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Stakeholder salience and standardisation: The case of the industrial internet of things

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ABSTRACT

New innovative systems may address societal challenges such as climate change and energy scarcity. Often, these innovative systems are realized following a set of predefined standards. Sometimes, multiple standards compete for market dominance. This paper addresses factors that affect standard competition and dominance. It investigates how the composition of standardization organizations with respect to their salience influences the success of standards by applying a refined method for identifying stakeholders and their salience. The paper contributes to the literature by providing initial evidence that stakeholder salience affects standards dominance. It appears that user engagement and the involvement of definitive stakeholders, holding power, urgency and legitimacy increases standards dominance and that avoiding dangerous stakeholders that lack legitimacy has a possible effect on standards success. These are important considerations to consider by practitioners.

1. Introduction

Today, our world is faced with major societal challenges including energy scarcity and climate change. These challenges may be addressed by developing and commercialising smart and sustainable solutions, such as smart grids and predictive maintenance. Such solutions can be realized through application of Industrial Internet of Things (IIoT) systems. Within IIoT system, interconnection is defined at four levels: data ingestion, data transmission, data processing and data utilisation (Gupta, 2024). Successful deployment of an IIoT system could start with sensors within a factory that monitor equipment vibration data (data ingestion). This data is transmitted via an industrial network to a central control system or cloud data lake (data transmission). The data is processed (aggregation, decrypting, transformation, etc.) into actionable insights (data processing). Finally, the processed data is displayed on an operator dashboard. Based on the displayed data appropriate actions can be taken. For example, allowing maintenance teams to monitor the equipment condition in real-time and schedule predictive maintenance (data utilization).

For an Industrial Internet of Things system to become fully realized, single common standards will have to be defined for each of these levels. Standards development and standards battles are in full effect, and the question is which factors will affect the chances that a particular standard reaches market adoption. Although researchers have studied factors for standards dominance and adoption, they have not yet studied how the mix of stakeholder types and positions within standardization initiatives affects standards selection.

This paper focuses on the question of how the type of stakeholders, and their salience, affect standards selection in each of the four levels within IIoT systems. It explores whether patterns can be found in stakeholder types and levels of market adoption. It interprets the findings, discusses contributions to the research, and discusses recommendations for policymakers.

2. Theory

Several researchers have looked at standards battles (Schilling 1999, Shapiro and Varian 1999, Funk 2002, Gallagher and Park 2002, Schilling 2003, Gallagher 2012, Van de Kaa and De Vries 2015). These researchers have analysed how companies must operate to ensure that their standard becomes successful by either ratification or adoption. In the mid-1980 s, network economists emphasized existence of network effects (Farrell and Saloner 1985, Katz and Shapiro 1985) that lead to standards that are adhered to by many different consumers often becoming successful. These network effects can be direct, which means that when adoption increases, the standard's value increases with it. For example, when a smart phone is adopted by only one user, the value that users accrue from that phone is only coming from its technological

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stand-alone value. While when more users adopt the smart phone, the value increases as users can reach more people. Network effects can also be indirect, e.g. when the value of a platform might increase because of the existence of complementary goods. For example, Windows as an operating system is quite popular because people can exchange their Microsoft Word and Excel documents. Given the significance of network effects in standards based markets, installed base (market share) is a factor for standards dominance in itself (Shapiro and Varian 1998).

Researchers in strategic management (Garud & Kumaraswamy 1993; Garud et al., 2002) have studied how firms can increase a standard's installed base. They have investigated various case studies of standards battles in depth and they have inductively arrived at factors that affect standards dominance. Building upon these researchers, Suarez (2004) stresses the importance of strategic manoeuvring. By entering early, firms can pre-empt the market and thereby reach a more favourable position in terms of the installed base as opposed to competitors (Mitchell 1991, Kristiansen 1998, Lieberman and Montgomery 1998). Furthermore, a standard's implementation can be priced below its costs. Through such a 'penetration pricing' strategy required installed base can quickly be amassed (Katz and Shapiro 1985). The importance of market campaigns has been addressed, as expectations count a lot in standards-based markets. Through such campaigns, the expected and perceived installed base can be increased (Schilling 2020).

To apply these strategies, complementary assets are required (Gallagher and Park 2002). For example, reputation and credibility are relevant (Axelrod, et al. 1995) so firms that enter early but lack a reputation may not be taken for granted, which might result in consumers not adopting the standard. Marketing campaigns are often costly and lengthy and firms will need ample financial resources to sustain this strategy (Schilling 1999). Finally, when demand for a standard's implementation is high, a firm that lacks sufficient production capacity to keep up with demand will be unsuccessful (Suarez and Lanzolla 2005).

Standardization scholars have studied the effect of the composition and structure of the standards committee on standards dominance (Van de Kaa 2018). They have investigated how size of the committee affects consensus in standards committees and found that a higher size is detrimental for consensus building (Vercoulen and Van Wegberg 1998, Rada 2000) unless the urgency among participants in high (Van de Kaa, Papachristos and De Bruijn 2019). Furthermore, scholars have found that when a standardisation organization is diverse in terms of industry representation, the probability that the standard will become dominant in the market will be higher than a standard that was developed by a more homogeneous consortium (Van de Kaa 2012).

In another research stream, standardization scholars have focused on stakeholder identification in standardization. Building upon Mitchel et all. (1997), De Vries et al. (2003) have developed a method to identify stakeholders in standardization processes and their salience. In this method, nine search directions are distinguished (See Table 1).

After the relevant stakeholders have been identified through the nine search directions, their level of power, urgency in the process, and legitimacy is assessed with the stakeholder salience model (Mitchell et al., 1997). The stakeholder salience model (Mitchell et al., 1997) is used to determine the salience of the stakeholder. Power refers to whether the stakeholder has the time, expertise, and (financial) resources to affect the success of the standard. Urgency refers to the degree to which stakeholders desire quick action. Finally, legitimacy refers to whether the stakeholder's actions are deemed legitimate by others within the standardization process.

