

**MANAGING CONSISTENCY BETWEEN PRODUCT
DEVELOPMENT AND PUBLIC STANDARDS EVOLUTION**

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ABSTRACT

This paper examines the management by equipment suppliers of consistency between their product development efforts and the evolution of public standards. We specify structures which make explicit the role of a firm's standards management and provide a unified perspective of its interdependences with other groups, internal and external to the firm. Based on a sample of cases provided by nine standards managers in three firms we develop five standards management structures which are used to provide consistency between product development and public standards evolution. We also show how these structures can be changed systematically with changes in goals and how they are related to three basic building blocks which we refer to as Information Management, Commercial Exploitation and Standard Development. The paper makes two main contributions. First, it enables individuals involved in the design or implementation of a standards strategy to create a simple and realistic visual representation of the binding which channels their activities. Second, it provides a stable framework within which standards managers can work to analyze, design, implement, modify and evaluate standards programs.

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MANAGING CONSISTENCY BETWEEN PRODUCT DEVELOPMENT AND PUBLIC STANDARDS EVOLUTION

I. INTRODUCTION

The objective of this paper is to examine how equipment suppliers ensure consistency between their product development efforts and the development of public standards by standards-setting organizations.

A standards strategy is a plan to achieve consistency between product development and public standards evolution. The focus of the plan is the alignment of the purpose of the firm's participation in standards development, the identification of the activities to be undertaken, and the structure required to implement these activities. Any misalignment will increase product development interval and waste scarce resources.

Each standards strategy focuses on the evolution of a set of standards (e.g. method to convert an analog signal such as voice to a digital format, method to communicate graphic images between computers). Typically, the relevant stakeholders within the firm develop a document that describes the standards strategy to which they have agreed. This document defines the goals to be attained by the firm (e.g. establish a preferred specification as the public standard, define a direction for product evolution, gather market intelligence) and guides the tactics to be pursued in forums which produce standards accredited by national or international bodies (e.g. Committee T1, ISO or ITU) and in industry workshops which produce implementation agreements (e.g. North American ISDN users' forum). The standards strategy document is reviewed and updated periodically.

By their very nature, the standards strategies of equipment suppliers deal with product and technology development and marketing activities within the firm, with public standard setting activities external to the firm, and with the links between the two. Thus, any structure which a firm puts in place to support the design and implementation of a standards strategy must include roles and linkages between groups and individuals both inside and outside the firm.

While the strategic importance of standards is established and progress has been made in understanding it, less is known about how to effectively design and implement standards strategies. A few researchers provide the basic rationale for investing in the development of standards strategies and describe the conditions for their success. They, however, say little about the structure required to design and implement standards strategies.

Most of the academic literature on standards is concerned with the economic analysis of network externalities and compatibility [16, 17, 18, 28, 29, 33, 34, 35, 37, 62], the role of standards as tools of competitive strategy [5, 6, 20, 22, 23, 25, 48, 49, 50], and the determinants of the use for, and supply of standards [7, 32].

The professional management literature on standards has been mainly concerned with the study of the organizations charged with the promulgation of standards [8, 68, 69], the mechanisms for standardization [30, 42, 63], the evolution of standardization activity [59], the characteristics of successful standards [52, 53] and the adaptation of government resources to augment and accelerate the process of standards-setting [45].

The lack of research in how to manage consistency between a firm's product development process and the external standards-setting environment is surprising given the impact of the evolution of standards on the future product direction and technology strategy of firms [48, 49, 50, 63]. The few known insights on how to manage standards strategies have been provided by practitioners and experienced consultants [14, 39, 67, 71].

In the next section, we describe the role of a standards manager and explain why standards management is difficult. In section III we review the coordination mechanisms available to manage the interdependences associated with standards management and argue that a system level view of standards management structures is needed. In section IV we describe our case data and how it was collected. In section V we identify five standards management structures from the data. In section VI we analyze these structures, identify the changes in structure which can be used to support changes in standards strategy, and identify the three basic building blocks of standards strategy. Finally, conclusions are presented in section VII.

II. STANDARDS MANAGEMENT

Products and services of firms operating in rapidly changing industries such as telecommunications, computing and electronics are highly interdependent with standards. Standards are often defined before introduction of the product(s) to which they are relevant. They may be written while the product is being developed or years before the market is ready [53]. This has a significant impact on the firm's activities leading to product conceptualization, high level design, design refinement, and implementation as well as on business strategy [9, 53, 60, 70]. For example, product design decisions that do not consider how related standards will evolve may result in high re-design costs and long development intervals.

The nature of the cooperative standards-setting process has important implications for competition. Few firms have the market power to set de facto standards. Most must accommodate choices made by other firms located in various different countries. This requires the firm to carefully manage standards management structures to ensure consistency between efforts to develop products and the evolution of public standards.

Firms maintain standards organizations staffed by permanent personnel and rotating staff from various product divisions. Rotating staff are often assigned because of their technical expertise and/or because the operations they manage are directly

affected by an evolving standard. Standards activities are usually overseen by an executive committee of representatives from key product divisions [24]. Executives rely on the standards organization to ensure that product development activities are consistent with the evolution of public standards.

Standards managers are technical specialists with expertise in how to plan and implement the firm's standards strategies. The abilities to recognize the value of external information, facilitate its use for commercial purposes, and influence the characteristics and timing of standards, are critical requirements for a standards manager.

Standards managers are responsible for the interaction between product development and public standards evolution on behalf of the firm. They are concerned with activities that lead to the design and implementation of standards strategies. These strategies provide up to date standards information which can be used to guide the development of proprietary technical devices or products within the firm. The only way to influence the characteristics of the standard is to participate in the standards-setting process. As a consequence standards managers are involved with complex and interdependent transactions that effect resource allocations, proprietary activities and institutional arrangements over a long period.

A standards strategy defines the goals to be attained from the firm's participation in the development of a set of public standards (e.g. establish a preferred specification as the public standard, gather market intelligence, identify a direction for product evolution). It is common practice to develop a standards strategy by first identifying goals and then decomposing these goals into activities and sub-activities (e.g. develop contribution, participate in standards meetings of particular standards bodies, stimulate feedback on the firm's contributions).

Standards Management is Difficult

Standards management is difficult for five main reasons. First, standards management requires collaboration among a large number of internal and external stakeholders. These stakeholders are organized around rapidly changing and highly decentralized networks. The focal concern of the standards strategy for which the standards manager is responsible is embedded in a variety of other worries of a large number of individuals and groups, many of which are external to the firm. Each group works independently, is capable of sophisticated problem solving and has different viewpoints on the standard and how to manage the respective strategy and tactics.

