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Int. J. Production Economics 75 (2002) 213–228

international journal of production economics

www.elsevier.com/locate/dsw

Managing IT infrastructure standardisation in the networked manufacturing firm

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Abstract

This paper discusses managerial aspects of information technology (IT) infrastructure standardisation in networked manufacturing firms. It shows that in these firms, where local initiative is very important and strict central hierarchical control is lacking, standardisation of IT infrastructure is nevertheless highly important for effective co-ordination of activities. A strategic framework to guide managers in making sensible decisions regarding IT infrastructure standardisation, based on a number of pre-existing economic and management theories, such as transaction cost theory, organisational design, economics of information goods and IT maturity growth stages has been presented. It also points at different standardisation requirements for different kinds of business processes and explains that, in networked firms, managers should still strive for IT standardisation but also that the classical approach of coercive standardisation by hierarchical command is but one of the management policies possible, next to collaborative or competitive standardisation. Relevant examples of IT standardisation efforts in a networked multinational manufacturer in the electronics industry have been added. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Organisational networks; Information technology (IT); Standardisation; Organisational design; Business processes; IT strategy; Electronics industry

> I keep six honest serving-men (They taught me all I knew); Their names are What and Why and When And How and Where and Who.
>
> Rudyard Kipling, from The Elephant's Child

1. Introduction

It is becoming increasingly clear that the manufacturing organisation of the coming decade is the extended enterprise or the networked firm: a semi-permanent group of strongly interdependent companies that jointly serve one or more markets [1–4]. Many traditional managers find this a scary concept, since this concepts leaves them still "in charge, but no longer in control" [5]: the members of such networks all enjoy considerable degrees of independence and there is no clear-cut hierarchy to resolve conflicts.

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PII: S0925-5273(01)00201-8

It would therefore appear to be in the same line of thinking that, in these networked firms, information technology (IT) infrastructure standards would be a relic from the past, not something management should be striving for in the future. However, this line of thinking is wrong. Interestingly enough, it is precisely in this type of organisational context that strict adherence to standards for communication becomes extremely important. Many of these standards may no longer be recognised as such. Speaking one natural language, usually English, is taken for granted in today's multinationals. Having one standard time, e.g. Greenwich time, has also been a natural development, indeed the entire metric system is one de facto standard across most of the world today. Standards in currency, such as the American dollar or, in 21st century Europe, the Euro, are on the increase as well.

The topic of IT standardisation has been studied from different angles. The economics literature contains theories that explain *why* standardisation is all the more important in such decentralised contexts. From the field of organisational design come several guidelines on *what* to standardise, and *when*. Literature on IT infrastructure design indicates *where* in the IT architecture to look for items to standardise. There exists a separate school of research on standardisation at the industry sector or societal level, which helps to understand *how* standardisation can be achieved in networked environments.

This article attempts to synthesise these different threads into a coherent, albeit exploratory, unified theory on IT standardisation in the networked firm. Such a theory should encompass all six of the honest "servingmen" from Kipling's original poem. The "who" in this list refer to the managerial perspective of this article: our viewpoint will be that of managers having to deal with this issue. (Which is very different from suggesting that it is managers, and managers alone, that are or should be involved in setting standards.) In the remainder of this article we will focus on the other five basic questions.

2. Research method

There exists today a vibrant body of knowledge on standardisation [6,7]. However, most of this material discusses standardisation on an industry or societal level; there is little theory at the firm level, leave alone the networked firm level. Moreover, there exist significant amounts of usable theory in other areas, such as organisational design and economics. This research attempts to *synthesise* these different theoretical threads into a usable set of managerial recommendations that are well-grounded in the academic literature.

We have not attempted to provide a full literature overview of all the relevant publications in these various fields. That literature is in some cases vast and not central to our research question. Rather, we have focused on one or more seminal or exemplary publications from each area.

In this article we employ a real-world "running case" of successful and unsuccessful attempts at IT standardisation within a networked European electronics firm. This empirical material is employed primarily for explanatory purposes and to give additional weight and credibility to our theoretical reasoning, less as a direct basis for inductive theory-building. The empirical data for this case, which sometimes go back several decades, were mainly reproduced from the recollections of the second author, who has been a senior manager at the IT department of this company for most of that time. The first author has drawn from his much more recent experiences as a consultant with this company in the areas of supply chain management and product data management.

The starting point for our attempt at providing a synthesis has been formed by Kipling's "six honest serving-man", which stand for the basic questions that every manager wants answers to: who, why, what, where, when, and how. These questions have guided us in the selection of pre-existing academic literature pertinent to the issue of IT infrastructure standardisation in the networked firm, as we will explain further in the next section.

3. Managerial design guidelines

In this section we outline our managerial design guidelines for dealing with IT infrastructure standardisation issues in networked firms. These design guidelines also form the basis for the structure of the current article. As such, they are summarised in Table 1.

The first question to be addressed is *why* managers should standardise at all in networked firms. Our brief discussion of this topic in Section 5 shows that standardisation is especially important in such contexts, amongst others because of the crucial importance of smooth communication there. Section 6 takes an IT architecture perspective and addresses the question *where* in this architecture one should look for standardisation opportunities. It argues that one should ignore local, fast-changing applications and focus on shared and standard ones. Section 7 draws on the organisational design literature. After all, IT is intended to support organisational activities and the organisational design literature contains guidelines on *what* parts of those activities to standardise: the inputs to these activities, their outputs or the activities themselves.