When a stakeholder in a standardization process has power that means that this stakeholder can influence the standardization process in a certain direction. For example, powerful stakeholders such as large firms can have the financial means to send many of their experts to standardization meetings thereby affecting the decisions made in their favor. Stakeholders with urgency but lacking power want to participate but do not have the power to influence the process in a certain direction.

Table 1
Search directions, adopted from De Vries, et al., 2003.

No.	Search direction	Summary
1	Production chain	Includes all firms in production, from raw material suppliers to disposal. Involves transporters, service, and maintenance.
2	End users and related organisations	Separate stakeholders with significant influence on standards. Includes helpdesk providers, large firms, small medium enterprises, and employees.
3	Designers	Stakeholders who design the product, often involved in production. Key in IT security system design.
4	Physical system	Interaction with technical systems, hardware/software compatibility. Involves developers of surrounding systems.
5	Inspection agencies	Conduct inspections or certifications. Include producers, customers, testing labs, and government bodies.
6	Regulators	Governments and regulators ensure standards comply with existing laws. Their cooperation boosts standard adoption.
7	Research and consultancy	Universities, research institutes, and consultants influence and are influenced by standards. Key in IT management.
8	Education	Involves organisations responsible for educational programs that include standards, ensuring clarity and accessibility.
9	Representative organisations	Serve member interests (e.g., unions, consumer groups). Often involved independently in standardisation processes.

When a stakeholder has high legitimacy but lacks power, this means that their attendance in the committee is recognized by other stakeholders, but these stakeholders do not necessarily have an influence in decision making. By combining these three dimensions seven stakeholder types can be distinguished.

Definitive stakeholders are stakeholders that are powerful, feel the urgency, and are legitimate. These committed stakeholders can make a difference in the process. Dominant stakeholders are important stakeholders that are powerful and legitimate but do not feel the urgency. However, these stakeholders are quite important for standardization and, according to De Vries et al. (2003), their involvement should, therefore, be strived for. Dangerous stakeholders are powerful and feel the urgency, but they are not legitimate. These stakeholders do not formally belong in the process, but they are often present. These are, for example, companies that adhere to competing standards and are only present to observe the competition. Dependent stakeholders are not powerful and, therefore, lack required resources to participate in the standardization process. However, they are legitimate, and they feel urgency. Dormant stakeholders are powerful but cannot use that because they lack legitimacy and urgency. However, these should be monitored closely as when they acquire urgency, they potentially become dangerous. Discretionary stakeholders are legitimate but lack power and urgency and are, therefore, often not found in standardization organizations. However, their presence may be desirable. Demanding stakeholders feel the urgency for standardization but are not powerful and lack legitimacy and are therefore considered 'irritating' (Mitchell, Agle and Wood 1997).

The stakeholder salience model has successfully been applied (Wood et al. 2021), also in the context of standardization (Van de Kaa and Greeven 2017), showing its applicability. Furthermore, utilizing the method, Wang et al. (2016) found that organizations are more motivated to adopt a standard when more diverse types of stakeholders are involved during its development. This new research by Wood et al. (2021) states that the stakeholder salience model is still relevant and its use has been validated multiple times by esteemed research (Magnuss, 2008; Parent and Deephouse, 2007; Neville and Menguc, 2006). This study goes beyond these prior works in that no research has focused on

the effect that the composition of the committee in terms of stakeholder type and salience has on standards dominance.

3. Method

In order to give an answer to the research question a historical comparative case study (Yin 2009) was conducted, studying the stakeholders that were involved in the development of a set of standards and their salience. For each of the four levels in IIoT systems, a successful and an unsuccessful standard was selected. Success is operationalized through the number of products in which the standard is implemented. This resulted in eight standards: four of which did not reach market adoption and four of which did. The selection of standards was based on relevance and availability of experts and information.

The selected standards are presented in Table 2. The first column shows the level in the system architecture; the second column presents the standard; the third column shows whether the standard is successful (including a reference to where that is mentioned); and the final column shows a small description of the standard.

Data collection was carried out as follows. Per standard, we identified the relevant stakeholders and their position by following the stakeholder identification approach as outlined in De Vries et al. (2003) and discussed in the theory section of the current paper. For each of the standards presented in Table 1, we followed the 9 search categories and for each of the stakeholders that were identified we assessed whether they possess any of the three attributes distinguished in the method. This was done by utilized primary data sources in the form of interviews. We have asked interviewees questions to assess the level of power, urgency and legitimacy for each stakeholder. A list of interviewees can be found in Table 3 The interview questions are presented in annex 1.

Data analysis was carried out utilizing the software package Atlas. TI™. We applied open and axial coding. First, we determined various synonyms for power, urgency and legitimacy and we scanned three sources (primary data in the form of interview transcription, academic papers (see annex 2), and grey literature (see annex 3)) for these synonyms or other text fragments that refer to each of these three dimensions. Each time this was mentioned, we marked the text fragment with the label power, urgency, or legitimacy. By utilizing the three sources, triangulation of data was possible. For example, the following sentence is quoted from one of the interviewees: *"And I think this is exactly where standardisation organisation like GS1, act as this catalysator"*. This sentence was then coded Legitimate and Powerful. By combining this with the other codes, the results from this interview on EPCIS had the following results for the stakeholder GS1: legitimacy: 4, urgency: 4, power: 3 (meaning that legitimacy was, e.g., mentioned four times in separate codes). We then searched for patterns to determine the overall level of power, urgency, and legitimacy of stakeholders. Combining these dimensions we then determine the salience of each stakeholder. This results in one table per case study, which was analysed for patterns relating stakeholder salience to standards dominance.

The research was conducted from June 2024 to January 2025. Data collection took place in the same timeframe. It was solely driven by genuine interest in the standardization process, technological development and Internet of Things. The study is designed to contribute both to academic understanding as well as adding practical results to standardization and Internet of Things sectors. The authors were not involved in that sector and therefore researcher bias is minimal.

Table 3
List of interviewees.