Second, complexity and uncertainty limit the usefulness of project management tools as a basis for standards management particularly since the individuals and groups involved can make significant decisions about work processes independently. In managing standards, firms commonly use milestone charts, Gantt charts, full wall scheduling, and the precedence network techniques - CPM and

PERT [13]. In situations with high uncertainty and many groups involved, work breakdown structures and schedule representations are complex and unstable.

Third, the implementation of a standards strategy requires that tasks be assigned to groups and individuals over long periods of time marked by intervals during which there is little or no standards activity within the firm. Activities and sub-activities are specified and assigned to individuals and groups deemed qualified to perform them with the expectation that the sum of these sub-activities will come together to attain the goals some time in the future. This can result in the undertaking of many disjointed activities that subtract from one another [21, 27, 46, 64, 65].

Fourth, standards are being set by many different organizations all over the world and the distinctions between computer and telecommunications technologies are blurring. This increases the costs of capturing and synthesizing standards related information and increases the need for standards specialists with broad up-to-date technical knowledge. For example, for many years the International Telecommunication Union (ITU) through its Consultative Committees, CCITT and CCIR, developed international telecommunications standards. Today, telecommunications standards are developed by the regional committee for North America known as T1, for Japan known as TTC and for Europe known as ETSI and by user groups. In addition other standards setting organizations such as ISO and IEC are moving closer to what was regarded as the domain of CCITT [70].

Fifth, existing organizational procedures make it difficult to put forward effective arguments to justify the investment in standards management activities and to improve the processes standards managers use to design and implement standards strategies. Standards managers negotiate their funding in terms of interim work-items (e.g. production of technical reports, consulting interventions) or tangible piece-meal activities (e.g. number of trips to standards forums, standards to be covered). The case for investment in standards strategies is often made in terms of minimizing the costs of producing solutions to sub problems at the expense of the costs of managing the complex system of interdependences inherent in a standards strategy over long periods.

III. INTERDEPENDENCE MANAGEMENT

A standards manager is responsible for the management of a complex set of interdependences between a number of individuals and groups each of which has its own priorities, decision making capabilities and perspectives, and over whom no one centre of authority has power. Although a wide variety of coordination mechanisms have been discussed in the management literature, there is little that is of real use to the standards manager.

Appendix 1 provides an overview of the coordination literature by classifying coordination mechanisms according to their key characteristics. These mechanisms are either specified at a very abstract level (e.g. establish rules, make

plans), not possible in standards management (e.g. standardize work processes, form self-contained task groups), presume a unity of purpose and perspective not relevant to the standards manager (e.g. adjust mutually), or presume a central authority with the power to control interdependences (e.g. form a matrix structure, appeal to a power hierarchy).

The central coordination problem of the standards manager is to have a clear and systemic view of the interdependences involved, and to use this systemic view to engage in the activities that are necessary for effective coordination (e.g. set goals, generate resources, allocate responsibilities, allocate tasks).

We argue that a view of the entire set of interdependences among the groups and individuals involved in ensuring consistency between product development and standards evolution can make standards management more effective. This perspective emphasizes the view that, implementation of a successful standards strategy must be driven by the congruent assembly of organizational components rather than by the characteristics of individual components within the firm [40, 44].

Individuals and groups will undertake activities which detract from one another unless the mental model that influences how they act incorporates an adequate representation of the structure that holds them together. Problem solving research holds that representational adequacy significantly effects performance and communication [47, 54, 57, 58].

A shared view of what needs to be created and managed in order to ensure consistency between product development and standards evolution will result in better group decision-making and communication. This is particularly true for standards strategies in which there is: a) a complex set of interdependences between individuals and groups involved, b) a high level of task uncertainty, i.e., uncertainty in whether or not a task is necessary, what its precedence relationships with other tasks are, and what its duration will be, and c) a significant level of decision making autonomy for these individuals and groups.

IV. SAMPLE AND DATA COLLECTION

In order to capture a broad array of interdependence issues we selected three equipment suppliers that differed with respect to size and technological domain. These firms included: i. a large multinational designer and manufacturer of a broad range of telecommunications equipment, ii. a small designer of graphics, video-text and teletext products for the broadcasting industry, and iii. a medium sized designer and manufacturer of real time board level computer systems for military and civilian use. All three firms generated more than 30% of total revenue through international sales and participated continuously in international standards-setting forums.

Nine standards managers in the three firms agreed to participate in the research study. Each was a technical expert who had at least five years experience in

managing standards and had been responsible for a particular standards interaction of interest for at least a year.

We excluded firms which were service providers or users quite deliberately. Service providers and user firms do have standards strategies. However, these standards strategies are not coupled to product development activities.

Data Collection

The data were comprised of the nine standards managers' perspectives on the history of how their firms ensured consistency between product development and the evolution of nine standards. The data were gathered using semi-structured interviews each of which lasted from two to four hours. Each interview had two parts. The first focused on acquiring general information on: i. the sequence of goals, and their timing, which were pursued by the standards manager on behalf of the firm, ii. the importance of the standard to the firm, iii. the firm's position on the standard being developed over time, iv. a time line of important events, v. the effectiveness of the standards group's activities, vi. the standards forums in which the firm had participated, and vii. the lessons learned from the firm's participation in standards-setting.

The second part of the interview focused on obtaining specific information on: i. the internal and external individuals and groups involved and the documents and texts they created, modified, and used as work objects to ensure consistency between product development and standards evolution; and ii. the associations between the individuals and groups involved and the work objects they shared to achieve each goal.

Data Used

Following each interview, the two researchers prepared detailed notes on the interviews independently. Six different goals for standards strategies were identified from these notes. Data was partitioned into a sequence defined by the goal of the standards strategy. A total of 19 instances of the six different goals were identified as shown in Table 1.

Seven instances of the goal C (Define a standards strategy for a specific product design) were identified. This is the goal most frequently identified in the sample. The two goals with the least number of instances in the sample were B (Define a standards strategy for the firm's product markets) and D (Attend standards meetings, develop contacts and produce reports). Both goals were identified only once in the sample of nine cases.

TABLE 1.

FREQUENCY IN WHICH SIX STANDARDS STRATEGY GOALS WERE IDENTIFIED IN THE NINE CASES IN THE SAMPLE

	GOAL OF STANDARDS STRATEGY					
	A	B	C	D	E	F
	Influence definition of a standard and/or time of its accreditation	Define a standards strategy for the firm's product markets	Define a standards strategy for a specific product design	Attend standards meetings, develop contacts, and produce reports	Establish a preferred definition as the standard	Recognize a problem or opportunity and communicate concerns
Frequency the goal was identified in the cases	4	1	7	1	4	2

Method

The models of standards management structure that support the six goals shown in Table 1 were derived using four steps. First, each researcher worked independently to develop diagrammatic representations of the structures corresponding to the 19 goal instances shown identified in the data. Second, the researchers worked together to compare their diagrams and arrive at a consensus view of the standards management structure of each of the 19 goal instances.