An important reason for uncertainty with managers of networked firms regarding standardisation is that they are no longer able to exercise hierarchical control over all relevant activities. But this assumes that there is only one answer of *how* to achieve standardisation, i.e. a coercive approach. Theories from network economics as well as the literature on IT standardisation at the industry level point at other models, i.e. collaborative and competitive standardisation. These models, which may apply better to networked firms, are treated in Section 8. Finally, Section 9 deals with the issue of *when* to strive for standardisation, given that organisations and their constituent processes tend to go through certain specific stages in their life cycle. Here we apply the recommendations from Nolan [8], which suggest that attempts for standardisation should wait until some degree of maturity has been reached.

4. An empirical example: Standardisation at Electroco

Electroco is a real-world example of a networked firm and its experiences with IT

Table 1
Managerial design guidelines and structure of article

Management issue	Theoretical basis	Main topics	Section no.
Why standardise in a networked firm?	Transaction cost theory (Coase, Williamson); Supply chain design (Fine)	Lowers communication costs Facilitates changes in organisational design Allows for economies of scale	5
Where in the IT infrastructure should we standardise?	IT architecture (Weill and Broadbent)	Not for fast-changing local applications but for shared and standard ones	6
What elements of our organisational design should be standardised?	Organisational design (Mintzberg)		7
How can we achieve standardisation in decentralised contexts?	Network economics (Arthur, Shapiro and Varian) and IT standardisation (Jacobs)	Competitively Collaboratively Coercively	8
When in our IT maturity should one standardise?	IT maturity (Nolan)	Not in the initation phase Collaboratively in the growth phase Coercively in the control phase	9

infrastructure standardisation. We will use Electroco throughout this article to illustrate our theoretical reasoning. Electroco's core business is the production and sales of electronic products for the consumer market, such as TVs and audio equipment. It also produces goods for industrial markets, such as machine goods or medical equipment. In addition, it produces many of the components and subassemblies it uses in its electronics equipment. For instance, it has a semiconductor product division of substantial size.

Electroco is not a network of fully independent legal entities. Rather, it is a firm on its way from being a fully vertically integrated firm to a much more networked organisation. To zoom in on its semiconductor branch, this supplies less than 20% of its production to other Electroco branches, the rest is sold on the open market, amongst others to direct competitors of these Electroco branches. Substantial parts of its production, such as assembly and testing of integrated circuits (ICs), are outsourced to third parties, in which Electroco may or may not have a minority interest. It own production facilities have to meet reach high loading levels to be profitable and therefore are starting to work for external customers as well. Increasingly also, business units of this semiconductor division engage in very close partnership with its key customers, for instance when an IC needs to be designed-in with a new product of these customers and short product life cycles require joint design of the total product.

5. *Why*: Benefits of standardisation in networked contexts

The topic of standardisation of IT systems is often associated with one-size-fits-all solutions for unique business processes, with generic "best practices" that rarely fit well with the established ways of doing business in specific firms. In short, IT standardisation is firstly associated with the creativity-stifling policies of the fully integrated command-and-control firm of the past, not with the networked firm of the future. This can be a costly misunderstanding, especially in an economy where Internet-enabled business networking has become possible precisely because of tightly standardised the infrastructural aspects of the Internet, from TCP/IP to HTML and Java. A central tenet of this article is that standardisation of IT infrastructure is far more important for the networked firm than for the classical organisational pyramid.

We see three main drivers for this increased importance. Firstly, in the unified firm, inter-unit collaboration to achieve synergies can (in theory at least) be ordered from the top. But in the networked firm, *collaboration has to be achieved through communication*. For such communication to be effective, one needs not just the same natural language, but also common IT functionality to accommodate it. If "cost price" means one thing in unit A and another in unit B, there is a problem in communication. If this communication has to take place via a different E-mail system or via traditional means of communication, internal transaction costs [9,10] become higher, thereby having a profound impact on the competitiveness of the organisation.

Secondly, standardisation of IT infrastructure *facilitates changes in the organisational network*. If a new partner is to be added to the network, one should not have to design separate interfaces to link the new partner's systems to all the individual units of the network. One standard interface should do. This allows not just for effective coordination of activities in the network, but also for frequent redesign of the network, which according to some authors is becoming the new lasting competitive core competence in "a world of temporal advantage" [3]. For instance, back in the early 1990s Electroco found that it simply could not sell its then-dwindling component business because it could not unbundle its IT systems from those of the parent company so as to enable its operation independent.

Thirdly, there is the classic argument that *standards allow for economies of scale*. This has long been true for product-related aspects such as e.g. 220 V or QWERTY keyboards, but is becoming increasingly important for organisational processes as well. As IT costs become a larger

and larger part of added value for manufacturing firms, the potential of achieving economies of scale through standardisation in this area becomes bigger and bigger as well. This goes well beyond cost price of equipment due to larger purchasing quantities. For instance, computers of brand A may or may not be technologically superior to those of brand B, but if one of the two is the standard machine and therefore it takes the IT department just as long to configure one non-standard machine as it costs to configure twenty standard ones, then the choice for the discerning manager becomes quite simple.