No.	Name	Position	Standard
Expert 1	IoT Solution Provider	Director	LoRaWAN
Expert 2	IoT Solution Provider	Director	LoRaWAN
Expert 3	Digital Manufacturing	Consultant	General
Expert 4	Standards Developing	Manager	EPCIS
Expert 5	IoT Solution Provider	Chief Officer	LoRaWAN
Expert 6	Telecommunications	Product Manager	LoRaWAN
Expert 7	Academia	Professor	General
Expert 8	Standards Developing	Manager	EPCIS / RFID UHF
Expert 9	Embedded Systems	Engineer	IRNAS
Expert 10	Industrial Automation	Manager	Ignition / General
Expert 11	Academia	Professor	General

4. Results

This section will present four case studies. For each case study we will describe the standards involved and the milestones in the standardization process in terms of, e.g., development and ratification dates. Furthermore, the results of the stakeholder analysis will be presented which will consist of a breakdown of the involved stakeholders and an assessment of their salience.

4.1. Case study one

Case study one focuses on data ingestions standards for IIoT (RFID UHF vs The Zephyr Project). The first standard in the case study is RFID UHF. This standard concerns the use of electromagnetic fields to automatically identify, and track RFID tags attached to objects. It is most used for purposes like inventory management and asset tracking. It uses radio waves to identify tags on objects. Because of its high frequency it offers an interesting standard for a long-range distance. In the 2000 s, big supply chain and retail companies joined forces to develop the standard which was released in 2007. In 2013, it was approved by ISO as ISO/IEC 18000–6:2013.

A main catalyst of the technology was sports retailer Decathlon which implemented the standard throughout its supply chain. It started source-tagging all its branded products at the manufacturing plants in 2013, and, currently, shoppers use the technology to check out in their stores. The standard is successful as it is widely adopted. However, it is not adopted by every company. For example, as commented by expert eight: *"Supermarkets won't work because you need 100 % [RFID tagging], otherwise it won't work. Because if a product costs 30 cents, then 5–10 cents [for an RFID tag] on a product that costs so little is too much… If you don't have 100 % of your items tagged, then it's chaos at checkout."*.

Eleven relevant stakeholders were identified across six search directions. These include four definitive stakeholders (RFID manufacturers, Decathlon, Retailers (e.g., H&M and Zara), and logistics

Table 2
Selected cases for the empirical analysis.

Level	Standard	Market adoption	Function
1) Data Ingestion	RFID UHF	Yes (Chang, 2023)	Long range, high frequency RFID technology.
	Zephyr Project	No (Github, 2024)	Open-source real-time operation system for resource-constrained IIoT devices.
2) Data Transmission	LoRaWAN	Yes (Fremont, 2024)	Long-range, low-power wireless protocol for IoT.
	Sigfox	No (IoTNow, 2022)	Low-power, wide-area network for IoT.
3) Data Processing	EPCIS	Yes (HDA Research Foundation, 2021)	Standard for sharing RFID data in the supply chain.
	UPnP	No (Arghire, 2020)	Network protocol for automatic device communication without requiring manual configuration.
4) Data Utilisation	Ignition	Yes (Hechtman, 2022)	Industrial automation platform for visualising and managing data.
	GE Predix	No (Bold Business Insights, 2017)	IIoT platform designed to analyse data from industrial machines.

companies), three dominant stakeholders (government regulators, standardization organizations (such as ETSI) and certification bodies (e.g., GS1 Europe), two dependent stakeholders (RFID solution providers and consumer organizations) and two discretionary stakeholders (IT consultancy firms and RFID industry associations).

The second standard selected for this case study is The Zephyr Project, a real-time operating system (RTOS) designed for embedded devices (for example, the computer part of an IIoT temperature sensor). The system is open source and optimised for resource-constrained devices on various platforms and architectures. Development began in 2015, and the first version of the standard was released in 2016. Over the years, the project has seen multiple iterations. In 2018, the Zephyr Project introduced the Zephyr Security Working Group which, according to Expert nine, improved the security in RTOS.

Seven relevant stakeholders were identified across five search directions. These include two definitive stakeholders (Zephyr Project Members (e.g., Analog Devices, Google, Intel), End users (e.g., IIoT Device Makers)), three dominant stakeholders (Embedded device manufacturers, Chip vendors (e.g., Intel, NXP), and the Linux Foundation), one dangerous stakeholder (Open-source developers), and one discretionary stakeholders (Universities and research institutes (e.g., Northeastern University, Research Institutes of Sweden)).

4.2. Case study two

Case study two focuses on data transmission standards for IIoT (LoRaWAN vs Sigfox 0G). LoRaWAN is a LPWAN standard that focuses on energy-efficient, long-range and low-power wireless communication. Work on the standard started in 2013. The first specification was released in 2015 and in 2021 it was approved by the International Telecommunication Union (ITU) under ITU-T Y.4480. The LoRaWAN standard has gained market adoption in the IIoT industry and currently works on 130 million devices.

Eleven relevant stakeholders were identified across five search directions. These include five definitive stakeholders (Semtech, the things industries, the things network, LoRa alliance, and Telecom companies), two dominant stakeholders (device manufacturers and solution providers), one dependent stakeholder (municipalities), and three discretionary stakeholders (government regulators, standard setting bodies, and academic institutions).

Sigfox is a French network operator which specialises in wireless networks for low-power objects like smart meters. It developed Sigfox 0G, also a low-power wide-area network (LPWAN) that uses ultra-narrowband technology. Using this standard, information is sent using very tiny slices of radio waves.. Currently, it supports the connectivity of 11 million devices worldwide which is significantly lower than its competitor LoRaWAN. Development of the Sigfox global network started in 2010. In February 2019, it publicly released its radio specifications to advance standardisation efforts. Facing financial challenges, Sigfox S.A. filed for bankruptcy protection in January 2022. Subsequently, in April 2022, the company was acquired by UnaBiz.

Seven relevant stakeholders were identified across four search directions. These include three definitive stakeholders (Sigfox operators (e.g. Heliot), Device manufacturers (e.g., Adeunis, Sagemcom), Solution providers (e.g., Thinxtra, UnaBiz)), one dominant stakeholders (Chip vendors (e.g., ON Semiconductor, STMicroelectronics), one dangerous stakeholders (Sigfox S.A.), two discretionary stakeholders (End users (e.g., Logistics companies, utility providers) and Research institutes (e.g., IIoT Research Labs, IEEE)).