In the third step, each researcher worked independently and used the consensus views of the 19 goal instances to develop diagrammatic representations of the standards management structure for each of the six goals. For example, each researcher developed a model for goal E (Establish preferred definition as the standard) as the synthesis of four consensus views arrived at during the second step.

Finally, in step four, the researchers arrived at a consensus view of the six coordination structure diagrams that supported the goals identified in Table 1.

At each step of the process the standards management structure models were developed following [51]: relevant individuals, groups and work objects were identified; a dictionary was created which described the responsibilities of each individual and group; the associations between individuals or groups and work objects were identified; and the main characteristics of each individual or group, work object and association were identified. With these data, a work object based model of standards management structure was created. This process has been applied to examine the structure of technology based partnerships and ASIC design projects [3, 4].

V. STANDARDS MANAGEMENT STRUCTURES

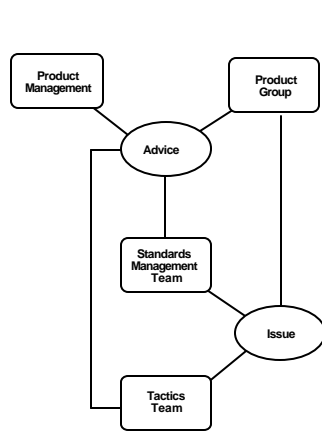
Figure 1 provides the models of standards management structure corresponding to the six goals identified in Table 1. Definitions for the organizational elements shown in Figure 1 are provided in Appendix 2. The models derived for goals D and F were essentially the same. Thus, we only show five models. Each standards management structure is represented by a configuration of individuals and groups (shown as squares), work objects they affect during the implementation of standards strategy (shown as circles) and the associations between individuals and groups and the work objects (shown as connecting lines).

Figure 1. Models of Standards Management Structure

Model 1 Supports Goals D and F

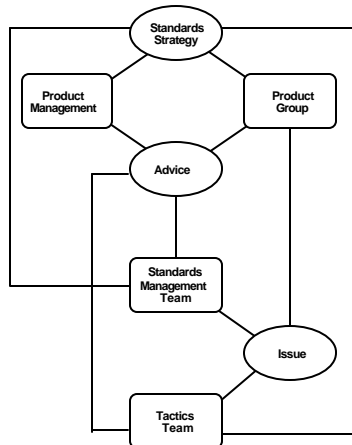
Attend standards meetings, develop contacts, and produce reports

Recognize a problem or opportunity and communicate concerns



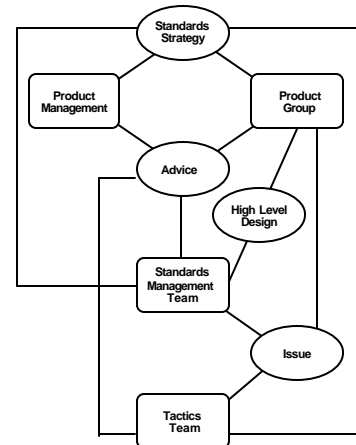
Model 2 Supports Goal B

Define a standards strategy for the firm's product markets



Model 3 Supports Goal C

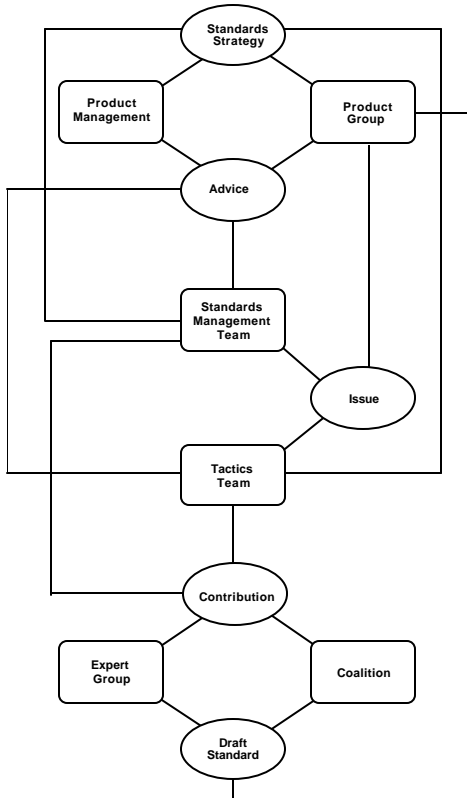
Define a standards strategy for a specific product design



Rounded squares refer to individuals and groups; the ovals to the objects they create, use and modify when ensuring consistency between product development and standards evolution; and the arcs denote associations between individuals or groups and the objects they affect

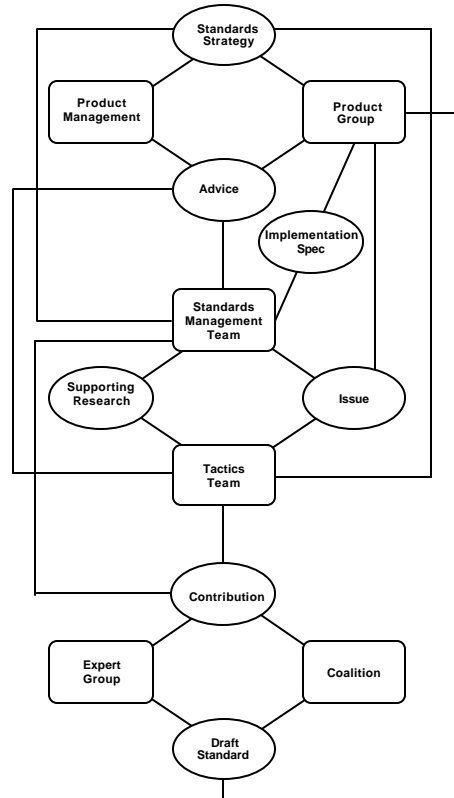
Model 4 Supports Goal A

Influence definition of a standard and/or time of its accreditation



Model 5 Supports Goal E

Establish a preferred definition as the standard



In Model 1 information on external events is captured and transformed into recommendations to act by the Tactics Team and the Standards Management Team. The work object containing these recommendations is labeled "Advice" in Appendix 2. This model supports two strategies: D (Attend standards meetings, develop contacts, and produce reports) and F (Recognize a problem or opportunity and communicate concerns).

To support goals D and F the standards management structure used to ensure consistency between product development and standards evolution is one where the Tactics Team, Standards Management Team, Product Management and Product Group interact to evolve the information in the two work objects, "Issue" and "Advice". Synchronization of the information evolution in these two work objects is what matters.

