,*																									X								X		X					X	

2016	Feng *et al.*,																										X																
2016	Owolana and Booth	X	X	X				X					X										X		X	X		X		X		X				X				X		X	X
2015	Nguyen and Hens																																										
2015	Yusoff *et al.*,	X																				X																		X			X
2012	Arena *et al.*,																									X	X					X											
2012	Turk		X											X																					X		X	X				X	
2011	Lam *et al.*,								X																																		
2011	Rodriguez *et al.*,																		X								X															X	X
2011	Terio and Kahkonen																																										
2010	Haslinda and Chan												X					X	X											X	X												
2010	Sakr *et al.*,																X																									X	
2010	Tambovceva																												X													X	
2009	Turk		X										X				X			X											X			X	X							X	X
2008	Frondel *et al.*,																																										
2007	Selih		X			X							X				X													X		X											
2005	Curkovic *et al.*,																																										
2005	Swaffield and Johnson							X																																			X
2004	Christini *et al.*,																										X					X										X	X
2004	Zutshi and Sohal		X	X				X					X										X																			X	X
2003	Adetunji *et al.*,																																										

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2003	Babakri *et al.*,										X	X						X				X				X			X			X				X						X
2002	Ball																																									
2002	Ofori et al.,		X		X								X																							X	X				X	
2002	Shen and Tam	X	X	X	X		X	X		X	X	X		X	X	X				X		X	X	X	X																X	
2002	Valdez and Chini																																	X								
2001	Pun *et al.*,																	X																								
2001	Tse		X		X							X				X				X				X		X				X	X								X			X
2000	Ofori *et al.*,		X		X								X																							X				X	X	
2000	Quinn																																									
1999	Kein *et al.*,																											X						X								
		4	#	5	4	2	2	6	2	2	3	#	4	2	2	8	1	6	1	3	1	6	2	5	4	8	2	2	5	4	6	1	2	8	2	6	2	2	5	2	#	#

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doi: 10.1680/jensu.23.00038

Table 9. Classification of HR benefits and barriers highlighted in literature

		Benefits								Barriers									
Year	**Authors**	**Employee environmental awareness**	**Morale Building within the organisation and fulfilling the customers' expectations**	**Environmentally motivated employees**	**Cooperation between management and employees**	**Subcontractor relations**	**Top management involvement and commitment**	**Increasing staff skills**	**Better working conditions**	**Need for tailor made training**	**Lack of experienced consultants**	**Lack of experience, expertise, or knowledge**	**Lack of training**	**For sales not environmental stuff**	**Lack of worker support, involvement, or resistance**	**Inadequate organisational structure**	**Time**	**Lack of awareness**	**Change is stressful**	**insufficient leadership**
2022	Horry *et al.,*	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
2020	Bailey *et al.,*		X						X	X		X	X		X		X		X	
2020	Johnstone	X														X				
2019	Chiarini *et al.,*			X	X		X	X										X		
2018	Ololade and Ramestse											X	X		X			X		
2017	Schmidt and Osebold								X			X	X							
2016	Campos *et al.,*											X								
2016	Owolana and Booth	X	X							X		X	X		X		X			
2015	Nguyen and Hens	X																		
2015	Yusoff *et al.,*	X		X				X		X			X							
2012	Turk											X								
2011	Lam *et al.,*																X			
2011	Rodriguez *et al.,*											X	X							

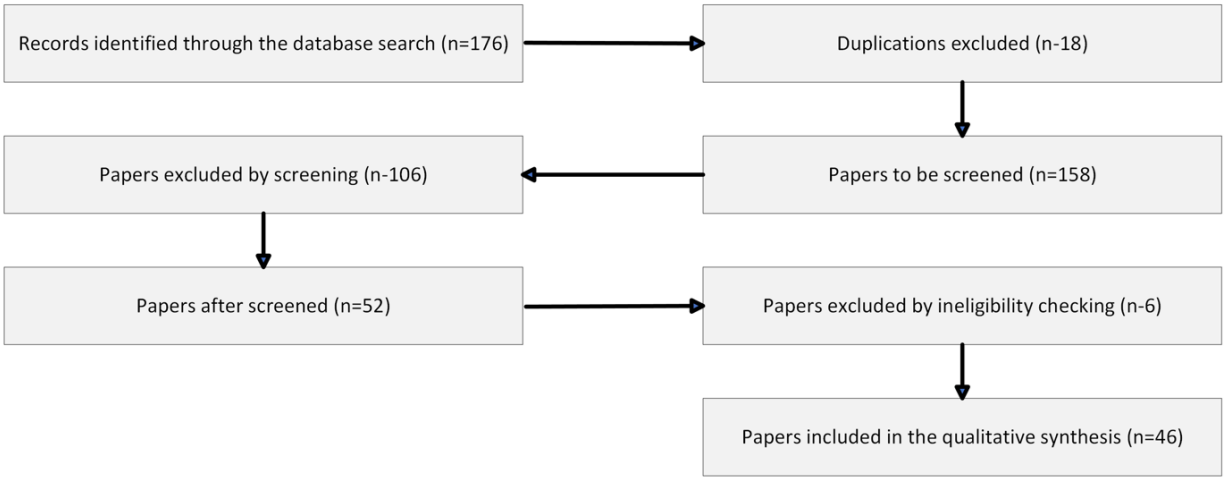
2011	Terio and Kahkonen															X			
2010	Haslinda and Chan		X	X															X
2010	Sakr *et al.,*										X								
2010	Tambovceva										X						X		
2009	Turk					X			X		X	X		X		X			
2007	Rodriguez *et al.,*	X																	
2007	Selih													X					
2005	Curkovic *et al.,*			X															
2005	Swaffield and Johnson											X		X					
2004	Christini *et al.,*	X						X			X	X							
2004	Zutshi and Sohal										X	X		X			X		
2003	Babakri *et al.,*											X		X		X			
2003	Adetunji *et al.,*		X																
2002	Ofori *et al.,*										X						X		
2002	Shen and Tam									X	X		X	X	X	X			X
2002	Valdez and Chini													X					
2001	Pun *et al.,*																		X
2001	Tse						X			X			X			X			
2000	Chen *et al.,*															X			
2000	Ofori *et al.,*										X	X							
		7	5	5	1	2	3	4	4	6	2	16	13	2	12	3	10	6	2	3

