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## Multi-mode standardisation: A critical review and a research agenda

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### ABSTRACT

Standardisation is key to shaping new technologies and supporting major ongoing trends, such as the increased importance of platforms, developing ‘smart’ technologies and innovating large-scale complex systems. Standardisation plays a key role in shaping the rules that govern these developments and their effects on society. Due to the large variety of actors involved in these trends, the associated standardisation processes are likely to involve all three modes of standardisation identified in the literature: committee-based, market-based and government-based. This multi-mode standardisation challenges the theoretical views on standardisation which predominantly focus on one of the modes. In this paper, we review the existing literatures on individual modes and on multi-mode standardisation. By recombining existing evidence, we generate new insights into multi-mode standardisation processes. These first insights relate to the contributions that each mode can make to such processes’ outcomes and suggest that their impact depends on factors, such as their initiation’s timing and the institutional context in which the standardisation process occurs. Moreover, we consider the conditions under which actors can launch each mode. Based on our observations, we formulate an agenda for future research to obtain a better understanding of multi-mode standardisation. We offer recommendations for industry actors, NGOs, researchers and policy makers involved in shaping technological and societal change.

### 1. Introduction

Standardisation can be critical in determining a technology’s success and often plays a vital role in supporting major technological and societal trends. Many important ongoing developments, such as the transformation towards a platform economy, making things ‘smart’ and innovating large, complex systems rely on standardisation (e.g. Featherston et al., 2016; Geels, 2004; Ho and O’Sullivan, 2017). Standardisation’s key aim is limiting the number of solutions when using many different options simultaneously is ineffective and inefficient. One would expect the standardisation world to adopt this approach to its own processes and ensure that standardisation itself is ‘standard’. However, closer inspection reveals that this is not the case.

Current literature is organised around three modes of standardisation: committee-based standardisation, sometimes referred to as de-jure standardisation (e.g. Jain, 2012; Narayanan and Chen, 2012); market-based standardisation, sometimes referred to as de-facto standardisation (e.g. Schilling, 2002; Suarez, 2004); and government-based standardisation (e.g. Büthe and Mattli, 2010). Extant literature describes cases where these modes jointly contributed to the final outcome (e.g.

Gao, 2014; Garud et al., 2002; von Burg, 2001), and shows that many impactful standards (such as the ISO shipping container, GSM or Ethernet) emerged in multi-mode standardisation processes, but provides limited theoretical insights into these processes. As we argue in Section 2.1, multi-mode standardisation is likely to become increasingly important in the future. Most (if not all) major ongoing trends, which shape technology and society, bring together previously unrelated stakeholders from different backgrounds (e.g. in terms of industry sector and geography) (e.g. Kenney and Zysman, 2016; Porter and Heppelmann, 2014). As they use standardisation to facilitate and coordinate these developments, they are likely to bring different standardisation ‘cultures’ and strategies to the table and employ the modes of standardisation that they are familiar with, resulting in a large number of multi-mode processes.

Despite this increasing importance of multi-mode standardisation, it has received surprisingly little attention in research. The predominant view in the literature (e.g. Leiponen, 2008; Schilling, 2002) assumes that every standardisation process relies on only one of these three modes. Although many historical cases (e.g. the market battle between VHS and Betamax or ISO 9001’s committee-based development) are in

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line with this view, it leaves an increasing share of cases unexplained (Section 2). In this review paper, we make four contributions towards generating a better understanding of these trends and the associated standardisation processes. First, we review existing literature and derive the three ideal-typical modes of standardisation that drive the emergence of standards (Section 3). Second, we summarise available theory on multi-mode standardisation and identify its gaps (also Section 3). Third, we recombine evidence from existing literature to make some first steps in formulating additional theory on multi-mode standardisation (Section 4). Fourth, we propose an agenda for research which can add to a more complete understanding of the phenomenon (Section 5.1). Based on these findings, we also offer recommendations, based on the currently available evidence, for industry actors, NGOs, researchers and policymakers in standard developing organisations (SDOs), industry associations and communities of practice involved in shaping major technological trends (Section 5.2).

## 2. Trends in standardisation

Standardisation aims to resolve situations where involved actors prefer a common solution to a problem, but have not yet agreed which option to choose. For example, this can often be observed during the development of technical specifications for new technologies with network effects. Such network effects mean that the technology's benefits for an individual actor increase along with the number of others using the same technology. The conflicts arising between actors supporting different solutions have been modelled game-theoretically as 'battle-of-the sexes' games (see e.g. Belleflamme, 2002; Besen and Farrell, 1994; Farrell and Saloner, 1988; Mattli and Büthe, 2003). These battles can result in wars of attrition where actors block agreements in the hope that the other side concedes (Farrell and Saloner, 1988; Farrell and Simcoe, 2012). To establish a common solution, standardisation pursues coordination between actors by developing solutions which are then implemented by all of them (Farrell and Saloner, 1988; Farrell and Simcoe, 2012). We group the literature on processes for establishing common solutions around three modes of standardisation in which such coordination occurs: (1) committee-based, (2) market-based and (3) government-based (see Section 3 for a detailed discussion).

