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Beyond Partnering: Rethinking Project Management

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ABSTRACT: At its core, this paper is about information and how it can be used to better manage construction projects. Starting from a case example, we critique current approaches to project management. Current best practice, including partnering, copes only with the speedy resolution of uncertainty and complexity in the construction process and lacks an ability to optimally resolve problems. We generalize this viewpoint drawing from economic coordination theory and production theory. These theoretical perspectives suggest that traditional construction planning and control systems (and associated contractual and organizational assumptions) need to be rethought. An organizational and contractual system that allows firms to work together to optimally and speedily solve problems is needed. Dimensions of such a system are discussed and a comparison between construction and current best practice in manufacturing is drawn to highlight both possibilities for construction and aspects of the project management process that are unique.

Introduction

The construction or project management process is dynamic, requiring continuous adjustment to changing conditions. While planning acts to decompose complexity and reduce uncertainty for project participants, plans are seldom static. As projects come under increasing pressures to reduce time and cost and as designs are subject to continuous review, it is likely that change will become an ever greater fixture of the project management process. Thus how change is managed is one of the central measures of project performance. In this paper, we focus on changes in scope and schedule (and hence, cost) that affect multiple parties in the construction process. These changes are 'problems' that require 'solutions.'

Often, the path to a solution is a difficult one as there exists both a technical dimension of how to solve the problem (e.g., which changes to plan are feasible) and a contractual dimension that engenders further trouble when assigning and paying for the chosen technical solution. Coping with the contractual difficulties — assigning work, deciding which firm pays for what work, and deciding how much that work should cost — is a difficult and time consuming process that tends to reduce the speed at which solutions can be reached. This delay can often make problems worse; as such, the quick resolution of problems is a goal of good project management. The institution of partnering (Cowan, 1991) is an endeavor to create trust, understanding, and informal but mutually agreed upon mechanisms to mitigate the contractual difficulties of deciding and acting upon a solution to a problem. Partnering has in many circumstances been effective at reducing time and cost growth for projects by facilitating speedy resolution of problems. However, value to projects is added not only by quick resolution of problems, but also by arriving at an optimal or lowest cost solution. For any given change to schedule and scope, there are potentially many different technical possibilities. These will not have the same cost and hence alternate solutions must be compared to find the lowest cost solution. The contractual difficulties of coordinating a solution to a problem can retard the ability to search for and implement a good solution, even in cooperative environments such as partnering.

It is this criticism — the existence of a lowest cost solution and the difficulty of searching for it — that forms the central thesis of this paper. We discuss the nature of the problem of coordinating changes to schedule and scope in a case study that demonstrates current approaches to the management of such changes. These approaches are then criticized from both an information processing/information coordination perspective and a capacity based perspective on construction costs. These theoretical critiques form the basis of a technical vision for improvements in coordination of change. However, implementation of such a technical vision calls for increased information sharing and collaboration on projects. This requires new contractual arrangements. Dimensions of such arrangements are discussed and compared with similar systems in manufacturing industry. We conclude with some thoughts on what practical steps firms can take to move towards an environment conducive to swift and optimal coordination.

Case Study — The Durand Centre Project

The Durand Centre is a shopping mall located in southwest London, United Kingdom.[1] Project size was £100 million; stores were open by November 1991. Construction on an existing site posed difficult problems. Limited access to site and little on-site storage required careful coordination of site activities to minimize conflicts and to ensure a smooth work flow towards completion. Construction was accomplished in two phases: demolition and construction of temporary facilities to provide access to adjacent stores (Phase I), and construction of the new shopping mall (Phase II). Overall on-site construction schedule was limited to five years. The project was successful, completed on-time and within budget, and was nominated for a national award.

The Durand Centre project was let to Stone Builders, a division of Stone Construction plc, a large UK based construction firm. Stone acted as a management contractor. Under this form of contract, all physical work is subcontracted by competitive bid, with the management contractor paid a fixed fee for its services. Stone coordinated the activities of the subcontractors; however, it also held the contracts of the subcontractors and was contractually responsible for completing the project. Penalty for late delivery was £50,000 a week. Design was completed by an architect/engineering team separate from Stone.

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1 'Durand,' and 'Stone' have been used to mask the names of the firms involved. Any relation to real firms of the same name is coincidental. All dates, contract values, and prices to accelerate work have been modified.

