



Analysis of Standardization Activities for City Resilience From Research Projects: A Literature Review

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ABSTRACT

Building resilience in cities requires, among other things, translating relevant research findings into practice at the city level. In this regard, standardization is an effective means of supporting the dissemination of research findings on particularly complex topics such as city resilience. To evaluate the scientific landscape on standardization activities for city resilience from research projects, a literature review was carried out using the Web of Science database. Only 6 of the 22 articles identified actually relate to city resilience and standardization, and a further 23 articles were found on so-called Workshop Agreements to provide evidence of the use of standardization activities in research projects in general. They were mainly published in the last five years and dealt little with standardization. The results confirm the lack of relevant scientific publications, and therefore, research should focus on standardization activities in research projects in general and on city resilience in particular.

KEYWORDS

CEN, City Resilience, ISO, Research Project, Resilient Cities, Smart Cities, Standard, Standardization, Urban Resilience, Workshop Agreement, WoS

INTRODUCTION

The importance of standards and standardization for the various phases of the innovation process was already described several years ago (e.g. Blind, 2013). Other literature focuses mostly on the economic benefits of standardization (e.g. Blind et al., 2011) or the general relationship to innovation in various domains (e.g. Blind et al., 2016). Within research projects, however, the topics of standards and standardization play no or only a very minor role. This has changed significantly in recent years.

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In this context, Sanjuán et al. (2011) already pointed out more than 10 years ago how important it is to consider standardization during all phases of a research project. Almost simultaneously, research projects began to systematically use existing standards to review the state of the art in their field of research and to conduct standardization activities to transfer their project results into new standards (e.g. iNTeg-Risk, 2021). This was triggered by new European Commission regulations promoting standardization as a tool to support the dissemination and exploitation of research projects (e.g. European Commission, 2018). Nevertheless, most researchers are still not aware of the benefits of standards and standardization for their projects. Bringing together relevant stakeholders on a particular research topic is one of the main benefits that standardization offers, especially for complex topics (e.g. Lindner et al., 2021a). For example, city resilience is such a broad topic that it requires the involvement of a wide range of stakeholders to achieve.

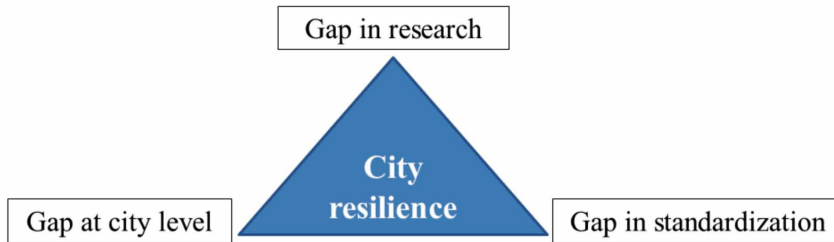
The topic of city resilience was already introduced several years ago. However, it has come into the spotlight more than ever due to the recent floods in Europe, which caused the highest number of deaths from a natural hazard in Germany in almost 60 years (Fekete & Sandholz, 2021), and due to the still ongoing COVID-19 pandemic (e.g. McCartney et al., 2021). However, existing approaches supporting resilience, such as the “Sendai Framework for Disaster Risk Reduction 2015-2030” (UNDRR, 2015), or various resilience-enhancing tools derived from research projects (e.g. SMR, 2021), have been available for years but have not had a significant impact on countries and cities to apply them to prepare for such crisis situations. For example, Fekete and Sandholz (2021) have already analyzed the gaps and challenges of the recent flood in Western Germany by sorting them according to the four different priority areas of the Sendai Framework. The difficulty of managing the large number of volunteers was one of the identified challenges during and after the flood. However, this aspect has already been addressed since 2017 in an international standard, the ISO 22319 on ‘Security and resilience - Community resilience - Guidelines for planning the involvement of spontaneous volunteers’ (ISO, 2021).

In addition, research projects on city resilience have involved cities to varying degrees in the development and implementation of resilience-enhancing tools. These and related research usually have the difficulty of effectively engaging cities, as they are often unable to participate in joint resilience-enhancing projects due to the usual workload of cities. However, because the involvement of relevant stakeholders is critical to the success of a project, funding authorities such as the European Commission require the integration of end-users, such as city representatives, in the development of tools in research projects over several years (European Commission, 2015). This led, for example, to increased participation of cities in resilience-related projects. Furthermore, some projects used standardization to also verify project results with additional project external cities and further stakeholders. As a result of one of these projects, the CEN Workshop Agreement (CWA) series CWA 17300 on ‘City Resilience Development’ has been available since 2018 to support cities in their activities to become more resilient (CEN, 2021). Although there are some standards related to city resilience, they seem to be poorly known by cities. Nevertheless, relevant standardization committees have included resilience in their work programs to meet the demand of cities and communities for guidance to support their resilience building efforts. Further research activities to support the transformation of cities to become more resilient, as planned by the European Commission under Horizon Europe (European Commission, 2021a), can build the basis for new standardization activities and thus help to fill relevant research gaps (Zuccaro et al., 2020).

Figure 1 summarizes the three above identified gaps for city resilience.

As mentioned above, the literature landscape focuses mostly on the relationship of standards and standardization to innovation; literature assessing the relationship to research and research projects is lacking. But this type of research is necessary to analyze the possibilities of standardization for research projects and to provide researchers with more detailed information about standardization approaches for research projects. To address this problem and gain more knowledge about how the integration of standards and standardization is addressed in research projects, for example on city resilience, a systemic literature review is required. Therefore, this research explores the question of what literature exists that relates to the integration of standardization activities in research projects in

Figure 1.
The three gaps related to city resilience



general and in the complex topic of city resilience. In this regard, the aim of this work is to provide a comprehensive overview of the literature landscape, which initially relates to the general integration of standardization in research projects, and then specifically within projects on city resilience. The most relevant scientific articles are identified and assessed, as well as additional secondary data (e.g. research areas and publications per year) are provided. These activities will stimulate further research by raising new research questions that can then help to fill the three gaps described in Figure 1.

