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Burden or benefit: do standards work for IoT SMEs?

A report for BSI and recommendations on the next steps

British Standards Institution

UCL STEaPP

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Executive summary

This British Standards Institution (BSI) - University College London (UCL) research project aims to bridge the operational and organizational challenges Small and Medium Enterprises (SMEs) are facing when navigating, adopting, and implementing Internet of Things (IoT) standards and barriers when participating in standards development. The project extends to give recommendations to the BSI to consider in their approach to IoT standards development and SMEs involvement, including a consideration of trade associations in representing SME's interests.

A mixed methods approach was taken to carry out the investigation. These comprise of:

- Online survey: 35 respondents with statistical analysis and qualitative comparisons.
- Semi-structured interviews: 12 participants interviewed for a deep dive into the ideas behind the survey; gathered more information on the way standards are currently being utilised and suggestions for improvement.
- Desk-based research: literature review covering the IoT, innovation, standards, and SMEs.
- Participant observation: attending various standards and IoT industry events to engage with stakeholders within the IoT and standard development landscape.

Key Insights:

The main findings from the interviews and survey include:

- A large variety of standards are being utilised by organizations including formal, open, industry-driven standards and some communication protocols (e.g. SigFox).
- SMEs innovating in the IoT ecosystem utilise standards for benefits such as ensuring compliance, safety and security.
- Standards provide a baseline for the market, facilitating an agreed set of definitions and common methodology, which promotes trade and interoperability.
- Standards are also employed to boost an organizations' reputation and provide confidence their products and services which enables them to scale, as well as stimulate innovation.

However, SMEs encounter numerous barriers when dealing with IoT standards and standards development process. These include:

- Complexity of the IoT ecosystem and a fragmented IoT standards landscape results in lack of awareness of the available standards relevant to IoT SMEs.

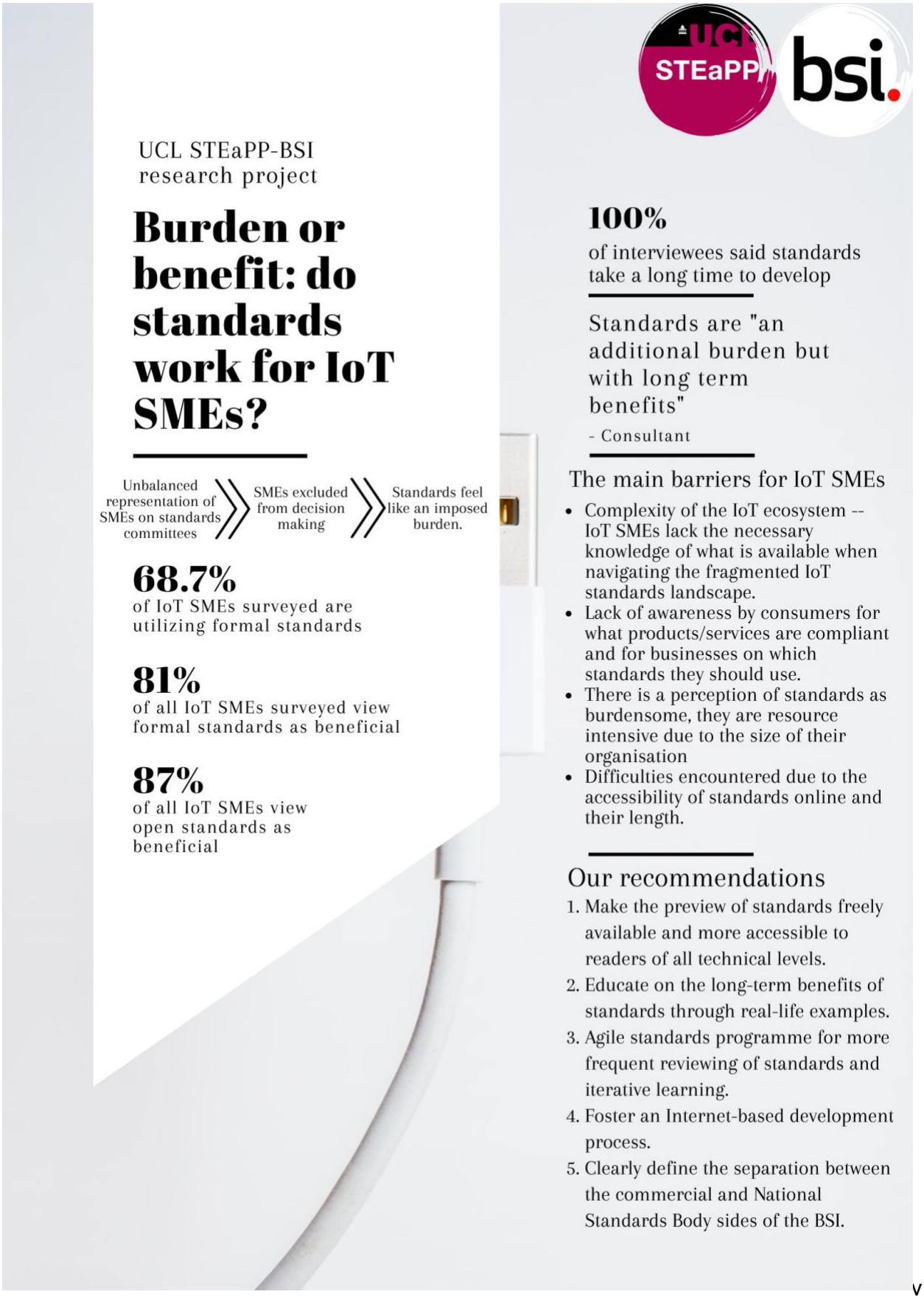
- Lack of awareness by consumers for what products/services are compliant, and for businesses on which standards they should use; and lack of awareness of standards development activities such as public consultations.
- Understanding the benefits and necessity of standards. There is a perception of standards as burdensome and devices can be sold without complying to a specific standard.
- Resource intensive due to the size of their organisation, SMEs do not have the financial, time nor human resources to pay for multiple standards or be involved in the standards development process.
- Difficulties encountered due to the accessibility of standards online and their length.
- Barriers to business growth as IoT SMEs avoid working with larger companies due to their compliance standard requirements.

The findings also demonstrate the current state and opinions on the standards development landscape, especially as it relates to SMEs and innovation. The prolonged formal standards development process cannot keep up with the fast pace of disruptive technologies. 'Agile' standards and standards development was explored as a response to the changing needs of these innovative industries.

This work is the output of the collaboration between the BSI's Student Research Programme and 4 Master of Public Administration (MPA) candidates at UCL Science, Technology, Engineering and Public Policy (STEaPP). Our research has built upon the white paper 'Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups', conducted by BSI and PETRAS Cybersecurity of the IoT Research Hub.[1]

[1]Irina Brass, Kruakae Pothong, and Mariyam Hasham, "Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups", White Paper. BSI and PETRAS Internet of Things Research Hub, 2019.

Infographic



Glossary

Term	Definition
The Internet of Things (IoT)	'An infrastructure of interconnected objects, people, systems and information resources together with intelligent services to allow them to process information of the physical and the virtual world and react.'[2] [3]
SME	Small to Medium-sized Enterprise. A company with less than 250 employees.[4]
Formal standard (De jure/consensus based standard)	A standard is a document which provides voluntary rules for an agreed way of doing something, for example in regards to producing a product or managing a process.[5] Standards are established through a consensus process and approved by a recognised body, incorporating consolidated expert knowledge on science, technology and experience, and aimed at the promotion of optimum community benefits.[6]
Open standard	An open standard is a free publicly available standard that is developed/approved and maintained through a transparent consensus and collaborative process. Any interested party must be able to join the standardization process, and cannot be dominated by a single interest, aiming to ensure a balanced development process.[7]
De facto standard	These are guidelines widely adopted and created by industry alliances and interest associations the IoT landscape, generally representing the interests and intellectual property of those who set them and lack formal approval by an officially recognized standards organization.[8]
Regulation	Regulation is a mandatory legal requirement, backed up and enforced by a government authority.[9] The CE mark is an example of a certification mark that demonstrates compliance to relevant mandatory EU regulations and directives.[10]
Guidelines	Guidelines are issued under the umbrella of a regulatory system in order to guide those being regulated with what is expected of them by the regulator.[8] For example, the UK Department of Digital, Culture, Media, and Sport (DCMS) have released guidelines on consumer IoT security called 'Secure by Design'.[11]
Protocol	A set of rules or procedure for transmitting data information and how it will be structured and sent or received between electronic devices. An example is a TCP/IP. They are established by international or industry wide organizations.[12]

[2] ISO/IEC CD 20924. "Information technology. Internet of Things (IoT). Vocabulary." ISO/IEC 2018.
[3] There is currently no international agreement on a single definition of IoT.
[4] Department for Business, Innovation & Skills. "Mid-Sized Businesses". GOV.UK..
[5] BSI Group. "What Is A Standard? & What Does It Do? | BSI Group". *Bsigroup.Com*. 2019.
[6] ISO/TMBG, "ISO/IEC Guide 2:2004". ISO/TMBG, November 2004.
[7] Cerri, Davide, and Alfonso Fuggetta. "Open standards, open formats, and open source." Journal of systems and software 80, no. 11: 1930-1937, 2007.
[8] Allen, Robert H., and Ram D. Sriram. "The role of standards in innovation." Technological Forecasting and Social Change 64, no. 2-3 : 171-181, 2000.
[9] Joyce Tait and Geoff Banda, "Proportionate and Adaptive Governance of Innovative Technologies.".BSI Standards Ltd, March 2016.
[10] BSI Group, "What Is CE Marking? | BSI Group". *Bsigroup.Com*. 2019.
[11] Department for Digital, Culture, Media & Sport, "Secure by Design", GOV.UK, 28 February 2019.
[12] Encyclopaedia Britannica. "Protocol". in Encyclopaedia Britannica, inc., 31 August 2018.

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1. Recommendations for BSI

After an analysis of our findings, the following set of recommendations is proposed to the BSI:

1.1. Make the preview of the standards freely available and more accessible to readers of all technical levels.

Rationale: Making the previews for standards freely available allows organizations to better understand the standard before purchasing. The preview should be written in plain English to make it more accessible for all SMEs. This would help to reduce the barrier related to SMEs and standards accessibility.

1.2. Educate more on the long-term benefits through real-life cases.

Rationale: When speaking directly with IoT SMEs it was uncovered many of them do not adopt formal standards as they do not recognise enough of a benefit to outweigh the cost. The current pricing of standards represents an additional financial burden, especially when some standards cross-reference others, requiring the company to purchase more standards for which they may not have the resources. Therefore, it is vital to increase understanding, especially amongst SMEs, on how standards can benefit them in the long run. By promoting real-life examples of standards saving organizations money, one can change the perception of standards as an unnecessary financial burden and encourage earlier investment within SMEs.

1.3. Continue piloting the 'agile' standards programme, including more frequent reviewing of standards and iterative learning.

Rationale: Participants from IoT SMEs and standards development were receptive to ideas for agile standards including faster review processes of standards. This programme can address the issues around published outdated standards that have not been adapted as technology evolves. Living, iterative documents opened for review in shorter timescales can also allow more involvement from those with limited time resources such as SMEs. Consider an alternative name for the 'agile' programme due to the contrasting connotations of the word, for instance 'adaptive.'

1.4. Foster an Internet-based development process, including online alerts for public consultations.

Rationale: Those working in IoT are increasingly dependent on online community tools and forums such as GitHub. Integrating these into standards-making processes will enable increased levels of involvement, especially for underrepresented groups with more limited resources such as IoT SMEs. Adaptive standards-making should take advantage of virtual tools that facilitate involvement without having to commit to the entire committee process. Communication alerts solve the barrier IoT SMEs face in the lack of awareness of when standards are being developed and this will increase transparency in the development making process. Thus, standards will not feel as burdensome for IoT SMEs.

1.5. Define more clearly the separation between the commercial and National Standards Body sides of the BSI, especially on BSI materials such as the website and social media.

Rationale: This recommendation stems from comments made during the interviews about how it is difficult to navigate BSI due to the blurred lines between the different entities – the side that is the National Standards Body of the UK in charge of developing national and international standards, and the commercial interests side which includes the certification schemes. This could be achieved by mentioning it more clearly on the BSI's website, event promotion, and social media posts.

2. Introduction

This report provides an insight on the current IoT landscape and challenges IoT SMEs are facing in adopting and implementing IoT standards. Moreover, the following report details the types of standards currently in use, the role of standards in promoting innovation, and SMEs' involvement in IoT standards development.

IoT is a key area of rapidly emerging technologies (especially for consumers). IoT encompasses the technology used to provide smarter services to users by connecting various devices across the Internet and allowing these devices to exchange information.[13] Applications of IoT range widely from smart watches and voice-controlled assistants to connected electricity grids and smart meters. The standards landscape is further complicated by vertical versus horizontal standardization activities around IoT (see 6.7 for further detail).

The introduction and expansion of IoT products and services presents numerous new policy challenges, encompassing social, economic and technological disruptions. In order to combat these issues and prevent them from becoming more problematic, preventative measures have been taken by government such as the Department for Digital, Culture, Media and Sport (DCMS) in the UK, who introduced 'Secure by Design' guidelines in order to ensure that all IoT devices are secure by manufacturers and ready for use before they enter the market.[14]

Disruptive technologies, such as those emerging within the IoT ecosystem, further complicate standards development. This is mainly due to the current fragmentation of standards internationally, and the latency problem in which standards cannot keep up with the fast pace development of technologies. Formal standards produced at BSI can take between 1 to 4 years to develop, depending on the complexity of the subject and the range of stakeholders involved. International standards take longer to develop than national standards.[15]

Additionally, standards for IoT tend to be fragmented as a single IoT product or service can fall under various traditional categories of products. Gaps that may result from the fragmented formal standards landscape are often addressed through de facto standards that emerge via industry alliances and interest associations.

[13] Park, Hyuncheol, Hoichang Kim, Hotaek Joo, and JaeSeung Song. "Recent advancements in the Internet-of-Things related standards: A oneM2M perspective." ICT Express 2, no. 3, 126-129, 2016.
[14] Department for Digital, Culture, Media & Sport, "Secure by Design", GOV.UK, 28 February 2019.
[15] BSI Standards Institution, "BS 0:2016".