Subcontracts were awarded by a pre-selection and bidding process. Stone assembled a short list of subcontractors deemed competent for each work package, e.g. foundation work, steel frame, mechanical equipment, etc. Firms on the short list were invited to bid on the work package. Selection was by low bid, although technical differences between bids did justify selection of higher price bids in a few cases. Subcontracts were typically lump sum, an agreement to complete work for a fixed price, or bill of quantities, a fixed price per unit of material installed. Lump sum contracts could also include a schedule of prices per unit installed for variation. Subcontracts included a clause for liquidated damages, passing the risk for late delivery to subcontractors.

Conceptually, Stone breaks management of the construction progress into two primary areas: On-site and off-site processes. On-site construction is the typical domain of construction contractors; activities here are often represented graphically either in bar-chart or network form. Off-site activities are usually not represented in project networks and lie outside the traditional concerns of contractors. Stone pays particular attention to the management of these off-site activities and makes a point of distinguishing the management of these processes from the management of on-site activities.

Appointed subcontractors with significant off-site fabrication tasks are given schedules for completion of that work. Typically, the subcontractor rejected this schedule as unfeasible or uneconomic. A revised schedule for off-site fabrication was then agreed upon by both Stone and the subcontractor. The revised program was highly detailed and gave specific start and finish dates for the activities involved. This program was called a marker program and was used to monitor progress. Stone personnel responsible for packages telephoned and visited subcontractor sites periodically to monitor progress and check quality, using the marker programs as reporting devices. A similar procedure was used to design marker programs for on-site activities. Stone and subcontractors would agree upon a construction sequence and a detailed program would be created, used for planning and monitoring. On-site marker programs include hand-over dates for completion of work so following trades may start.

The extensive planning and monitoring of off-site work generally accomplished its purpose with one significant exception: Steel erection fell six weeks behind schedule. As steel was a critical path activity, this delay caused serious problems to following subcontractors. In this case, Stone decided that it did not wish to allow the delay to propagate throughout the project and requested that subcontractors submit an estimate of costs for acceleration of their programs to put the project back on schedule. This required careful re-negotiation and re-scheduling of marker programs. Around the general plan to contain the effects of the delay, several iterations of rescheduling were performed, and in some cases subcontractors proceeded with accelerated programs before agreeing on a price and final schedule. Table 1 lists the subcontractors affected, lead time between award and scheduled start on site, value of the package, and agreed upon price to accelerate the program. All affected packages were fully scoped at the time of award, with no special requirements for design coordination, making acceleration of works primarily a function of increasing resources on-site.

Subcontractor / Package	Procurement Lead Time in Weeks	Package Value	Price to Accelerate Program
Floor Slabs	20	£1,119,000	£146,000
Fire Protection	16	528,000	54,600
Blockwork	26	1,327,000	30,400