4.3. Case study three

Case study three focuses on Data processing standards for IIoT (Electronic Product Code Information Services (EPCIS) vs Universal Plug and Play (UPnP). EPCIS (Electronic Product Code Information Services) is a GS1 standard that allows businesses to capture information about the movement and status of products, logistics units, and other assets in the supply chain The standardized event data it captures shows what happened to an item, when, and where it happened, making it useful for supply chain visibility. Development started in 2005. EPCIS versions were ratified as follows: 1.0 in April 2007, 1.1 in May 2014, 1.2 in September 2016, and 2.0 in June 2022.

Nine relevant stakeholders were identified across seven search directions. These include four definitive stakeholders (GS1, Retailers (e.g., FMCG, fashion), Manufacturers (e.g., Pharma, Technical industries), and Other end users (e.g., Logistics companies, distributors)), three dominant stakeholders (Hardware providers (e.g., RFID, barcode manufacturers), Certification bodies (e.g., ISO, IEEE), and Government regulators), and two discretionary stakeholders (Solution providers and Academic institutions (e.g., Universities, Research institutes)).

UPnP is a set of networking protocols for devices to automatically discover and communicate with each other on a network. UPnP is often associated with device discovery and configuration. It also plays a role in data processing by allowing devices to expose their capabilities and share data services without manual setup. Its introduction in 1999 by Microsoft was aimed to increase the ease of configurating devices on the network, primarily in homes or small businesses. At first, it was widely adopted in consumer electronics, supported by companies like Sony and Intel and became a standard for routers and servers. Despite the introduction of updated versions, UPnP has struggled to achieve widespread market adoption due to its security vulnerabilities. For example, a vulnerability which was identified in 2020 allowed the exploitation of UPnP for data and DDoS attacks. These security issues impacted user and manufacturer confidence, hindering its market penetration. Since 2016 the standard has been managed by the Open Connectivity Foundation. The UPnP device architecture was adopted as a de jure standard by ISO and IEC under ISO/IEC 29,341 in 2017. The latest revisions were published in 2020.

Eight relevant stakeholders were identified across six search directions. These include one definitive stakeholder (Open Connectivity Foundation (OCF)), three dominant stakeholders (Device manufacturers (e.g., Consumer electronics, IIoT Devices), Network equipment manufacturers (e.g., Cisco, Netgear), and Software developers (e.g., Application developers, Firmware engineers), one dangerous stakeholder (UPnP Forum) and three discretionary stakeholders (Certification bodies (e.g., IEEE, ISO), End users (e.g., home users, SMBs), and Academic institutions (e.g., Universities, Research labs).

4.4. Case study four

Case study four focuses on Data utilisation standards for IIoT (Ignition vs GE Predix). Ignition is a platform for data visualisation. It allows users to create custom dashboards, set up alarms and notifications, and generate reports. Ignition supports integration with industrial devices, standards and databases Ignition is developed by Inductive Automation, an industrial application platform for building SCADA (Supervisory Control and Data Acquisition) systems, HMI (Human-Machine Interface), and IIoT (Industrial Internet of Things) applications (Inductive Automation, n.d.). The first version was released in 2010.

Thirteen relevant stakeholders were identified across nine search directions. These include three definitive stakeholders: Inductive Automation, Industrial companies (e.g., manufacturers, energy firms), and Government regulators. six dominant stakeholders were identified: System integrators, Industrial hardware manufacturers, OPC Foundation, MQTT Standard Organizations (e.g., OASIS), Industry associations (e.g., International Society of Automation), and Cybersecurity firms). Furthermore, two dependent stakeholders were identified: Certification bodies (e.g. NIST) and IT Consulting firms). Finally, two discretionary stakeholders were identified: educational institutions and universities and research institutes.

GE Predix is a platform-as-a-service (PaaS) standard for tools, visualization, and application development. General Electric developed

Predix to create applications that can monitor equipment performance. It aimed to use its own cloud environment to handle large volumes of industrial data. In 2015 its development started and in 2016 the first version was released. Poor execution and unclear communication led to an unadopted standard (Batte, 2025).

Eight relevant stakeholders were identified across seven search directions. These include one definitive stakeholder (General Electric) and five dominant stakeholders (IT Consulting firms (e.g., Accenture, Deloitte), Industrial hardware manufacturers, Certification bodies (e.g., ISO, IEC), Government regulators, and End users (e.g., Manufacturing, Energy, Aviation, Healthcare Companies). Furthermore, one dependent stakeholder was identified (Independent Software Vendors (ISVs)) and one discretionary stakeholder was identified (Universities and research institutes).

4.5. Comparative case study

The results from the four case studies are combined in Table 4 which shows a matrix that combines all search directions, stakeholders, standards and stakeholder classifications. For easy of readability the letters in the table correspond as follows: A: definitive stakeholders, B: dominant stakeholder, C: Dangerous stakeholders, D: dependent stakeholders, E: dormant stakeholders, F: discretionary stakeholders and G: demanding stakeholders.

If we look closely at the table, we can observe several things. First, in standards that have become successful, end-users and related organizations are always included, and they are, most of times, definitive stakeholders. Second, dangerous stakeholders are involved in three of the four unsuccessful standards and in none of the successful standards. Third, 36 percent of the stakeholders involved in the successful standards are definitive stakeholders, while 23 percent of the stakeholders involved in the unsuccessful standards are definitive stakeholders. These

Table 4
Final results.