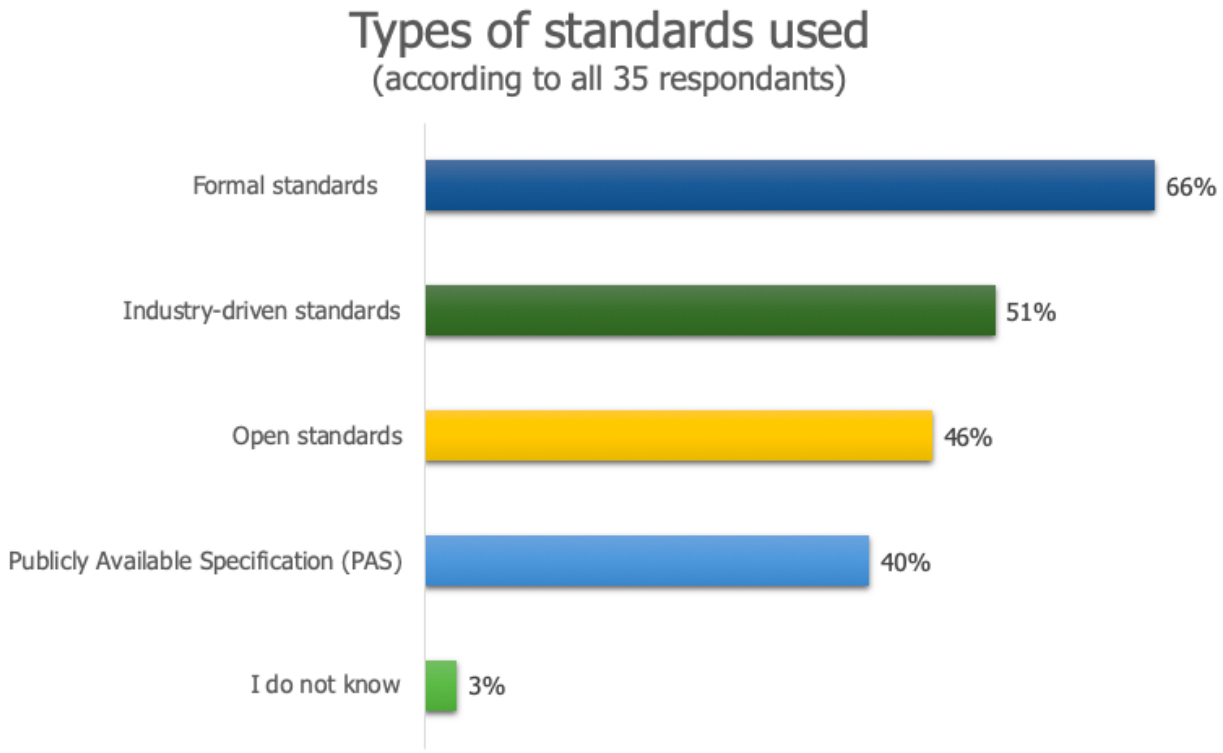
The complicated world of IoT and standards can therefore seem daunting and difficult to navigate for SMEs whose main business priorities may focus more on entering the market and scaling their business to be successful.[16] The primary research within this report encompasses findings from an online survey, semi-structured interviews, and participant observations to give a better insight into how SMEs feel about the IoT standards landscape.

[16] Irina, Pothong, and Hasham, "Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups."

3. Main findings

3.1. Types of standards used

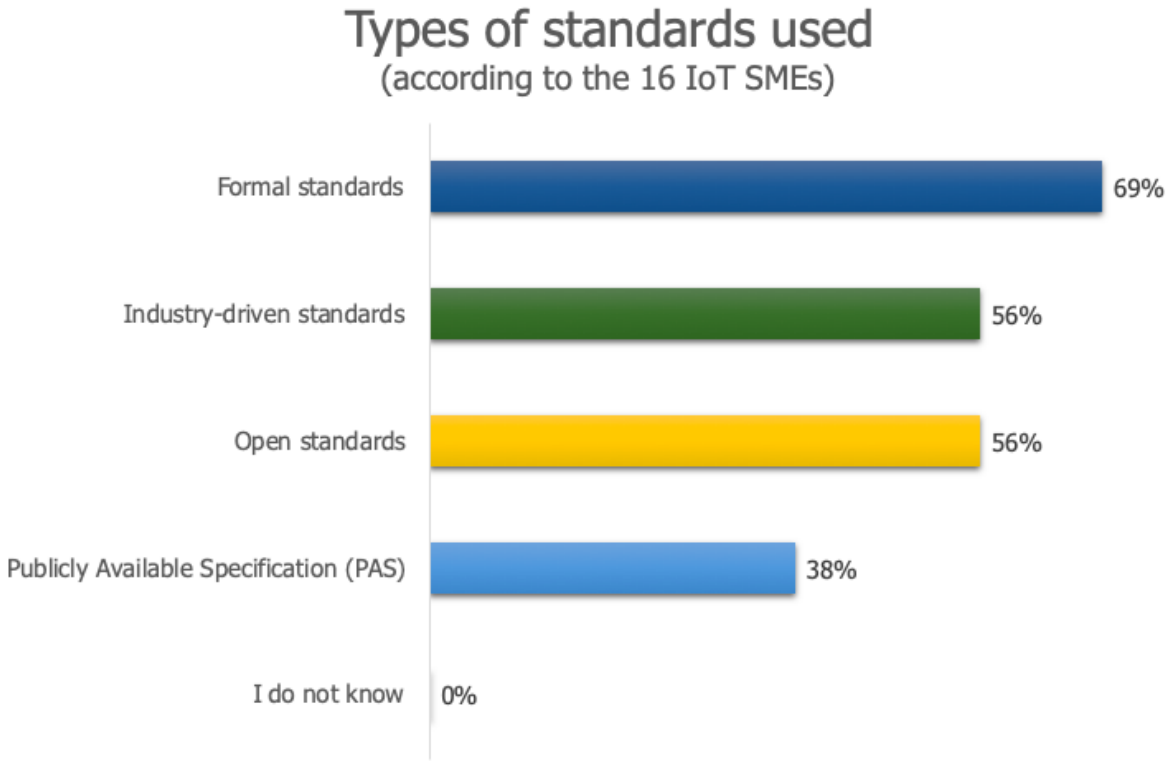
The following section will discuss the different types of standards currently being utilised, the purpose and benefits of using standards for SMEs innovating in IoT, as well as the barriers and challenges they are facing in relation to standards and their involvement in standards development. Finally, the suggestions on how to improve BSI's current standards landscape have been compiled into two categories: improvements on standards usage, and improvements on standards development process. The survey included 35 respondents, 22 of which are involved in the IoT ecosystem and 16 of which were IoT SMEs.



UCL-BSI Survey. *Understanding Innovation and the IoT Ecosystem: the role of standards in meeting SMEs' Strategic Priorities.* Fig. 1.

As seen in Fig. 1, the largest percentage of the type of standards currently used by organizations are formal standards with 23 of the 35 respondents selecting this option. Industry-driven were the next most utilised type of standard with 18 respondents; additionally, 16 respondents use open standards and 14 respondents use PAS standards.

Therefore, the percentage of standards utilised which are not formally produced by national or international standards such as ISO or BSI standards are in the majority, as 67% of respondents use these types of standards versus the 32% using formal standards.



UCL-BSI Survey. *Understanding Innovation and the IoT Ecosystem: the role of standards in meeting SMEs' Strategic Priorities.* Fig. 2

Formal

For all 35 participants of the survey, 77% agree that formal standards are beneficial to organizations in the IoT ecosystem. However, when it is filtered by the 22 organizations currently involved in IoT, it increases to 81%. Thus, those involved within the IoT ecosystem were more likely to agree that they are beneficial.

Our analysis finds that 11 of the 16 IoT SMEs currently use formal standards (Fig. 2). Therefore, 68.7% of IoT SMEs surveyed are utilizing formal standards and 81% of all IoT SMEs view them as beneficial.

However, 7 out of 12 interview participants did not use BSI or ISO standards. A possible explanation is that standards are too costly as it was mentioned throughout our interviews and participant observations. This is later discussed in section 3.3 on the 'financial cost' of standards.

Open

For all 35 participants of the survey, 71% agree that open standards are beneficial to organizations in the IoT ecosystem. However, when filtered by the 22 organizations currently involved in IoT, it increases to 86%. Thus, those involved within the IoT ecosystem were more likely to agree that they are beneficial.

Our results find that 9 of the 16 IoT SMEs surveyed currently use open standards (Fig 2.). Therefore, 56% of IoT SMEs surveyed are utilizing open standards and 87% of all IoT SMEs view them as beneficial. This highlights a big difference between what is seen as beneficial and what is used in practice for IoT SMEs.

This confirmed the participant observations made after interacting with different IoT communities. A few SMEs and start-ups were using open standards over formal standards for multiple reasons such as the open standards are free and easily accessible in comparison to formal standards. Stakeholders support open-source software principles which extends to how they believe standards should be made (i.e. more open, collaborative, and transparent).

Industry-driven

For all 35 participants of the survey, 80% agree that industry-driven standards are beneficial to organizations in the IoT ecosystem. However, when filtered by the 22 organizations currently involved in IoT, it increases to 81%. Thus, those involved within the IoT ecosystem were more likely to agree that industry driven standards are beneficial.

Our analysis finds that 9 of the 16 IoT SMEs currently use industry-driven standards (Fig 2.). Therefore, 56% of IoT SMEs surveyed are utilizing industry driven standards and 81% of all IoT SMEs view them as beneficial. This highlights a big difference between what is seen as beneficial and what is used in practice by IoT SMEs. Therefore, this shows that organizations trust de facto (industry-driven) standards at the same level of formal standards, despite de facto standards not being formally published by a national standards body. In the interviews, 3 participants stated using industry-driven standards.

Overall, industry-driven are the most beneficial of all the types of standards to organizations in the IoT ecosystem as found by all survey respondents. However, when filtered to organizations working in IoT ecosystem open standards are more beneficial.

Protocols

It is interesting to note that 6 of the 12 interviewees stated they use standardized protocols to ensure best practice, 6 of these were from IoT SMEs. 4 employees from IoT SMEs use protocols such as communication protocols SigFox and LoRaWAN. SigFox is a protocol built into the technology and the founding company (also called SigFox) creates specification standards to which organizations comply. These specifications may also be referred to as proprietary standard since they are controlled by one company. Other types of protocols mentioned include transmission protocols, software protocols and data protocols such as MQTT and COAP.

As there is no formal standard for IoT, an IoT SME employee explained that they follow telecommunication standards such as one to do with radio frequency and emission levels. They describe protocols as a set of rules for how the technology should look like, not designed for the technology.

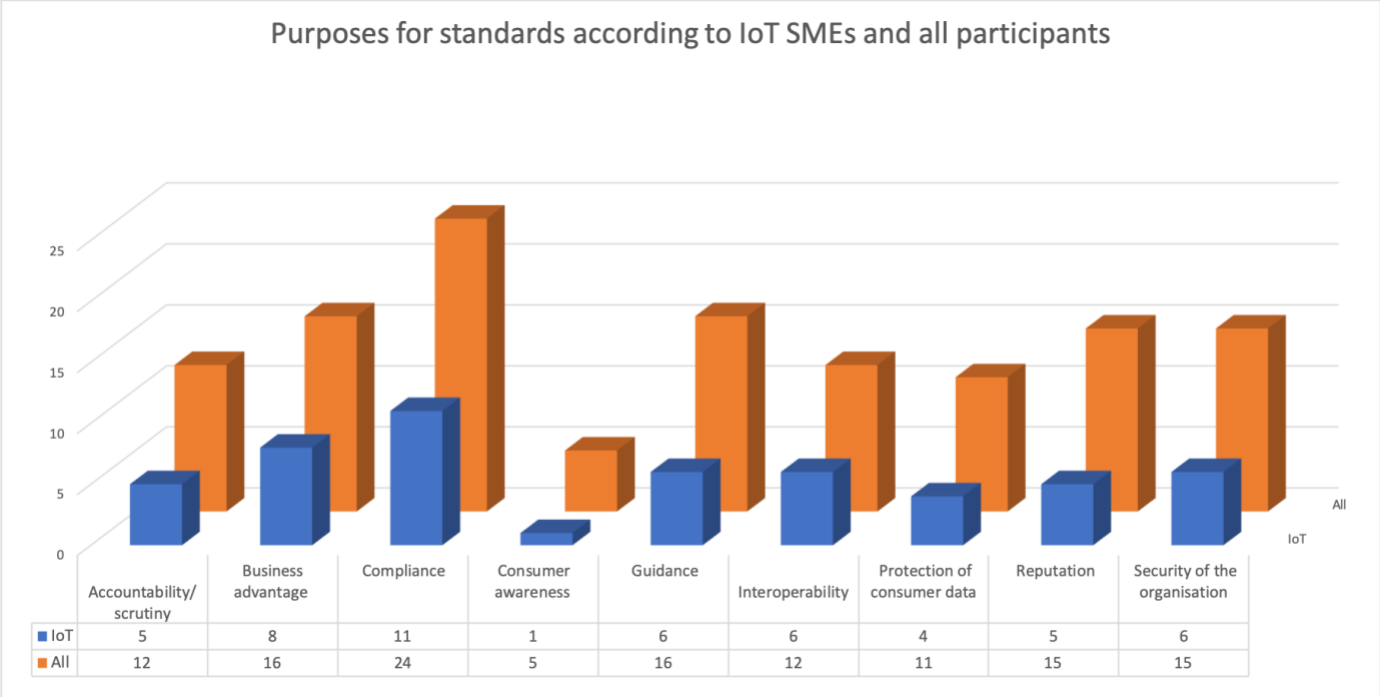
Certifications

2 IoT SME representatives additionally mentioned in interviews that they were using or buying software compliant hardware such as the CE or WEEE marking for physical devices.

3.2. Benefits of standards

Many respondents admitted they use standards mostly for compliance matters as this was the most popular reason for using standards. Security of the organisation, business advantage, and reputation were the next most popular reasons for applying standards within organisations. However, multiple businesses buy products that are previously industry and standard-compliant so they do not need to apply them themselves. The following section will investigate the benefits of using standards and what is commonly seen on the IoT market.

SMEs operating within the IoT ecosystem use standards for a number of factors. The following chart represents the results from the survey in which the team asked for what purpose IoT SMEs are currently using standards.



	Accountability/ scrutiny	Business advantage	Compliance	Consumer awareness	Guidance	Interoperability	Protection of consumer data	Reputation	Security of the organisation
IoT	5	8	11	1	6	6	4	5	6
All	12	16	24	5	16	12	11	15	15

UCL-BSI Survey. *Understanding Innovation and the IoT Ecosystem: the role of standards in meeting SMEs' Strategic Priorities.* Fig. 3

Compliance

From the chart above, 24 respondents out of 35 said they utilise standards for compliance; 11 of these were IoT SMEs. Compliance was the most chosen purpose for adopting standards, especially as there is pressure from buyers to obtain IoT products or services that are compliant with best practices. However, some SMEs do not refer to any particular standards directly, rather they choose to utilise the protocols attached to the products or services they are integrating. Standards may be seen as something

organizations must comply with rather than a tool that will benefit them. The literature notes standardization constrains activities, yet compliance helps with credibility, scaling the business, and increasing profits in markets for new technologies as well as reducing undesirable outcomes.[17]

> *"Standards tend to be demanded when a large amount of money is at risk." (IoT SME)*

However, only 5 of the 12 interview participants said IoT SMEs utilise standards for regulatory compliance or they buy compliant hardware or software if they do not have the time or resources to adhere to 5 or 6 standards. It is also important to note that some interviewees seemed confused about the difference between complying with mandatory legal requirements and mandatory standards. Regulation serves as a means of conformity with a legal requirement, whereas most of standards remain voluntary.