This paper is structured as follows: The 'Background' section provides more information on city resilience frameworks and standardization activities for city resilience. The methodology and data used for the literature review are described in the section 'Data and Method'. The 'Results' section illustrates and analyzes the identified literature that is discussed and leads to suggestions for further research in the section 'Discussion of the results'. Finally, the 'Conclusion' section highlights the key findings of this research.

BACKGROUND

Existing Frameworks on City Resilience

The importance of city resilience, or in other cases called urban resilience, has increased significantly in recent years. A recent literature review of Bueno et al. (2021) identified more than 250 scientific documents showing that city resilience is a growing subject that affects a variety of other topics and stakeholders. One topic is smart cities, with which city resilience is associated in various literatures (e.g. Arafah & Winarso, 2017; Oke et al., 2020). Furthermore, the study concluded that there is a pressing need for further research on resilience of cities. The literature identified in this study focused mainly on finding responses to the effects of natural hazards such as climate change, earthquakes or floods. However, topics such as cybersecurity, pandemics and citizen commitment remain under-examined.

To support the overall understanding of city resilience in the context of this research, the following definition of city resilience is used: "the ability of a city or region to resist, absorb, adapt to and recover from acute shocks and chronic stresses to keep critical services functioning, and to monitor and learn from ongoing processes through city and cross-regional collaboration, to increase adaptive abilities and strengthen preparedness by anticipating and appropriately responding to future challenges" (Maraña et al., 2019).

Several resilience initiatives have developed guidance frameworks for improving the resilience of cities. For example, the Rockefeller Foundation's 100 Resilient Cities established a City Resilience Framework that defines resilient systems as those that have qualities such as robustness, redundancy, flexibility, resourcefulness, inclusion, and integration. Furthermore, a city must have a combination of effective city leadership, good infrastructure, social cohesion, collective identity and relative prosperity (Rockefeller Foundation & ARUP, 2014). The United Nations Office for Disaster Risk Reduction (UNDRR) developed the Sendai Framework (UNDRR, 2015), as successor of the Hyogo Framework (UNDRR, 2005) to reduce the risks and losses of disaster and to strengthen city assets for Disaster Risk Reduction (DRR). The Sendai Framework outlines the following four priority actions

supporting to: understand disaster risk, strengthen disaster risk governance to manage disaster risk, invest in DRR for resilience, as well as enhance disaster preparedness for effective response and to ‘Build Back Better’ in recovery, rehabilitation and reconstruction. In addition, the National Institute of Standards and Technology has developed a Disaster Resilience Framework that provides cities and communities with an approach for their resilience planning. For this, the improvements to buildings and infrastructure systems are prioritized according to their importance for supporting social institutions and economic functions in the city or community (Gilbert et al., 2015).

The existing city resilience frameworks particularly list the key role of stakeholders in the process of building resilience, as they are at the forefront of a disaster (Aldunce et al., 2016). In this regard, stakeholders are individuals, groups or organizations who can affect or are affected by the resilience-building process. They can be part of the government, emergency services, critical infrastructure providers, citizens, volunteer organizations, the media, scientific entities, and public and private companies (Malalgoda et al., 2014).

Standardization Activities for City Resilience

In recent years, relevant resilience-enhancing methods and tools have been introduced into standardization helping to fill identified gaps in standardization (e.g. Linkov & Palma-Oliveira, 2017). ISO/TC 268 ‘Sustainable Cities and Communities’ and ISO/TC 292 ‘Security and Resilience’ are the relevant international standardization committees whose standardization work focuses, among other topics, on city resilience (ISO, 2021). At the European level, CEN/TC 465 ‘Sustainable Cities and Communities’ was recently established to mirror the international activities in Europe and to foster the development of European standards (CEN, 2021). One of the most important items of its work program is standardization related to city resilience. In summary, there can be highlighted three international standards focusing directly or partly on city resilience:

- ISO/TR 22370:2020 - Security and resilience - Urban resilience - Framework and principles
- ISO/TR 37121:2017 - Sustainable development in communities - Inventory of existing guidelines and approaches on sustainable development and resilience in cities
- ISO 37123:2019 - Sustainable cities and communities - Indicators for resilient cities

Furthermore, there is another related standard currently under development, called ISO/AWI TR 37112 ‘Sustainable cities and communities - Good practice case studies in how smart city operating models support effective public-health emergency response’ (ISO, 2021).

However, standardization is not only taking place in the traditional committee system. With regard to research projects, the standardization community usually provides three steps for integrating standards and standardization: (1) the analysis of existing standards to support among others the state-of-the-art assessment of the research topic, (2) the identification of standardization potential based on the project results, and (3) the development of new standards such as Workshop Agreements or the contribution to ongoing or existing standards developments (CEN & CENELEC, 2021). Research projects partly apply these steps to different extents and a common approach for integrating standardization is lacking, as a study on resilience-related research projects confirms (Lindner et al., 2021a).