The interdependences between the individuals and groups involved in a standards strategy is specified through their associations with the work objects they create, use, modify and discard. Note that the models of standards management structure in Figure 1 do not require that things happen in a given order. For example, the scenario whereby a recommendation to act is made first and the information on events that test this recommendation is gathered afterwards is supported by Model

1 as well as the scenario whereby previously unknown information is discovered and a recommendation to act is issued subsequently.

In Models 2 and 3 information on external events and proposals for action are transformed into a standards strategy agreed to by all the internal stakeholders. The difference between the two models is that a high level view of a product design (labeled "High Level Design" in Figure 1) anchors the development of a standards strategy in Model 3 but not in Model 2.

Model 2 supports goal B (Define a standards strategy for the firm's product market) while Model 3 supports goal C (Define a standards strategy for a specific product design). In both Model 2 and Model 3 the output is a standards strategy that has been assimilated and agreed to by the relevant internal stakeholders. The strategy specifies the forums and topics that will be covered during the interaction, the individual and groups in the firm that will participate in the interaction, the expert committees of which representatives of the firm will be a part, the specific goals of the strategy, a high level view of the tactics to be pursued, the success criteria, the perceived risks involved, and a contingency plan.

The standards management structure that supports goal B has two characteristics. First, the Standards Management Team, Product Group and Product Management channel their efforts around "Standards Strategy" and "Advice". Second, the Standards Management Team, Tactics Team and Product Group channel their efforts around "Issue". Groups within the firm maintain consistency in the evolution of the information in "Standards Strategy" and "Issue" while negotiating around "Advice".

The arrival at an agreement on a standards strategy and the capture and interpretation of information on external and internal events guides how groups and individuals work together in Model 2.

The standards management structure that supports goal C shares the same two characteristics as that for goal B. In addition, the Product Group and the Standards Team must guide their efforts around the development of a "High Level Design" of the products involved.

The development of a high level product design, arrival at an agreement on a standards strategy, and the capture and interpretation of information on external and internal events guide how individuals and groups work together in Model 3.

Models 4 and 5 represent standards management structures that support the development of "Draft Standard", a work object external to the firm. The goals for Models 4 and 5 can be distinguished by the firm's incentive to promote a preferred specification as the standard. Model 4 supports the development of a standard, without regard to what the standard is. In Model 5 the firm pushes a preferred specification for the standard. This preferred specification is interdependent with the details of the implementation of a particular product design. To push a preferred

definition of the standard the firm must invest time and effort to acquire the required technical and market knowledge to support a position. As a consequence two work objects, "Implementation Spec" and "Supporting Research", appear in Model 5 but not in Model 4.

In both Models 4 and 5 decisions on standards strategy arrived at by internal individual and groups are transformed into contributions released to the external standards-setting environment to affect the development of a standard. Both require decisions as to the nature and amount of information which should be released to the standards-setting forums to support the standards strategy.

Model 4 supports goal A (Influence definition of a standard and/or time of its accreditation). The plan to achieve goal A seeks to affect the timing and characteristics of a standard and to incorporate the standard into the firm's product designs. It supports the timely adoption of the standard by the product groups. In Model 4, the firm is committed to the adoption of the definition of the standard that results from standards-making.

Model 5 supports goal E (Establish a preferred definition as the standard). Typically, the characteristics of the preferred definition of the standard is heavily influenced by a particular implementation of a design by the product group. Model 5 supports setting a public standard that provides the firm with a competitive advantage via the implementation of the desired product design.

Use of the Models as Management Tools

The models shown in Figure 1 can be detailed further by describing the attributes of the elements in the models. For example, we can use a verb phrase taken directly from the description of the coordinated situation to name each association. The verb phrase can describe the action directed from an individual or group to a work object (e.g. Tactics Team uses Standards Strategy, Product Group develops Standards Strategy), communication about a work object (e.g. Standards Management Team disseminates "High Level Design", Standards Manager communicates "High Level Design"), ownership of a work object (e.g. Product Management controls "High Level Design"), or satisfaction of some condition specified by the work object (e.g. Product Group follows "High Level Design"). For the purpose of presenting the results in a simple fashion we have chosen not to label the associations or describe the attributes and activities of the individuals and groups shown in Figure 1.

VI. DISCUSSION OF RESULTS

The overall objective of this paper is to facilitate the management by equipment suppliers of consistency between their product development efforts and the evolution of public standards. To do so we specify structures which make visible the role of a firm's standards management and its interdependences with other groups, internal and external to the firm. We examined standards managers' perceptions of

nine cases and identified 19 instances of six different standard strategies goals. Based on these data we developed five system level models for standards management structures that support the strategies leading to the six goals. Each standards management structure is specified by a configuration of a set of individuals and groups, the work objects they create, use and modify, and the associations between them.

Distinguishing between Standards Management Structures

Table 2 shows that the five models in Figure 1 can be distinguished on the basis of whether or not a specific design or a contribution are part of the standards management structure. Categorized in this way the five models fall into three groups. Models 1 and 2 support information gathering by the firm with no commitments as to the directions that either product development or standards should take. Model 3 supports participation by the firm in the standards setting process with a commitment to use an evolving standard in the firm's product development but without a commitment to a particular standard. Models 4 and 5 support a commitment by the firm to influence the evolution of the standard.

TABLE 2.

MODELS CLASSIFIED ACCORDING TO WHETHER OR NOT A PARTICULAR PRODUCT DESIGN OR CONTRIBUTIONS ARE PART OF A STANDARDS MANAGEMENT STRUCTURE

		Particular Product Design is Part of Standards Management Structure	
		NO	YES
Contributions are Part of Standards Management Structure	NO	Models 1 & 2	Model 3
	YES	Model 4	Model 5

In Models 1 and 2, the standards manager is not concerned with the evolution of an existing design or the development and introduction of contributions. The standards manager is concerned with the recognition, assimilation and communication of information. The standards manager is responsible for selecting the forums and topics to be covered; identifying the individuals to be part of the standards team;

identifying the recipients of the information produced by the standards team; and organizing the search for external information.

In Model 3, the standards manager is concerned with anchoring the recognition, assimilation and communication of information around the evolution of an existing high level product design. The standards manager is responsible for the development and assimilation by the firm of a standards strategy interdependent with a particular product design.

In Models 4 and 5 the development of contributions and the release of information by the firm's Tactics Team into the standards-setting infrastructure concern the standards manager. Unlike Models 1, 2 and 3, the standards manager in Models 4 and 5 is responsible for ensuring consistency between contribution development and dissemination and standards development. Coalitions are formed to support contributions in order to influence the development of the standard. In Model 4, however, the evolution of a product design specification is not part of the standards management structure. A particular product design specification is an important component in Model 5.