6. *Where*: IT infrastructure architecture

6.1. The IT infrastructure pyramid

From an IT perspective, does it make a difference what type of IT infrastructure is to be standardised? IT infrastructure specialists Weill and Broadbent [11] argue that it does. To them, IT infrastructure is considerably more than just computers and the cables connecting them, i.e. IT hardware. They define *information technology* as "a firm's total investment in computing and communications technology. This includes hardware, software, telecommunications, the myriad of devices for collecting and representing data (such as supermarket point-of-sale and bank automatic teller machines), all electronically stored data and the people dedicated to providing these services" (p. 6). Weill and Broadbent view the total sum of this investment as the information technology portfolio. This portfolio is founded upon the firm's longer-term information technology infrastructure, which is in turn linked to public infrastructures, such as the Internet and telecommunications providers. It is this close combination and integration of these internal and external infrastructures that they call "the new infrastructure" and that they consider central to the networked firm.

In this new infrastructure, where should one look for standardisation opportunities? As Fig. 1 shows, a certain hierarchy in this information infrastructure can be distinguished. At the bottom

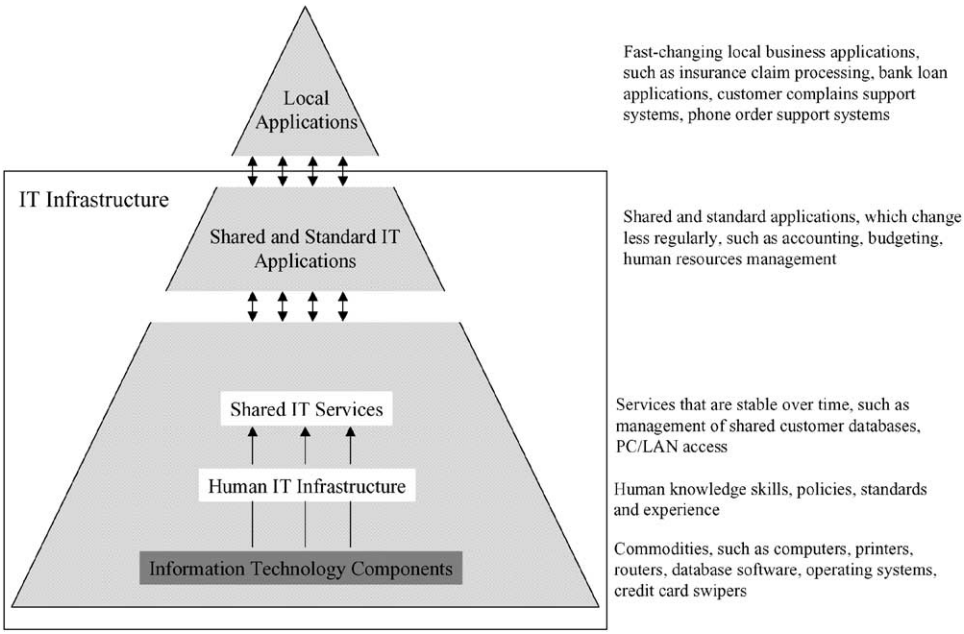

Fig. 1. The structure of information technology infrastructure (after [11, p. 86]).

are generic information technology components, such as computers, printers, routers and the like. It takes human skills, policies, standards and experience to transform these into IT services and applications. Weill and Broadbent see different layers of IT services. Firstly, there are shared IT services, which are stable over time, such as the management of shared customer databases or PC/LAN access. These services are used for IT applications. Here a distinction is made between local versus shared and standard IT applications.

Local applications are seen as based upon, but not part of, the IT infrastructure. Local applications are indeed local, fast changing and used by a limited number of people. Shared and standardised applications, such as accounting or payroll services, change much less regularly and are used throughout the firm. Weill and Broadbent stress that local applications need not be standardised. For them, the dimensions relevant for standardisation include (a) its local versus integral nature, (b) its speed of change and (c) the number of people that use it. Local, fast-changing applications used by small groups should not be standardised. Integral applications that remain stable over longer periods of time and that have large user groups should be standardised.

6.2. *Standardisation of IT infrastructure at Electroco*

Electroco has a long history of attempts at standardisation of IT infrastructure, with mixtures of success and failure. Back in the 1970s, the company described itself as a matrix organisation [12]. One axis of this matrix was formed by relatively independent national organisations, which conducted market-driven trading in all products of the company but also in products that were bought from third parties. The product divisions (PDs) formed the other axis; they were responsible for the development and manufacturing of products. In this period, standardisation efforts were aimed mainly at the bottom level of the infrastructure pyramid of Fig. 1: standards for information equipment like communication hardware, processing hardware, data base management systems, programming languages and the like were established. The purpose of this effort was to ease communication between the various organisational units, hence to lower transaction costs and of course to keep information processing costs under control.

In the 1980s the matrix was simplified. The product divisions gradually got control over "their" part of the sales organisations and the role of the national organisations became a supportive one. Efforts concentrated on the use of standard information systems in each of the units and on product division level systems to support the control of the supply chain. Each product division started to standardise transactions in the supply chain management area by means of enterprise resource planning (ERP) systems. In the terminology of Weill and Broadbent these were shared IT applications. Meanwhile, the corporate body concentrated on the consolidation process in the accounting area, i.e. standard IT applications.

During the 1990s, technological developments such as client–server architectures, PCs, multiple ERP packages and the associated different languages, hardware and database management systems made the IT infrastructure picture for the whole company very diverse indeed. Local applications, in the Weill and Broadbent terminology, started to become dominant in the whole IT infrastructure. Towards the end of the decade the strategic apex came to realise that, as a result of this, Electroco ran the risk of falling apart in separate, disassociated entities and decided to take action. The goal as stated was that the company should standardise the information infrastructure in such a way that specific entities could be sold or added without major disturbances or efforts.

