

**Positive and Prescriptive Conceptions of  
Construction Network Organizations  
- A Rational Systems Approach**

by

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## **I. Introduction**

The construction industry is characterized by specialist firms that organize contractually on a project-by-project basis through a bidding mechanism. Conventional approaches such as Transaction Cost economics fail to explain this organization form. As construction firms operate in uncertain and complex conditions, standard make/buy conceptions of firm boundaries suggest that construction should be organized as a single hierarchy. This can be explained only by conflicting dimensions of current theory. A new concept — the network organization — is proposed as an analytical tool to model construction organization. The network form explains not only the existence of construction subcontracting relationships but also the frictional environment of production in the construction industry. Network organizations are fertile, positive models of construction organization. Particular emphasis in this paper is given to modeling interdependence between members of the network organization. Drawing from production theory, it is proposed that interdependencies between firms can be modeled and predicted. This lays the groundwork for a normative theory of boundary setting within construction organizations allowing increased cooperation and information sharing, but does not prescribe a stable governance mechanism to achieve this.

## **II. Overview of Construction Environment and Project Organization**

The construction industry<sup>1</sup> specializes in design and manufacture of goods for the built environment. Construction projects are characterized by their uniqueness and by their temporary nature. Projects begin when an organization has a need for a constructed facility and end when the completed facility is turned over to that organization (typically called the owner in the construction parlance). The construction industry splits up the

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<sup>1</sup>The term construction can mean both the industry and the physical process of manufacture; it is conventional to define a construction firm as an organization specializing in production operations at the physical location of the facility (also known as the construction site).

project into a number of sequential phases: concept and feasibility studies, engineering and design, procurement, construction, start-up and implementation, and operation or utilization (Barrie and Paulson 1992). Feasibility and design are typically the responsibility of specialist design firms that bring knowledge determined by the needs of the unique project. When design is near completion, the owner contracts with a construction firm to build the project as designed. The construction firm then assembles (procures) a collection of specialist firms to build the project. When constructed, the facility undergoes testing and start-up; if satisfactory, the facility is turned over to the owner for use.

Responsibility for each of the phases of construction falls to one or several firms within the industry. In general, the industry has a strong division between firms specializing in design and those specializing in construction. This division is characterized by strong professional and cultural norms; architects and engineers are professionals and work in offices; construction personnel are craftsmen and managers who work in the field. This division is somewhat blurred as there are firms that specialize in both design and building, and all construction firms are responsible for the engineering of temporary works (such as scaffolding) that support the construction process. Designers will also specify use of pre-engineered products (such as fans) that are designed by firms specializing in the manufacturing of goods for construction. And it is a current trend to include “constructability” considerations in the design, where construction firms are contracted with early in the design stage to provide specialized knowledge of construction technique. Despite blurring around the edges, the organizational and technical separation between design and construction exists within the construction industry.

This paper focuses on the organization structure of firms carrying out the construction of a project. The typical model of construction project organization is that of a general contractor that is responsible for completion of the entire project and which

procures the services of specialized firms as needed. These specialized firms are subcontractors who carry out work on-site, and suppliers who manufacture products off-site and deliver them to the site as needed. The governance structure between these firms is contractual; the general contractor will hold the contracts of subcontractors, while both the subcontractors and the general contractor will hold contracts with the suppliers for delivery of materials. Whether the general contractor or the subcontractor holds the contract with the supplier will vary due to financial wherewithal, specialization of the material or component needed, and convention. Contractual form varies from cost-plus contracts to fixed-price contracts; the majority of contracts are variations on the fixed price format. Contracts typically call for delivery of goods and services on an agreed upon date, with penalty clauses for delay to the activity of other firms. Such contracts also attempt to shift risk away from the general contractor to subcontractors and suppliers.