In Model 4, the standards strategy is to adopt the technical specification for the standard, whatever it turns out to be, while in Model 5 this is not the case. In Model 5, the product group continuously compares the relative merits of their preferred solution with the technical solution evolving for the standard and may decide not to adopt the standard if it finds it inconsistent with their preferred solution.

Change in Goals

Changes in standards strategy goals lead to changes in standards management structures. What are the changes in structure to which the standards manager must attend when there is a change in goals?

Changes in structure can be considered as a set of changes to an existing configuration of individuals and groups, the work objects that they create, use and modify and the associations between them.

A configuration of associations such as those shown in Figure 1 can be changed by: i. adding new individuals, groups and work objects, ii. associating individuals and groups with work objects unlinked previously, iii. changing the responsibilities, attributes and activities of existing individuals and groups, iv. eliminating from consideration individuals, groups or work objects, v. disassociating individuals or groups from work objects previously linked, and vi. changing the parameters of associations.

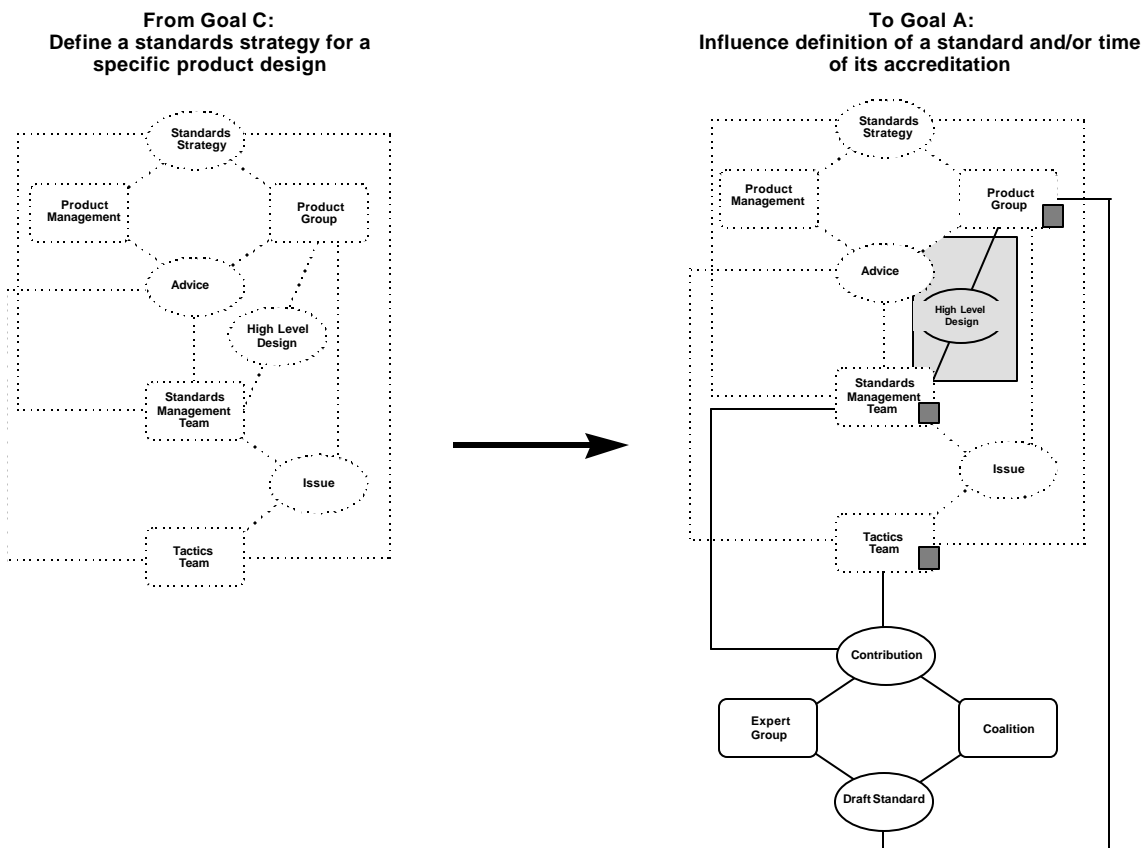
For example, Figure 2 illustrates the four changes required to move from goal C (Define a standards strategy for a specific product design) to goal A (Influence definition of a standard and/or time of its accreditation). It was arrived at by comparing Models 3 and 4. First, two new groups (Expert Group and Coalition),

two new work objects ("Contribution" and "Draft Standard"), and their four associations must be added. Second, three new associations (between Tactics Team and "Contribution", between Product Group and "Draft Standard", and between Standards Management Team and "Contribution") must be added.

Third, the product design is no longer part of the standards management structure and it can be eliminated from consideration in the analysis. This does not mean that the product design is no longer important. It does mean that the firm is already committed to adopting the new standard. Thus, the definition of the product design no longer constrains the definition of the public standard in the context of goal A.

Fourth, the responsibilities and activities of the Standards Management Team, Tactics Team, and Product Group will change. This is represented by the highlighted squares that protrude from the individuals and groups shown in Figure 2.

Figure 2. Changes in Structure Required to Support Changing from Goal C to Goal A



Building Blocks

We identified three modules that can be used as basic building blocks in the creation of the five standards management structure models developed above.

The first building block, which we refer to as *Information Management*, is the configuration of Standards Management Team and Tactics Team, with the three work objects "Issue", "Advice" and "Supporting Research". This module is found with slight variations in all five coordination structure models shown in Figure 1. In each case, the two groups take on responsibility for recognizing issues that are important to the firm, for producing recommendations regarding what to do and for making use of this information to further the ends of the firm in standards-setting. The *Information Management* module increases the standards team's absorptive capacity. Cohen and Levinthal [10] define absorptive capacity as the ability to recognize the value of new, external information, assimilate it and apply it to commercial ends. In models 4 and 5, *Information Management* is responsible for generating information for possible release into the standards-setting environment.

The second module, which we name *Commercial Exploitation*, is the configuration of Product Management, Product Group and Standards Management Team, which

jointly produce and use "Standards Strategy". This module resolves the tension amongst the technical refinements that the design community would like, the market position that the product management would like, and what the standards management team believes is achievable. A specific product concept (e.g. "High Level Design" in model 3 and an "Implementation Specification" in model 5) sometimes constrains the resolution of the tension between what the standards management team thinks is achievable and what the product management and/or the product group would like.

The third module is found only in standards management structures models 4 and 5. It is the configuration of Expert Group, Coalition and Standards Management Team and the two work objects "Contribution" and "Standard". It can be called *Standard Development*, and represents both the process and the output of standardization. It is consistent with the view set forth in previous studies that a standard is best thought of as a coordinating mechanism around non-proprietary knowledge that organizes and directs technological change [48, 49].