7. *What*: Organisational design mechanisms

In the organisational design literature, the importance of standards has long been recognised. In particular, standards have been suggested as effective vehicles for overcoming the complexity that arises from the many interactions that occur

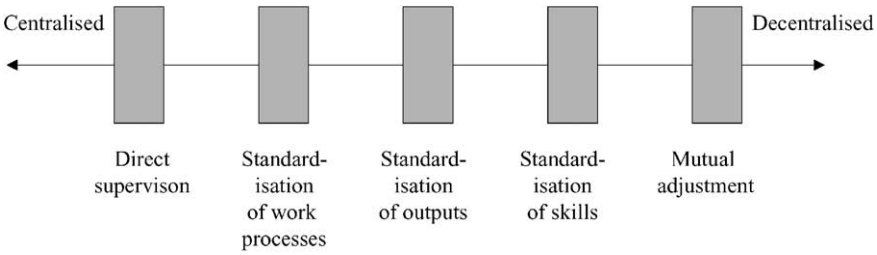

Fig. 2. Mintzberg's co-ordinating mechanisms on a continuum of decentralisation (from [12, p. 108]).

in larger organisations with many stakeholders, be these vertically integrated or networked. In this section, we will look at answers this literature may suggest for the managerial issue of *what* parts of these interactions to standardise.

7.1. Standardise inputs, processes or outputs

Organisational scientist Henry Mintzberg [12] first distinguished between different aspects of standardisation. Fig. 2 illustrates his thinking. It shows how standardisation of the *inputs*, i.e. the skills required to do the work can be seen as the most decentralised way of co-ordinating. This is in fact a very common degree of standardisation, observable in organisations as diverse as hospitals, trucking firms or football teams. It implies hiring people with similar background or skills and leave standardisation at that. "Mutual adjustment" from there on are sufficient to co-ordinate activities.

At the other extreme lie organisational contexts where the *work processes* themselves have been standardised as well. This may apply to nurses, accountants and factory line workers alike. The middle ground is taken by standardisation of *outputs*, where people are free to decide how they wish carry out their work, as long as their outputs confirm to certain criteria. Obviously, which degree of standardisation is preferable will be dependent on many factors specific to the organisational setting under investigation. To mention one criterion: the more diverse and changing the work conditions and requirements are, the more difficult it will be to standardise up to the work process level. But different types of business processes have different degrees of predictability and repeatability, as we will see next.

7.2. Five different kinds of business processes

It has long been recognised that not all organisational processes and transactions have to be equally rigorously standardised. In his *Structure in Fives* Henry Mintzberg [12], described five different views, or theories, of how organisations function. These five could be seen as five different systems of flows, or, in our terminology, business processes:

- the flow of *formal authority*, supported by e.g. the accounting infrastructure;
- the flow of *regulated activity*, supported by e.g. ERP systems;
- the flow of *informal communication*, supported by e.g. electronic mail;
- the flow of work within a set of *work constellations*, supported by e.g. design management systems; and
- the flow of *ad hoc decision* processes, supported by e.g. a decision support system (DSS) or executive information systems (EIS).

Roughly speaking, the need for control, predictability and hence for standardisation becomes less for each subsequent flow. Annual reporting will often be fully standardised, not just in terms of its outputs (profit and loss statements, balance sheets) and its processes but even in the allowed inputs. On the other hand, strategic decision-

making processes are almost by definition not standardised in any way.

7.3. Standardisation of accounting and supply chain management processes at Electroco

The importance of understanding what the needs – and possibilities – are for different kinds of business processes becomes evident from discussing experiences related to the standardisation of different processes within Electroco, in particular the accounting processes and the SCM processes.

Typically, one would expect that systems that support the flow of formal authority such as an accounting system would be relatively easy to standardise throughout a firm. This is not true in a multinational company: in each country there are quite different opinions and traditions in accounting and every government has established its own rules. Already in the 1970s, Electroco realised this and therefore decided to concentrate the standardisation efforts on the consolidation of financial data. The legal entities of the firm were forced to send their reports in a structured electronic way every month to company headquarters. A great deal of effort was put into the standardisation of data elements and the messages. A specialist group in the centre drove this standardisation. The Board of Electroco supported the development by forcing the accounting community to deliver reports within ever-shorter periods. These days, the result has been two-fold: Electroco is able to give detailed accounting reports just a few days after closing of the months and the entities in the countries have standardised their accounting procedures so that they are now able to deliver accounting information timely. So not just the outputs, but also the processes themselves have been standardised.

Standardisation of regulated activity processes such as supply chain management has proved to be far more difficult at Electroco. As early as the 1960s, Electroco has started to work in this area by introducing automated information systems in the sales organisations, in the PD centres and in the factories. Interfaces between these on the operational level were maintained by messages, notably order and invoice messages. Standardisation was supported by attempts to standardise the packages used for these information systems. Results were mixed. Each system helped considerably in improving the operational efficiency in its unit but the overall stock levels and customer service did not improve to the required levels. The use of standardised messages by means of electronic data interchange (EDI) was below expectations, so a great deal of manual re-keying had to be done to transfer the data from system to system.

In the 1980s, Electroco undertook a huge effort to improve the situation in its consumer product divisions. Two projects were started, one in the factories and one in the product divisions. The first one was a success; both MRP 2 and JIT concepts were implemented and flexibility in the factories, measured in terms of manufacturing throughput time, increased enormously. Stocks as percentage of turnover decreased with 30%, freeing up a great deal of working capital. But the PD level project failed totally, basically because of disagreements about the nature of the business processes involved and the required levels of standardisation. Here political strife ruled.