Examples are the Horizon2020 funded research projects ‘SMR Smart Mature Resilience’ and RESIN ‘Climate Resilient Cities and Infrastructures’, which aim to improve the city resilience against a variety of hazards, such as climate change, critical infrastructure dependencies or societal aspects (SMR, 2021; RESIN, 2021). SMR included as partner seven cities (Bristol, Glasgow, Kristiansand, Riga, Rome, San Sebastian, and Vejle) and the RESIN project four cities (Bilbao, Bratislava, Manchester, and Paris). Both projects used a similar method to integrate several tiers of cities to develop, validate and implement the tools. Thus, the initial amount of cities involved in the projects increased to 14 (SMR) or 21 (RESIN) respectively. This ensured gathering input from the cities to better address their needs and challenges. However, the two projects were different in their way of presenting the research outcomes to the cities

and the public. RESIN provided several tools on city resilience on their webpage and proposed some of them for standardization (de Jong et al., 2018). The SMR project also integrated the tools on the website, but in the same time developed the standards series CWA 17300 ‘City Resilience Development’ out of the project tools, thus making the project results widely available and applicable (Maresch & Lindner, 2018). The CWA 17300 series includes three documents:

- CWA 17300:2018 - City Resilience Development - Operational Guidance
- CWA 17301:2018 - City Resilience Development - Maturity Model
- CWA 17302:2018 - City Resilience Development - Information Portal

Other project examples related to city resilience are the Horizon2020 projects ARCH ‘Advancing resilience of historic areas against climate-related and other hazards’ and SHELTER ‘Sustainable Historic Environments holistic reconstruction through Technological Enhancement and community-based Resilience’. The ARCH project involved the cities of Bratislava, Camerino, Hamburg, and Valencia. As part of the project, a Disaster Risk Management Framework has been created that has been transferred into the CWA 17727 ‘City Resilience Development – Guide to combine disaster risk management and climate change adaptation - Historic areas’. The document complements the CWA 17300 series of the SMR project and has been developed through a co-creation approach involving the relevant project internal and external stakeholders (Lindner et al., 2021b). The SHELTER project also develops a resilience-enhancing framework. Partners of the project have joined the CWA 17727 activities and provided insights from their framework.

DATA AND METHOD

The literature review was conducted by using the systemic review approach of Tranfield et al. (2003). These authors describe three stages for the review, consisting of (1) Planning the review, (2) Conducting a review, and (3) Reporting and dissemination. This has been further used by Dorasamy et al. (2013), who proposed five stages as review methodology, which we will apply generally in this research and the systematic literature review. These include:

- Step 1: Plan the review (see below in this Section): Management reviews are mostly viewed as an exploration, discovery and development process and therefore an in-depth planning of the literature review should not be conducted (Tranfield et al., 2003). However, at least the aim and outcome of the literature review should be described (Dorasamy et al., 2013).
- Step 2: Identify and assess relevant articles (see below in this Section): At first, relevant keywords for the systematic search are identified, followed by a search strategy that enables the search to be replicated. The output of the search is a full list of papers that were derived from the sources chosen (Tranfield et al., 2003).
- Step 3: Extract and synthesize the data (see below in this Section): The initial identified articles are then extracted to the relevant ones and reasons for exclusion, usually based on a rather subjective view of the research team, are illustrated (Tranfield et al., 2003).
- Step 4: Report descriptive findings (see next Section ‘Results’): The set of identified articles are then described according to different information available on the articles, such as year of publication, authors and country of authors’ affiliation, and of course relevant content to answer the research questions (Tranfield et al., 2003).
- Step 5: Utilize results to inform scientific and practice (see Section ‘Discussion’): Finally, it is important to formulate the findings for the target group of the literature review in a meaningful and sustainable manner. For this purpose, for example, major identified gaps in the evaluated articles and suggestions for future improvements can be provided (Dorasamy et al., 2013).

Step 1: Plan the Review

The main goal of this review is to provide a comprehensive overview of the literature on the topic of standardization in research projects in general and city resilience in particular. The outcome of this review process is to identify gaps in the existing literature and to provide several research ideas to advance the topic to help fill the three gaps previously identified.

Step 2: Identify and Assess Relevant Articles

The sources for the literature review are articles of journals and conferences that provide essential information on standardization in research projects on city resilience and have been published by the end of August 2021. Because resilient cities are often directly related to smart cities, articles focusing on smart cities are also in the focus of this research (e.g. Arafah & Winarso, 2017). Prior to the literature search on standardization and city resilience, an initial assessment of standardization activities in research projects in general was conducted to also provide an overview of non-resilience related topics. Therefore, the previously identified Workshop Agreements, as possible major suitable standardization outcomes for research projects, were searched in existing literature (CEN, 2021). The findings of this search give an indication of how and how often these Workshop Agreements are already known and used in the scientific landscape.

For both searches the Web of Science (WoS) database has been used, due to its amount of core records and number of conferences included (Pranckute, 2021). Especially publications via conferences are a typical dissemination method within research and innovation projects. As one major topic is standard or standardization, articles including the word ‘standard’, but does not have the meaning of a standard, i. e. standard deviation or standardized approach, are left out of the relevant studies. In addition, the reference of the identified articles to research or innovation projects was sought. Table 1 summarizes the keywords and Boolean operators used to identify the most appropriate articles in both searches.

Step 3: Extract and Synthesize the Data

Search on Workshop Agreement

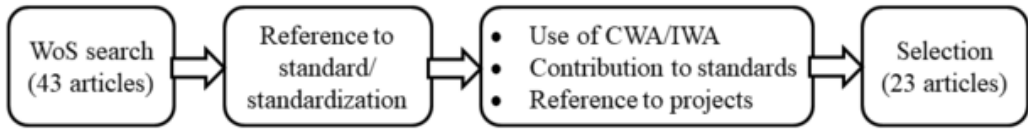
The search for ‘Workshop Agreement’ in WoS resulted that in total 22 hits have been found in conjunction with CEN, none have been found with CENELEC and 23 have been found with ISO. As two of the results were doubled the total amount of articles found was 43. In order to extract the most relevant articles on Workshop Agreements, the selection criteria provided in Figure 2 were used for the search.