### **III. Boundary Setting in Construction — A Positive Perspective**

Constructed facilities are unique artifacts that require some firms to make specific investments in customized products for each project. Beyond such specific investments, the construction process or task environment is characterized by complexity, stochasticity, and uncertainty. Complexity arises from the need to install a number of overlapping, heterogeneous systems in a confined space, implying a need for communicating the location of installed systems and the need for a strict ordering of construction processes; this requires close coordination and scheduling of the activities of firms working concurrently and that share resources such as space, time on cranes, etc. Construction activities are stochastic as the time required to complete activities varies from the predicted or allotted time, making coordination and scheduling more difficult. Construction is also subject to uncertainties (risks) in the environment, such as weather, unforeseen soil conditions, labor disputes, bankruptcy of firms, etc., which disrupts

progress. In this environment, construction firms carry out their work at times designated by a master project schedule that is created by the general contractor. As time to complete activities varies, the schedule is constantly updated to reflect the reality of site progress.

The characteristics of the construction — uniqueness requiring specificity of investment, and a task environment characterized by complexity, stochasticity, and uncertainty — imply that firms entering a project organization invest in materials and learning making it difficult for a general contractor to find replacements on short notice. Nor is it easy for subcontractors to move immediately to a different project and make use of resources allocated for the initial project. Once in a project structure under a contract, firms are essentially locked into relationships for the duration of the project. The specificity of investment and exclusivity of contractual relationships creates a small numbers bargaining and holdup problem; because of a lack of substitutes firms can act opportunistically. This aspect of the transaction between firms on a project, combined with the need for close coordination of complex activities, would suggest that construction project organizations would be characterized by single firms using hierarchy as a governance structure (Williamson 1975).

The nature of construction project organizations is not explained by Williamson's Transaction Costs framework and provides an interesting challenge to his theory. The failure of the theory can be explained by competing transaction costs: Opportunism is offset by asset use. Firms make specific investments to get very good at certain production technologies, for example, some firms specialize in pre-cast concrete construction. As each project is unique, there are different combinations of technologies needed. It does not pay for a firm to develop a host of capabilities as these will not be needed on every project and the investment in these capabilities will not be fully leveraged. The subcontracting, specialist form makes more efficient use of these capabilities as it allows firms to combine just the resources needed for each project. As

parts of the project are completed, resources of specialist subcontractors are freed to move to new projects, which would not be the case if project organization consisted of a single firm in a hierarchy.<sup>2</sup> As firms typically enter project organization through a bidding or price mechanism, construction can be seen to be allocatively efficient: firms with spare resources bid low and win a place on a project, while those that are fully utilizing resources will bid higher and will not win in the bidding process. This more efficient use of assets can offset the costs of opportunism.

Of course, opportunistic behavior does exist in construction. It is especially evident when there are changes made in plans or schedules — subcontractors charge for damages that are more than their actual costs. Coordination through a contractual mechanism makes it difficult to observe actual costs; this, together with the lack of substitutes, makes opportunistic behavior a problem for the industry. Opportunism is mitigated somewhat through reputation effects, where firms that can reasonably expect to contract on future projects will limit opportunistic behavior in the hope of future gain.

The need for efficient allocation of specialized resources in the context of unique, temporal projects gives rise to the subcontracting structure found in construction. However, the presence of opportunistic behavior leads to very tight boundaries between firms on a project. There is a general atmosphere of distrust, and adversarial relationships are common. The task environment exacerbates this by making changes to plan a common occurrence, increasing the number of possibilities for opportunistic behavior to occur. The construction environment, in these conditions, is characterized by very tight boundaries between firms on a project, leading to ‘friction’ in the coordination of the construction process and in the workings of the governance mechanisms.

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<sup>2</sup>Of course, large, hierarchical firms could shift resources between projects, achieving a flexibility similar to subcontractor relationships. However, this is problematical: as the needs of projects vary with time and scope, there is the question of how much of a resource is needed to be shared among multiple projects. Powell (1990) writes “extreme demand fluctuation makes resource leveling impossibly difficult for an integrated form.” A large firm will at times need more than it has on-hand and at times need less. This would require that large firms subcontract additional capacity to and from direct competitors, exacerbating problems of hold-up and small numbers bargaining. The subcontracting mode is simply more flexible.