Business advantage and reputation

Business advantage was the next most selected purpose for standards with 16 respondents, 8 IoT SMEs choosing this benefit (Fig.3). This was further referenced in the interviews, where an IoT SME employee agreed that standards promote business growth if a reputable institution writes the standard. Standards help keep an organization ethical as end users know what to expect from the organization. It further aligns with the organization's core business priority of keeping their business safe. Standards can act as a commercial advantage for SMEs, allowing a company to scale up. From the breakout sessions at the BSI conference, a participant said that standards empower organizations to make their products or services better and should not be seen as just 'another thing to do'. This is further supported in literature where it is found that standards enable market access whilst also supporting business performance improvement.[18]

Moreover, standards can enhance an organization's reputation as standards help provide confidence in the company's new techniques, services and outputs, and boost performance, according to a standards organization representative. Standards establishing trust and increasing reputation were further referenced in the breakout sessions. In the survey, 43% of respondents chose reputation as a reason for using standards; however, only 31% of IoT SMEs chose reputation as a reason for complying with standards. Therefore, reputation is not as important to IoT SMEs, despite standards enhancing their reputation. Without this confidence mark, a standards organization representative believes it can be difficult for new technologies to gain traction.

[17] G.M. Peter Swann, "Economics of Standardization: Update to Report", Report for the UK Department of Business, Innovation and Skills (BIS) Innovative Economics Limited, 27 May 2010.
[18] Steedman, Scott. "Standards – Enabling Innovation and Change in the Digital Economy." BSI Group, 8-9, 2017.

Safety and security

Two interview participants from an IoT SME and a consultancy believe standards are helpful and necessary as they provide people with peace of mind. Thus, this reduces the risk for a company to adopt compliant solutions and enhances consumer protection as standards make the products and services safer and more secure. Standards are beneficial as they set a bar for organizations to determine whether their products or services are at a certain accepted or harmful level.

Interoperability

Standards are used for interoperability, as in the survey 12 of the respondents choose interoperability as one of the reasons why these use standards. A standards organization representative commented that standards facilitate interoperability as they create an agreed set of definitions and provide one common methodology which everyone can utilise and contribute to. Standards are used for software development to make them interoperable particularly as interoperability makes it easier to design and implement a system and prevents incompatibilities. This has been further supported by the literature, as some standards have been designed to bridge the gaps between heterogenous semantics, ontological semantics, and protocols.[19] Additionally, during a breakout session at the BSI conference, a participant explained that standards give structure to interoperability between systems and the IoT products.

Innovation

> *"[Standards are an] additional burden but with long-term benefits." (Consultancy)*

Interoperability can be highly advantageous to innovative technologies as 'standards as a whole enable rather than hinder innovation' (Standards organization). Additionally, another standards organization employee does not see why standards and innovation cannot go hand in hand. Standards can benefit innovation so when ideas and techniques begin to emerge there is a common vocabulary to avoid any potential confusion. This idea has been further supported by the literature as standards provide a baseline for the market and act as an innovation enhancer. Innovation is here triggered as suppliers would compete on quality and price. It is also interesting to note the importance of SMEs in contributing to innovation. Indeed, despite limited resources, SMEs and start-ups invest in niche market and changing technologies.[20] However, in a few instances, standards have

[19] Gyrard, Amelie, Antoine Zimmermann, and Amit Sheth. "Building IoT-Based Applications for Smart Cities: How Can Ontology Catalogs Help?." *IEEE Internet of Things Journal* 5, no. 5: 3978-3990, 2018.
[20] Cusmano, Lucia, and Benjamin Dean. "Chapter 1: Intellectual Asset Management, Innovation and SMEs." 16.

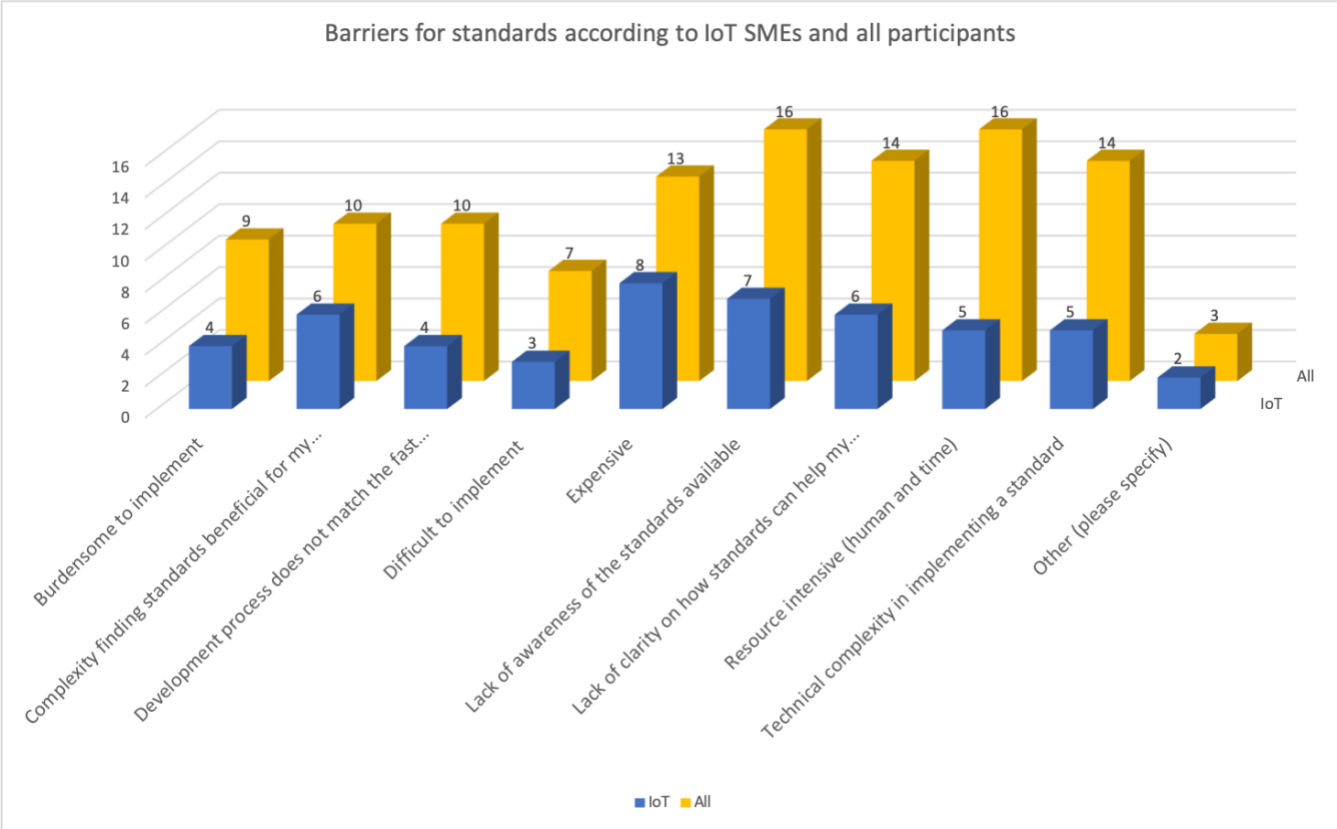
been used to prevent, intentionally or not, competitors and new entrants to the market by producing standards in favour of one part of the industry.[21]

It is important to note, 3 of the 12 interview participants who believe standards benefit innovation were previously or currently involved in the development of standards. Nevertheless, IoT SMEs understood that standards can be seen as an 'additional burden but with long-term benefits.' (Consultancy)

[21] Tait and Banda. "Proportionate and Adaptive Governance of Innovative Technologies."

3.3. Barriers and challenges of standards

Our preliminary findings from the interviews, surveys and participant observations found there a number of barriers encountered by IoT SMEs looking to adopt and implement IoT standards. Barriers were discussed in all 12 interviews and 32 of the 35 of the survey respondents reported facing barriers and challenges in adoption and implementation of standards. Of the 3 respondents who selected they do not see any barriers to standards in the survey, 2 of these were IoT SMEs.



UCL-BSI Survey. *Understanding Innovation and the IoT Ecosystem: the role of standards in meeting SMEs' Strategic Priorities.* Fig. 4

Complexity of the ecosystem

A barrier for SMEs adopting and implementing IoT standards is due to the complexity of the ecosystem. Within this ecosystem 'you have a lot of moving pieces' (IoT SME) where there are hundreds of different bodies developing IoT standards. This is causing the IoT marketplace to become highly fragmented as 2 IoT SME representatives commented that the world of IoT covers all industries and all sizes and types of companies. Both these interview participants and conference attendees remarked on the fact that industry-driven standards are often created when there is a gap in available standards and when organizations want standards more specific to their own projects. However, this leads to further fragmentation of the IoT

standards landscape and puts interoperability at risk, as supported by the findings on interoperability in the BSI-PETRAS white paper (see section 6.3).

This ecosystem is becoming increasingly difficult for SMEs to navigate as there are various different standards which apply to each use case, and a number of bodies developing competing standards which 'people have strong opinions about' (IoT SME). For example, there are many conflicting standards from ISO and other organizations producing standards on data protocol. Thus, this creates a barrier for IoT SMEs due to their lack of knowledge of what is available as they look to adopt and navigate through this fragmented standards landscape. This confirmed the findings from the white paper which identified that a lack of an easily accessible knowledge base from the complex ecosystem results in a lack of knowledge of the latest best practices and the benefits and costs of investing in these new IoT services.[22]

Lack of business awareness

From the survey the first most chosen barrier to standard adoption was the lack of awareness of the available standards with 16 of the 35 respondents selecting this barrier, 7 of which were IoT SMEs (Fig 4). This could be partially due to the fragmented ecosystem as detailed above. This is further highlighted in the interviews where an IoT SME representative does not think most SMEs are aware they need to comply with any standards. If SMEs are aware of standards, there is a lack of awareness over what specific standards affect their organization. Some SMEs are not aware of standards unless it is part of a consumer specification. Due to this lack of awareness and understanding of standards, many providers develop their own proprietary standards and think of it is as a way for them to manage themselves.

> *"[Standards] don't play a very large role on a daily or even weekly basis." (IoT SME).*

Large technology companies often place more effort into standards, as they have more understanding on the benefits of utilising and adopting standards. In contrast, according to an IoT SME employee, there is a lack of awareness of these benefits for both consumers and SME manufacturers. This is confirmed from the survey data where 14 of the survey respondents cited a lack of clarity of how standards can help their organization as a barrier for adopting standards.

Additionally, this was evident at the IoT Expo where a number of start-ups and SMEs present at the event with their products and services were unaware of the relevance of standards to their organization nor did a few start-ups know what a standard was. This was also mentioned at the BSI Conference and highlights

[22] Brass, Pothong, and Hasham. "Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups."

a lack of awareness amongst SMEs and start-ups of what is available, what is compulsory, what factors are missing and what overhead it may place on people.

Lack of consumer awareness

As previously found in the white paper and by interviewee participants, there is a lack of consumer awareness of standards where consumers do not verify if the IoT product or service is standard compliant, nor do they have the ability to.[23] According to an IoT SME, the last thing consumers consider are the risks and security issues for a product or service.

Perception of standards

There is currently a 'debate about whether standards are necessary' and for IoT SME, '[standards] don't play a very large role on a daily or even weekly basis' (IoT SME). It is further speculated if standards end up costing the ecosystem too much, it may be decided to let the market choose who is the winner.

> *"If you're in the innovations stage, getting people to adopt [standards] is more challenging." (IoT SME)*

If organizations are currently able to sell their devices without complying to a standard, it creates a challenge to encourage them to begin adopting standards. It raises the question of why they would comply to a standard when it has not been proven to distinguish between a good device and a bad device. A quarter of the IoT SMEs selected standards are burdensome and an IoT SME employee remarked if the bigger SMEs do not feel the rest of the ecosystem will apply the standard, then they may not endorse it. Thus, the rest of the SMEs will not adopt the standards as well. Therefore, standards can appear burdensome if SMEs do not see the need to implement them.

Barrier to business growth

Nevertheless, an IoT SME and a standards organization representative commented that IoT SMEs only used for standards in regards to compliance to qualify them to work with a larger company. It is ticking boxes that larger organizations require, but not because the IoT SME believe it adds any value to what they do as a business. This mindset towards standards is they feel they have to 'jump through a hoop' (IoT SME) to tick a compliance box. This can create a barrier to business growth as IoT SMEs are avoiding approaching certain larger companies due to their standard requirements. This is mirrored in the survey where 10 respondents (6 IoT SMEs) encounter complexity in finding standards beneficial for their organization.

[23] Brass, Pothong, and Hasham. "Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups."

Resource intensive - financial

Almost every interview participant mentioned the cost of standards, either describing the burden of the cost of standards or else expressing a desire for IoT standards to be freely available. This is particularly due to the nature of the industry and market where there are a significant proportion of SMEs and start-ups than other industries. These companies predominately do not have the financial resources to pay for these standards and will therefore, opt to look for cheaper sources to standardize their business. A large tech company interviewee uses a lot of standards from an Estonian standard organization as they are European (EN) standards and are cheaper than other formal standards. One participant from an IoT SME feels there is an exploitation of companies due to the cost of standards where they are over charging for a basic service to place a stamp on something for their own gain. This confirmed our findings from the BSI Conference where it was found that cost is a significant problem. Standards are often seen as too expensive to access and utilise. In the survey only 13 participants of the 35 respondents cited cost as a barrier to standards adoption. However, for IoT SME respondents, standards as expensive was the most chosen barrier with 8 of 16 IoT SMEs choosing this barrier. Thus, this highlights how IoT SMEs view cost as a significant barrier in comparison to larger companies who have the financial resources to buy these standards unlike smaller organizations.

> *"[Standards] feel like a tax on small companies." (IoT SME)*

An IoT SME representative remarked on they are unaware what is contained within a standard and if it is beneficial to their organization until after they have paid for the standard. They said the cost is further dependent on the number of pages in the standard, rather than what the standard will be used for. This creates a barrier for IoT SMEs who do not have the resources to purchase any number of standards which might affect them and when the standard is an optional extra (not a mandatory requirement from government) the cost of deploying the standard and going to the market is a barrier for their organizations.