At first, the ‘correct’ use of the keyword ‘standard’ has been analyzed, resulting that articles using only wordings such as ‘standard deviation’ or ‘standardized approach’ were dismissed. Articles referring to formal or informal standards, such as from ISO or IEEE, have been further assessed regarding the use of Workshop Agreements, the use and development of or proposal for standards, as well as for reference to research or innovation projects. This extraction led to the identification of 23 relevant articles. Of the remaining articles, three articles that did not correctly refer to ‘standard’, 15 articles without reference to CEN/ISO Workshop Agreements and two articles without reference to research or innovation projects were discarded.

Table 1.
Keywords used for the literature review

Topic	Keywords
Workshop Agreement	Workshop Agreement AND CEN OR CENELEC OR ISO AND Standard OR standardization AND Research project OR innovation project
City Resilience	City resilience OR urban resilience OR resilient cities OR smart cities AND Standard OR standardization AND Research project OR innovation project

Figure 2.
 Approach for selecting articles on Workshop Agreements



Search on City Resilience

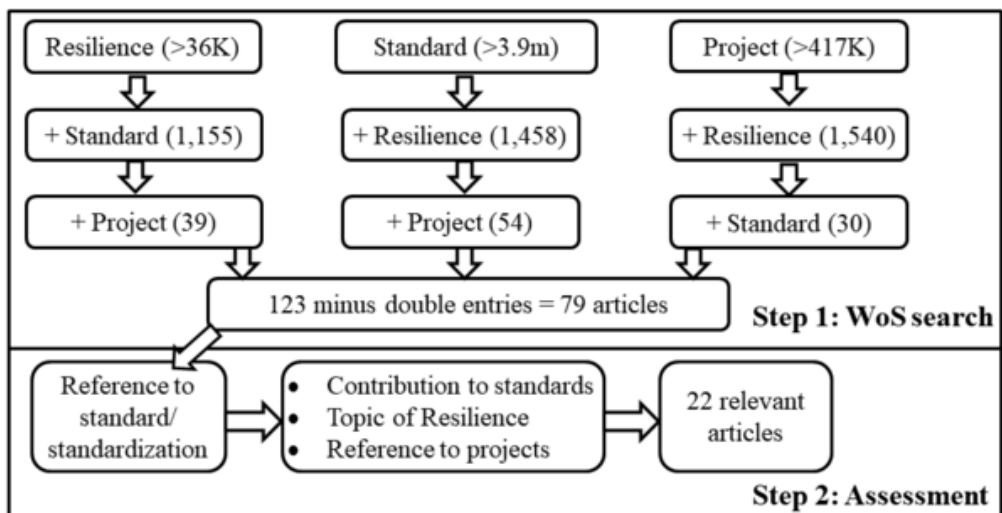
In order to identify relevant articles on ‘City Resilience’ in the WoS database, three different searches were carried out using the keywords shown in Figure 1 to ensure that more relevant articles could be identified.

Similar to the extraction of relevant articles on Workshop Agreements, each identified article was then examined for the use of the search term ‘standard’, for relation to city resilience or smart cities, and for references to research or innovation projects. Figure 3 provides an overview of the three searches and the hits obtained in WoS, as well as the further assessment of articles.

At first, in total 123 hits on WoS were counted of which 44 were double or triple entries, resulting in 79 probably relevant articles for the research. Afterwards within the assessment of these identified articles, 50 articles were discarded for missing reference to ‘standard’, four for a lack of relation to city resilience or smart cities and three for missing reference to research or innovation projects. Finally, 22 articles were identified for having relevance for the research. The following section presents the relevant papers identified for the two different searches.

In summary, the relevant papers from the WoS search were extracted based on the search and assessment methods described above in Figure 2 and Figure 3. This approach builds the basis of selecting papers for the review. However, the approach also has limitations due to the specific extraction process of relevant articles, which is partly also a subjective point of view, and the sole use of the WoS database. The next section presents an overview of the articles that were relevant based on our extraction and selection process.

Figure 3.
 Search and assessment method for articles on city resilience and standardization



RESULTS

This section presents the descriptive findings of the search and analysis of articles on ‘Workshop Agreement’ and ‘City Resilience’, the methodology of which was described in the previous section. Of the initial 43 and 79 articles of the two searches, only 23 and 22 articles were selected for the final assessment. For both searches the articles identified and the results of the content assessment are listed, followed by a further evaluation of the articles with regard to the research area, the year of publication, the geographical distribution based on the affiliation of the first author and all authors, origin, number of citations, and the number of words that appear most frequently in title and abstract. As the main focus of the paper is on the literature on standardization and city resilience, more information and graphical illustrations are provided for this topic.

Step 4: Report Descriptive Findings

Search on Workshop Agreement

As described above, the review of articles on Workshop Agreements resulted in 23 relevant articles. Table 2 provides an overview of the articles identified and the results of the content assessment, including the kind of Workshop Agreement (WA) identified, the use (U) and/or contribution (D=Development or Pr=Proposal) to standardization and the reference to research or innovation projects (P).