			Standards							
			Market adoption				**No market adoption**			
			RFID U.	LoRa.	EPCIS	Ignition	Zephyr P.	Sigfox	PnPP	Predix
Stakeholders	**Production chain**	RFID manufacturers	A							
		Logistics companies	A							
		RFID Solution providers	D							
		Embedded device manufacturers					B			
		Chip vendors					B	B		
		Semtech		A						
		Sigfox operators						A		
		Device manufacturers		B				A	B	
		Network equipment manufacturers							B	
		Industrial hardware manufacturers				B				B
	End users and related organizations	Decathlon	A							
		Other retailers	A		A					
		End users					A	F	F	B
		Zephyr Project members					A			
		Telecom companies		A						
		The Things Industries		A						
		Municipalities		D						
		Manufacturers			A					
		Logistic companies, distributors			A					
		Industrial companies				A				
	Designers	Open-source developers					C			
		Solution providers		B	F			A		
		Software developers							B	
		Inductive Automation				A				
		System integrators				B				
		General Electric								A
	Physical system	Cloud service providers								
		Independent Software Vendors								D
		Hardware providers			B					
		OPC Foundation				B				
		MQTT Standard Organizations				B				
	Inspection agencies	Certification bodies	B		B	D			F	B
		Cybersecurity firms				B				
	Regulators	Government regulators	B	F	B	A				B
		Standard setting bodies	B	F						
	Research and consultancy	IT Consulting firms	F			D				B
		Universities and research institutes			F	F	F	F	F	F
		Educational institutions	F			F				
	Education	Academic institutions		F						
	Representative organizations	Consumer organisations	D							
		Industry associations	F			B				
		Linux Foundation					B			
		The Things Network		A						
		LoRa Alliance		A						
		Sigfox S.A.						C		
		GS1			A					
		UPnP Forum							C	
		Open Connectivity Foundation							A	

descriptive percentages are not intended for inferential testing. Fourth, in successful standards, more stakeholders are involved compared to unsuccessful standards. Finally, dormant and demanding stakeholders were not identified.

5. Discussion and conclusion

This paper has looked at the extent to which the presence of certain types of stakeholders and their characteristics influences the success of standards. We see that end-users and related organizations are always involved in the successful standard. Literature on standardization has studied the possibilities and challenges related to end-user engagement in standardization (Jakobs 2006, Caputo et al., 2023, Iandolo et al., 2024). Jakobs emphasises that standards shaped without significant user input risk becoming irrelevant or incompatible with the actual needs of users. He points out that users in the ICT domain must contribute their specific requirements early in the process to ensure that standards meet their operational environment. Moreover, he highlights that coordinated user representation in standards-setting bodies is crucial to avoid the development of standards that benefit only a select few (Jakobs 2006). Coordinated user representation could be done through the knowledge-based framework discussed by Caputo et al. (2023). Similarly, Iandolo et al., (2024) finds several stakeholder management strategies in risk management. By institutionalising responsibility and continuous monitoring of stakeholders, they remain controllable. They advise regular assessment of stakeholder behaviour.

Our data also shows that dangerous stakeholders are always involved in the unsuccessful standard and, therefore, seem to hinder standards adoption. Interestingly, we show that dangerous stakeholders can even be the main proponents of standards as can be seen in the case of Sigfox and UPnP. Furthermore, our data shows that when more (definitive) stakeholders are involved in the standardization process this is beneficial for standards success. On the one hand, this contradicts the literature, as we know that more stakeholders lead to delays (Vercoulen and Van Wegberg 1998, Rada 2000). On the other hand, we also know from the literature that if there is urgency, more participants lead to faster consensus (Van de Kaa, Papachristos and De Bruijn 2019). This leads us to believe that the urgency surrounding this standardisation process might be high. Aaltonen, Kujala & Oijala (2008) argue that perceptions of salience can be shaped by certain strategies by stakeholders, for example active lobbying or accusation regarding wrongful environmental calculations. Finally, diversity in terms of the stakeholder salience attributes represented in the standardization organizations might be related to success. One could argue that more different types of stakeholders require more efforts to bring these stakeholder together which might be detrimental to consensus formation. In our data we do not see a significant difference in stakeholder salience attributes diversity for successful or unsuccessful standards but analyzing other cases may reveal patterns. This is an interesting area for future research.

5.1. An exploration of stakeholder dynamism throughout the standardization process

In this section, we will explore the notion of stakeholder dynamism in relation to standardization. Several researchers argue that technological innovation often takes place in different stages. Evolutionary economists argue that technological discontinuities usher in periods of radical change up until the moment that a dominant design appears after which incremental changes are more dominant (Abernathy and Clark 1985). These scholars argue that designs appear as a result of path depedencies (Arthur 1989). On the other hand, innovation management scholars argue that various maturity stages can be identified for technologies and that in each of these stages different factors for technology dominance are relevant (Suarez 2004). Standardization scholars distinguish several phases including the formation of standards committees, the development of standards and the institutionalization of standards (Lyytinen and King 2006).

Our data covers two of these stages and shows that the Zephyr Project, Sigfox, UPnP, GE Predix find themselves in phase two: standards development while RFID UHF, LoRaWAN, EPCIS, Ignition are located in phase three. When analyzing the salience attributes of the first four standards we notice that dangerous stakeholders that have high levels of urgency and power but lack legitimacy are mostly involved. When analyzing the latter four standards we see that mainly definitive stakeholders that have high levels of legitimacy, urgency and power are involved.

Unfortunately, our data does not cover the first stage so additional research is needed here but we propose that since this stage is often characterized by enthusiasm, it will probably attract stakeholders that hold high levels of legitimacy and urgency, but lack power. In this stage, the first ideas and technological developments are made and shared by a smaller group of enthousiasts. Our results show that in the second stage, as dangerous stakeholders join, not all stakeholders may have rightful intentions. Finally, the data shows that in the third phase, we can see that the dangerous stakeholders have left, and the standard and its stakeholders have matured. This pattern is illustrated in Fig. 2 (where the left part of the figure is our proposition and the middle and right part is based on our empirical data).