#### IV. Construction Project Organization as Network Organization

Friction is a more complex notion than opportunism; the concept of friction also encompasses the difficult and costly coordination of activities that occurs in construction project organizations. Because firms are related by a contracts with penalty clauses, they tend to very guarded about sharing information that may later be used against them. To counteract the possibility of disclosing damaging information, firms compress information by coordination through a price mechanism: to accomplish  $x$  will cost  $\$y$ . Thus when there are deviations from plan — a common occurrence given the nature of the construction process — firms respond through a clumsy use of prices. To illustrate this, consider the following real example: A subcontractor is late delivering and erecting steel on a construction-site. It does not meet the planned schedule, forcing delays in the start of following activities. Rather than letting the delay propagate, the general contractor obtains estimates of how much it will cost to speed work from subcontractors whose work directly follows the erection of the steel. These estimates are responses to specific scenarios, e.g. to meet the planned completion date will cost  $\$x$ . Upon obtaining estimates, the general contractor knows the cost of one possible scenario. To try a different scenario, e.g. miss planned completion date by one week if the steel subcontractor is three rather than four weeks late, requires another iteration of specifying a scenario and obtaining estimates. This is a cumbersome and costly process that by no means ensures the best solution will be found and can be considered a form of friction in the coordination process.

It is costly to respond to deviations from plan because this requires a shift in the use of resources; as resources have finite capacity, altering their use has costs. Overtime may need to be employed, equipment must be rented for extra days, resources are kept idle or are kept from moving to other projects, etc. Thus in a tightly coordinated production system, actions of one firm can directly affect the costs of other firms. As

firms are locked in contractual relationships, there is a certain degree of mutual dependence. Borrowing Thompson's (1967) framework, Borys and Jemison (1989) classify interdependence between firms as pooled, sequential, or reciprocal. Supply relations exhibit sequential interdependence, where each firm must "hand off" its piece to the next firm and "the key issue is ensuring a fit between points of contact." This explanation does not fully capture the subtleties of the supply relationship in construction. Borys and Jemison's view of production is that of an assembly line, where there is no overlap between stages. Construction, on the other hand, is a more complex environment where many processes run concurrently and the actions of one firm can affect the operations of another firm, typically by use of pooled resources such as space and time on a crane. Different construction methods will make use of pooled resources in varying ways, making selection of methods an interdependence variable. Responses to changes in schedule can be varied as there is a wide latitude in choice of response and cost of response. Choices can affect overall project cost as well as cost for each firm, through changes in its resource profile and by influence of use of shared resources. Thus construction firms may be said to exhibit reciprocal<sup>3</sup> interdependence, where actions have shared ramifications for cost and schedule.

Insofar as a construction project organization manages these interdependencies, it can be said to be a network organization, defined as an "organization integrated across formal groups created by vertical, horizontal, and spatial differentiation for any type of relation." (Baker 1992) The construction project organization coordinates the activities of multiple firms in a relatively horizontal relationship marked by spatial differentiation (firms produce goods off-site) and temporal integration (scheduling activities on-site). Baker writes that the network form of organization is "a flexible and self-adapting organization ... well-suited to unique customized projects, close customer and supplier

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<sup>3</sup>Borys and Jemison (1989) do note that supplier relationships can be reciprocally interdependent; however, they define reciprocal interdependence at the level of business strategy and engineering and design, not within the operating environment.

involvement in the production process, and complex, turbulent environments.”

Construction is just such an environment, and the construction organization adapts with each project. Other authors have noted that construction organization can be seen as a network form: Powell (1990) reinterprets earlier work by Eccles (1981) to suggest that construction is a network form of craft production, while Miles and Snow (1992) view construction subcontracting and supplier relations as a network form.