Resource intensive – human and time

In the survey, resource intensive (encompassing human and time resources) was tied as the most chosen barrier for IoT standards with 16 of the respondents, 5 of which were IoT SMEs citing this barrier. This was mirrored in the interviews as participants referenced standards and the involvement in standards development as very time intensive. This was additionally mentioned at the BSI Conference, where small companies do not the time or resources to send employees to sit on committees unlike larger corporations. Nor do they the time and human resources to adhere to and implement five or six different standards. Therefore, a common practice is to buy standard compliant software or hardware.

A resource intensive barrier is potentially a short-term problem for SMEs. When the company scales, hires more employees and creates more revenue, their resources will grow and have the capacity to accommodate the financial, human and time intensive costs of standards that SMEs are currently finding challenging to IoT standard adoption and development.

Online accessibility

> *'The ways standards are presented, are not sexy.' (IoT SME)*

Most interview participants described difficultly in accessing and implementing standards and provided several recommendations on how to make standards and standards development more accessible. Standard accessibility is a barrier as an energy consultant remarks the standard adoption process may require in depth detail of the company's information before they can view the standard. Certain companies may abandon this if they find the process too burdensome. Additionally, at the BSI Conference it was found the BSI standards catalogue is difficult to access in comparison to online community platforms, such as GitHub.

Length of standard

The length of the standard was referenced by interview participants as they felt the standards supported 'irrelevant information' (Consultant) and increased the cost of the standard as previously mentioned. From the survey it was found 14 participants, (5 IoT SMEs) found there was a technical complexity in implementing a standard. The complexity is due to the length of the standard and the technical elements contained within a standard. Moreover, 7 survey respondents find standards difficult to implement in general.

Competitor advantage

There is a disagreement on whether standards provide competitive advantage to SMEs from the literature and our findings. As at the BSI standards conference it was found that if there is no regulation and clients do not ask organizations, SMEs do not see the point of adopting standards as they do not believe there is a competitive advantage. It is at the design stage producers must secure their devices with standards in order to maintain their reputation. On the other hand, from our literature is it found that standards build competitive advantage as they provide a common platform for industry by creating a level playing field

within all market economies, as well as a 'passport for trade'.[24] See Appendix B for more detail from the literature.

Interoperability

A barrier found in the white paper occurs when there is an absence of interoperability due to the current lack of standardized ontologies and data communication protocols.[25] This makes it difficult for SMEs to integrate with third party platforms or providers and limits their competitiveness and ability to work towards comprehensive IoT services.

> *'I think the market has gotten to a point where we desperately need a standard, otherwise everyone is just doing their own thing and it's actually stifling the market growth instead of encouraging innovation.' (IoT SME)*

From the survey findings on what IoT standards could be developed to address, 17 participants chose security issues, 16 chose interoperability, 15 chose privacy and data protection and 15 chose safety. This small margin of difference reconfirms the white paper findings that there is a trade-off challenge between priorities such as security and interoperability. There is difficulty in facilitating everything that organizations believe needs to be addressed. Particularly for SMEs with more limited resources.[26]

Innovation

While standards can benefit innovation, an IoT SME representative believes the market has gotten to a point where it desperately needs an IoT standard, since everyone is conducting their own business and it is 'actually stifling the market growth instead of encouraging innovation' (IoT SME). When industry is fragmented with hundreds of conflicting de facto IoT standards, interoperability is threatened. As identified by an IoT SME survey respondent, a barrier to their adoption of formal standards is that 'standards don't yet exist for data interoperability' (IoT SME survey respondent). An audience member at the BSI conference breakout sessions suggested SME's are reluctant to implement standards as they may harm innovation.

[24] Steedman. "Standards – Enabling Innovation and Change in the Digital Economy." 8-9.
[25] Brass, Pothong, and Hasham. "Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups."
[26] *Ibid.*

3.4. Involvement in standards development

Across the board, participants agreed that standards development occurs in a lengthy and hard-to-access matter. Standard development experts and stakeholders within the IoT ecosystem believe due to the disruptive nature of emerging technologies, more focus must be brought to 'agile'/flexible standards.

Standards development

All 12 interview participants mentioned the lengthy process of developing standards. This was attributed to several barriers such as the difficult task of finding the right balance of people to work on the standard, the need for those standards-makers to dedicate their time and resources to the process, the complexity of issues being tackled within the standard, the research the standard requires, and the extensive time that is necessary for consensus building, especially for international standards. In light of these challenges, most argued that a faster development process would benefit the changing needs of industry, especially for standardizing new, innovative technologies. There were also several comments in our interviews and at the BSI conference breakout sessions about the need for more diversity and representation in standards-making. A general lack of awareness around opportunities to be involved with standards-making activities, such as public consultations, was found in both the interviews and conference focus groups.

3 people were interviewed who work directly with standards. One participant from a standards development organization mentioned a new tool they are using to ensure best practice in accordance with a published standard: thematic reviews conducted 6 months to a year after publication. These reviews involved qualitative interviews that are conducted to receive feedback from users on their experiences with the standard. Another participant said the development of standards has not changed much over the last decade, but now there is a need for much more rapid consensus building, and higher degree of flexibility once the output is released.

Developing standards for the IoT

'Standards as a whole enable rather than hinder innovation.' (Standards organization)

Half of our interviewees work at different SMEs operating in the IoT space. These participants spoke on the challenges of developing standards for innovative, emerging technologies such as IoT. Emerging technologies make standardization difficult as these technologies are very new and constantly evolving, with one participant suggesting that it would be challenging to assess these technologies for standardization when they have so recently landed on the market. Standards can take 1-4 years to

revise whereas the technology may have already moved on by the time the revision is complete. This latency between the development of standards versus the very high rate of technological development was also mentioned in the focus groups conducted at the BSI Conference. In the survey, a quarter of respondents from IoT SMEs agree a barrier for using formal standards is that the development process of standards does not match the fast pace of emerging technologies.

As mentioned in the literature review, adaptive governance represents a new approach to address the latency issues between the fast pace of disruptive technologies and slower pace of governance (standards, guidelines, or regulations). In the early stages of technological development, regulatory efforts can focus on maintaining as much variety in the market as possible until it becomes clear which form of the technology is dominating. Soft law, such as de facto consensus standards and PAS, can be developed to address procedures, specifications and expectations relevant to emerging IoT technologies.[27] The following section discusses specific efforts at the BSI to make their standards more adaptive.

Agile standards development

UCL-BSI Interviews. *Understanding Innovation and the IoT Ecosystem: the role of standards in meeting SMEs' Strategic Priorities.* Fig. 5

[27] Tait and Banda. "Proportionate and Adaptive Governance of Innovative Technologies."

Interview participants were receptive to new development tools in order to adapt and be more responsive to the changing needs of industry. A team at BSI is working on initiatives to make standards development more agile. Having interviewed a representative of BSI to get an idea of this work, they clarified the programme will not ultimately be called agile standards because of the different meanings implied by the word 'agile.' Confusion about the meaning of 'agile' in this context was supported by comments in interviews – there were conflicting interpretations of the word, for instance some people assuming it was the same as agile project management. The person from BSI said their work is not the same as agile project management. They explained the key focus of the programme is the speed of the development process and flexibility of the output after publication.

Some of the 'agile' or adaptive ideas involve introducing new ways of working on standards which make it easier for organizations to participate including virtual methods of collaboration and facilitating focused afternoon sessions that are less time intensive. Increasing the efficiency of participation will aim to make it easier for SMEs that might otherwise not have the resources and time to be involved. They also want to increase the flexibility of the standards outputs, such as working on shorter timescales for initial agreements on common approaches. The participant explained that even a set of agreed definitions can be very advantageous to innovative technologies. The team at BSI is piloting rapid iteration of standards so that they can keep pace with emerging technologies and adapt new approaches, which allows them to respond more quickly and learn in an iterative way. The pilot programme involved a living document which was posted for people to review, comment and suggest changes in faster weekly cycles. These efforts align with adaptive governance ideas found in the literature, as an agile approach seeks to navigate the pace of technological change through 'adaptive, human-centred, inclusive and sustainable policy-making.'[28]

> *'That's what it means to be agile - you bend and flex according to your most important requirement.' (Standards development)*

All interview participants were questioned about their thoughts on agile standardization. 10 of the 12 people interviewed were supportive of the concept, especially in regard to the efforts to make standards development processes quicker, more responsive and more open. They support changes to standards development that will make it easier for organizations with limited resources to participate, such as more open and collaborative ways of commenting, less in-person meetings, more flexibility to respond to changes in industry, and shorter time requirements. This is further supported by the comments observed at the BSI

[28] Elmi, Nima, Kris Broekaert, and Anne-Marie Engtoft Larsen. "Agile Governance: Reimagining Policy-Making in the Fourth Industrial Revolution."

conference, including the suggestions for more use of the online community, a clear and shorter timescale for involvement in the standards-making, and a live standard that can be updated as the technologies evolve.

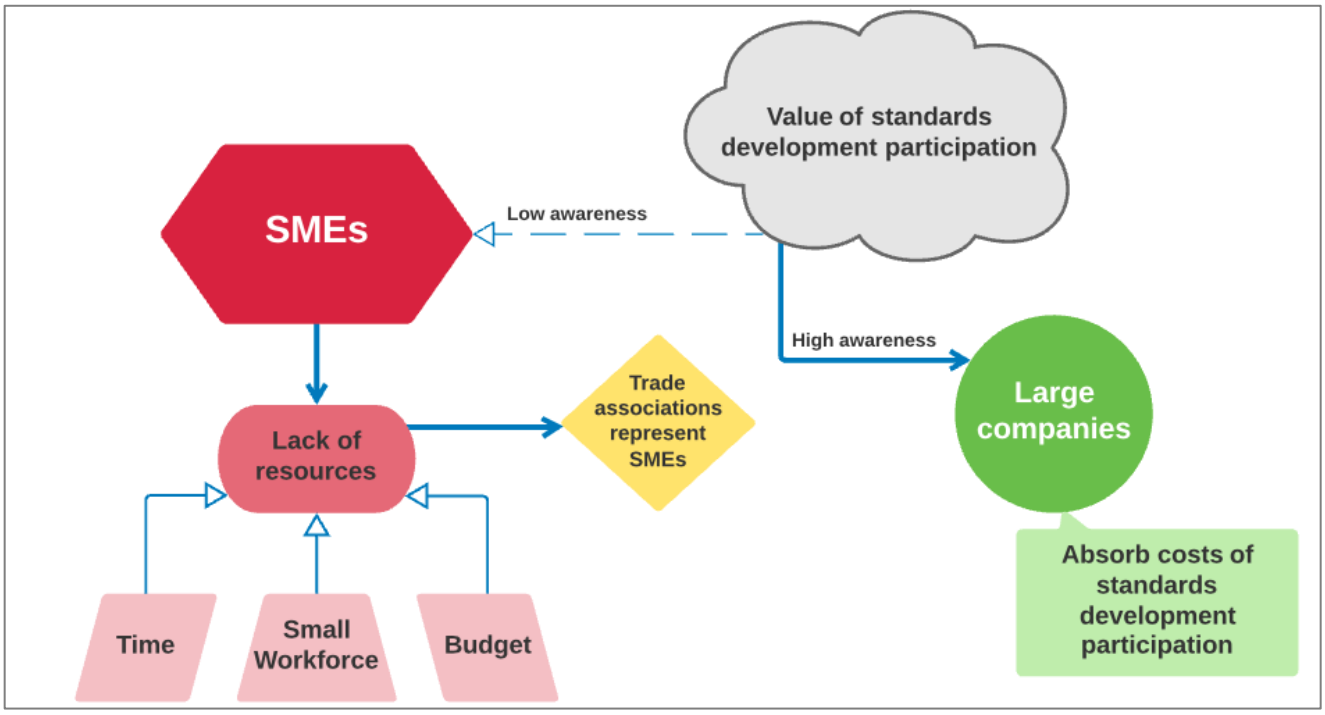
Participation in standards development

The participants working with standards also stressed the importance of balanced representation within the committees and working groups. Participants agreed that many SMEs struggle to get involved in standards development; however, several people noted that consultancies (including small-to-medium sized ones) tend to be make up a significant portion of the committees, as they may be able to dedicate more time to their involvement in standards-making. It was also suggested that participation in standards-making can support the business priorities of consultancies since it can facilitate important networking contacts and some consultants may even make money by selling a service related to the implementation of standards. A participant with experience in public consultations mentioned these consultants tend to be at an arms-length from the industry. They suggested this could be a good thing because then the consultants are not putting their own opinion into the standard, yet also worried that it means they would not understand how the standard will be used.

Finding the right people to create standards is a difficult task. According to several participants, it takes significant time to find balanced representation, because it is necessary to look for experts in a wide range of areas within the sector. Participation can also be further complicated by the personal politics involved in the process, as many committee members are representatives who may need to know the right people in order to be nominated for the committees, according to one standards development representative. However, people may additionally join in an individual capacity if they feel their knowledge or experience of the topic can make a valuable contribution to a standard's development.[29]

[29] BSI Group, "Help Make the World Better: Getting Involved in Developing Standards." British Standards Institution, 2019.

Barriers for SME involvement in standards-making



UCL-BSI Interviews. *Understanding Innovation and the IoT Ecosystem: the role of standards in meeting SMEs' Strategic Priorities.* Fig. 6

In interviews, 8 people spoke about the unbalanced representation of SMEs in standards development, mainly due to the lack of resources in SMEs which is necessary for committee members and general involvement in standards. As mentioned in the literature review, SMEs experience structural disadvantages stemming from limited resources.[30] Interviewees noted the difficulty of getting senior management to invest the time required for their technical employees to participate in standards, especially since there is no specific payment for committee work and SMEs will likely not have enough people or budget to allocate for this purpose. One interviewee who previously worked for a large tech company said larger companies are aware of the value of participation in standards-making and are more willing to absorb these costs into their overhead. Most participants agreed that bigger companies are more represented in standards-making and SMEs are unlikely to be involved as it may be difficult for them to justify the amount of time required. However, several noted that trade associations can represent SMEs and attend the committee meetings on their behalf. From the 16 IoT SMEs survey respondents, 6 said their organization is involved with developing standards, yet only 3 said they were personally involved.

[30] Cusmano, Lucia, and Benjamin Dean. "Chapter 1: Intellectual Asset Management, Innovation and SMEs."

One person interviewed who works for a standards development organization believes there is a lack of transparency in the standards development process. According to them, the decision-making process is not very open, and this can cause standards to feel more like a hurdle. Particularly, they found the current methods of development prevents SMEs from gaining access to the decision-making process. Therefore, the standard can feel as though it is an imposed burden on them.