Table 1: Packages Affected by Delay of Steel Hand Overs

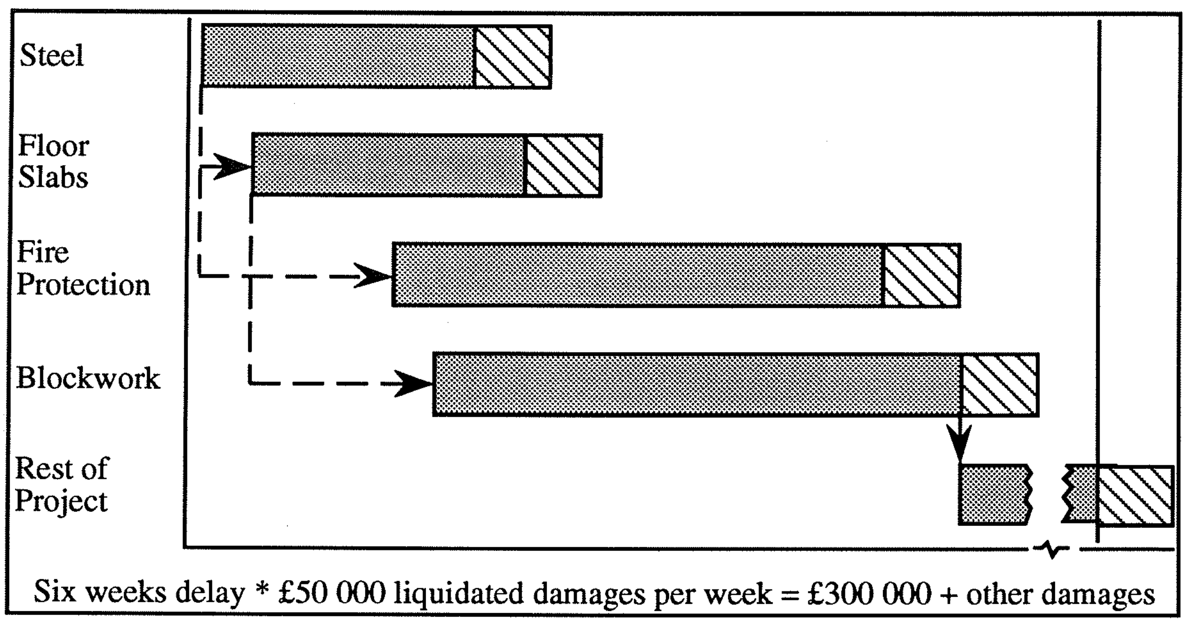

Figure 1: Planned Schedule and Impact of Six Week Delay (Diagonal Lines)

Figure 1 shows the a subset of the planned schedule and the impact of a six week delay on the Durand Centre Project. At £50,000 per week for liquidated damages, the penalty for a six week delay is £300,000. This is the penalty from the owner; subcontractors may also claim damages for delay tot their work. This cost and delay was unacceptable to both the owner and Stone and the delay was made-up by accelerating the work of following subcontractors as a cost of £231,000, with the final revised schedule shown in **figure 2**.