Of course, construction network organizations operate with a great deal of friction; if construction fails on one dimension of Baker’s definition it is a lack of integration between the participants on construction projects. Powell (1990) notes that in the network form there are “gains to be had by the pooling of resources ... in essence the parties to a network agree to forego the right to pursue their own interests at the expense of others.” This is not, in general, true of construction where opportunism is always a threat and, while there is a perceived mutual dependence, there are no explicit mechanisms to explore joint gains. Thus Powell notes that “each point of contact in a network can be a source of conflict as well as harmony.” As construction is characterized more by discord than harmony, can there be improvement in the performance of the organization? Miles and Snow (1992) write that “while networks of subcontractors have been commonplace in the construction industry, many recently designed networks expect a more proactive role among participants — voluntary behavior that improves the final product or service rather than simply fulfilling a contractual obligation.” The construction industry perceives that improvement is possible, although it has yet to find an organizational mechanism to accomplish further integration of construction (Business Roundtable 1983); construction researchers have focused primarily on technical methods of integration. Some efforts have been made to improve the industry through Partnering, or the informal agreement of parties to work together to solve problems, or through joint venturing between dissimilar firms to create an exclusive arrangement within a locale (Hampson 1993).

## V. Dimensions of the Network Organization

Network organizations are characterized by their ability to combine the expertise of various organizations in a flexible manner, quickly responding to changing conditions while making efficient use of resources. There are three explanations for this performance characteristic: First, hierarchical firms cannot effectively utilize all the resources needed to provide a complete product, therefore they “vertically disaggregate,” recombining with formerly underutilized assets as needed. This allows firms to focus on specialization while giving rise to an organizational form able to handle complexity. (Miles 1989, Miles and Snow 1986) This is essentially the argument for the subcontracting relationship in construction. Second, the network form allows an efficient matching of expertise to problems, whereas bureaucracies maintain a limited set of formal procedures to cope with all problems. Baker (1992) writes that “at least in metaphor, the network organization is a market mechanism that allocates people and resources to projects in a decentralized manner. Like a market, efficiency is assumed.” Third, information sharing in networks tends to be “thick” compared to markets and “free” compared to hierarchies. (Powell 1990) Information is shared through non-price mechanisms and is rich or thick, while not colored by communication in a hierarchy where there are concerns of perception and status. Thus networks are efficient organizational forms with the flexibility to match know-how with problems, encouraging free flow of information between members of the network while utilizing only the resources needed for any particular project.<sup>4</sup>

Relationships between firms in a network are durable, modular, and exclusive.<sup>5</sup> Networks are established with the expectation that they will persist for some time,

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<sup>4</sup>Of course, the network organization has limits to its usefulness. A very stable environment, that is, one marked by slow technical change and a fixed demand for a product or service, would suggest organization under a single hierarchy as opposed to multiple firms. Moreover, the network form will not supplant markets where they exist and are efficient.

<sup>5</sup>The classification system of durability, modularity, and exclusivity is my own and is a synthesis of the literature reviewed. My conception of modularity and inertia appears to be an extension to the extant literature, although my literature review is far from exhaustive.

although different authors vary in their prescription about the durability of network organization. Powell (1990) is most explicit in describing networks as long-standing relationships based on cooperation, sharing, and trust. Such relationships take effort to develop and maintain, and are best governed by norms of reciprocity. Baker (1992) and Miles and Snow (1986) suggest that network forms are more flexible or “dynamic,” allowing networks to be established for each project. Stable governance structures are difficult to construct for one-time projects; it seems that networks are established and exist over the long-run, with certain members of the network being called upon as needed for each new project. This allows trust and open communication to develop over time while maintaining flexibility.

The notion of constructing or recombining networks flexibly leads to the idea of modularity. Firms need to occupy a well defined and bounded role of value adding in the network. Moreover, if firms are to move in and out of networks in a dynamic way, this role must be understood and defined across networks. Thus firms occupy well defined, modular positions within a network; specialist subcontractors within construction as an example, where there are well defined types such as pre-cast concrete or steel erectors. In this way, there is an institutional environment that defines the roles firms play in the network form; this is a source of inertia that can impede the evolution of the scope of activities that firms within a network undertake. Modularity and inertia imply that firms will expand into new areas of endeavor in discrete jumps defined by the institutionally segregated modules.