UCL-BSI Interviews. *Understanding Innovation and the IoT Ecosystem: the role of standards in meeting SMEs' Strategic Priorities.* Fig. 7

Role of trade associations

As mentioned above, trade associations were considered by 6 interviewees to be an option for more representation of the needs of SMEs. Trade associations were described as beneficial by some due to their ability to provide relevant information and guidance to SMEs as well as representing them in the committee meetings. However, a large tech company participant involved in standards committees noted that in working groups, each person at the table gets only one vote, regardless if they are an SME, a trade association or a big company. They added that trade associations may represent as many as 800 companies and argued that these representatives should get more votes in order to reflect the diverse profiles of these companies. An interview participant who works at a trade association explained that people in the UK are rarely employed to work mainly on standards, so trade associations have more capacity to attend committee meetings, digest the feedback, draw on a wider range of uses for the standards, and contribute opinions on behalf of the sector.

> *'Trade associations are really important, because that's a way for SMEs to get information and to get the chance to be represented.' (Large tech company)*

Participants from IoT SMEs, however, tended to not be aware of specific associations or are not currently represented by a trade association. There were a couple of comments that since IoT is so broad, there are no high-profile trade associations that currently fit their purpose. An IoT SME representative mentioned that instead, they have joined self-supporting networking groups on LinkedIn which serve as de facto trade associations. Of the 16 survey respondents working for IoT SMEs, 8 said they have sought guidance on how to implement standards, yet only 2 selected trade associations as the source of this guidance. Additionally, 6 of the 16 IoT SMEs said they have memberships at various trade associations, but only 67% agreed with the statement that trade associations effectively represent their organization in standards development.

3.5. Suggestions

The following section will develop on the different recommendations made to improve the current state of the standards making process and standards usage, in light of the participants' knowledge and personal experiences, regrouping data from the interviews, the survey and the BSI conference.

Suggestions on standards usage

Improving online database

A recurrent theme at the BSI conference on how to improve standards usage was about making the online database easier to navigate.

- Including a cover page with a preview of the standard was proposed by one of the participants. This has been further supported by 5 interviewees as it would enable users to have a better understanding of the standard before buying it.

- A blurb with an explanation of the standard and its purpose was also suggested at the BSI conference. This proposition was supported by all interviewees who discussed this idea, since before purchasing a standard the content might not be very explicit. In addition, the language used should be accessible to anyone and not specific to the standard community or the tech community.

- A participant at the conference mentioned introducing a star ranking system with reviews, so other companies could base their judgement on others' experiences. Interviewees had mixed thoughts on this suggestion. Some saw it as a good way to rank standards as it exists in a lot of platforms nowadays. On the other hand, an interviewee from a standards development organization explained that each standard has its own utility and thus a ranking system will not help a new user finding standards adequate for their needs. The honesty and validity of the comments left by consumers was also questioned during the interviews.

- A participant at the BSI conference suggested improving search filters on the database. This proposition has been largely agreed on by interviewees. Indeed, the search for a standard can be overcomplicated but participants were also aware of the work that this improvement represents for BSI.

- An IoT SME representative proposed introducing a mapping tool that would enable the user to compare what standards are being developed and what is available at the international and European level - i.e. ISO, CENELEC– and in other National Standard Bodies. This was also supported by a person in the survey.

Accessibility of standards

As explained earlier, the price of a standard can be a significant barrier for businesses.

- Having more affordable standards was first mentioned at the BSI conference and then highly supported during interviews. Indeed, high prices might discourage businesses that cannot be certain the standard will be relevant until they own it. One participant from an energy consultancy suggested that the price of standards should be uniform across BSI and not depend on the number of pages. While BSI might see this suggestion as a loss of revenue, a standards organization employee proposed that BSI increases its activity through other channels such as providing trainings, holding conferences, among others, as a means to compensate.

- A participant from an IoT SME proposed to introduce self-certification or certification through a third party, other participants only focused on making the standard free in order to promote adoption. High costs might discourage businesses to buy BSI standards and push them to look for alternatives as highlighted by an IoT consultant. Indeed, a participant from a large tech company highlighted the fact that their company prefers to use standards coming from the Estonian Standard Body as it provides EN standards, valid in the whole of Europe but cheaper than the British equivalents.

- In addition, a survey respondent from an IoT SME explained the formulae for increases in charges for the standard is not very clear and should be revised and published to ensure transparency.

- It has also been suggested by another IoT SME employee to a allow a discount when a certain number of standards are needed to ensure compliance. As another survey participant explained some standards cross-refer to other standards, pushing people to purchase more standards than they intended.

- Finally, introduction of a 'lite' version with lower price and limited accessibility. Some participants from the interviews saw this suggestion as a good way to solve the affordability issue, as it will allow more users to access standards. However, the main drawback to this proposition is that a lite version will have to be shorter than the official standard, which might result in the removal of

critical information. If anything goes wrong with the implementation of the lite version, the standard body will be to blame, warned an employee from a standard organization.

Awareness

A recurrent topic during the interviews was about BSI's public image and public awareness. While participants agreed on the beneficial nature of BSI as an entity promoting quality products, this point is not always clear for businesses, in particular for SMEs. Indeed, from our interactions with SMEs at IoT conferences the team found that some IoT start-ups or SMEs do not use standards or at least not voluntarily.

- Participants highlighted the need for BSI to better promote itself as a trusted entity providing beneficial products, which are ultimately in line with their companies' priorities.

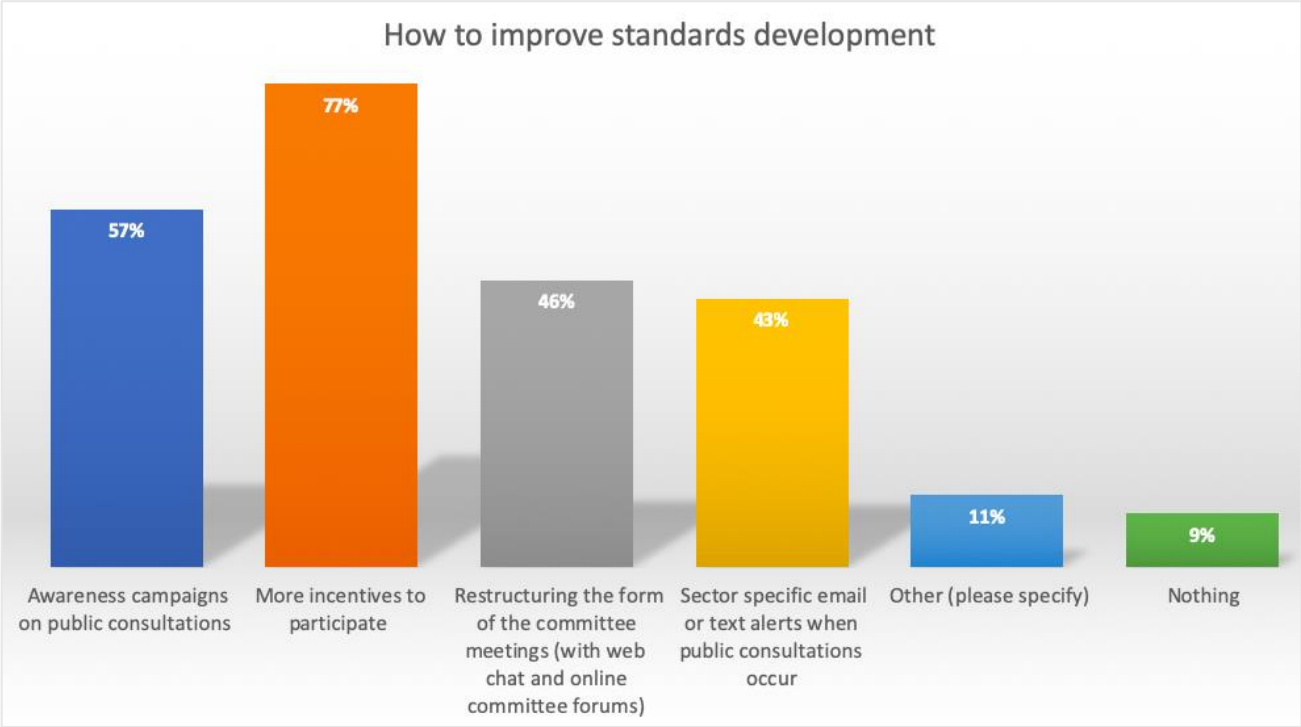
- It has also been advised that BSI improves its outreach to its users in order to better identify the needs of its clients and how to improve their user experience, by, for example, sending out a questionnaire, as suggested by a representative of a standards development organization.

- A standards developer highlighted the fact that there is a lack of awareness regarding standards and the value of standards for society and how young people consider standards in their future career. This participant said standards-makers should be send to schools to raise awareness of standards at all ages, starting as early as primary schools. Another participant from a large tech company supported this idea of increasing education on standards.

- BSI should show IoT SMEs real-life examples of savings, growth, efficiencies, increased collaboration, etc. that can help IoT SMEs understand how standards can benefit them, said an employee from a standards development organization.

- A flow chart could be introduced to represent the output of things the company should do, as well as the associated fees, as proposed by an employee from an IoT SME. Participants recognized that open source standards are directly competing with formal standards, but underlined the fact that BSI enjoys a trusted image associated with quality products.

Suggestions on standard making process



UCL-BSI Survey. *Understanding Innovation and the IoT Ecosystem: the role of standards in meeting SMEs' Strategic Priorities.* Fig. 8

Pace of standards development

There were a lot of propositions on how to make the developing process more agile, especially by encouraging more collaboration and comments from the industry or anyone exterior to the committee at different stages:

- Promoting more collaboration in the process, maybe with standard coalitions across working groups. A participant at a breakout session at the BSI conference reinforced this idea by highlighting that the correct development process is collaborative, so innovation is not lost through the commercial interests of some stakeholders.

- Encouraging colleagues from the industry to give feedback on the different drafts of the standards, not only at the end of the process.

- Ensuring people can give their feedback whenever they are willing to, without having to commit themselves to the entire standard development process.

- Raising public awareness on when public consultations are held was suggested during the interviews and the BSI conference, with for example a sector-based alert or a text alert, in addition from the survey 43% of the respondents supported this proposition (Fig. 8). Some interviewees agreed with this idea but an employee from a standards development organization underlined the fact that it should only be sector-specific, in order to avoid unnecessary emails. The role of trade associations in spreading such alerts should not be neglected, as BSI should work hand-in-hand with tech trade associations.

- A lively, moving standard which can be updated due to the fast nature of technologies emerging and evolving where the standard will be quickly out of date, was suggested by the participant at the BSI conference. This idea was also supported by a survey respondent. While an agile process has been praised by most of the interviewees, it has been highlighted that constant modifications and new versions of a standard might lead to more confusion for IoT SMEs.

Better management of timescale and online community

As explained, IoT technology is developing faster than standards, especially formal standards. While some interviewees advocated for the reduction of the timescale, others have reminded us of the necessity to not rush the developing process as every stage contributes to the quality of the final standard. At the BSI conference a participant highlighted the fact that BSI does not set a time scale on the development of a standard as there are currently no expectations of when the standard will be published, which does not reconcile easily with people's working environment. In addition, 2 survey respondents supported the proposition to speed up the development process.

An interviewee from an energy company supported the use of electronic participation such as video conference call technology during committee meetings. A participant at the BSI conference encourage BSI to utilise the online community, by for example having a more interactive group chat platform. Another interviewee from a standards development organization said in their previous work commenting on a standard's consultation, it was all via email correspondence and then they never heard back from the standard-makers. They added it would have been beneficial to be part of a webinar or roundtable to discuss the changes of the standards with other colleagues in the industry during this consultation stage.

In addition, from the survey question on how to improve standard making process, 57% of the respondents agreed with raising public awareness (Fig. 8), making it the second most popular response. One can see that restructuring the meetings was the third most popular option for improvement, with 46% of the total data respondents, as it would require less travel time, therefore less commitment, and greater ease for participants.

More incentives to participate

An employee from a standards development organization reported that members of their trade association complained about the difficulty to apply to BSI committees due to a lot of administrative work (such as providing a CV and a reference among others) which can be discouraging for businesses, especially SMEs. This proposition was supported by a survey respondent. 2 participants suggested that BSI simplifies the process to access a committee.

According to 11 IoT SME survey respondents (out of 16), there should be more incentives to participate in standards development.

In order to get SMEs involved in the standard developing process:

- SMEs could be paid or obtain financial advantage to be part of a committee.
- A specific budget should be set aside by BSI - proposed an IoT SME during an interview.
- A participant at the BSI conference suggested that BSI incentivizes companies to send employees to committee meetings to improve the lack of diversity on the committees and have people at an earlier stage of their career. This view was further supported by a survey respondent in an open question.

Additional Suggestions

An interviewee from an energy consultancy explained that the separation between the commercial and non-commercial side of BSI can be hard to understand, especially for people outside of the organization. The two branches have different purposes and not being able to clearly differentiate the various events organised by each entity can be seen as unfair competition from BSI's competitors.

Standards should be drafted in plain English to promote inclusion and diversity, and not only designed for the high skilled tech community. In addition, a survey participant suggested to develop 'a governance model which enables an industry group to develop an agreed ontology for knowledge representation' (IoT SME), and employees from IoT SMEs underlined the importance to concentrate on issues on cybersecurity.

4. Conclusion

Combining all of the primary and secondary research, this report encompasses the benefits, barriers and alternatives for IoT SME standards adoption and participation and the suggestions to BSI for improvement. The key findings found show 68.7% of IoT SMEs respondents are currently utilising formal standards, with 81% of IoT SMEs viewing them as beneficial for their organisation. Only 56% of the IoT SMEs are using open and the same number are using industry standards. 87% of IoT SMEs view open standards as beneficial and 81% view industry driven standards as beneficial. This highlights a big difference between what is seen as beneficial and what is used in practice for IoT SMEs. As well as open standards, a number of interview participants use communication protocols, such as SigFox.

The key barriers identified for standards were the complexity of the IoT ecosystem results in a fragmented IoT standards landscape which results in lack of awareness of the available standards for IoT SMEs; there is a lack of awareness for businesses on which standards they should be adhering to and by consumers of what products or services are standard compliant. There is an overall perception of standards as burdensome and as being too resource intensive for SMEs. Lastly, there have been difficulties encountered due to the accessibility of the standards online database and the overall length of standards.

The main barriers involved in standards development are emerging technologies change faster than the lengthy pace of the standards development process; there is a lack of awareness of the standards-making activities; and there are significant barriers to SME involvement – they generally do not have the human and time resources necessary to participate in the standards development process.