Towards the end of the 1980s, Electroco gave up its matrix organisation and made the product divisions the dominant axis. As a result, each of these PDs embarked on its own project to structure and standardise the SCM systems infrastructure on a world-wide basis. This again proved to be problematic, even with strong hierarchical support. The emphasis in standardisation was placed on the use of standard packages and the available technical infrastructure. But to arrive at common procedures and common product and other data definitions turned out to be very complicated. Each organisational entity had its own position on the market place, its own distribution channels policy, etc. As of today, Electroco still has not achieved full standardisation of this business process throughout its networked company. Moreover, increasingly different demands placed upon its various businesses make this ever more challenging to achieve in the short run.

8. *How*: Standardisation in decentralised contexts

8.1. A typology of standardisation mechanisms

In this section we look at *how* standardisation can be achieved in decentralised contexts. In general, we can distinguish two extremes of standardisation, which we will label *coercive* and *competitive*. The traditional management view on standardisation is that it should be achieved in a coercive manner, i.e. ordered by some governing body. The other classical way of achieving standardisation is by competitive forces, in which standards emerge out of market transactions without hierarchical orders or even despite such orders for a specific standard. This is in line with classical transaction cost theory: standardisation either lowers transaction costs within a firm or it lowers transaction costs in the market place. Nowadays, a third way of standardisation is increasingly recognised as being well suited for the network economy: *collaborative* or alliance-led standardisation [13].

As is illustrated in Table 2, this collaboration mechanism can again take three different forms. There is the centrally ordered alliance, such as can be observed in the telecom sector where formal government-ordered standardisation preceded industrial adoption. On the other side is the consortium-led standardisation effort, such as can be observed in the computer sector, where alliances emerge out of fierce competition amongst rival groups of companies, all striving for their product to become *the* standard (cf. [14]), and, there is a middle form, *voluntary* alliances, such as those that brought about the standardisation ·and hence the success – of the World Wide Web, in particular HTML and HTTP (cf. [15]).

Table 2
Typology of standardisation mechanisms

Type	External market example
(1) Coercive standardisation	EC: Euro conversion
(2) Collaborative standardisation	
(2a) Hierarchically ordered collaborative standardisation	Telephony sector: GSM
(2b) Voluntary collaborative standardisation	Internet: HTML, HTTP
(2c) Consortium-led collaborative standardisation	Computers: Unix
(3) Competitive standardisation	Computers: Windows vs. Mac

We will now discuss all these different mechanisms for standardisation, both from the perspective of the industry sector and from the perspective of management of a networked firm.

8.2. Coercive standardisation

According to Weill and Broadbent [11], senior management of any firm that wishes to keep its information technology infrastructure strongly supportive of its overall business strategy should be leading the way in making IT investment decisions, such as deciding on standardisation of IT infrastructure elements. This goes a fortiori for firms that want to drive their business strategy by IT, not just have IT respond to demands from strategy. Only senior management can push through IT investments that are for the common good of all the organisational units but which may not be locally optimal for many of the individual units. Weill and Broadbent provide a framework to link these IT investments systematically with decisions on overall strategy and existing IT infrastructures and label this approach "management by maxim" as opposed to, in their view the much weaker "management by deal" that they observe with many of their clients.

This policy is ideal if management (a) has the power to enforce this standardisation, (b) has made the right strategic choice for a specific type and degree of standardisation and (c) the environment does not change so much or so rapidly as to invalidate the wisdom of this earlier choice. At an industry sector level, a successful example is that of the telephony sector, where at the International Telecommunications Union (ITU) government officials of the member states of this body routinely decide on selection of standards.

However, if product life cycles are much shorter than in telecom and network effects are less profound, points (a) and (b) can make management by maxim much more problematic (cf. [16]). Indeed, in general the de facto evolutionary

character of standardisation processes in complex organisations makes life difficult for coercive approaches. Monteiro and Hanseth [17] point out that this evolutionary character takes place not just at the moment when a standard is defined, but also once it gets implemented. During the defining stage, "there is a necessary vagueness and shifting character of the information infrastructure (…) which immediately translates into a critique of the assumptions [underlying coercive standardisation] about stability and well-definedness" [17, p. 3]. Moreover, once such a standard is implemented, it becomes by definition a localised phenomenon: "Standards are not universal (…) they are only universal as abstract constructions. When they get implemented, they are linked to and integrated with local systems and practices. (…) Their universality and homogeneity disappear as standards get implemented. They are locally embedded (…) and they are continuously changing – in different directions in different localities" [17, p. 3].

8.3. Competitive standardisation

Standards need not be ordered from the top, they will emerge anyway when networks of people start interacting more frequently. Our daily lives are filled with standards that have emerged out of fierce competition between different possible standards in which, in the end, the winner took all. Classical examples are the width of railroad tracks, the QWERTY keyboard, compact disk (CD) technology and – still ongoing – English in academic discourse.

Standards emerge in markets because of the interactions between a considerable number of dynamic effects. In this article we will touch upon six of these. The first effect stems from the beforementioned *transaction cost theory*: if interactions take place based upon a common standard, costs become lower and so the units in the network that use the standard will have lower costs than those that do not.

The second effect is *lock-in* [14]. Lock-in relates to the switching costs that are inherent with any investment decision that you make. Once you have become an Apple Macintosh computer user it becomes increasingly costly to transfer to another type of hard- and software, since you will no longer be able to utilise your previous investment. So units that use a standard will be inclined to keep on using it. But since the transaction costs with the standard are lower, non-standard using units will be tempted to switch to the standard as well. Which brings us to the third dynamic effect, increasing returns [18].