While modularity can be considered a measure of substitutability within the network form, exclusivity acts to limit entrance. When firms enter long-term relationships to establish norms of reciprocity (which tend to act as governance mechanisms), they by nature exclude others from the network either by explicit barriers or by informal evolution of conduct and learning. (Powell 1990) The exclusive nature of networks acts to establish strong linkages within networks but not across networks,

limiting the ability of firms to flexibly recouple in a modular fashion (Miles and Snow 1992). Powell (1990) writes “in practice, subcontracting networks ... influence who competes with whom, thereby dictating the adoption of a particular technology and making it much harder for unaffiliated parties to join the fray.” Trust and cooperation, insofar as they are necessary for the operation of the network form, are generated by long-term, exclusive association.

These three dimensions — durability, modularity, and exclusivity — describe the network organization. Durability and exclusivity are complementary notions; however, modularity can act to limit network effectiveness. Thus while modularity is an important attribute of boundaries between firms in the network, the conception of substitutability reduces the commitments between firms and the network. “Networks are composed of sovereign organizations whose continued existence may or may not depend on the network’s performance; this sovereignty is a constant threat to the *stability* and continuity of the network.”<sup>6</sup> (Borys and Jemison 1989) The more partners the firm works with, the less it values any one relationship. This raises the issue of dependence between firms in the network. Authors who stress the flexibility of the network form suggest that mutual dependence comes from limited ability to quickly substitute one module of the organization for another, with limited interdependence between modules at the production level. Coordination is accomplished through market mechanisms “rather than plans and controls” while governance is accomplished using “full disclosure information systems” to support an explicit structure of payments for value added (Miles and Snow 1986). On the other hand, authors who stress the durability and exclusivity of networks acknowledge a broader notion of reciprocal dependence, where as networks evolve both burdens and benefits are shared, and “it becomes more economically sensible to exercise voice rather than exit.” (Powell 1990) Durable, exclusive networks use normative

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<sup>6</sup>Borys and Jemison (1989) use the term hybrid; I have substituted network for clarity. The terms are interchangeable.

standards of reciprocity and commitment to sustain relationships and act as informal governance mechanisms.

Within a network, maintenance of boundaries between firms is as important as the boundary between the network and the environment (Borys and Jemison 1989). Firms need to maintain a large enough value adding contribution to remain a viable, self sustaining organization, or else they may be threatened by other firms taking on their activities (Miles and Snow 1992). Information sharing can also be a threat to the network if firms do not have clearly defined boundaries and value-adding roles. Sharing may cause firms to give away proprietary knowledge that is valued by others wishing to expand into that firms role. Moreover, as firms may work within multiple networks, the problem of information sharing is exacerbated. Working within multiple networks also raises the question of which part of what firm belongs to which network. “Decisions must be made about how much of each partner’s resources can be legitimately claimed by the network and to what extent each partner’s governance structure has power over the network.” (Borys and Jemison 1989) Boundary permeability becomes an important aspect of network form. Which attributes — “resources, authority, obligations” — cross intra-network boundaries are important elements of the capabilities and characteristics of networks. The degrees and nature of interdependence will affect the flows across boundaries. The greater the interdependence, the greater the boundary permeability and thus the more likely the exclusivity and durability of the relationship. Interdependence, exclusivity, durability, and reciprocity are compatible notions that reinforce each other. Modularity and substitutability suggest less permeable boundaries and less interdependence, requiring reconciliation of multiple purposes into a common purpose (Borys and Jemison 1989) and explicit relationships for compensation (Miles and Snow 1992).