Therefore, the recommendations include that the BSI provide previews of standards that are freely available and more accessible to readers of all technical levels; introduce an agile standards programme for more frequent reviewing of standards; the BSI should foster an Internet-based development process; and finally to clearly define the separation between the commercial and National Standards Body sides of the BSI. Our main recommendation is to educate on the long-term benefits of standards through real-life examples. IoT SMEs may view standards as burdensome, however, highlighting the benefits of standards for their organization will encourage IoT SMEs to change their perception and encourage the adoption of standards within their organizations. Thus, turning the burden into a benefit.

Next steps

- Throughout our research it was found that the terms 'standards' and 'standardized' are often misused. In addition, people have various perceptions of standards and the use/meaning of the different types of standards (open, de jure, de facto, and protocol), even people working for standards organizations or closely with standards. Further research could explore people's understanding of the various standards available and more clearly define 'standards' versus the general use of the word 'standardization'.
- As previously mentioned, it can be difficult to differentiate the commercial and non-commercial sides of BSI. BSI could investigate further the various issues people might encounter while navigating between the two sides.
- Further research could be conducted on how to improve the relationship between BSI and IoT SMEs as the barriers faced by SME might evolve over time.

5. Appendix A - Background to the report

5.1. Overview

The British Standards Institution (BSI) in association with the PETRAS Cybersecurity of the IoT Research Hub have demonstrated in their white paper, 'Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups', that Small and Medium Enterprises (SMEs) encounter several difficulties in relation to standardization.[31] Their paper is the 'first step' to understanding the opportunities and challenges SMEs face in the development of IoT products and services, what SME's priorities are, and how the standards development communities can both engage and support them. Our project is a continuation of this work through conducting desk-based research, online survey sampling, and semi-structured interviews.

5.2. Rationale and Scope

The importance of this research lies in its aim to speak directly with SMEs in the IoT ecosystem to understand they participation, or lack thereof, in standards development, how they currently use standards, any barriers they face with standards and what might facilitate their increased implementation of standards. Standards are beneficial to SMEs as they can improve the safety of the products on the market, and the business who use and create them. This research aims at improving the relationship between standards and IoT SMEs, which enhance the quality of the products and services delivered by SMEs, as well positively impact their business model.

The scope of the project is encompassed by the following research questions:

- What are the types of IoT standards currently available to SMEs?
- How do SMEs implement IoT standards in comparison to larger technology companies?
- What are the major effects of adopting these standards by IoT SMEs?
- How can standards help SMEs in IoT further innovate?
- Why do SMEs not implement IoT standards? What is their alternative to ensure best practice in IoT product and service development?
- Are there examples in other countries with a successful approach to IoT standards for SMEs?
- How does the BSI's current standards development practices affect SMEs?
- Can agile standards development improve engagement with SMEs?
- How effective are trade associations and professional bodies in representing SMEs in the standards development process?
- How can SMEs better engage with IoT standards development?

[31] Brass, Pothong, and Hasham. "Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups."

- What can BSI do to evolve and improve their approach to developing IoT standards with the unique challenges of SMEs in mind?

5.3. Objectives

As negotiated by the team and the client, the main objectives of the report are:

- Identify SME priorities for IoT standards and standardization.
- Map the operational and organizational challenges SMEs face when navigating, adopting and implementing IoT standards.
- Consider the role played by trade associations and professional bodies in representing SMEs' interests in IoT standards development.
- Propose recommendations for BSI to consider changing its approach to standards development with regards to SME involvement in IoT standards development.

5.4. Methodology

The project was conducted in three phases that included desk-based research, participant observations, and both qualitative and quantitative methods with the semi-structured interviews and an online survey.

Phase I: Secondary desk-based research

In the first phase of our research, the team conducted desk-based research in the form of a literature review to analyse the problem and the current state of play. The literature was mainly sourced from UCL's online library database, in the form of conference papers and journal articles. This report has also sourced information directly from BSI reports to investigate how they interpret the standards landscape. Additionally, several papers from PETRAS and UCL STEaPP researchers were important to the literature review.

Contacting SMEs, working with BSI and industry experts was adamant to understanding what gaps exist in the standards sphere. Conducting not only desk-based research but also in the field is imperative to a project such as this in order to clearly understand what is required, and in order to make the best recommendations for the BSI. Desk-based research is simply not enough to base recommendations on as there is little to no research done on this specific topic of SMEs in the IoT ecosphere who may or may not use standards.

Phase II: Participant observations

BSI Standards Conference

The team attended the BSI conference and held three break-out sessions based off the topic in order to start a conversation and hear first-hand what people who work for SMEs, standards-makers and industry experts had to say. This was an opportunity to gain a basis for our research and have a baseline understanding of what was to come. We received excellent commentary and feedback from attendees of all three sessions and used this information to build our survey. More on these findings at the conference in the below section on primary research results.

IoT Tech Expo

We also expanded our network by attending the IoT Tech Expo at Olympia. At this event we encountered numerous different businesses, in particular start- ups and SMEs. One observation we made upon asking companies of their involvement and interactions with standards was that the majority of them utilised open standards rather than formal standards. Or else we found out that companies prefer to bring elements of their products/services such as software which are already standard-compliant. We further encountered some start-ups who did not even know what a standard was, which proved very insightful for our research.

TechUK: 'Standards for Dummies'

A TechUK event on 'Standards for Dummies: why standards matter for tech' was attended on the recommendation of an attendee of one of the break-out sessions from the BSI conference. This consolidated the group's relationship with some of the stakeholders at the BSI and TechUK. This event was further attended in order to ensure our understanding of standards and make contacts with people who have insight into the standards-making process. This was a great opportunity for networking as it strengthened our tie with a Programme Manager at TechUK who had previously offered at the BSI Conference to allow us to use his contact list of SMEs to help disseminate our survey.

NCF workshop

We also attended a National Consumer Federation (NCF) workshop. This workshop provided a chance to network, while also giving us another insight into the IoT ecosystem: the consumer rights perspective. Consumer safety for IoT devices is a critical priority for many organizations and future research should be conducted to further investigate how standards can help.

IoT London Meetup

Furthermore, we presented at the IoT London Meetup. This event gave us another opportunity to meet with industry stakeholders and present our research objectives. At this meetup, there was a general lack

of awareness about BSI and standards, and it was another event that confirmed people disagree with paying for standards.

Phase III: Survey

IoT	IoT SME	Start-up	9
		Consultancy	5
		Corporation	2
	Large IoT	Industry	1
		Industry alliance	2
		Corporation	3
Not IoT	SME	Start-up	2
		Consultancy	4
		Corporation	1
	Large	Corporation	3
Others			3
Total			35

Table listing the survey participants according to their companies. Fig. 9.

The main rationale of the survey is to stress test the initial findings collected from the BSI conference and interactions with people at the IoT Expo, BSI, and other events. A survey was chosen in order to have a wider range of opinions and views, to collect insightful quantitative as well as qualitative data on the topic, and to be better informed what the best next steps are in terms of the recommendations to the BSI. A survey workshop was organised by our mentors to consolidate within the group what data the team wanted to gain from the surveys and design the survey accordingly. Our team received a lot of insightful feedback from our mentors and BSI staff. The survey was designed in such a manner that it is not too lengthy to complete, that the answers can be easily processed, and finally that the group could visualise the data from the survey. A total of 35 amount of surveys was collected. The survey was mainly disseminated by using BSI's mailing list. The link to the survey was available on social media such as LinkedIn and Twitter and was sent to our individual contacts as well. The survey should have only required 10 min to complete. Most of the questions have pre-defined, multiple-choice answers, and there is only one open question. A weekly update on the survey data was sent to the group for analysis.

Phase III: Semi-structured interviews

Type of organizations	Number of participant(s)
Large tech company	1
IoT SME	6
Energy consultancy	1
Trade association	1
Standards development organization	3
Total	12

Table listing the interview participants by type of organizations. Fig. 10.

The decision to hold interviews was one taken by the group as a way to collect qualitative data. As opposed to the survey, semi structured interviews allow a deep dive into the topic, as the interviewees can explain in depth their opinions and give insights. 12 people in total were interviewed. We contacted employees from IoT SMEs, large tech companies, trade associations, as well as standards development organizations. 'Semi-structured interviews' means the team used pre-written questions, yet left space for interviewees to provide unstructured insights and opinions on the matter. We used survey questions as a starting off point and the interview was split into 4 parts: introduction, current use/operation of standards, involvement in standards-making process, future-improvements (see Annex 1 for an example of interview guide). For each interview, a customised set of questions was drafted by the team, in order to better capture the expertise and area of the interviewees. Some spontaneous questions came up during the discussion to gather a better understanding of the interviewees' opinions, and their participation in standards development process or usage. As explained in the ethics section and to the participants, their participation was voluntary. Each interview was conducted by 2 team members, and among the 12 interviews, 3 were conducted in person, and 9 via video calls or phone calls. The interview guide was designed for interviews lasting between on average 45 mins to one hour; the length of the interview varied depending on the participants' availability. Most of the participants allowed the interview to be recorded, following the team's ethics application, enabling a more accurate gathering and analysis of the data collected, as well as the use of reliable direct quotes in this report.

5.5. Ethics

All of the data collected within this report was consensually given, and ethically stored. Our ethics application was submitted to the board at UCL for a formal review process in order to ensure everything was in order before we started conducting research. After an extended ethics process, the ethics board at

UCL approved our project and the primary research could begin. The process ensures that as a group, we understand the ethics of the project, how to respect the data that we collect and the privacy of participants that we interview or survey, which must be in line with GDPR and the UK data protection act.

6. Appendix B - The IoT standards landscape and SMEs

This section will attempt to gather and sum up critical information present in the current literature on the IoT ecosystem, the types of standards available, innovation, and the challenges SMEs face regarding developing and implementing standards. It is important to remind the reader that the area we are investigating represents a moving target, as the IoT ecosystem is in continuous expansion.

The specific intersections of standards, innovation, IoT, and SMEs – especially SMEs innovating in IoT and their relationship with standards – is currently under researched. Therefore, the bulk of our literature review involves looking at these concepts more distinctly. Our three main areas of research fall into the categories of standards and standards development, IoT and innovation, and SMEs.

6.1. Description of BSI

The British Standards Institution (BSI) is the UK's National Standards Body (NSB), responsible for producing national and international standards. Founded in 1901, BSI remains among the world's largest and most active NSBs, publishing around 2,500 new standards annually.[32] Standards are agreed ways of making or doing something and play an invaluable role in underpinning the infrastructure of a modern economy. They gain their authority from being written through a process of wide consultation that leads to an expert consensus. BSI works with academic and industry experts, government bodies, trade associations and consumer groups to understand good practice and, based on this knowledge, creates standards that help organizations succeed. BSI actively reaches out to SMEs to try and persuade more businesses to start using standards. Standards are an accessible and cost-effective source of trusted information for SMEs aiming to become more competitive.[33]

6.2. The different types of standards

Formal standards (de jure standards)

A standard is a document which provides voluntary rules for an agreed way of doing something. For example, when managing a process or delivering a service. Standards are based on expert stakeholder consensus upon a wide input and knowledge on science, technology and experience, representing the needs of their organization such as manufacturers, sellers or buyers; and aimed at the promotion of optimum community benefits.[34] Through a consensus it ensures that all interests of those likely to be affected by the standard are considered. Once the new proposal/revision has been drafted in a working

[32] BSI Group. "UK National Body". Bsigroup.Com, n.d.
[33] BSI Group. "About BSI". Bsigroup.Com, n.d.
[34] ISO/TMBG, "ISO/IEC Guide 2:2004". ISO/TMBG, November 2004.

group, it is sent to a committee group before making the draft available for public consultation. These comments are either accepted or resolved and the draft is then sent to the national member bodies for approval before publication.[35] This lengthy process can take anywhere from 1-4 years to develop depending on the number of stakeholders, the complexity of the topic and whether they are national or international standards.[36] Standards are not regulations or legislation; however, the government often draws on the expert technical knowledge expressed in standards to create legislation or guidance documents.[37]

Formal standards are created by international, regional and national standards bodies. Organizations such as the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) enable representatives of member states to design international standards. At the regional level, the European Standards Organizations (ESOs), for example, consist of European Committee for Standardization (CEN), European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI).[38] National Standards Bodies, such as the British Standards Institution (BSI) are highly involved in the standard making process at both global and regional levels. For example, among all the national standards published in the UK annually, 95% are international or European.[39]

Publicly available specifications

A Publicly Available Specifications (PAS) is a type of open standard consisting of a consultative document where any organization, association or group can document a standardised best practice on a specific subject developed and formatted on the formalised British Standard model. Subject to the BSI acceptance process, PAS are shorter to produce as they do not require full consensus between all stakeholders unlike a formal standard. PAS invite comments from interested parties, however, they are only necessarily incorporated. Thus, the time scale of these standards is around eight months and are often referred to as the 'Rapid Standard Development Process'.[40] The UK government often commissions BSI to produce PAS.

Open standards

There is no single definition to describe an open standard as there are various interpretations of the term and alternative views on how these standards should be defined and updated. An open standard is

[35] BSI. "Pocket Guide to Standards Development." *Bsigroup.com,* 2012.
[36] BSI Group. "How Are Standards Made? | BSI Group." *Bsigroup.com*, 2019.
[37] BSI Group. "What Is a Standard | BSI Group." Bsigroup.Com, 2019.
[38] CENELEC. "European Standards Organizations (ESOs)." About CENELEC.
[39] Steedman. "Standards – Enabling Innovation and Change in the Digital Economy." 8.
[40] BSI. "What Is A PAS? ISO Standards | BSI Group." *Bsigroup.Com*, 2019.

developed/approved and maintained through a transparent consensus and collaborative driven process. They should not be dominated by a single interest to ensure a balanced process. They facilitate interoperability and data exchange amongst varying products and services. Other elements of an open standard may include that they are publicly available.[41] Any interested party must be able to join the standardization process where decisions are based on, for example, a consensus procedure. The standard must be free to implement.[42]

Therefore, open 'concerted' standards are created through an open participation process where the standard is defined and managed. Open 'de jure' standards are managed and owned by national and international standardization bodies such as ISO and ANSI.[43]

Industry-driven standards (de facto standards)

Due to the formal standards lengthy development process, numerous industry alliance and interest associations have responded by creating their own guidelines to be adopted and utilised in the IoT landscape.[44] These guidelines generally represent the interests and intellectual property of those who set them. These are widely accepted and adopted and are sometimes formalised; however, they generally lack formal approval by an officially recognized standards organization.[45] Moreover, some industry alliances promote their own trust marks and certification schemes to illustrate compliance with proposed guidelines.[13] The development and introduction of de facto standards increases the complexity of the IoT standards landscape for SMEs who face great difficulty navigating this complex landscape of standards, best practices and guidelines as they are uncertain of which testing, verification and certification scheme they should utilise.