### 2.1. Complexity in standardisation

We observe several empirical cases of widely used and impactful standards emerging from complex processes, where actors use diverse strategies to influence the outcomes, involving multiple modes of standardisation (see Table 1). Moreover, we expect the role of multi-mode standardisation to increase in the future in line with several major trends which underlie the increasing digitalisation of society: large scale innovation of complex systems, the development of smart technologies, the increasing importance of platforms, growing demands for sustainability and responsibility in global supply chains, and globalisation in general. All of these developments bring together a large variety of previously unrelated actors, and rely on coordination between these actors to be able to function. Pursuing these changes is beyond the capabilities of individual firms and even industries, requiring actors to interact and/or cooperate across sectors, and exposing them to new sets of stakeholders (Porter and Heppelmann, 2014). Kenney and Zysman (2016) argue that these trends can even affect actors from all parts of society and require them to find common solutions, not only to technical questions, but also to non-technical issues. Standardisation can be important in establishing these solutions and getting them accepted (e.g. Featherston et al., 2016; Geels, 2004; Ho and O'Sullivan, 2017; Schmidt and Werle, 1998). This implies that standardisation is not only relevant to industry, but also to many other stakeholders. For example, NGOs play an increasingly important role in standardisation (Boström and Tamm Hallström, 2010). The EU's Horizon 2020 programme for funding research projects specifically

considers participation in standardisation as a research output (European Commission, 2011a, 2011b; European Parliament and Council of the European Union, 2013). Germany's government also operates a funding programme for scientists who work on incorporating their research findings into standards (BMW, 2016).

As the involved actors develop standards to support these trends or cope with them, they are likely to base their approaches on standardisation 'cultures' that they are familiar with. These differ greatly. For example, the ICT sector has a standardisation 'culture' where consortia and markets play a big role, whereas other sectors rely to a larger degree on committee-based standardisation (e.g. Blind and Gauch, 2008). The degree to which actors in standardisation rely on collaboration or competition also varies widely across countries (Büthe and Mattli, 2011; Tate, 2001). The role of government in standardisation differs as well. The government plays a defining role in Chinese standardisation (e.g. Chuang, 2016; Gao et al., 2014; Gao, 2014), whereas the "New Approach" in Europe aims to limit the influence of government on technical details and depends on private stakeholders contributing their expertise to standardisation (Borraz, 2007). This implies that standardisation processes, which bring together the diverse actors who are involved in shaping these trends, will rely on multiple modes. Standardisation of the Internet of Things and smart manufacturing is an example of an area driven jointly by players from the ICT field and traditional manufacturing industries and involves elements of all three standardisation modes (see Ho and O'Sullivan, 2017; Lu et al., 2016). Also, national standardisation strategies outline the relationship between government and the other modes of standardisation, for example in China (CNIS, 2016), the Republic of Korea (Choi, 2016), the USA (United States Standards Strategy Committee, 2015), the UK (CBI et al., n.d.), Germany (Deutsche Bundesregierung, 2009); France (Evrard, 2014), Austria (Österreichische Bundesregierung, 2016), and Russia (RF Ministry of Industry Energy, 2008).

Given the increasing complexity in standardisation and the importance of multi-mode standardisation for ongoing technical and societal developments, it is a phenomenon that warrants further investigation.

### 2.2. The predominant view on standardisation

Much of the existing literature assumes that standards are developed and diffused strictly within the boundaries of one mode (e.g. Belleflamme, 2002; Blind et al., 2017; Chiao et al., 2007; Farrell and Simcoe, 2012; Greenstein, 1992; Leiponen, 2008; Rosen et al., 1988; Schilling, 2002; Timmermans and Epstein, 2010), and thus treats the modes of standardisation as mutually exclusive. Typologies of standardisation are built on this premise and classify cases into the different modes without considering the possibility that some standardisation processes may involve elements of several modes (e.g. Botzem and Dobusch, 2012; Büthe and Mattli, 2011; p. 19; Büthe and Mattli, 2010; David and Greenstein, 1990). Following from this, the literature on success factors in standardisation is divided into different streams of research. The first stream identifies ways to influence processes within standard developing organisations (SDOs) (e.g. Jain, 2012; Leiponen, 2008; Mattli and Büthe, 2003). Another stream focuses on success factors for winning market battles (e.g. den Uijl, 2015; Schilling, 2002; Suarez, 2004; van de Kaa et al., 2011; van den Ende et al., 2012). Work on how actors can successfully influence government-based standardisation is scarcer, although cases have been described (Gilmore et al., 2006) and success factors for lobbying in general (e.g. Bouwen, 2002; Klüver, 2011; Mahoney, 2007) are likely to apply.

This theoretical assumption of standardisation processes taking place within one mode's boundaries is supported by many empirical cases. For example, ISO 9001 originated in the committee-based mode (Tamm Hallström, 2004). Examples of the market-based mode include the battle between AC and DC electricity in the 19th century (David, 1992; David and Bunn, 1988) and VHS vs. Betamax (Cusumano et al.,

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