## VI. Conclusion: Towards a Normative Theory of Boundary Setting in Construction Network Organizations

The existence of friction<sup>7</sup> in construction can be interpreted in the context of interdependence in the network form. Interdependence between firms within construction is high — sequential at the least, and tending towards reciprocal interdependence. Yet the construction form is highly modular with tight — impermeable — boundaries between firms. A mismatch between dependence and strength of boundaries causes the friction in construction and leads to the clumsy use of price mechanisms to search for solutions to problems. Borys and Jemison (1989) state that “the primary determinant of success in supplier relationships is management of boundary permeability and the value creation process.” Construction, with its complex and uncertain task environment, does not manage boundary permeability very well, impeding efficient operation of the value creation process.

However, the mismatch between dependence and modularity is not necessarily pernicious. As mentioned earlier, there have been efforts to increase cooperation and information sharing in construction, and Eccles (1981) notes the existence of long-standing, exclusive relationships in New England housing construction. These efforts are more the exception than the rule, however. Partnering has had limited success despite its initial promise, and joint venturing is uncommon. Long-term relationships between firms are not unknown in the industry, but it is important to note that the housing construction industry, the subject of Eccles’ research, creates relatively routinized facilities of low complexity. In this case the task environment is relatively free from uncertainty and,

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<sup>7</sup>Williamson (1985, p. 84) writes about transactions in the middle range between markets and hierarchies: “If such transactions flee to the extremes, what are the reasons? If such transactions can be stabilized, what are the governance processes?” Construction, insofar as it has evolved to a middle range, has an interesting governance structure that is stable but highly frictional. This leads to the notion of a matching of organizational function, industry/organizational form, and stable governance structure. Each dimension of the ‘match’ implies the other, while the notion of stability implies processes of change and evolution. Research into the joint evolution of function, form, and governance would be very interesting to carry out. There may be multiple, stable, equilibrium that can be reached along the way, perhaps precluding arrival at an optimal solution. This conception supports the popular notion of comparative analysis.



because houses are not complex, firms can more easily understand the interdependencies between firms and develop routines that fit and complement each other. As construction projects grow larger and more complex, this type of coordination is more difficult to develop, particularly as projects are not repeated (whereas houses typically are copied). Thus one of the problems in construction is that the different firms who fill the modular roles on the construction site do not have a good idea of the needs of the other firms or how interdependencies manifest themselves on the project. Borys and Jemison (1989) write that network “management is seldom as straightforward as expected because partners often lack reciprocal understanding of the other’s operations, and, therefore, resistance arises from unexpected sources.” If firms can develop better understanding of the interdependencies on site, performance of construction networks may improve. The limited success of industry efforts such as Partnering supports this premise.

In the early 1970’s, Lawrence Bennisson noted that project managers receive a lot of help from researchers on project planning but not much help on cooperation and coordination. In response, he developed a technique called TREND<sup>8</sup> that maps dependence relationships from project network data to the hierarchical organization chart of a firm to highlight potential problems for management due to asymmetric relationships in power and dependence (Bennisson 1972). Although meant to be used to illustrate coordination problems within a single firm, it has been successfully adapted to multi-firm environments such as construction where subcontractors are placed in a hierarchy under the general contractor.<sup>9</sup> TREND has only a limited conception of how dependencies manifest themselves on projects and can only be considered a starting point for deeper theory. Unfortunately, not much more work has been done to develop understanding of dependence relations in construction, and the situation that Bennisson found in the 70’s remains today.

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<sup>8</sup>TREND: Transformed Relationships Evolved from Network Data. ‘Network’ means project schedule network such as PERT or CPM, not organizational network.

<sup>9</sup>Personal communication with Prof. Raymond Levitt, Dept. of Civil Engineering, Stanford University.