Model 1 shown in Figure 1 is principally the *Information Management* module. Models 2 and 3 are both combinations of *Information Management* and *Commercial Exploitation*. Models 4 and 5 are combinations of all three modules: *Information Management*, *Commercial Exploitation* and *Standard Development*. Note that the Standards Management Team led by the standards manager plays a role in all three modules. One can infer that how well standards managers contribute to the consistency between the firm's product development efforts and standards evolution depends on how well they can manage the associations between these three modules.

VII. CONCLUSIONS

The development of commercially viable products and services in industries such as telecommunications, computing and electronics require the design and implementation of standards strategies. These strategies are directed at ensuring that design and development activities remain consistent with activities leading to the establishment of public standards. We have specified standards management structures that support different standards strategy goals.

The models we have developed provide the standards manager with system level visibility, a stable perspective, and ease of understanding of a complex situation.

Standards managers can build standards management structures to achieve the firm's goals as combinations of modules such as: *Information Management*, *Commercial Exploitation* and *Standards Development*. This holds the promise of developing a pattern language for managing standards analogous to those developed in architecture and currently being worked on intensively for software development. A pattern language can assist standards specialists in the management of the firm's direct interface with the standards-setting environment and the integration of the firm's standards strategies with design and development,

product management, systems groups, and marketing in much the same way as those that assist architects to design towns, neighborhoods, buildings and houses [2] and software designers to develop object-oriented programs [26].

The approach introduced in this paper makes visible the structure of the interdependences required to implement a standards strategy and how the elements within the structure are related operationally. Visibility improves the sharing and evaluation of information. It facilitates overcoming the barriers which inhibit the building of new knowledge by groups and individuals with different specialist skills [15].

System level visibility is particularly important to the standards manager who must acquire resources for standards activities from a variety of stakeholders all of whom have other major concerns and few of whom readily understand the complexity of standards management. The standards manager can use the models to encourage the individuals and groups involved in a standards strategy to share information and subject it to criticism much more readily than textual representations. The development of the models for standards management structure requires answers to very specific questions pertaining to how groups will work together to achieve standards related goals. The models examined in this paper make visible answers to questions such as: who are the internal and external individuals and groups involved? what are their responsibilities? what are the work objects these individuals create, use and modify? what are the associations? what guides how individuals and groups work together? what changes are necessary to support a change in goals?

Individuals can discuss in specific terms their interdependences and the nature of the work objects for which they are jointly responsible without communicating at cross purposes as is all too commonly done in complex situations such as standards management. The models facilitate the management of part-whole relationships by making visible information on a whole system and on its parts. The models make system level patterns easy to identify while at the same time explicitly presenting the nature of specific parts such as the associations between a group and a work object.

There is an extensive research literature on coordination and coordination mechanisms. However, the results of this literature are not widely used by managers [1]. The coordination mechanisms studied in the literature focus on interdependences between activities of stable organizational entities such as the one between purchasing and manufacturing. A stable perspective to manage coordination in complex, dynamic and uncertain situations is difficult when interdependences of activities is the focus of inquiry. The models developed in this paper provide a stable perspective since they are based on the identification and utilization of work objects which persist in the problem domain. Each model provides a stable framework that can be used from problem analysis, through design, to implementation of standards management structures.

REFERENCES

- [1] P.S. Adler, Interdepartmental Interdependence and Coordination: The Case of Design/Manufacturing Interface, *Organization Science* (forthcoming).
- [2] C. Alexander, S. Ishikawa and M. Silverstein, *A pattern language* (Oxford University Press, New York, 1977).
- [3] A.J. Bailetti, and J.R. Callahan, The Coordination Structure of International Collaborative Technology Arrangements, *R&D Management*, 23, 2 (1993) 129-146.
- [4] A.J. Bailetti, J.R. Callahan and P. DiPietro, A Coordination Structure Approach to the Management of Projects, *IEEE Transactions on Engineering Management*, November (1994).
- [5] S.M. Besen and L.J. Johnson, *Compatibility Standards, Competition, and Innovation in the Broadcasting Industry* (Rand Corporation, Santa Monica, California, 1986).
- [6] S.M. Besen and G. Saloner, The Economics of Telecommunications Standards, in R. W. Crandall and K. Flamm (Eds.), *Changing the Rules: Technological Change, International Competition and Regulation in Communications* (The Brookings Institution Washington DC, 1989) 177-220.
- [7] D. Bottaro, *Analysis of Factors Affecting the Demand for and Supply of Voluntary Consensus Standards*, Working Paper MIT-EL-82-003WP (MIT Energy Laboratory, Boston, MA, 1981).
- [8] C.F. Cargill, Standards and Standards Organizations, *Communications Standard Management* 61-10-10 (1989) 1-15.
- [9] C.F. Cargill, *Information Technology Standardization: Theory, Process and Organizations* (Digital Press, Bedford, Massachusetts, 1989).
- [10] W.M. Cohen and D.A. Levinthal, Absorptive Capacity: A New Perspective on Learning and Innovation, *Administrative Science Quarterly* 35 (1990) 128-152.
- [11] K.G. Crowston, *Towards a Coordination Cookbook: Recipes for Multi-agent Action*, Ph.D. Thesis (Alfred P. Sloan School of Management, Massachusetts Institute of Technology, Boston, 1991).
- [12] R.L. Daft and R.H. Lengel, Organizational Information Requirements, Media Richness and Structural Design, *Management Science* 32 (1986) 554-571.

- [13] K.A. Cori, Fundamentals of Master Scheduling for the Project Manager, *Project Management Journal*, June 1985.
- [14] B.R. DeMaeyer, External Standards Activities at a Government Regulated Company, in Robert Toth (Ed.), *Standards Management* (American National Standards Institute, New York, 1990) 265-280.
- [15] D. Dougherty, Interpretive Barriers to Successful Product Innovation in Large Firms, *Organization Science* 3, 2 (1992) 179-202.
- [16] J. Farrell and G. Saloner, Standardization, Compatibility, and Innovation, *RAND Journal of Economics* 16 (1985) 70-83.
- [17] J. Farrell and G. Saloner, Installed Base and Compatibility: Innovation, Product Preannouncement, and Predation, *American Economic Review* 76 (1986) 940-955.
- [18] J. Farrell and G. Saloner, Coordination Through Committees and Markets, *RAND Journal of Economics*, 19 (1988) 235-252.
- [19] J. Galbraith, *Designing Complex Organizations* (Addison-Wesley, Reading, MA, 1973).
- [20] P.C. Grindley, Standards and the Open Systems Revolution in the Computer Industry, in T. Khalil and B. Bayraktar (Eds.), *Management of Technology II* (Industrial Engineering and Management Press, Norcross, Georgia, 1990) 993-1003.
- [21] J.R. Hackman, *A Normative Model of Work Team Effectiveness*, Research Program on Group Effectiveness, Technical Report #2 (Yale School of Organization and Management, New Haven, Conn., 1984).
- [22] S.Hariharan and C.K. Prahalad, Technological Compatibility Choices in High-Tech Products: Implications for Corporate Strategy, in L. Gomez-Mejia and M. W. Lawless (Eds.), *Proceedings: Managing the High Technology Firm Conference*, (University of Colorado at Boulder, Colorado, 1988) 403-409.
- [23] D. Hemenway, *Industry Wide Voluntary Product Standards* (Ballinger, Cambridge, MA, 1975).
- [24] D.E. Henise, Staffing and Professional Development, in Robert Toth (Ed.), *Standards Management* (American National Standards Institute, New York, 1990) 53-70.