6.3. PETRAS-BSI white paper

This research draws upon the research paper conducted by the BSI with PETRAS Cybersecurity of the IoT Research Hub. In their published white paper, 'Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups,' [46] they looked at the main opportunities and challenges that SMEs and start-ups are facing in the development of IoT products and services. They also identified their standardization priorities and how the standards development communities can both engage and support them.

[41] ITITU. n.d. 'Definition of "Open Standards."
[42] Cerri, and Fuggetta. "Open standards, open formats, and open source." 1930-1937.
[43] *Ibid.*
[44] Brass, Irina, Leonie Tanczer, Madeline Carr, Miles Elsden, and Jason Blackstock. "Standardising a moving target: The Development and Evolution of IoT Security Standards." 24-9, 2018.
[45] Allen and Sriram. "The role of standards in innovation."
[46] Brass, Pothong, and Hasham. "Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups."

Barriers for SMEs and standards

The white paper focused on six key issues in the fragmented policy landscape for IoT and the challenges they present for SMEs. Some of the barriers identified include:

- *Security* - There is a barrier in understanding and assessing the trade-offs between security and operational effectiveness, and also in the trade-off between investment in interoperable products development, ecosystem development and providing as a service IoT security.
- *Safety* – For IoT SMEs there is a limited availability in the number of risk assessment guidelines to enable them to develop safety and security maintenance services for products via a subscription model.
- *Privacy* – For IoT service and product providers there is an uncertainty over their legal liability, particularly in a 'complex data flow and processing ecosystem'.[47]
    - Moreover, the cost of implementing and monitoring compliance with best industry practice for data protection, security and safety in an effective manner may disadvantage SMEs compared to larger established businesses.
- *Interoperability* – A barrier is prevalent in the current lack of standardized ontologies and data communication protocols which makes it difficult for SMEs to integrate with third party platforms or providers. Thus, this limits SMEs competitiveness as well as their ability to work towards comprehensive IoT services.
- *Transparency* – A lack of trust marks and labels affects SMEs openness for innovation as they cannot convey information about their data processing and security practices.
- *Awareness* – Poor consumer awareness over secure IoT devices and services and their ability to identify responsible manufacturers, makes it difficult for SMEs to adopt and implement best industry practices as well as certify new products if there is no pressure to have these marks of trust.
- *Knowledge* – A lack of easily accessible knowledge base results in a lack of awareness of the latest best practices and the benefits and costs of investing in new IoT services

These are several of the challenges and barriers faced by IoT SMEs as identified by the white paper[48] which across devices, systems and platforms may hinder brand reputation as well as damage SMEs' business growth.

[47] Brass, Pothong, and Hasham. "Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups."
[48] *Ibid.*

6.4. Role of standards in innovation

'Certainly, standardization does constrain activities but in doing so creates an infrastructure to help trade and subsequent innovation. Standardization is not just about limiting variety by defining norms for given technologies in given markets. Standardization helps to achieve credibility, focus and critical mass in markets for new technologies. Moreover, well-designed standards should be able to reduce undesirable outcomes.'[49]

Most of the literature praises the role of standards as a way for different entities to communicate according to an agreed way of doing a product, a process or a service. The power of standards is reached when they are universally adopted by the industry. Indeed, a client could then choose among different suppliers, yet being confident that the product produced will meet its demands. Innovation is here triggered as suppliers would compete on quality and price. Standards represents an ideal tool to enhance innovation and market development. Most scholars agree on the benefits of standards, in terms of competition and as a 'passport for trade', as well as building trust between two entities (company and supplier, employees and employers, etc).[50] According to a study conducted by BSI and Cerb, in 2013, standards contributed to 28.4% of annual UK GDP growth, equivalent to £8.2 billion.[51] As there is an established way to do something, 'innovation becomes less risky'[52] as standards provide businesses with the essential tools which support both new product development and market access. They create competitive advantage as standards provide a common platform for industry. Standards enable market access whilst also supporting business performance improvement. Thus, they create a level playing field within all market economies.[53] In a large number of engineering professions, mainly high usage sectors, standards are depicted as a compliance tool, and not a strategic enabler for industry actors.[54]

In some instances, standards had the opposite effect of fostering innovation as it can be used, accidentally or deliberately, to build technical obstacles for competitors or to prevent new entrants to the market.[55] Additionally, when regulatory systems are more onerous, time-consuming and expensive, they are more dominated by large multinational companies and it becomes increasingly difficult for smaller companies to gain a competitive advantage.[56]

[49] Swann, GM Peter. "The economics of standardization: An update." Report for the UK Department of Business, Innovation and Skills, 2010.
[50] Steedman. "Standards – Enabling Innovation and Change in the Digital Economy." 8-9.
[51] Hogan, Oliver, Colm Sheehny, and Rajini Jayasuriya. "The Economic Contribution of Standards to the UK Economy: 2015." British Standards Institution, 2015.
[52] Steedman. "Standards – Enabling Innovation and Change in the Digital Economy."
[53] *Ibid.*
[54] *Ibid.*
[55] Steedman. "Standards – Enabling Innovation and Change in the Digital Economy." 13.
[56] Tait and Banda. "Proportionate and Adaptive Governance of Innovative Technologies."

6.5. IoT standards

Barriers highlighted by the white paper can be addressed by standards. For example, interoperability specifications guarantee that IoT devices from different vendors can communicate with each other. As the realization of IoT is still in its early stages, manufacturers of IoT devices and web service providers are defining their proprietary protocols. Consequently, IoT becomes heterogeneous in terms of communication protocols and hardware capabilities. Some open standards have been designed to bridge communication gaps with various IoT devices.[57] Interoperability, however, is not limited to relationship between technologies. Interoperability has also a semantic and an ontological dimension. Ontology is a set of concepts and categories of a business ecosystem explicitly describing relationships between the different elements.[58] Having a shared ontology helps developers to share application domain knowledge using a common vocabulary across systems, ecosystem, and platforms.[59] Thus, users and organizations can communicate with one another even if they use products from different providers.[60]

IoT standards are being developed at the global stage, as they provide interactions between IoT devices connected over the Internet. Even though BSI is an active member in ISO, other standard bodies have also developed standards related to IoT in parallel.[61] Standards for the IoT ecosystem are not limited to interoperability. Indeed, security, safety, data integrity, data protection, privacy are also areas in which standard bodies try to develop standards.[62] For example, the recent effort made by oneM2M, an international standards body, focused on developing a standardised vocabulary in the IoT ecosystem.[63] In order to maintain users' confident in IoT devices, BSI has also developed a Kitemark for IoT Devices as a mean to help consumers to identify IoT products which are safe, secure and functional.[64] The Internet of Things will present new challenges for the regulation of, privacy, security and safety, as connectivity and compute power become embedded in our physical environment. In fact, new aspects of information and human security will have to be included. In the case of autonomous vehicles, software must be resilient against terrorists or malicious actors, as well as take into consideration abuse cases such as if a child can use her smartphone to direct the car to go to school, for example.[65]

[57] Jazayeri, Mohammad, Steve Liang, and Chih-Yuan Huang. "Implementation and evaluation of four interoperable open standards for the internet of things." Sensors 15, no. 9: 24343-24373, 2015.
[58] Gyrard, Zimmermann, and Sheth. "Building IoT-Based Applications for Smart Cities: How Can Ontology Catalogs Help?."
[59] *Ibid.*
[60] Cerri, and Fuggetta. "Open standards, open formats, and open source." 930-1937
[61] Park et all., "Recent advancements in the Internet-of-Things related standards: A oneM2M perspective." 126-129.
[62] Brass, Pothong, and Hasham. "Navigating and Informing the IoT Standards Landscape: A Guide for SMEs and Start-Ups."
[63] Park et all., "Recent advancements in the Internet-of-Things related standards: A oneM2M perspective." 126-129.
[64] BSI Group. "BSI launches Kitemark for Internet of Things devices." 2018.
[65] Leverett, Éireann, Richard Clayton, and Ross Anderson. "Standardization and Certification of the 'Internet of Things'." In Proceedings of WEIS, pp. 1-24, 2017.

The IoT committee at ISO, which BSI's IoT/1 Committee mirrors, is labelled JTC 1 SC 41. In 2014, ISO released a review of ISO IoT Standards. Within the standard, IoT is defined as 'An infrastructure of interconnected objects, people, systems and information resources together with intelligent services to allow them to process information of the physical and the virtual world and react.'[66] The more recent JTC 1 SC 41 developments on IoT & interoperability include 20 published ISO standards, and now 11 are directly being developed by JTC 1 SC 41. This committee includes 3 working groups, architecture, interoperability and applications; thus, giving a range of topics covered.

There have been several IoT standards developments since 2014, and their range of use has expanded to industries such as retail, healthcare and machine learning. The aforementioned ISO standard covers: stakeholder requirements, data management and market requirements; however, does not cover all essential areas within the IoT ecosphere.[67] For example, the Google Home was caught listening in on private conversations, but there are currently no formal standards that cover privacy around IoT devices such as the Google Home. The one piece of legislation that covers privacy is the General Data Protection Regulation 2018 (GDPR)[68] which only includes the EU.

6.6. Standards in other tech sectors

Artificial Intelligence (AI) standards

There have further been 3 published ISO standards under the responsibility of ISO/IEC JTC 1/SC 42, but 12 in progress and development. Three basic technologies–information technology, consumer electronics and telecommunications - converge in the sense that the same fundamental technologies are applied in all three areas. This can be termed horizontal convergence; the resulting technology is often called ICT. The advent of ICT demanded a closer overall cooperation, in the standardization arena, among the 3 key international standards organizations: ISO, IEC and the International Telecommunication Union (ITU). Simultaneously, IT progresses into all aspects of life (business, industry, home, administration, education, charity, etc.), with conventional processes and applications now exploiting the capabilities offered by ICT. This may be termed vertical convergence[69]. New ICT applications are characterized by the involvement of different technologies and high complexity; in general, they cannot be covered by a single standard, but are part of an interdisciplinary system. This demands closer cooperation between technology oriented and application-oriented experts, both in product and in standards development.[70]

[66] ISO/IEC JTC 1. "Internet of Things (IoT) Preliminary Report 2014". ISO / IEC, 2015.
[67] *Ibid.*
[68] Official Journal of the European Union, "REGULATION (EU) 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL". 2016.
[69] ISO/IEC JTC 1, "ISO/IEC JTC 1/SC 42 Committee Page - Artificial Intelligence." ISO, 2017.
[70] ISO/IEC JTC 1. "Internet of Things (IoT) Preliminary Report 2014."

Thus, the ISO working group for AI provides a single forum where a wide array of technologies can be integrated into serviceable standards. As these converging technologies become pervasive in every aspect of modern life, infrastructure standards developed, are the essential building blocks for the implementation of many other technologies.[71] Artificial intelligence committees have written standards around: 'Big data -- Overview and vocabulary'; 'Big data reference architecture'; 'Use cases and derived requirements' and; 'Big data reference architecture, a Standards roadmap'.

Blockchain standards

ISO/TC 307 has no current standards, only the committee on blockchain. However, it has 11 ISO standards that are currently under development. Considering how long the technology has been around and how disruptive it has been, notably in recent years with the emergence of popularity in cryptocurrency, standards need to be developed soon in order to ensure safety. However, with such an evolving and innovative technology, a more 'agile' standards development process would perhaps be beneficial.

There have been several industry papers that have been released however, which plays on the fact that industry create standards faster than public bodies do, as they have the resources and expertise to do so. Examples of industry papers include the following published by IEEE who has a working group on blockchain standards, these industry papers include but are not exclusive to: Digital Inclusion through Trust and Agency (DITA) and Supply Chain & Trials Standardized Technology and Implementation.[72]

6.7. 'Agile' standards development

Innovative technologies, such as those emerging within the IoT ecosystem, further complicate standards development. In particular, standardization for IoT is difficult due to the application domains IoT encompasses such as consumer goods, mobility, essential services, industrial processes and critical infrastructures. Moreover, due to the security dimensions and blurred boundaries in regards to data protection, consumer protection, safety, resilience, trustworthiness and reliability.[73] Standards for IoT tend to be fragmented across the international standards landscape since a single IoT product or service can fall under various traditional categories of products and these products and services are used globally. The fragmentation amongst the standards landscape is further complicated by the differences between

[71] Cihon, Peter. "Standards for AI Governance: International Standards to Enable Global Coordination in AI Research & Development." Oxford: University of Oxford, 2019.
[72] IEEE, "IEEE Standards Association - Digital Inclusion, Identity, Trust, and Agency", 2019.
[73] Brass, Irina. "Week 9 - Standardize, Nudge, Mandate, Repeat". Lecture presented at the Term 1 Digital Technologies and Public Policy Module, UCL STEaPP, 30 November 2018.

horizonal standards versus vertical standards. Horizontal standards contain 'fundamental principles, concepts, definitions, terminology, and similar general information applicable over a broad subject area', for instance, standards for safety, security, or privacy.[74] Vertical standards, on the other hand, address the necessary information specific to a particular application, domain or product.[75] There is also generally a latency problem in which standards cannot keep up with the faster paced development of technologies.

Therefore, there is a demand for standardizing IoT in inventive new ways to support the positive impacts of these technologies while also minimizing their potentially negative consequences. Agile standards development (also sometimes referred to adaptive), is a proposed approach to these new methods of standards-making. The use of the word 'agile' in development processes has been around since the 1990s in the software sector.[76] Agility or agile generally describes the method of being nimble, fluid, flexible or adaptive. Agile governance is seen as an approach that seeks to navigate the pace of technological change through 'adaptive, human-centred, inclusive and sustainable policy-making.'[77]

An example of agile governance of innovative technologies is when, in the early stages of development of a disruptive technology, regulators attempt to retain as much variety in the market as possible until it becomes clear what the 'winning technology' will be.[78] Therefore, the focus shifts onto tools like PAS's or de-facto consensus standards that have been developed in collaboration with companies and experts in the area. These standardization tools are developed as 'soft law' (i.e. voluntary) until the future technology and its adoption becomes more clearly defined.[79] After these standards are adapted to the technology they can be later formalized as guidelines ('medium law'), which can form the basis for the future regulatory system ('hard law') of the disruptive technologies.[31] This also means that complying with the voluntary standards when the technology is in early stages, can help prepare organizations for future mandatory legal requirements.