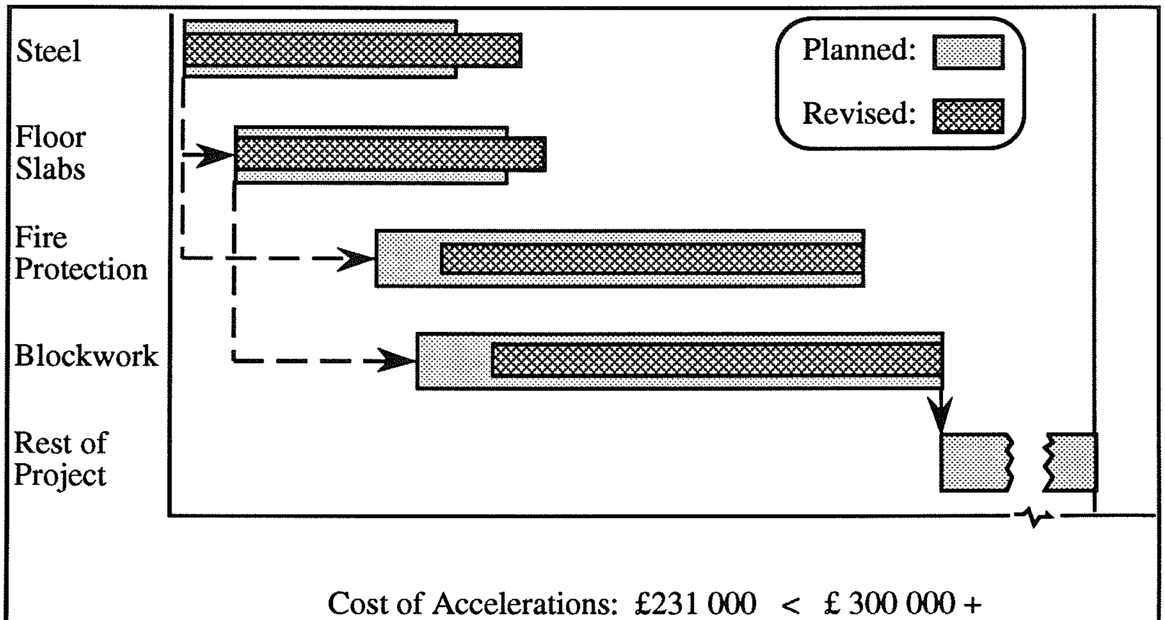

Figure 2: Revised Schedule to Make-Up Delay

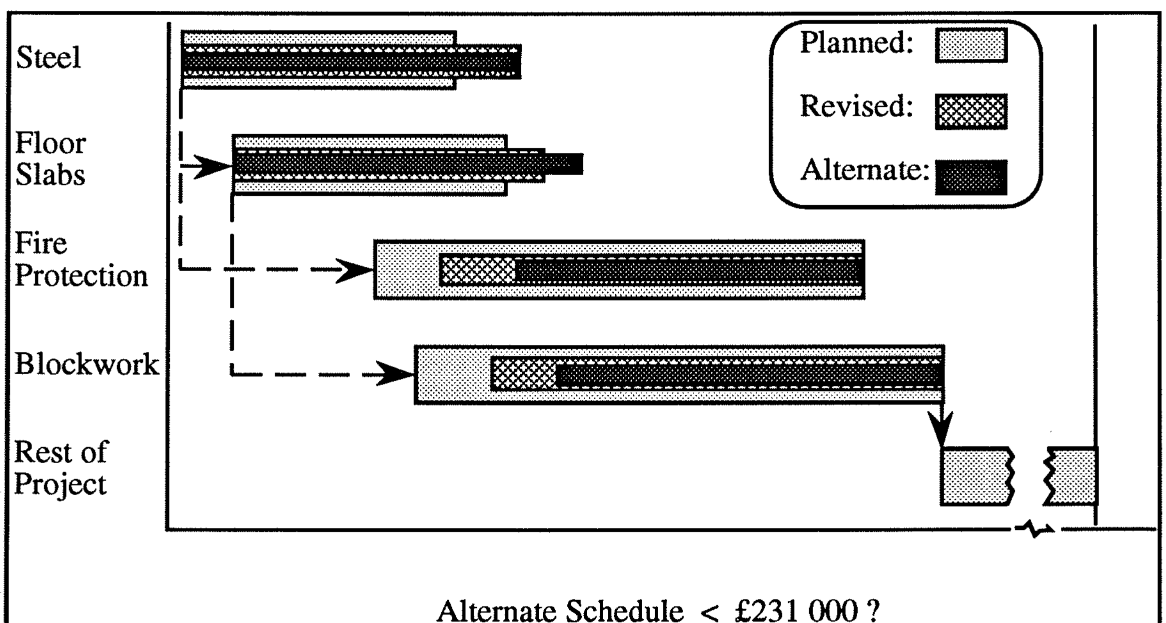

Figure 3: Possible Alternate Revised Schedule

The cost of acceleration, £231,000, was less than £300,000; in this context, Stone made a good decision to make-up the delay. However, the concrete subcontractor installing the floor slabs offered two options: Accelerate at £146,000 or complete work with a six week delay at an additional cost of £70,000. If Stone had selected this lower cost option, it is unknown if following trades could have made up the delay for total cost of less than £231,000. As both blockwork and fire protection are highly labor intensive, it is possible that these activities could have been further accelerated at a cost less than £146,000 - £70,000 = £76,000, which would have a total cost lower than £231,000. This possible alternate revised schedule is shown in **figure 3**. Further, it is unknown if some other combination, perhaps involving more of the following subcontractors would have had a cost less than £231,000. Thus there is no assurance that Stone selected the least cost response to the delay; the response is only good compared to the £300,000+ penalty for liquidated damages, which may be seen as a worst case.

Critique of Current Practice — Theoretical Perspectives

The Durand Case describes current approaches to finding a solution to the problems of changes in schedule and scope. In general, best practice is a heuristic method that attempts to keep problems from growing to more than a few firms. This policy may be described as containment: Contain the impact, time, and cost of any change. By limiting affects of changes to as few firms as possible, this policy also minimizes the coordination work required of the general contractor, helping quick resolution of problems. However, in the Durand Centre case, it was possible to construct a plausible argument that lower cost solutions existed. A policy of containment reduces the ability of the general contractor to search for the least cost solution by excluding firms from consideration. The need for quick solutions also limits the ability to spend time searching for a good solution of time amongst the firms affected, as shown in the possible alternate revised schedule for the Durand project.

In general, current best practice gives a limited sense of whether or not the negotiated change is the best or lowest cost solution, and gives only a limited ability to search among possible options. In the rest of this section, we develop some theoretical perspectives on why this is so. In particular, we critique from an economic lens the nature of information sharing and construction of solutions among the multiple project participants. Production theory is employed to describe the nature of the costliness of changes for each firm. Combined, these perspectives provide a powerful view of project costs and coordination needs. Before applying the theory, it is important to review some basic definitions and assumptions from the field of coordination economics.