Some of the articles on Workshop Agreements can be highlighted. For example, Ciffroy et al. (2016) provided information on the process of a CEN Workshop as well the resulting CWA 16938 on standard documentation for chemical exposure models. Matocha (2015) proposed changes to an existing CWA in order to prepare its adoption as European standard (EN). Furthermore, several articles refer to the development of a CWA and focused on the content provided in it (e.g. Neubauer et al., 2018; Reynolds et al., 2010). However, none of the relevant articles is related to city resilience. In total, 18 articles referred to CWAs, whereby only five refer to IWAs. Nine articles have used standards, 13 articles developed standards, and four articles proposed new standards (with each only having one IWA included). Finally, 16 articles refer to research or innovation projects, whereby only one has a relation to an IWA.

Most of the articles come with eight or seven from the research area ‘Engineering’ and ‘Material Science’. In addition, there are three articles each from the areas of ‘Business Economics’, ‘Computer Science’, ‘Rehabilitation’, and ‘Science Technology Other Topics’. The first publication is from 2002, but most were developed within or after 2016. For almost 74% of the articles, i.e. 17 out of 23, the first author comes from Europe, and only 17% (4 out of 23) from Asia and 9% (2 out of 23) from America. The European dominance is confirmed with the evaluation of all 84 authors’ affiliations, where a total of 80% (67 out of 84) of all authors come from Europe, and only 14% (12 out of 84) from Asia, 5% (4 out of 84) from America, and 1% (1 out of 84) from Australia. Nearly 70% of the articles are originally from conferences, and only 30% were published directly in journals. With regard to the citations, Dekker et al. (2018) is most frequently cited with 11 citations, while three more (Hack et al., 2016; Matocha, 2015; Pozdneev et al., 2016) were cited six or seven times. Furthermore, the evaluation of words in the titles and abstracts of the 23 identified relevant articles showed that the words ‘European’, ‘CEN’, ‘Workshop’, ‘System’, and ‘Agreement’ each had more than 20 hits.

Search on City Resilience

As result of the search for articles focusing on standardization and city resilience (or smart city), Table 3 summarizes for each identified article the consideration of standards or standardization (i.e. as reference (R), being used (U), contribution to standards development (D) and proposal for new standards (Pr)), the thematic field: Smart City (S) and/or City Resilience (R), as well as the reference to research or innovation projects (P).

With 18 articles, the majority of the articles identified refer directly to smart cities and with exception of two articles not even mentioning somehow city resilience. One of them, Marsella and Marzoli (2017)

Table 2.
Extracted articles on Workshop Agreements

Authors	Article Title	WA	U/D/Pr	P
Burger, D.; Guillou, P. (2006)	Towards web accessibility certification: The findings of the Support-EAM project	CWA	D	X
Ciffroy, P. et al. (2016)	Development of a standard documentation protocol for communicating exposure models	CWA	D	X
Dekker, S. et al. (2018)	Standardized and modular microfluidic platform for fast Lab on Chip system development	IWA	U	
Gaal, M. et al. (2004)	Optimizing detector trials for humanitarian demining	CWA	D	X
Hack, E. (2016)	An inter-laboratory study of the calibration of optical full-field systems for measuring deformation	CWA	U/Pr	X
Hack, E. et al. (2016)	An evaluation of a protocol for the validation of computational solid mechanics models	CWA	D	X
Joseph, T. (2021)	Management System Approach for Addressing Biosafety and Biosecurity of Emerging Pathogens in a Biosafety Level-3 Core Facility	CWA	U	
Knels, R. et al. (2010)	Eurocode International Blood Labeling System enables unique identification of all biological products from human origin in accordance with the European Directive 2004/23/EC	CWA	D	X
Kocak, M. et al. (2007)	Fracture assessment of flaws in weldments using FITNET FFS procedure: an overview	CWA	D	X
Leitner, M.-L. et al. (2006)	Web accessibility conformity assessment - Implementation alternatives for a quality mark in Austria	CWA	U	X
Malsch, I. et al. (2020)	Embedding Ethical Impact Assessment in Nanosafety Decision Support	CWA	U/Pr	X
Matocha, K. (2015)	Small-Punch Testing for Tensile and Fracture Behavior: Experiences and Way Forward	CWA	U/Pr	X
Mueller, C. et al. (2003)	Performance demonstration for humanitarian demining	CWA	U	X
Neubauer, G. et al. (2018)	Approaches on how to analyze terms and definitions applied in the domain of crisis and disaster management	CWA	D	X
Pozdneev, B. et al. (2016)	Development of educational programs and ICT skills of personnel based on harmonization of standards requirements	CWA	D	X
Reid, D; Christensen, M. (2002)	Using IWA 1 to span the health care Quality Chasm	IWA	U	
Reynolds, M. et al. (2010)	European coding system for tissues and cells: a challenge unmet?	CWA	D	X
Rice, D. et al. (2011)	Training ICT professionals in Universal Design - a Workshop Agreement on curriculum guidelines	CWA	D	X
Stutenbäumer, U.; Meister, G. (2004)	A pan-european eID card ? Recent standardisation projects	CWA	D	
Tantra, R. et al. (2016)	Role of standard documents in advancing the standardization of microfluidics connectors	IWA	U/Pr	X
Teotia, S. et al. (2021)	Effect of porosity and loading height on the performance of household LPG gas stoves	IWA	U	
Valdivia, S. et al. (2016)	ISO Guidance Principles for the Sustainable Management of Secondary Metals	IWA	D	
Wagener, S. (2008)	International Laboratory Biorisk Management Standard A Cen Workshop Agreement	CWA	D	