6.8. SMEs and innovation

SMEs and start-up businesses play a critical role in supporting innovation across the UK economy, contributing to the creation of high-wage employment, and enhancing the growth of productivity in their sectors. SMEs are sources of important industry knowledge and serve as 'bridges of innovation' that interact

[74] ANSI Contributor, "Vertical and Horizontal Standards - What?!", The American National Standards Institute (ANSI) Blog, 3 May 2017.
[75] *Ibid.*
[76] Nima, Elmi, Kris Broekaert, and Anne-Marie Engtoft Larsen, "Agile Governance: Reimagining Policy-Making in the Fourth Industrial Revolution." White Paper. World Economic Forum, January 2018.
[77] Idem. 8.
[78] Tait and Banda, "Proportionate and Adaptive Governance of Innovative Technologies." 4.
[79] Idem. 7.

with other key industry players.[80] SMEs contribute significantly to innovation dynamics and despite their structural disadvantages stemming from limited resources, they now have new opportunities with niche-markets and changing technologies.[81] According to an OECD report, in certain high-technology sectors (e.g. semiconductors, biotechnology), emerging sectors (e.g. green industries) and creative industries (e.g. film production, publishing, architecture, etc.), innovative SMEs and start-ups are key players and drivers of innovation. Even in traditional sectors, SMEs in OECD countries represent between 33-50% of innovative firms SMEs. They are particularly interested in procuring the benefits of IoT technology, with 70% of SMEs in an IoT Analytics survey reporting that they are using IoT technology to improve current products; in addition, 52% responded that they are trying to implement new IoT service-based models.[82]

Standards can provide a baseline for the market which promotes innovation as well as facilitating trade, enhancing consumer protection and a framework for achieving economies and efficiencies and a standard across industry allows their business to scale up.[83] Therefore, it is vitally important for organizations such as SMEs to utilise standards.

[80] Cusmano and Dean. "Chapter 1: Intellectual Asset Management, Innovation and SMEs."
[81] Idem. 16.
[82] Lueth, Knud L., Dirk Glienke, and Zaña Diaz Williams. "Guide to IoT Innovation (SME Focus)." IoT Analytics, September 2017.
[83] Allen and Sriram. "The role of standards in innovation."

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Brass, Irina, Leonie Tanczer, Madeline Carr, Miles Elsden, and Jason Blackstock. "Standardising a moving target: The Development and Evolution of IoT Security Standards." 24-9, 2018. Available at: https://doi.org/10.1049/cp.2018.0024.

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Annex 1: Example of an interview guide

Ideally have two people to facilitate the interviews - one to lead the interview, the other to take notes and make sure the recording equipment is working.
Ensure participant consent forms are available and ready to be signed.
Check there are no objections to the use of the recorder [if applicable].

Introduction to the session (read aloud to interviewee)
My name is XX and I will be conducting this interview today, my colleague XX will be taking notes. First, thank you very much for taking the time to participate in this interview.

The purpose of this interview is to gather data for our research project between University College London (UCL) and the British Standards Institution (BSI) on *Understanding Innovation and the Internet of Things (IoT) Ecosystem: The Role of Standards in Meeting Small and Medium Enterprises' (SMEs) Strategic Priorities*.

Our project aims to bridge the challenges SMEs are facing and identify SMEs' strategic needs and priorities for IoT standards and their operational and organizational challenges when navigating, adopting and implementing IoT standards. The project extends to give recommendations to the BSI to consider in their approach to IoT standards development and SMEs involvement, including a consideration of trade associations and professional bodies in representing SME's interests in regards to IoT standards development. We will further develop a framework to map these challenges and how SMEs can engage more systematically in IoT standards development.

The BSI is the UK's National Standards Body responsible for producing national and international standards. BSI produces technical standards on a wide range of products and services, and supplies certification and standards-related services to businesses.

We will be asking a short set of questions regarding your organization's involvement in standards in order to better gauge participation from SMEs in the development process of standards within the IoT realm.

Your participation is voluntary. A refusal to participate will not disadvantage you in any way or affect your relationship with UCL.
Do you have any questions thus far?
No? Let's begin.

Semi-structured interview questions

1. **Introduction – Warm-up**
    a. What type of a company do you work for? Can you describe what your company is doing?
    b. What is their role within the IoT ecosystem?
    c. Have you previously taken the survey?
    d. At what point in your career did you become aware of standards?
    e. So, from previous conversations we know you are involved in environmental compliance, would you have any involvement in the IoT side of the company?

2. **Involvement in standards-making process**
    a. What is your involvement in standards development process?
    b. How long have you been sitting on this/those committee(s)?
    c. Was it your choice or did your company push for it? Is your company accommodating taking time off?
    d. What is the average age of people sitting in those committees?
    e. In the time you've been there, how long does it take for standards to be created and released?
    f. Are there any SMEs involved? Did you witness any power dynamic between the different entities?
    g. Do you think the needs of SMEs are being represented on these committees?
    h. How does your organization interact with SMEs?
    i. What would you like to see changed in the standard development process?

3. **Current use/ operation**
    a. What are the main standards that your organization has implemented and why?
    b. At what stage does your organization most use IoT standards? E.g manufacturing, software, procurement, c-suite, business to business.
    c. Does your company use any standards developed by BSI?
    d. What purpose are they used for? (Accountability/scrutiny, Business advantage, Compliance, Consumer awareness, Guidance, Interoperability, Protection of consumer data, Reputation, Security of the organization)
    e. Who is involved in the implementation process?
    f. Who decides what standards they need?

g. Are you seeking any guidance on what standards to utilise?
h. Is there a gap between the demand and what is available?
i. How do you see standards aligning with your organization's business priorities? Are they helpful or burdensome? (any barriers) (What types?)

4. Future – Improvement

a. What incentives should be included to encourage adoption + usage of standards?
b. From the conference we were given these suggestions, do you agree or disagree with any of these suggestions?
    - Include cover page with a preview of the standard
    - Blurb with an explanation of the standard and its purpose
    - Reviews using a star ranking system
    - Improved search filters on the database
    - Introduce a 'lite' version with lower price and limited accessibility
    - More affordable standards
    - Sector specific email or text alert when public consultations occur
c. What actions can be taken to achieve the improvements in standards you have envisioned?
d. In particular what improvements would you like to see implemented by the BSI?

Conclusion

Thank you very much for coming in today. We really appreciate your feedback. We will send a digital copy of the participant information sheet and of the consent form.

e. Do you know anyone else that you would recommend for us to interview?

Annex 2: Survey questions

Understanding Innovation and the IoT Ecosystem: the role of standards in meeting SMEs' Strategic Priorities

Welcome to the University College London (UCL) - British Standards Institution (BSI) survey on Internet of Things (IoT)- Small to Medium Enterprises (SMEs) standards. Our research project investigates the role of standards in meeting the unique challenges faced by SMEs in the IoT ecosystem.

The project will:

- Identify SMEs' strategic needs and priorities for IoT standards.
- Identify the operational and organizational challenges SMEs face when navigating, adopting, and implementing IoT standards.
- Provide BSI with recommendations for their approach to involving SMEs in IoT standards development.
- Aim to develop a framework that will help SMEs to engage more systematically in IoT standards-making.

The British Standards Institution (BSI) is the UK's National Standards Body (NSB), responsible for producing national and international standards. BSI consults with academic and industry experts, government bodies, trade associations and consumer groups to understand good practice and gain expert consensus in order to create standards.

This survey should take around 10 mins to complete.

Free access to BSI standards

By taking part in this survey your organization will benefit from 3 months of free, view-only access to British Standards Online (BSOL), starting 1st of September. BSOL is an online standards database, allowing the user to browse the large catalogue of standards. To ensure you don't miss out please enter your email address at the end of this survey. Please contact Elizabeth Down at elizabeth.down.18@ucl.ac.uk if you have any questions.

Privacy statement

Your participation in this survey is entirely voluntary. Declining the opportunity to participate will not disadvantage you in any way or affect your relationship with UCL.

Your survey data will be collected by the BSI, and stored securely with the BSI and UCL, following university guidance. Your data will be fully anonymised and only the researchers involved in this project will have access to this data. The data will contribute to the MPA UCL-BSI research project. Data from the survey will be used in our own academic research and publications, presentations, and briefs. Your data and details

are not shared with third parties and will be collected and stored in accordance with the General Data Protection Regulation 2018 (GDPR) and the UK Data Protection Act 1998.

You must be 18 years or over to take part.

Questions

About your organization

SINGLE CODE

1. What type of organization do you work for?

Please select one answer only

- Start-up
- Corporation
- Trade association
- Industry alliance
- Consultancy
- Other (please specify)

SINGLE CODE

2. What is the size of your organization?

Please select one answer only

- Small-sized enterprise (<50 employees)
- Medium-sized enterprise (<250 employees)
- Large enterprise (>250 employees)
- I do not know

SINGLE CODE

3. Which statement best describes your organization's involvement in the IoT ecosystem?

Please select one answer only

- Develops IoT products or services (e.g. hardware, software, cloud services)
- Adds IoT connectivity to existing products (e.g. connected home appliances)
- Uses IoT products and services to diversify your business model (e.g. connected healthcare service)
- Consultancy dealing with organizations in IoT
- Other (please specify): *[Free text]*
- My organization does not work in the IoT ecosystem

Role of standards in your organization

SINGLE CODE

4. Does your organization currently use standards?

Please select one answer only

- Yes
- No
- I do not know

IF YES AT Q4

MULTICODE ALLOWED

4a. What type of standards does your organization use?

Please select all answers that apply

- Open standards (publicly available and free, and often produced through open process)
- Industry-driven standards (elaborated by single industry actors or industry associations or alliances such as industry codes of practice/guidelines)
- Formal standards (standards produced by national or international standard bodies such as BSI or ISO)
- Publicly Available Specification (PAS) (fast-track standardization document commissioned by individual organization via BSI structure)
- I do not know
- None of the above

IF YES AT Q4

MULTICODE ALLOWED

5. For what purposes are standards currently used within your organization?

Please select all answers that apply

- Accountability/scrutiny
- Business advantage
- Compliance
- Consumer awareness
- Guidance
- Interoperability
- Protection of consumer data
- Reputation
- Security of the organization
- Other (please specify): *[Free text]*

IF Q3 IS ANY CODE 1-5

MULTICODE ALLOWED

6. If you implement IoT, at what point in the provision of IoT products or services does your organization most use standards?

Please select all answers that apply

- Business to Business
- C-suite
- Manufacturing
- Procurement
- Software
- Supplying the service
- Other (please specify): *[Free text]*
- I do not know

SINGLE CODE

7. Has your organization sought guidance on how to implement standards in your organization?

Please select one answer only

- Yes
- No
- I do no know

IF YES AT Q7

MULTICODE ALLOWED

7a. Where has your organization sought guidance from?

Please select all answers that apply

- Consultancy
- Industry Alliance
- International Standards Body (e.g. ISO)
- National Standards Body (e.g. BSI)
- Online resources
- Trade Association
- Other (please specify): *[Free text]*
- I do not know

MULTICODE ALLOWED

8. What do you think are the barriers, if any, to using formal standards (standards produced by national or international standard bodies such as BSI or ISO)?

Please select all answers that apply

- Burdensome to implement
- Complexity finding standards beneficial for my organization
- Development process does not match the fast pace of emerging technologies
- Difficult to implement
- Expensive
- Lack of awareness of the standards available
- Lack of clarity on how standards can help my organization
- Resource intensive (human and time)
- Technical complexity in implementing a standard
- Other (please specify): *[Free text]*
- I do not see any barriers

Participation in standards development

SINGLE CODE

9. Is your organization involved with developing standards?

Please select one answer only

- Yes
- No
- I do not know

IF YES AT Q9

MULTICODE ALLOWED

9a. How is your organization involved in developing standards?

Please select all answers that apply

- Employees involved in Standards Committees
- Participation in public consultations
- Other (please specify): *[Free text]*
- I do not know

SINGLE CODE

10. Are you personally involved in developing standards?

Please select one answer only

- Yes
- No

IF YES AT Q10

MULTICODE ALLOWED

10a. How are you involved in developing standards?

Please select as many answers as apply

- Involved in Standards Committees
- Participation in public consultations
- Other (please specify): *[Free text]*

MULTICODE ALLOWED

11. What, if anything, do you think could be done to support involvement in the standards-making process?

Please select all answers that apply

- Awareness campaigns on public consultations
- More incentives to participate
- Restructuring the form of the committee meetings (with web chat and online committee forums)
- Sector specific email or text alerts when public consultations occur
- Other (please specify): *[Free text]*
- Nothing

SINGLE CODE

12. Does your organization have any membership with trade association(s)?

Please select one answer only

- Yes (please specify which one(s))
- No
- I do not know

IF YES AT Q12

SINGLE CODE

12a. Do you feel that they effectively represent your organization's interests in the standards development process?

Please select one answer only

- Yes
- No
- I cannot comment

Functionality of standards

MULTICODE ALLOWED

13. Which of the following topics, if any, do you feel IoT standards could be developed to address?

Please select all answers that apply

- Communicating/ signalling compliance
- Interoperability
- Market access
- Privacy and data protection
- Promoting consumer and business awareness
- Safety
- Security
- Other (please specify): *[Free text]*
- None of these

SINGLE CODE

14. To what extent do you agree or disagree that **formal standards** (standards produced by national or international standard bodies such as BSI or ISO) are beneficial to organizations in the IoT ecosystem?

Please select one answer only

- Strongly agree
- Tend to agree
- Neither agree nor disagree
- Tend to disagree
- Strongly disagree

SINGLE CODE

15. To what extent do you agree or disagree that **open standards** (publicly available and free, and often produced through open process) are beneficial to organizations in the IoT ecosystem?

Please select one answer only

- Strongly agree
- Tend to agree
- Neither agree nor disagree
- Tend to disagree
- Strongly disagree

SINGLE CODE

16. To what extent do you agree or disagree that **industry-driven standards** (elaborated by single industry actors or industry associations or alliances such as industry codes of practice/guidelines) are beneficial to organizations in the IoT ecosystem?

Please select one answer only

- Strongly agree
- Tend to agree
- Neither agree nor disagree
- Tend to disagree
- Strongly disagree

OPEN ENDED

17. What changes to formal standards, if any, would you like to see? [Open answer]

About you

SINGLE CODE

18. What is your role within your organization?

Please select one answer only

- Executive management level / C-suite level
- Middle management level / Director
- Managers / Advisors
- Entry Level / Associate

Thank you for participating.

If you would like to receive 3 months of free, view-only access to British Standards Online (BSOL), please select 'Yes' below and input your email. By clicking yes, you consent to sharing this information with BSI, for the purpose of providing access to the trial. [Checkbox, if yes open box]

Your details will be stored securely by BSI and UCL, according to university guidance, and will only be used to contact you to provide access to the trial.

In parallel to the survey, we will be conducting interviews to validate our research findings. If you would like to contribute, please contact Elizabeth Down at elizabeth.down.18@ucl.ac.uk.