The concept of *increasing returns* suggests that, for many information goods, higher market shares only lead to an ever-higher popularity of the market leader. The more people use Microsoft Windows as the operating system for their PC, the more applications will be developed for this platform. The more applications are being developed, the more attractive the platform becomes and hence the more users it will attract. In the end, Windows becomes the de facto standard for many PC users, until the next technology discontinuity makes it obsolete again.

A fourth effect is a corollary of increasing returns called *Metcalfe's Law*, named after the founder of 3Com Corporation, who stated that the value of a network goes up as the square of the number of nodes that are in it [19]. If two people own a telephone, the value of the network is limited. Three users can have three one-on-one conversations, but four can already have six conversations, five ten conversations and so on. In general, a conservative estimate is that n users can have a maximum of $n*(n-1)/2$ separate interactions. So if the size of a network is determined by its underlying communication standards, as with the Internet in general and E-mail in particular, then the usefulness of that standard (and hence its value to users) increases exponentially as the number of adherents to that standard increases.

The concepts of increasing returns and Metcalfe's Law explain the importance of the fifth relevant effect, which is that of *path dependency* [18,20]. This is an important driver behind the desperate urge with which Internet start-ups have been trying to obtain market leadership for their type of product very early on, regardless of costs. As more begets more, it becomes extremely important to establish the lead position for a standard very early on.

Finally, there is *market tipping*. Path dependency does not mean that every early leadership leads to a final outcome of winner-takes-all: not every market tips towards a single dominant technology standard, in the words of Shapiro and Varian [14]. High demand for variety and low economies of scale both make market tipping unlikely, they point out. This is a negative, or balancing, feedback loop that can counteract the positive growth loop of increasing returns. For any network, there is a critical combination of user interactions, increasing returns and switching costs that is just great enough for the positive growth loop to dominate the negative loops. That threshold is known as the tipping point [20]. Once the growth loop becomes the dominant one, the new standard "can spread like wildfire – that is, by positive feedback – limited only by the depletion of the [non-user] population" [20, p. 306].

8.4. Collaborative standardisation

Standards lower transaction costs for all parties involved in exchanges. Hence, establishing a standard can be seen as being for the common good. Not surprisingly then, that governments, as the natural champions of this common good, have been active in establishing standards by setting up official standard bodies. One successful example of this is the ITU or International Telecommunications Union, which is a formal treaty organisation and run under the auspices of the UN [16,21]. The telecommunications industry has relied on the ITU to set international standards starting as early as the 1860s, through radio in the 1920s and a multitude of standards today [14]. We will call this *hierarchically ordered collaboration*. This model can and has also been applied successfully at the firm level. Many if not most large manufacturing firms, including Electroco, have some form of a central standards department that owns the right to set standards on data format, transactions and the like.

Since standards are for the common good it is not surprising that *voluntary collaboration* on standards has been quite prolific as well. The International Organisation for Standardisation (ISO) is in this a classic example, but W3C, the World Wide Web Consortium, is a much more recent phenomenon. W3C has been responsible for establishing the two HTML and HTTP standards. These two innovations have provided the ability to easily transmit pictures, drawings and variant types of text over the Internet, which has made it an interesting medium for a wide variety of activities and has been highly instrumental in bringing about the success of the Internet [15]. Once again, the same phenomenon can be observed at the firm level, where such voluntary associations often start out as special interest groups that grow in scope and membership as they gain momentum.

Most people do not care much about who owns a standard or how it was just as long as there is one [15]. This basic notion has spurred the growth, especially in the information technology domain, of attempts at *consortium-led collaboration* in the standards-setting process. Firms build alliances with other firms around a common standard against other groups with competing standards because they see that they have little chance of becoming owners of *the* standard on their own. In dynamic markets, this approach to collaborative standardisation has advantages over the previous two because these are inherently slower. Their decision processes are designed to be open to all participants and to foster consensus, which next to many advantages does tend to slow down the decision-making process considerably [14,16].

A drawback of consortium-led standardisation efforts is that they may result in multiple standards, which may still be better than no standard at all but still is, from a transaction cost perspective, inferior to having a single standard. As has been shown by Axelrod et al. [22] in a formal analysis of the efforts in 1988 to create UNIX operation system standards, the likelihood of a deadlock situation occurring between two competing alliances can be very high in a market with high rivalry and considerable benefits from being on the winning side in a "standards war" [14].

Again, similar phenomena can be observed at the firm level as well, but usually much less openly, since organisational units are not supposed to compete with each other. Nevertheless, de facto

alliances with other business units (BUs) to have your current E-mail system or ERP package become *the* standard package for the whole company can be identified in many large companies, not necessarily just networked ones.

8.5. Hybrids

In practice, all of the above-mentioned standard-setting mechanisms can be witnessed, and often in conjunction with each other. There are many grey areas as well: company management may start endorsing a voluntary attempt at standardisation; individual firms will see it in their interest to join a successful alliance; an official standards body may choose an existing technology for which a specific firm holds essential patents. In the view of Vercoulen and van Wegberg [16], such hybrid forms are on the increase, especially in dynamic, complex industries. They provide the example of standardisation in Internet telephony, where two official standard setting bodies develop and select architectures, one of these and three corporate alliances focus on interoperability. In all these standard bodies many of the same firms are taking part, postponing their definitive choice until it becomes clear what the best bet will be. Some parts of the future standard look set to be determined by the dominance of a single firm, Microsoft, in the browser market. Similar hybrid situations can be expected to exist in corporate environments, as will be illustrated in Sections 8 and 9.