Coordination Economics: An Introduction

The discipline of economics is concerned with the allocation of scarce resources. As information relevant to economic activity is dispersed among many individuals and firms (agents), there must be transmission of information among agents for economic activity to occur. Coordination economics concerns itself with the ability of an economic system to transmit the necessary information for an efficient allocation of resources to occur. Efficiency is generally expressed in terms of Pareto optimality: Resources are allocated in such a way that any reallocation of resources makes some agents better off at the expense of other agents, i.e. there is no alternative allocation of resources where everyone is better off or at least no worse off (Reiter, 1989). This is a somewhat tenuous and abstract definition of efficiency; generally it is wise to ask "efficient for who?" A transaction may be efficient for the parties to an exchange but not for agents who are external to the exchange. Thus an owner and engineer may find it mutually beneficial to specify a low-cost HVAC system; building occupants may not agree. For the purposes of this paper we draw the boundary of the economic system around the group of firms working on a given project (including vendors and subcontractors). We define efficiency as the least cost for the entire system of firms; this is most productive in a strictly economic sense. However, this definition of efficiency may mean that some firms have higher costs than others; in a subsequent section, we briefly discuss ways firms can equitably distribute benefits from a systems improvement in construction coordination.

There are different ways a system can transmit information among its agents to coordinate economic activity. The standard distinction is coordination through markets versus coordination through hierarchies. Markets are associated with price-mechanisms; that is all information is communicated through prices for specified goods or services. Hierarchies transmit non-price information; communication between agents tends to be more information intensive in hierarchies (non-price) than in markets (prices only). In principal, any economic system of coordination can achieve an efficient allocation of resources; what varies is the amount of information that must be transmitted and processed by agents. Markets are favored over hierarchical (e.g., planned or centralized) economies because they economize on the amount of information that must be exchanged for efficient functioning of the economy (Hayek, 1945). However, in different settings, coordination through a price mechanism does not always economize the amount of information that must be processed and transmitted (Weitzman, 1974). Firms or hierarchies exist when the price-system fails as a mode of coordination (Arrow, 1974; Coase, 1937; Williamson, 1975).

Critique of Current Construction Coordination Policy

On a construction project, firms are typically brought together by bidding and allocate resources to the project under a master schedule. Thus initial coordination is accomplished via a form of price mechanism, that is, a market where specific goods and services are exchanged for a specified price. Of course, much non-price information may be exchanged to clarify the responsibilities of firms and provide some assurance that a firm is qualified to carry out the work it is assigned; this makes sense given the complexity of construction. But the central mode of coordination is through a price-mechanism—non-price information supports the contractual coordination mechanism of an agreed upon price to perform certain work.

Coordination through a price mechanism continues over the course of a project. This can be seen in the response to changes to project schedule and requirements, which are a frequent occurrence given the complexity, variability, and risk inherent in construction projects. Changes are costly because they require a shift in the use of resources. 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. To respond to the change, the general contractor typically obtains prices from the affected trade subcontractors. If these prices are plausible, e.g., less than liquidated damages in the case of a delay, then the general contractor has the trade subcontractors proceed in response to the change. Of course, this coordination through a price mechanism may be supplemented by non-price information as in bidding, but the central mode of coordination is specific work to be completed for a specified price.

If changes were rare, then construction projects would proceed smoothly. Of course, changes are frequent, and much of the fractious atmosphere of construction can be seen in the reaction to changes; firms are often as much involved in the process of shifting costs than they are in the process of solving problems. However, this fractious environment masks a much deeper problem of coordinating a response to a changed condition via a price-mechanism. In principle, there are many possible ways to react to a changed condition. And these may not all have the same cost. Coordination via a price mechanism requires that each alternative be priced separately. Searching among the many possible alternatives involves a cumbersome and lengthy process of specifying and pricing alternatives. In general, this search process is not carried out and therefore there is no assurance that the alternative chosen is the best response. This is demonstrated in the Durand Centre example.