5.2. Theoretical contributions

This paper contributes to the standardization literature (Gallagher and Park 2002, Schilling 2002, Suarez 2004, Gallagher 2012) in several ways. First, the main contribution lies in providing initial evidence that the presence of certain types of stakeholders and their characteristics in terms of the combination of certain salience attributes influences the success of standards. We also provide initial evidence that dangerous stakeholders who have power and urgency but lack legitimacy can create obstacles in the standardization process, leading to unsuccessful standards. Furthermore, we provide initial empirical evidence that the involvement of stakeholders possessing power, urgency, and legitimacy is crucial for a standard's success in the market. Additionally, it appears that broad stakeholder participation enhances the standard's credibility and acceptance. Also, it seems that dormant and demanding stakeholders are less actively participating in standardization for IIoT. In addition, we show not only that the stakeholder identification method can be applied to identify stakeholders and their salience for IIoT applications, but also how it can be applied. By including the specific questions used in our study, we refine the method and enable other researchers to replicate our approach. Finally, we show that stakeholder salience attributes can change per stage in the life cycle of the standard thereby providing empirical evidence of stakeholder dynamism within the context of standardization. This implies that stakeholder salience as depicted in Fig. 1 should be understood as a dynamic notion.

We also provide empirical evidence that end-user involvement leads to more successful standards thereby building upon earlier research that illustrated that active participation by end-users can bring momentum, legitimacy and practical relevance to the standard, which endorsement alone may not achieve (Backhouse, Hsu and Leiser 2006). However, IT professionals may use their power to exclude end-users from the standardisation process by redefining requirements at later stages (Gasson 1995). There is a tendence towards certain prejudice against end-users and their involvement. In stages after the system requirements have been set, requirements may not only be changed but they may also be interpreted differently by technical developers which may create a bias in the standard development process. However, we also know that end-users participation is positive for standardisation. This was argued by Werle & Iversen (2006) who proposes a similar process to mitigate the risk of bias in standardisation through direct participation of these types of stakeholders. And engagement of users or citizens is important beyond the context of standardization. For example, Caputo et al. (2023) provides a knowledge-based framework for promoting citizen

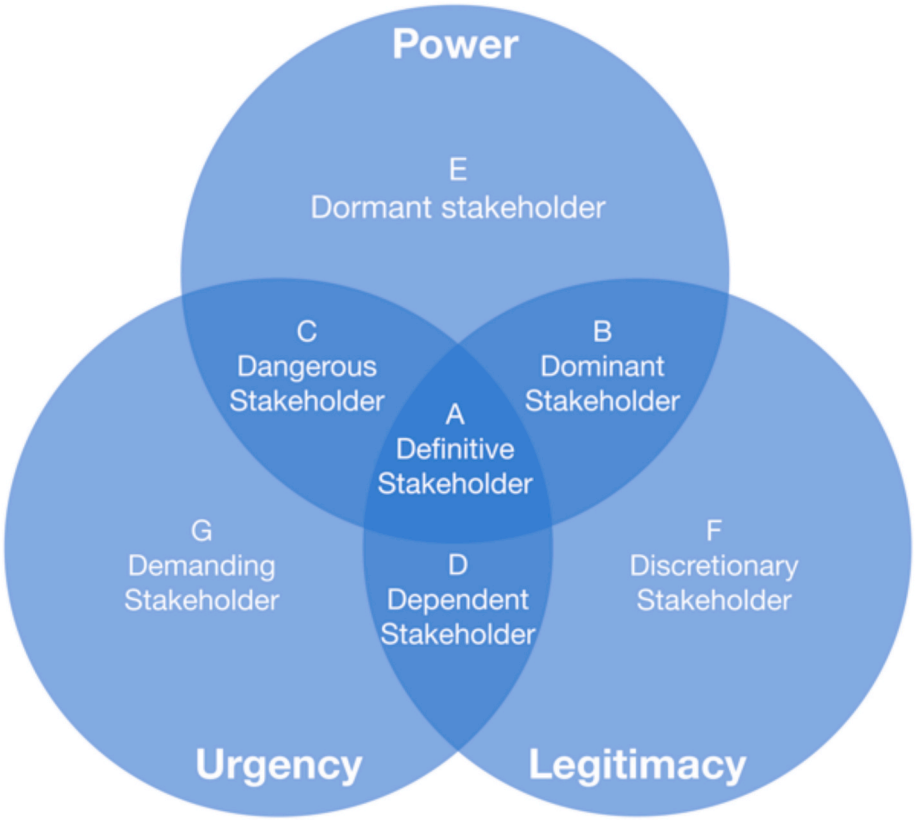

Fig. 1. The stakeholder salience model (as adopted from Mitchell, et al., (1997)).

engagement in smart cities, which is highly relevant because of the similarities between citizen and end-user engagement. Future research could address whether a standardisation approach focused on the levels proposed by Caputo et al., (2023) namely The Ecological level, The Socio-cultural level, The Semantic level, The Productive level, The Logistic level & The Governmental level, would improve end-user engagement in standardisation Fig. 2.

5.3. Practical implications

Various policy recommendations related to the contributions discussed before can be distinguished. First, to stimulate end-user engagement, policy makers are recommended to ensure inclusivity by involving underrepresented stakeholders. This can be accomplished by, e.g., eliminating financial barriers to participation. To increase the