8.6. Standardisation of EDI and E-mail at Electroco

The history of Electroco provides some interesting examples of non-coercive standardisation efforts. In particular in the communication with third parties (and between different organisational entities) this has always been an understandable course of action, even when the company was considerably less networked than it is today. We will therefore look briefly at the fate of EDI and E-mail within Electroco.

Electroco started the standardisation of data elements for some major business processes as early as the seventies. In the beginning this was a proprietary effort within the company. At the corporate level, an Office of Data Element Standardisation was established to organise the effort (i.e. hierarchically ordered collaboration in our terminology). Its goal was to supply information systems designers with standard data elements to improve speed and quality of the development of information systems. Soon it became clear that the effort should be complemented with an effort to standardise messages as well because different systems should be able to communicate with each other. For instance, the logistics system in the sales organisation should produce order and invoice messages for the central warehouse system.

Gradually, the need to be able to communicate electronically with systems outside the company became apparent, which led to the conclusion that it would be required to switch where possible to external standards. Therefore, the company became active in standard official setting bodies like UN Edifact to speed up the development of standards. However, the results of these efforts have been less than expected, for reasons in line with the overall developments in the world of EDI. Here, the move towards more collaboration has not led to successes yet.

The history of E-mail is a very different one, not just because standardisation has been more successful here but also because another approach to standardisation was chosen. At Electroco, E-mail standardisation has long remained a competitive effort, only to be replaced by a swift and effective coercive effort when the time appeared ready for doing so.

The use of E-mail systems started at the end of the 1970s. In the beginning, E-mail software was developed in house but gradually each organisational unit at Electroco made a choice for an E-mail system from an external supplier, in most cases related to the hardware environment they were using. This selection was most often made by the national organisations and they understandably selected systems that could support the local language. In this manner, a considerable number of different E-mail systems became used at Electroco. Communication between these systems was very difficult. It should be noted that, in the

same period, the fax became popular so a part of the intra-unit communication needs could be supported by this medium. Therefore, pressure to improve the situation was not very high.

In the 1990s, the suppliers of the E-mail packages started to develop bridge software to make the systems communicate. Besides that, the Internet grew which made it possible to exchange mail with people outside the firm based on the SMTP standard. From an infrastructure point of view, the whole picture became rather messy and the costs to support the different systems and the bridges were growing at a fast pace. Several attempts were made by the strategic apex to come to a standard using working parties to select one. (i.e. attempts at collaborative standardisation). However, this did not work: all parties underlined the need to standardise but wanted to have their current system as the standard to avoid considerable changeover costs (i.e. lock-in costs).

At the end of the century, using E-mail had become an essential element in the communication and disturbances could not be allowed anymore. Besides that, the much-feared Millennium bug would require an overhaul of some of the E-mail systems and the replacement of others, which would require considerable efforts and would bring high risks for the continuation of E-mail services. In view of this, corporate management decided to select one E-mail system and replace all the others (i.e. coercive standardisation). A working party made the selection and before the end of 1999 all the former E-mail systems were replaced by a single system.

9. *When*: Organisational and IT maturity stage

9.1. The Nolan growth curve of IT maturity

The final managerial issue regarding IT infrastructure standardisation we have to tackle is the question of *when* to aspire it. We interpret this question in the context of "when in the organisational growth phase of the organisation". Here we can build upon the work of Richard Nolan [8], who defined four stages of what was in the 1970s called "data processing growth". This framework has been used and amended many, many times since then, by academics and management consultants alike, Nolan himself notwithstanding. What has remained a central tenet of this theory is the claim that every company has to go through each of these stages; there are no shortcuts. The best thing management can strive for is that certain stages take less long than without managerial guidance. Nolan's original four stages are the following:

1. *Initiation*. IT usage by IT specialists, who experiment with technological possibilities, with a hands-off managerial attitude.
2. *Contagion*. Great enthusiasm with IT users, diversity of systems without coherence, increasing investments without integrated planning, more dedicated IT staff.
3. *Control*. Reorganisation of IT, high maintenance and adaptation costs, more formal planning of IT projects, managerial priority-setting, productivity increases in system development.
4. *Integration*. System integration and data structuring and standardisation; communication via networks and terminals, focus on education of users and IT staff, decentralisation of IT management.

Regarding standardisation, the key observation is that Nolan sees a typical growth path for managerial efforts at standardisation of data and processes. In the initial stages, management should maintain a hands-off attitude, but as IT usage proliferates, more strict project control will become required. System and data standardisation come next, up to the point where data are fully standardised and IT system responsibilities can again be strongly decentralised.

9.2. Standardisation of product data management at Electroco

So far in our discussions of standardisation efforts at Electroco we have focused on past events. The example of product data management is one that is at the time of writing still in full

swing. Given its relatively early stage in the Nolan growth curve, it seems plausible that this will continue to be the case for quite some years to come.

Product data management is concerned with the creation, storage and maintenance of all product-related information and the associated business processes affected, starting with product creation and penetrating from this most other business areas such as purchasing production, sales, logistics and accounting. Historically, product data management had been very much a local issue at Electro, if an issue at all. Applications to support it were inherently local and workgroup-specific. Under the criteria laid out by Weill and Broadbent [11], these applications were often not part of the IT infrastructure, hence their standardisation was not an issue. In recent years, this picture has changed considerably. The use of PDM has proliferated and moved up on the Nolan curve. No longer is product data management a local issue, but one that is becoming crucial for interactions between different business areas.