- [25] G.C. Hufbauer, The Impact of National Characteristics and Technology on the Commodity Composition of Trade in Manufactured Goods, in R. Vernon (Ed.), *The Technology Factor in International Trade* (Columbia University Press, New York, 1970).
- [26] R.E. Johnson, Documenting frameworks using patterns, in A. Paepcke (Ed.), *OOPSLA '92 Conference Proceedings* (The Association of Computing Machinery, New York, 1992) 63-76.
- [27] R. Kanter, *The Change Masters* (Simon and Schuster, New York, 1983).
- [28] M. Katz and C. Shapiro, Network Externalities, Competition and Compatibility, *American Economic Review* 75 (1985) 424-440.
- [29] M. Katz and C. Shapiro, Technology Adoption in the Presence of Network Externalities, *Journal of Political Economy* 94 (1986) 822-841.
- [30] I. Knight, Telecommunications Standard Development, *Telecommunications* January (1991) 38-42.
- [31] P. Lawrence and J. Lorsch, *Organization and Environment* (Division of Research, Harvard Business School, Boston, 1967).
- [32] D. J. Lecraw, Some Economic Effects of Standards, *Applied Economics* 16 (1984) 507-522.
- [33] S.J. Liebowitz and S.E. Margolis, The Fable of the Keys, *Journal of Law and Economics* XXXIII (1990) 1-25.
- [34] S.J. Liebowitz and S.E. Margolis, *Market Processes and the Selection of Standards* (Working Paper, School of Business Administration, University of Texas-Dallas, 1992).
- [35] S.J. Liebowitz and S.E. Margolis, *Understanding Network Externalities*, Working Paper (School of Business Administration, University of Texas-Dallas, 1992).
- [36] J.G. March and H.A. Simon *Organizations* (John Wiley & Sons, New York, 1958).
- [37] C. Matutes and P. Regibeau, Mix and match: Product Compatibility without Network Externalities, *RAND Journal of Economics* 19 (1988) 221-234.
- [38] J.E. McCann and J.R. Galbraith, Interdepartmental Relations, in P. Nystrom and W. Starbuck (Eds.), *Handbook of Organizational Design*, Vol. 2 (Oxford University Press, New York, 1981) 60-84.

- [39] T.J. McNamara, Company Participation in External Standards Activities, in Robert Toth (Ed.), *Standards Management* (American National Standards Institute, New York, 1990) 249-264.
- [40] C. Meyer, *Fast Cycle Time: How to align purpose, strategy, and structure for speed* (The Free Press, New York, 1992).
- [41] H. Mintzberg, *Mintzberg on Management* (The Free Press, New York, 1989).
- [42] J. Moad, The Standards Process Breaks Down, *Datamation* September (1990) 24-32.
- [43] D.A. Nadler and M.L. Tushman, Strategic Linking: Designing Formal Coordination Mechanisms, in M.L. Tushman, C.O. O'Reilly and D.A. Nadler (Eds.), *The Management of Organizations: Strategies, Tactics, Analyses* (Harper & Row, New York, 1989) 137-153.
- [44] D.A. Nadler and M.L. Tushman, Designing Organizations That Have Good Fit: A framework for understanding new architectures, in D.A. Nadler, M.S. Gerstein, R.B. Shaw and associates (Eds.), *Organizational Architecture: Designs for Changing Organizations* (Jossey-Bass, San Francisco, 1992) 39-56.
- [45] G.R. Nuss and A.R. Hoffman, Performance Criteria and Standards Development for an Emerging Technology, *Proceedings of the 16th Intersociety Energy Conversion Engineering Conference* (American Society of Mechanical Engineers, New York, 1981) 2227-2232.
- [46] T. Peters and R. Waterman, *In Search of Excellence: Lessons from America's Best-Run Companies* (Harper and Row, New York, 1982).
- [47] Z.W. Pylyshyn, *Computation and Cognition* (MIT Press, Boston, MA, 1984).
- [48] N.M. Reddy, Voluntary Product Standards: Linking Technical Criteria to Marketing Decisions, *IEEE Transactions on Engineering Management* 4 (1987) 236-243.
- [49] N.M. Reddy, Technology, Standards and Markets: A Market Institutionalization Perspective, in H. L. Gabel (Ed.) *Product Standardization and Competitive Strategy* (North Holland, Amsterdam, 1987) 47-66.
- [50] N.M. Reddy, S.G. Cort and D.R. Lambert, Industry wide technical product standards, *R&D Management* 19 (1989) 13-25.
- [51] J. Rumbaugh, M. Blaha, W. Premerlani, F. Eddy and W. Lorensen, *Object-Oriented Modeling and Design* (Prentice Hall, Englewood Cliffs, NJ, 1991).