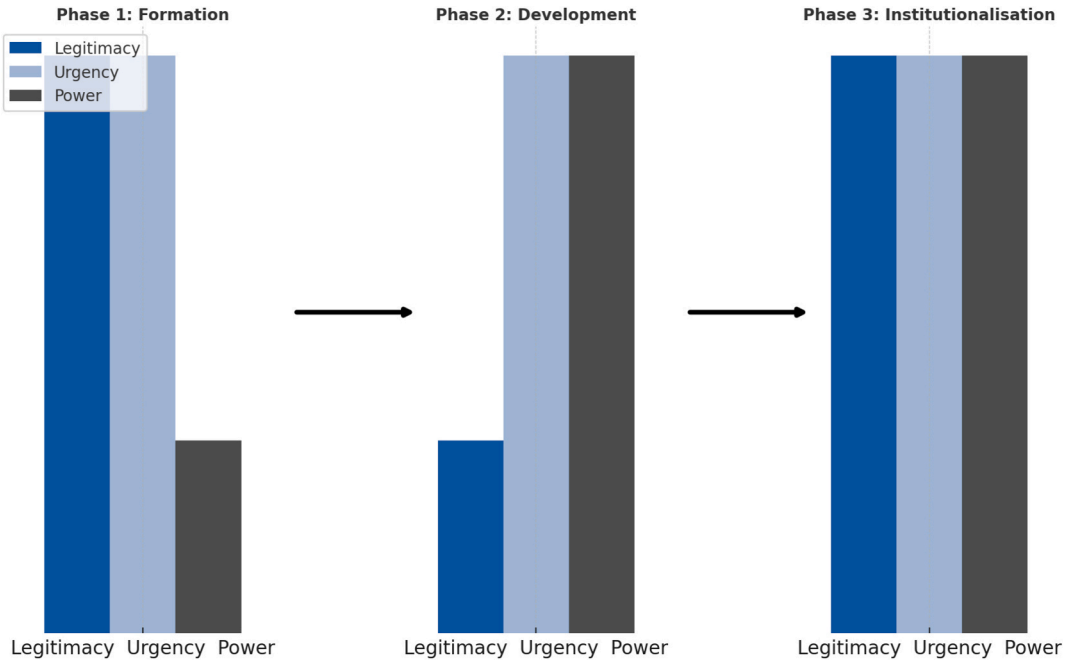

Fig. 2. Sakeholder dynamism throughout the standardization process.

involvement of users, they should be provided with accessible support. Furthermore, bias against end-users in the standardisation process should be addressed. This can be accomplished by mitigating exclusionary practices by IT professionals and ensuring that end-user requirements are not redefined or distorted during the system development phase, so that their original intent and relevance will be maintained. One of our interviewee's states that "user-engagement is beneficial to the standardisation outcome, but only if the end-users can come to an unambiguous set of user requirements. If the user requirements are contradictory because of a diverse stakeholder group, this is naturally counterworking." To deal with this, the interviewee proposes an actionable insight in the form of a dedicated requirement elicitation process prior to the standardization process. Here end-users could sort their requirements out, agree on a set of requirements and then feed that into the technical department, even before any standard development is done.

However, end-users may not even be aware of standardization. In fact, a recent report on SMEs and civil society inclusiveness in European standardisation which was done by the High-Level Forum on European Standardisation in 2024 points out that 35 percent of small-medium businesses and civil societies lack awareness of National Standards Bodies and their work (European Commission 2022). To increase end-user engagement, the Forum prescribes various best practices, including creating stakeholder groups that involve underrepresented stakeholders such as end-users, waiving membership fees for standardization organizations, or offering free in-person consultation on standardization efforts.

Standardization organizations should attempt to avoid dangerous stakeholders that lack legitimacy. However, it is difficult for standards committees to avoid dangerous stakeholders due to the open character of standardization. Ideally, for these stakeholders, some means need to be found so that they can participate with the approval from the other stakeholders so that they can achieve legitimacy in the eyes of the committee members and thereby be converted to definitive stakeholders (De Vries, Verheul and Willemse 2003). Practically this would mean a different form of standardisation setup than what is currently common; It would mean private or invitational standardisation processes.

Standardization organizations can attempt to increase the number of stakeholders involved in the standardization process. One way would be to decrease the amount of standards so that firms have to commit to fewer negotiations which could lead to more engaged stakeholders (De Vries, Verheul and Willemse 2003). The number of definitive stakeholders could be increased by trying to increase the salience levels of stakeholders that are already involved in the standardization process. In all the standards without market adoption there are plenty of stakeholders involved that could be influenced to become more powerful or urgent to the matter. Funding or providing resources to potential definitive stakeholders could translate to them becoming more powerful.

5.4. Limitations and areas for future research

The experts we interviewed work at companies that are also part of the group of stakeholders involved in standardization. A limitation might be that these experts are biased towards their company and see its role as more important. Furthermore, few people have been interviewed that have been involved in the development of the unsuccessful standards, leading to a potential bias in the results. This is not surprising in such cases, as in the case of an unsuccessful standard, the industrial engagement will gradually decrease over time. Because some of these standards had nobody actively working or advocating for them, information about specifics was limited. Future research could attempt to replicate our findings by studying standards battles that are currently enfolding which might decrease this bias.

In addition, the diversity between technologies such as the RFID UHF standard versus the Zephyr Project standard could limit the comparability of findings across cases. RFID UHF represents a mature, hardware-intensive technology with specific use cases in asset tracking, whereas the Zephyr Project is an evolving, open-source software standard targeting resource-constrained IIoT devices. Such technological heterogeneity could trouble the interpretation of stakeholder influence and the generalisation of patterns across cases. Thus, the results obtained might not be completely generalizable to other technologies or standardisation efforts outside the context of IIoT. Also, the limited amount of case studies (four) means that the findings cannot easily be generalized. Therefore, scholars are encouraged to use a similar approach to study the effect that stakeholder composition has on standards dominance. Furthermore, scholars are encouraged to focus on strategies that may be applied to increase the number of end-users in standardization, adapt or avoid dangerous stakeholders and increase the number of (definitive) stakeholders.

The study results reveal that ensuring only qualified stakeholders are involved could improve the standardisation processes. Then, it is important to understand whether illegitimate stakeholders are involved in the process. Future empirical research could focus on researching criteria to verify the quality of stakeholders (in terms of, e.g., their legitimacy).

Moreover, longitudinal studies are encouraged since scholars can identify changes occurring in stakeholder influence, market conditions, and the regulatory environment over time as standards mature or as competing standards emerge. This would also contribute to the three-phase model, where phase 1, formation, now misses empirical data. Longitudinal studies measuring the salience of stakeholders in early lifecycle cases of standardisation could confirm the model's assumption of missing power in early stages. Also, such empirical research on the evolution of standards over longer periods could further indicate how standards are sustained, what contributes to long-term adoption, and (linked to our study) what roles various stakeholders perform during the life cycles of standards. As aforementioned, such research could be conducted in any type of standard setting environment as the stakeholder analysis method is not industry specific.