Table 10. Sector benefits and barriers of ISO 14001

		Barriers							
Year	**Authors**	**Industry not ready**	**Relies on peer pressure and management incentives which may be ineffective**	**No major impacts in the sector**	**Lack of Government Pressure**	**Lack of guidelines**	**Competitive pressures**	**government demand or pressure**	**Sector weak in terms of env**
2022	Horry et al.,	X	X	X		X	X		X
2020	Bailey *et al.,*				X	X		X	
2018	Ololade and Ramestse			X					X
2017	Schmidt and Osebold				X				
2016	Owolana and Booth				X				
2009	Turk				X				
2007	Selih				X				X
2002	Ofori *et al.,*				x				
2002	Shen and Tam		X	X	X	X	X		X
2001	Tse				X				X
2000	Ofori *et al.,*				X				
1999	Kein *et al.,*	X			X			X	X
		2	2	3	10	3	2	2	6

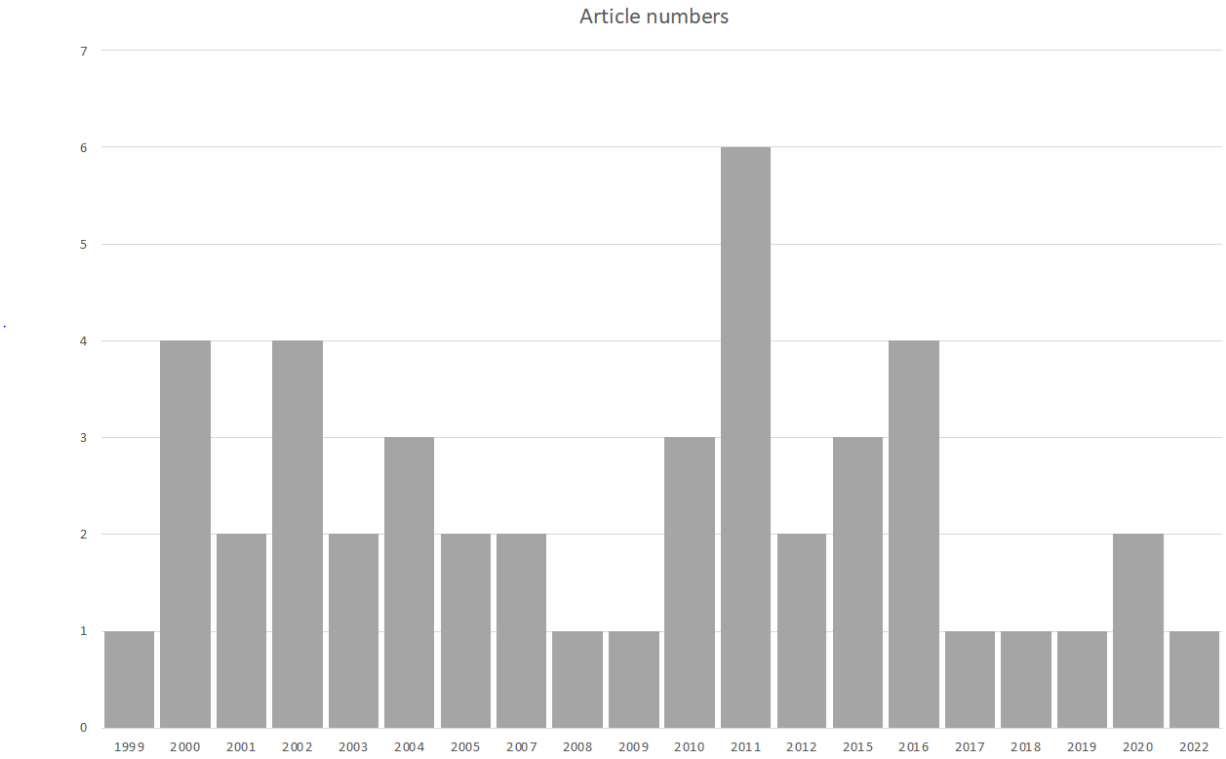
Accepted manuscript
doi: 10.1680/jensu.23.00038

Figure 1. PRISMA Flow Diagram of Literature Search and Selection Process (Adapted from: http://prisma–statement.org/prismastatement/flowdiagram.aspx)



Accepted manuscript
doi: 10.1680/jensu.23.00038

Figure 2. Annual number of scientific articles published between 1999 and 2022 within the engineering and construction sector which highlight benefits and barriers to the use of ISO14001



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doi: 10.1680/jensu.23.00038

Figure 3. Network visualisation of keywords presented in articles on ISO14001 in the engineering and construction sectors (from 1999-2022)