There are different areas of interaction where progress in PDM is crucial for Electroco. One such area is between product design, marketing and customers. More and more, interactions between product designers, marketers and customers are driven by product data specifications rather than by the product themselves. For instance, given the short product life cycles in the electronics industry, customers usually buy newly designed products on the basis of product specifications, not after inspection of the physical products themselves. If these product specifications arrive late from the design department, or worse, have to be created within the marketing function, time to market is delayed which hurts profits considerably. Another example is between product design and manufacturing. For instance, in semiconductor manufacturing, new IC types first have to be tested before they can be finally released. This requires that they be manufactured in small batches. If references to such products do not yet exist in the production database then planning their production becomes problematic.

Finally, also within the same business areas, communication regarding product data would increasingly benefit from data standardisation. In the design function, new products are more and more developed by multiple design teams operating in different geographic locations. They should be able to use the same underlying databases to work effectively and in production, third parties increasingly perform significant parts of the production and distribution of products. If different business units use different coding mechanisms and product data creating and modification processes, this makes such outsourcing difficult, time consuming and costly.

Despite the obvious business benefits from the standardisation of product-related data and their associated business processes, progress in PDM has so far been limited at Electroco. Central management has made some attempts at setting up a centralised effort for this by appointing process owners and project teams, but so far this has been unsuccessful. On the one hand, the various business units do not see the added value of a lengthy and complex central project: they want quick fixes that work for their environment. On the other hand, central management has trouble seeing how it can take the lead in this activity if so many things remain unclear.

From the perspective of Nolan's growth stages, we can quickly see an underlying reason for this. It would seem that the business process involved, as well as the underlying information technology that supports it, is still in its early stages of development (in Nolan's terminology, the contagion stage). One can observe a great deal of local enthusiasm, but also a diversity of different systems without any central co-ordination. We have seen that in such cases, strong managerial action may backfire.

We can also let our other theoretical perspectives guide us here. For instance, we can investigate the nature of the process that is being supported by the technology. Is it closer to what Mintzberg calls the flow of formal authority or regulated activity, or are ad hoc processes being supported and rapidly changing work constellations? If the latter, then standardisation is best limited to output specifications. If the former is the case, then standardisation may well have to

include process standardisation to some degree as well. In the case of PDM, the assignment of unique article codes tends to be a very formal activity, which proceeds according to precisely formulated steps. On the other extreme there is informal communication between designers and marketers regarding specs for a certain new product, possibly in the form of some workgroup operating from multiple geographic locations. Then there are regulated activities as creating product specifications and writing product documentation, and updating this information whenever the need arises.

Finally, there is the question of *how* to standardise. One promising approach in this concrete example might be to use a mix of various degrees of collaborative standardisation. For instance, one could start up several local projects to learn from and to create multiple de facto emerging standards (i.e. market-driven collaboration). Findings from these projects could be shared between business unit representatives (i.e. voluntary collaboration). These informal network meetings could be formalised, endorsed, financed and supported with specialist expertise by central management. Once sufficient maturity in both processes and technology had been achieved, this standard-setting body could recommend one or two common standards for the whole or a part of Electroco, a decision which would be approved by senior management. In this way, early lock-in into a losing technology would be prevented, and yet convergence towards company-wide standardisation would be speeded up. The initial stage could proceed quietly and in an evolutionary manner; rolling out the final standard would be much more intense.

10. Concluding remarks

This article has investigated the topic of managing standardisation of IT infrastructure in the decentralised, networked firm of the 21st century. Regarding this topic, it has stressed two basic messages. The first one is that, in such a networked firm, standardisation is more important than ever for business success, not less, as one might think at first. The second one is that, although the classical hierarchical command-and-control type of standardisation mechanism will be difficult to operate for management in networked firms, there exists a whole variety of other mechanisms that management can utilise to achieve rapid and successful standardisation.

With regard to the first message, one could say that this paradox, i.e. that more freedom means more underlying rules, is a very broad one which is not limited to the field of IT or even to business organisation. For instance, political thinker Geoff Mulgan writes: "A society which too loudly proclaims individual independence soon becomes an unpleasant one to live in. In a densely populated society it is hard to enjoy freedom if you can have no certainties about how others will behave. Freedom to walk the streets, happiness in a relationship, contentment in a job, all of these depend on confidence – that the streets will be safe, your partner will not suddenly walk out, you will not be suddenly sacked. For the same reasons, free markets rest on rules guaranteeing property rights and enforcing contracts, and policing against fraud" [23, p. 47].

With regard to the second message, one can argue as to how *new* these non-hierarchical standardisation mechanisms really are. We have seen that most of the theories that form the basis for our management guidelines have been around for several decades. Transaction cost theory goes back to the 1930s. Organisational growth stages date back to at least the 1970s. Mintzberg's classification schemes are from the 1980s. One can even argue that the recently published material on network economics has roots much older than the 1990s. From a practical perspective, managers are invited to look back at successful standardisation efforts they witnessed in the past, and see to what extent these were achieved solely by strong command-and-control. Therefore, we believe that the conceptual framework that we have presented in this is not a radical departure from established business imperatives, but much more an intensification of them. The past continues to contain important lessons for today and tomorrow, for those willing to learn from it.

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