Table 3.
Extracted articles on standardization and city resilience/smart cities

Authors	Article Title	R/U/D/Pr	S/R	P
Abreu, J. P. M.; Marchiori, F. F. (2020)	Enhancements for ISO 37120 “Sustainable cities and communities” from smart city concept	Pr	S	
Bui, L. (2015)	Breathing Smarter: A Critical Look at Representations of Air Quality Sensing Data Across Platforms and Publics	R	S	X
Cui, M. et al. (2017)	To examine appropriate deep-retrofit practice using simulation results in an EU-funded urban regeneration project	U/Pr	S	X
di Staso, U. et al. (2015)	Large-Scale Residential Energy Maps: Estimation, Validation and Visualization Project SUNSHINE - Smart Urban Services for Higher Energy Efficiency	U	S	X
Fernandes, R. F. et al. (2014)	Flexible Wireless Sensor Network for smart lighting applications	U	S	X
Gea, T. et al. (2013)	Smart cities as an application of Internet of Things: Experiences and lessons learnt in Barcelona	Pr	S	X
Javed, A. et al. (2020)	bIoTpe: Building an IoT Open Innovation Ecosystem for Smart Cities	U/Pr	S/(R)	X
Kazmi, A. et al. (2019)	Overcoming the Heterogeneity in the Internet of Things for Smart Cities	R	S	X
Lämmel, P. et al. (2017)	Enhancing Cloud based Data Platforms for Smart Cities with Authentication and Authorization Features	U	S	X
Lindner, R. et al. (2021a)	A Good Practice for Integrating Stakeholders through Standardization-The Case of the Smart Mature Resilience Project	R/D	R	X
Maraña, P. et al. (2019)	Towards a resilience management guideline - Cities as a starting point for societal resilience	R/D	R	X
Marsal-Llacuna, M.-L.; Wood-Hill, M. (2016)	The Intelligent method (III) for smarter standards development and standardisation instruments	R/Pr	S	
Marsella, S.; Marzoli, M. (2017)	Smart Cities and Cultural Heritage Protecting historical urban environments from climate change	U/Pr	S/(R)	X
Prandi, F. et al. (2013)	Using CITYGML to deploy smart-city services for urban ecosystems	R/U/Pr	S	X
Rom, W. et al. (2015)	DEWI - Wirelessly into the Future	U/Pr	S	X
Samano-Robles, R. et al. (2016)	The DEWI High-Level Architecture: Wireless Sensor Networks in Industrial Applications	U	S	X
Sivrikaya, F. et al. (2019)	Internet of Smart City Objects: A Distributed Framework for Service Discovery and Composition	U	S	X
Staller, H. et al. (2016)	+ERS - Plus Energy Network Reininghaus Sud: A pilot project towards an energy self-sufficient urban district	U	S	X
Vakula, M. A. et al. (2020)	Green and Resilient City: Obligatory Requirements and Voluntary Actions in Moscow	R/U	R	X
Vučinić, M. et al. (2018)	SODA: 6TiSCH Open Data Action	U/Pr	S	X
Wurster, S. et al. (2016)	Certified security systems for sustainable cities of the 21 st century	U/D	(R)	X
Zivkovic, M. et al. (2016)	Exploring scenarios for more sustainable heating: The case of Nis, Serbia	R	S	X

only shortly refer to the relationship of smart cities with city resilience. Moreover, they describe the activities related to standardization of the European project STORM, in which they studied, for example, the Common Alerting Protocol (CAP) standard for the project work and also identified standardization gaps related to climate change effects on cultural heritage, like a data standard for the different types of cultural heritage assets. The other article is from Javed et al. (2020), who only mentioned that the

outcomes of the European project bioTope could contribute to climate resilience and that future research should work towards a more robust and resilient ecosystem. Furthermore, the article of Wurster et al. (2016) on the European project CRISP only refers partly to city resilience. They used several international standards on conformity assessment and developed a CEN Workshop Agreement on ‘Guidelines for the evaluation of installed security systems, based on S-T-E-Fi criteria’.

With direct link to city resilience, only Maraña et al. (2019), Vakula et al. (2020) and Lindner et al. (2021a) refer to this topic. Maraña et al. (2019) provided information on the European city resilience project SMR, which has developed the above-mentioned standards series CWA 17300 on ‘City Resilience Development’ from the resilience-enhancing project tools. In addition, they mentioned the importance for including the end-users of the standards, such as the cities, already at an early project stage and referenced directly to the different city resilience frameworks described in the Background section. In comparison, Vakula et al. (2020) analyzed the resilience-related international standards ISO 37101 ‘Sustainable development in communities – Management system for sustainable development – Requirements with guidance for use’ and ISO 37120 ‘Sustainable cities and communities – Indicators for city services and quality of life’ for their potential application in Moscow, Russia. Finally, the recent published article from Lindner et al. (2021a) provides an extensive overview of the conducted standardization activities within the SMR project, resulting in the development of a five step approach to integrate standardization in resilience-related research projects and suggestions for further research on this topic. In addition, they referred shortly to the city resilience framework of the Rockefeller Foundation.

From the remaining 16 articles that relate directly to smart cities the following information on the linkage with standards and standardization can be highlighted. Sivrikaya et al. (2017) provided an extensive overview of the smart city standards and related activities of European and international standardization committees. Furthermore, Abreu and Marchiori (2020) suggested in their article changes to the ISO 37120 standard on ‘Sustainable cities and communities - Indicators for city services and quality of life’. Marsal-Llacuna and Wood-Hill (2016) referenced to standards such as from the British Standards Institute and provided suggestions for future standardization work. The outcomes show that only very few articles are focused on the topic of this research.