- [52] M.H. Sherif and D.K. Sparrel, The Role of Standards in the Introduction of Innovations in Telecommunications, in T. Khalil and B. Bayraktar (Eds.), *Management of Technology II* (Industrial Engineering and Management Press, Norcross, Georgia, 1990) 1013-1024.
- [53] M.H. Sherif and D.K. Sparrel, Standards and Innovation in Telecommunications, *IEEE Communications Magazine*, July (1992) 22-29.
- [54] H.A. Simon, *The New Science of Management Decision* (Prentice-Hall, Englewood Cliffs, NJ, 1977).
- [55] B. Singh, *Interconnected Roles (IR): A Coordination Model*, Microelectronics and Computer Technology Corporation Technical Report Number CT-084-92.
- [56] B. Singh and G.L. Rein, *Role Interaction Nets (RINs): A Process Description Formalism*, Microelectronics and Computer Technology Corporation Technical Report Number CT-083-92.
- [57] G.F. Smith, Defining Managerial Problems: A Framework for Prescriptive Theorizing, *Management Science* 35 (1989) 963-981.
- [58] G.F. Smith, Representational Effects on the Solving of an Unstructured Decision Problem, *IEEE Transactions on Systems, Man, and Cybernetics* 19 (1989) 1083-1090.
- [59] C.D. Sullivan, *Standards and Standardization* (Marcel Dekker, New York, 1983).
- [60] S. Temple, *A Revolution in European Telecommunications Standard Making* (European Telecommunications Standards Institute, Hull, UK, 1991).
- [61] J.D. Thompson, *Organizations in Action: Social Science Bases of Administrative Theory* (McGraw-Hill, New York, 1967).
- [62] J. Tirole, *The Theory of Industrial Organization* (MIT Press, Cambridge, MA, 1988).
- [63] R. Toth, *Standards Management* (American National Standards Institute, New York, 1990) 249-264.
- [64] M.L. Tushman and E. Romanelli, Organizational evolution: A metamorphosis model of convergence and reorientation, in Barry M. Staw and Larry L. Cummings (Eds.), *Research in Organizational Behavior* 7 (JAI Press, Greenwich, CT, 1985) 171-222

- [65] A.H. Van de Ven, Central Problems in the Management of Innovation, *Management Science* 32 (1986) 590-607.
- [66] A.H. Van de Ven, A. Delbecq and R. Koenig, Determinants of Coordination Modes within Organizations, *American Sociological Review* 41 (1976) 322-337.
- [67] M. Varrassi, Weighing the Costs and Benefits of Standards Involvement, *Communications Standards Management* 61-10-35 (1989) 1-4.
- [68] M. Varrassi, National and International Standards Organizations: A Primer, *Communications Standards Management* 61-10-25 (1989) 1-15.
- [69] M. Varrassi, The Making of a Standard, *Communications Standards Management* 61-10-15 (1989) 1-6.
- [70] G. Wallenstein, *Setting Global Telecommunications Standards: The Stakes, the Players & the Process* (Artech House, Norwood MA, 1990).
- [71] J.L. Wheeler, Managing the Organization's Participation in Industry Standards Development, *Communications Standards Management* (1989) 1-16.

APPENDIX 1

TYPES OF COORDINATION MECHANISMS IDENTIFIED IN THE MANAGEMENT LITERATURE AND KEY DISTINGUISHING CHARACTERISTICS

Key Characteristic	Types of Coordination Mechanisms
tasks are set out in detail before execution or not	<p>March & Simon [36]</p> <ul style="list-style-type: none"> • programmed • feedback <p>Van de Ven, Delbecq & Koenig [66]</p> <ul style="list-style-type: none"> • impersonal • feedback through personal and group modes
workflow interdependence between two units	<p>Thompson [61]</p> <ul style="list-style-type: none"> • rules and routines for pooled interdependence • schedules and plans for sequential interdependence • mutual adjustment for reciprocal interdependence
occupants of the role responsible for coordination	<p>Lawrence & Lorsch [31]</p> <ul style="list-style-type: none"> • integrative subsystems • specialists in integration • integrating teams <p>Van de Ven, Delbecq & Koenig [66]</p> <ul style="list-style-type: none"> • personal coordination mode • group coordination mode

information processing capacity

Galbraith [19]

- rules, programs and procedures
- organizational hierarchy
- common understanding of targets and goals
- creation of slack resources
- self-contained task groups
- information systems
- lateral linkages

Daft & Lengel [12]

- group meetings
- integrators
- direct contact
- plans
- special reports
- formal information systems
- rules and regulations

Nadler & Tushman [43]

- hierarchy
- liaison role
- cross-unit groups focused on an issue
- integrator role or department
- matrix structure

not specified (presumably characteristic is related to author's conceptualization of organizational structure)

Mintzberg [41]

- mutual adjustment
- direct supervision
- standardization of work processes
- standardization of outputs
- standardization of skills and knowledge
- standardization of norms

contingency and conflict resolution requirements

McCann & Galbraith [38]

- rules
- mutual adjustment
- hierarchy
- matrix structure

interaction of elements in layered processes underlying coordination

Crowston [11]

- interdependences between tasks
- interdependences between task and object
- interdependences between objects

linkages between roles that underlie organizational processes

Singh [55] and Singh & Rein [56]

- hierarchical composition
- levels of operation
- involvement
- superimposition

APPENDIX 2

INDIVIDUALS OR GROUPS AND OBJECTS IDENTIFIED IN THE NINE CASES EXAMINED

INDIVIDUAL OR GROUP	DEFINITION	GOAL BEING PURSUED WHEN IDENTIFIED*
Coalition	temporary alliance comprising customers, suppliers and representatives responsible for pushing and defining the standard	A, E
Expert Group	lowest administrative unit of standards-setting organization responsible for defining a standard	A, E
Product Group	group comprising designers, marketeers, planners and manufacturers responsible for incorporating new knowledge about standards into product designs	A, B, C, D, E, F
Product Management	executive(s) responsible for revenues of family of products some or all of which are interdependent with the standard	A, B, C, D, E, F
Tactics Team	standards specialist(s) responsible for the formulation and execution of tactics in one or more standards forums	A, B, C, D, E, F
Standards Management Team	group, led by the standards manager, responsible for the formulation of the firm's strategy for a particular standard and for creating and maintaining the coordination structure required to support it	A, B, C, D, E, F
WORK OBJECT CREATED, USED OR MODIFIED DURING IMPLEMENTATION OF STANDARDS STRATEGY		
Contribution	text and graphics conveying specific technical proposal to standards Expert Group	A, E

High Level Design	text and graphics describing, at a high level, the technical structure of a product	C
Implementation Spec	statements in formal design language and text specifying how the design of a product is to be implemented	E
Standards Strategy	text that describes the goals which drives the activities of the firm's standards experts and provides direction to product development and marketing activities	A, B, C, E
Advice	text recommending what standards related actions the firm should undertake	A, B, C, D, E, F
Issue	text providing information on important external events (signals, decisions, information)	A, B, C, D, E, F
Draft Standard	text describing the characteristics of the standard agreed to by actors using a process set by a standards-setting organization	A, E
Supporting Research	technical and market knowledge providing support and credibility for the Contribution being pushed by the firm	E

* Letters refer to the goals in Table 1

Goal A: Influence definition of a standard/and or time of its accreditation

Goal B: Define a standards strategy for the firm's product markets

Goal C: Define a standards strategy for a specific product design

Goal D: Attend standards meetings, develop contacts, and produce reports

Goal E: Establish a preferred definition as the standard

Goal F: Recognize a problem or opportunity and communicate concerns