The key dependence relation in construction is based on changes in the schedule and the associated changes in resource use by firms within the network. Essentially, changes to plan require costly reallocation of resources. This reallocation can be accomplished through a price mechanism, which, as discussed, is cumbersome and limited in its ability to explore options as an exhaustive search for an optimum solution requires many iterations. As there are bounded rationality constraints, the search is limited (often to a single iteration) and there is no guarantee that an optimal or even good solution has been found. It is much better if firms could share data about costs, capacity, and schedule constraints, as they could then directly search for an optimal solution to the problem (insofar as an optimum can be described).<sup>10</sup> The search for a response to changes in schedule is a form of reciprocal dependence between firms as it is a process of mutual adjustment and feedback, with ramification for the costs to individual firms and for the cost of the entire project.

Processes that firms use to accomplish production can be said to possess certain performance characteristics: Cost, stochasticity, and time to process. Added to this is the notion that a firm has a finite production capacity. These are common abstractions used in production/Operations Research theory where they are used to determine a cost minimizing/profit maximizing optimum solution to a modeled problem. This theory is usually set in a framework where there is a single decision maker, making it hard to adapt to decentralized production environments such as construction. However, these performance characteristics can be used to determine interdependence as the cost and time to respond to a deviation in schedule will be determined by a firm's performance characteristics. Time to process and capacity use gives an indication of how quickly a firm is able to respond to a change, while cost gives the expense of the change and stochasticity is an indication of the ability of the firm to meet new plans. Performance

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<sup>10</sup>Milgrom and Roberts (1992) discuss information efficiency in a chapter on coordination of plans and actions. In a model of production planning, they note that coordination through a central planner economizes on the amount of information needed, whereas a pure price mechanism fares quite badly on this metric.

characteristics, particularly stochasticity, also indicate a firm's likelihood and ability to meet schedule. These characteristics give an indication of how likely the firm is to affect the performance of the network (how much the network needs the firm) and an indication of how changes will affect the firm (how much the firm needs the network).

Production theory can give a deeper understanding of interdependence between firms on construction sites than current theory. Moreover, as performance characteristics are largely intrinsic to a production technology, they can be generalized to give an indication of the performance of each module type likely to be found in the network, allowing firms who know nothing about each other to sense the degree of their interdependence within the context of a given project. As interdependence increases, there are likely to be joint gains from increasing boundary permeability. Ascribing performance characteristics to modules is a normative concept that suggests what information should be shared with whom at the start of the project, giving a prescriptive theory of boundary definition both within the network and between the network and the environment.

Upon entering a project, production theory may provide firms with a normative basis to measure interdependence and develop closer ties, but does not provide a stable governance structure — it tends to focus on joint gains in a game theoretic fashion as opposed to reciprocity sustaining exchange.<sup>11</sup> There is little guarantee that firms in a project will not act opportunistically, creating a form of prisoner's dilemma for construction firms: cooperate and share information to reduce friction, or act opportunistically for individual gain? Firms that are most dangerous to the stability of the network are those which can greatly affect the performance of the network but which

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<sup>11</sup>See Powell (1990) for further discussion of cultural tenets and standards of reciprocity as opposed to a rational, game theoretic view.

the network will not greatly affect.<sup>12,13</sup> Production theory may give some indication of effective buffering strategies between these firms and the network, such as providing float in schedules and carrying inventory. Miles and Snow (1986) have suggested that full-disclosure information systems can provide a basis for governing the network by providing a way to acknowledge and compensate for value added, and are “substitutes for lengthy trust building processes based on experience.” Quantitative modeling using OR techniques can support this work, but I remain unconvinced that such a structure can adequately govern an organization that must deal with the complexity of the task environment and the attendant interdependence. Modeling performance characteristics of modules can prescribe relations for joint gains, but the search for an appropriate governance structure may remain something of a holy grail until the institutional environment and norms of the industry change.

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<sup>12</sup>One example may be vendors of building control systems. These are large firms that work on multiple projects, diminishing the importance of any one project to the firm. However, malfunctioning control systems can be very costly to the project, delaying the startup and commissioning of buildings.

<sup>13</sup>An interesting extension of modeling performance characteristics is to determine if a subset of firms can benefit from acting cooperatively while others do not.

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