A total of eight or 14 articles respectively referred to or used standards, three articles developed standards and nine articles proposed new standards. Furthermore, 20 articles are directly related to research or innovation projects. Almost half of the articles derived from the research area ‘Computer Science’, and a bit over a third from ‘Engineering’. Furthermore, approx. 20% of the articles are related to the research areas ‘Telecommunications’, ‘Energy Fuels’, and ‘Science Technology Other Topics’ (see Figure 4). The first publication from the relevant articles is from 2013, but almost half of the articles were developed in 2016 and 2017 (see Figure 5). The three most relevant articles on city resilience have even been published within the last two years. The analysis of the geographical distribution based on the affiliation of the first author showed that almost 82% (18 out of 22) of the articles come from Europe (including three each from Germany and Italy, and two from Austria), and only 14% (3 out of 22) from America and 4% (1 out of 22) from Asia. Of a total of 105 authors, 88% (93 out of 105) come from Europe (including 16 from Spain, 15 from Italy, and 12 from Germany), and just 6% (6 out of 105) each from America and Asia (see Figure 6). Five of the six articles identified on city resilience have their origin in Europe (two from Spain, one each from Finland, Germany and Italy), the remainder comes from Russia. The sources of the articles identified are conferences and journals, with more than three-quarters of the articles originating from conferences and the remainder from scientific journals (see Figure 7). Furthermore, a few articles were comparable often cited, such as from Gea et al. (2013) with 33 citations. Additionally, Zivkovic et al. (2016), Maraña et al. (2019), and Sivrikaya et al. (2019) have also more than 12 citations per article (see Figure 8). The words in the titles and abstracts of the 22 identified relevant articles were evaluated and all words that were at least five times mentioned are included in a word cloud. The words with at least 20 hits were ‘City/Cities’, ‘Smart’, ‘Project’, ‘Standards’, ‘Paper’, ‘Data’, ‘Development’, ‘Research’ and ‘Energy’ (see Figure 9).

Figure 4.
Research areas of the articles identified

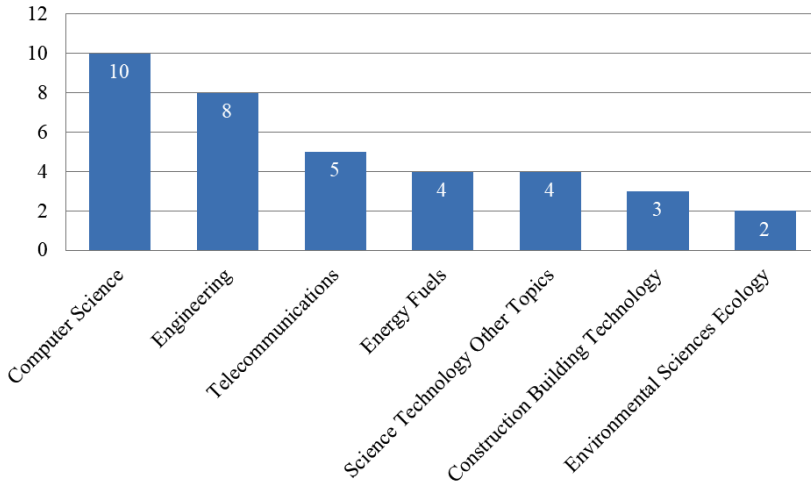


Figure 5.
Number of articles per year

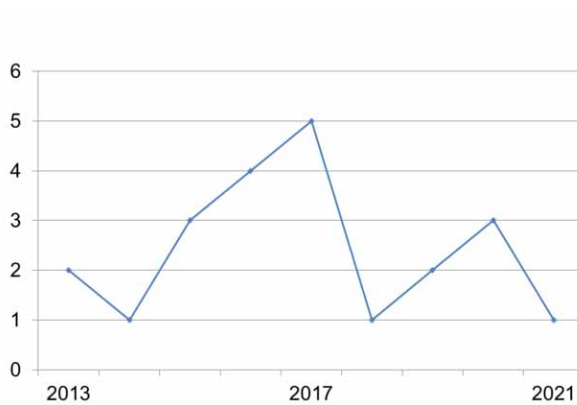


Figure 6.
Origin of first authors

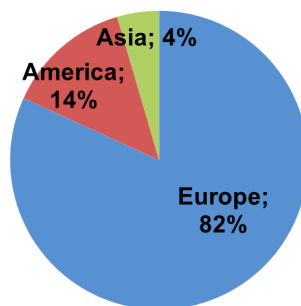


Figure 7.
Origin of article

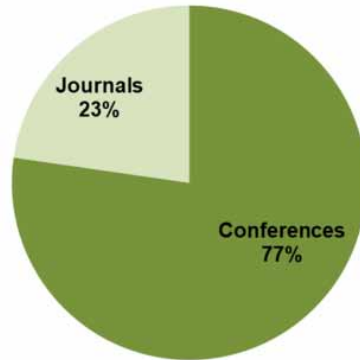
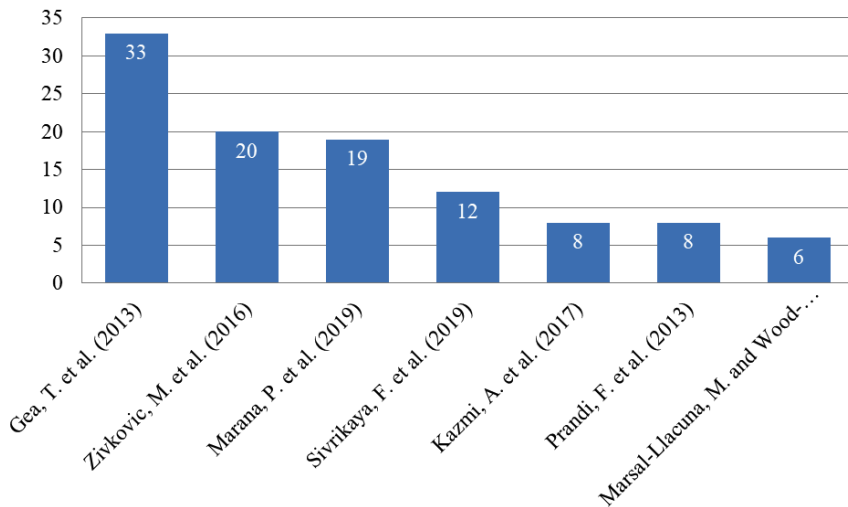


Figure 8.
Citations per article



DISCUSSION

The results of the search and assessment of relevant articles on ‘Workshop Agreement’ and ‘City Resilience’ have shown that, in general, there are only very few studies that are directly related to the research topic. Of the 23 and 22 articles identified, only a few partially relate to the topics examined.