We found that dangerous stakeholders are mostly involved in standards that eventually were unsuccessful. The question is whether the lack of legitimacy of these stakeholders is a cause or a consequence of the failure of the standard. It can be argued that when a standard becomes unsuccessful more illegitimate actions may be taken by stakeholders such as involvement in competing standards organizations. Furthermore, as one of our interviewees added: *"Once you built up trust you are good. But if you're involved in a mess not so much …"* Future research could study in more detail whether legitimacy is a cause or consequence of failure.

Finally, future research could study whether when more stakeholders are involved in the standardization process this would lead to more participation. It could be argued that when more definitive stakeholders are involved, stakeholders tend to participate more and their influence in the process is higher. Alternatively, when more stakeholders are involved, there might be more discussion resulting in certain parties leaving decreasing participation over time.

CRediT authorship contribution statement

Boris van Dongen: Writing – review & editing, Writing – original draft, Visualization, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Geerten van de Kaa:** Writing – review & editing, Data curation, Conceptualization. **Marcel Ludema:** Writing – review & editing.

Declaration of competing interest

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

Annex I: Interview questions

Stakeholder identification and search direction

1. Production chain

Who are the main suppliers and partners involved in the production and distribution of the standard? *Identifying key contributors.*

2. End-users and related organisations

Who are the primary end users of the standard, and how do they interact with it?

Evaluating end-users' influence and their direct experience with the standard.

What support services or organisations assist end users effectively?

Understanding the ecosystem supporting standard implementation.

3. Designers

Who is responsible for designing and developing your product or system?

Recognising stakeholders who shape technical features and implementation.

Do external designers or consultants contribute significantly to the product's development?

Assessing the role of external expertise in the design phase.

4. Physical system

What existing technical systems or infrastructures does the standard integrate with?

Examining interoperability dependencies.

Who are the developers of the systems that the standard interacts with or depends upon?

Identifying key technical stakeholders influencing integration.

5. Inspection agencies

Which organisations conduct inspections, testing, or certification of the standard?

Identifying certification bodies that validate the standard.

What industry standards or certifications must the standard adhere to?

Assessing external pressures on standard conformity.

6. Regulators What government agencies or regulatory bodies oversee the industry? *Understanding the formal authorities impacting the standard*

How do current laws and regulations impact development?

Assessing the regulatory framework affecting decision-making.

7. Research and consultancy.

Are any universities or research institutions involved in research related to the standard?

Testing the influence of academic research on development.

How do consultants influence the development or implementation of your product?

Evaluating consultancy influence on shaping the standard.

8. Education What educational institutions offer training or courses related to the standard and indus- try?

Understanding how education supports knowledge transfer and skills.

9. Representative organisations

What industry associations or trade groups are associated with the standard?

Clarifying the role of formal representative bodies in shaping standards.

Do consumer advocacy groups or unions influence the perception of the standard in any way?

Understanding public pressure and representation.

Stakeholder power

Which stakeholders have the most influence over the standardisation decisions?

Power assessment: Directly identifying the most impactful players in decision-making.

What resources (e.g., financial, technical expertise, market access) do these stakeholders control that give them power?

Resource assessment: Mapping the resource control that fuels stakeholder power.

Can you provide examples of how this influence has manifested in the standardisation process?

Power validation: Understanding real-world examples of influence.

Stakeholder legitimacy

Which stakeholders are considered legitimate participants in the standardisation process?

Legitimacy assessment: Determining key actors who are widely recognised as valid participants.

What factors contribute to their legitimacy (e.g., regulatory authority, industry reputation, community support)?

Legitimacy drivers: Identifying what confers legitimacy upon these stakeholders.

How is this legitimacy recognised or challenged by other stakeholders?

Interaction dynamics: Assessing how legitimacy is contested or affirmed.

Stakeholder urgency

Which stakeholders are pushing for immediate action or decisions in the standardisation process?

Urgency assessment: Identifying stakeholders who prioritise rapid progress.

What are the reasons for their urgency (e.g., market competition, regulatory deadlines, technological advancements)?

Motivational analysis: Understanding why stakeholders feel urgency.

How does this urgency impact the decision-making process?

Process influence: Gauging how urgency affects timelines and outcomes.

Interaction dynamics

How do the interactions between stakeholders with different levels of power, legitimacy, and urgency affect the standardisation outcomes?

Power-legitimacy-urgency interaction: Exploring how dynamics shape the final standard.

Can you describe any conflicts or collaborations that have occurred due to these dynamics?

Conflict/collaboration analysis: Identifying areas of stakeholder friction or alignment.

How are these interactions managed or mediated within the standardisation process?

Governance and mediation: Evaluating mechanisms for managing stakeholder interactions.

Influence on outcomes

How do you think the characteristics of these stakeholders (power, legitimacy, urgency) influence the success or failure of the standardisation efforts?

Outcome assessment: Understanding how stakeholder characteristics correlate with outcomes.

Are there any patterns or trends you've observed in how these characteristics shape the standardisation outcomes?

Pattern identification: Exploring recurring factors affecting standardisation success.

What lessons can be drawn from these cases that might apply to

future standardisation efforts?

Future implications: Extracting actionable insights for future projects.

External influence

How do external factors (e.g., government policies, market trends, technological advancements) influ- ence the power, legitimacy, or urgency of the stakeholders?

External context: Assessing how outside forces reshape stakeholder dynamics.

Have any external agents played a role in shifting the balance of power or urgency among stakeholders?

Power-shift assessment: Understanding external interventions in the process.

Future implications

What changes do you foresee in the stakeholder landscape for future standardisation efforts?

Trend forecasting: Anticipating changes in stakeholder involvement and influence.

How might these changes impact the standardisation process and outcomes?

Impact prediction: Exploring future outcomes based on changing stakeholder dynamics.

Closing questions

Is there anything else you would like to add regarding the role of stakeholders in the standardisation process?

Final insights: Allowing space for additional, unaddressed reflections.

Would you be willing to provide any documentation or additional contacts that might help deepen the understanding of stakeholder dynamics in this context?

Resource identification: Requesting additional materials for further exploration.

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Data availability

Data will be made available on request.

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