For example, with Ciffroy et al. (2016), Neubauer et al. (2018) and Lindner et al. (2021a) only three articles provided more information on the different steps of a CWA that need to be followed. In the same time, the number of publications related to IWAs is with four relatively small, which suggests that this type of Workshop Agreement is likely unknown in the scientific community. This is not surprising, however, since most research projects are carried out at European level, and the number of IWAs currently in existence is almost half with 22 compared to 39 CWAs (ISO, 2021; CEN, 2021). This certainly also relates to the limited knowledge of standardization and its possibilities in research projects.

As mentioned above, the number of articles identified is quite small. However, this can be partly justified by the relatively high number of articles on both topics over the past five years and the recent increased focus of research projects on city resilience. This shows that the research topic is of current interest and requires further research. As outlined in Figure 3, excluding research or innovation projects from the search would have resulted to more than 1,000 articles, a set of data that is more difficult to assess and does not lead to an answer to the research question. While more than the half of the articles identified on ‘Workshop Agreement’ describe the development of a standard, this is only the case with three articles on ‘City Resilience’. This impressively confirms the previously identified gap in the lack of scientific publications on the integration of standardization in research projects with focus on city resilience. In comparison, only few articles on ‘Workshop Agreement’ proposed new standards, while this is the case in more than 40% of the articles on ‘City Resilience’. This result shows that the topics are available for new standardization activities, and that those involved may not be directly involved in standardization or may not know how to get involved. Interesting to note is the fact that both searches resulted in articles from Europe. It can therefore be said that predominantly European authors assess topics relevant for standardization. However, since most of the international smart city standards, for example, from ISO/TC 268 ‘Sustainable cities and communities’, are significantly influenced by China and Japan (Atha et al., 2020; ISO, 2021), their applicability to other continents such as Europe is limited; a fact that is recognized due to the very limited number of related ISO standards adopted at European level or in European countries. Furthermore, more than 70% of the articles identified derived directly from conference contributions. This could mean that articles on standardization are easier to publish via conferences, and at the same time less in the focus of, for example, special issues of scientific journals.

Finally, although the Top 3 cited articles identified are of similar age for both searches, the number of citations of articles on ‘City Resilience’ is three times as high. This confirms Bueno et al. (2021) who have shown the increasing importance of city resilience in the literature. Further research on standardization and city resilience would not only support to bridge the gaps in research and at the city level in order to have applicable and recognized resilience-building tools for cities, but would also help to improve the existing standardization landscape on city resilience. To support this, the currently existing standards for city resilience should be more promoted, applied and further advanced within research as well as beyond.

CONCLUSION

This research focused on the conduction of a literature review on standardization activities for city resilience from research projects. In total, only three articles were found that relate directly to city resilience and standardization and thus approach the research question, three more relate somehow to city resilience and 16 focus on smart cities. The analysis has shown that the number of publications on the topics has increased over the past five years, confirming the high level of interest in city resilience, which is in the spotlight due to the increasing and impactful hazards cities have recently faced. Furthermore, 23 articles were found showing the relevance of so called fast-track standards, Workshop Agreements, which can, with duration of about 6 to 12 months, be developed perfectly in the framework of a research project (CEN & CENELEC, 2021).

Although so far only few projects and some literature deal with standardization and the topic of city resilience, the potential for more is relatively high due to the amount of related calls the European Commission is currently providing (European Commission, 2021b). This can also address the three existing gaps related to city resilience: lack of addressing standards and standardization in respective research activities, missing uptake of existing resilience building tools at city level, and availability of an appropriate set of relevant standards. Only if these gaps are closed, future crisis situations can be better managed and cities become more resilient.

Therefore, more research and best practices on standardization in research in general and on city resilience in particular are needed to show, among other things, the integration of standardization into research projects (de Vries et al., 2018). Further research should therefore take into account standards in their respective state-of-the-art studies and standardization for the dissemination and exploitation of their project results. Awareness-raising activities by the standardization community, such as ‘Standards + Innovation’ (CEN & CENELEC, 2021), can support to bridge the gap between research and standardization, which would also lead to more scientific publications on the topic of this research. These activities also support the European Commission’s current efforts to create a code of practice for researchers on standardization, for which a scoping study summarizing best practices on integrating standardization into research projects was recently presented (European Commission et al., 2022)

The research also has limitations as most of the articles found related to smart cities and less to city resilience. However, since city resilience is sometimes seen as part of smart cities, corresponding future smart cities activities could also include resilience issues. Due to the search method, other potentially relevant scientific publications could have been overlooked, which are likely to have only limited impact due to the relatively novel topics of standardization in research projects and city resilience. Overall, this research adds new knowledge, as it closes the gap of a systematic literature review on standardization in research projects. The topic and the increased consideration of standards and standardization within research projects in general offer great potential for further research, which is crucial and essential due to the advantages of standardization and the great importance that city resilience currently has.

COMPETING INTERESTS

All authors of this article declare that there are no competing interests.

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