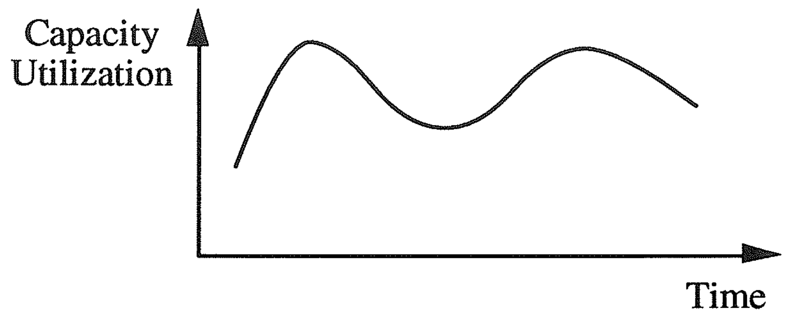

Figure 4: Capacity-Time Relationship for a Firm

Any firm may be said to have a finite capacity of labor and equipment; capacity utilization will vary over time as a function of a firm's resource commitments to projects (as shown in **figure 4**). When a firm has spare crews or equipment it has reserve capacity; when all crews or equipment are working it has no reserve capacity. Thus at a given time, a firm will be able to respond to a change in different ways depending upon its current level of capacity utilization. This can be seen in **figure 5**, where a cost dimension is added to a time-capacity curve. In general, costs are an increasing function of capacity utilization. This is known in manufacturing as congestion effects; in a system with variability, resources working at 100% of capacity tend to increase the backlog of work, which increases costs due to delays, carrying extra inventory, etc. (Banker, et al., 1988). At some point of low capacity utilization, overhead costs may be larger than savings in congestion costs, and the cost surface will be u-shaped. However, as firms tend to work towards full capacity utilization as much as possible, the relevant region will be that of increasing costs; thus to simplify, we show costs as an increasing function of capacity utilization. Bars on the capacity-time plane in **figure 5** show the firm's allocation of capacity to different projects over time. In the case of the shaded bar, the firm must decide when in time to allocate capacity to the associated project; because it has resource commitments to other projects, the firm's costs will vary over time. As a goal, the firm tries to minimize its total expenditures (subject to project constraints), which is the area under the expenditure path traced along the cost surface. Note that this view is different from a time-cost tradeoff model (Baker, 1974): Costs will vary not only with the duration of a construction activity, but also when in time the activity is to take place. And costs can change very quickly over time as a firm may have free resources available one day and on the following day have those resources committed to another project, sharply increasing capacity utilization and costs.

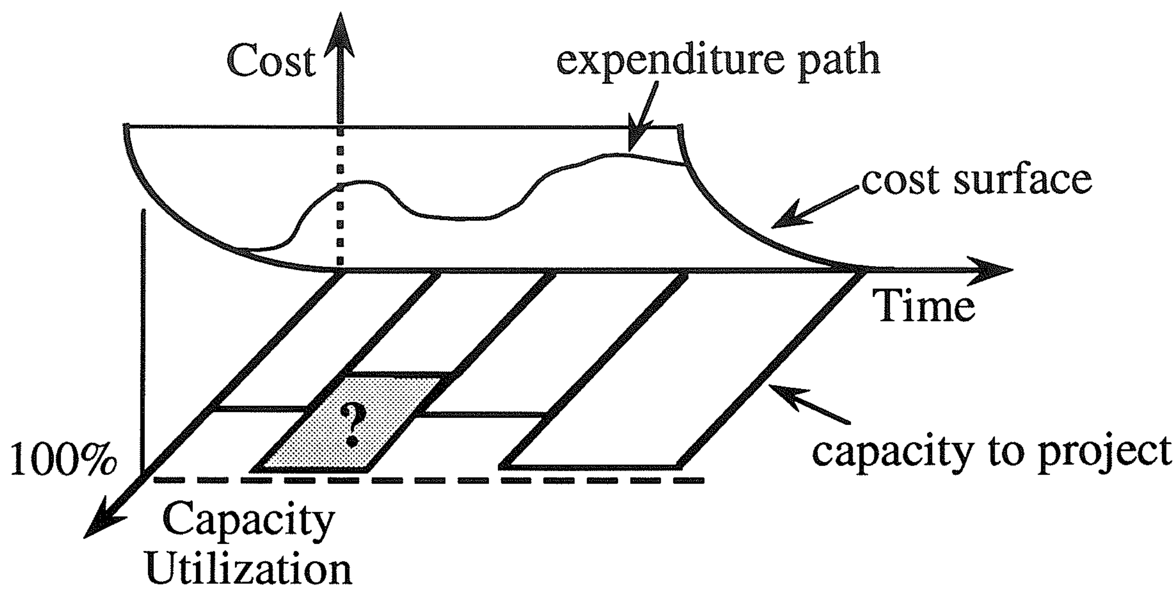

Figure 5: Cost-Time-Capacity Relationship for a Firm

Of course, a firm's decision of when to allocate capacity interacts with the decisions of other firms. This interaction involves many possible combinations or alternative choices that firms can make to react to a changed condition. These alternatives will have different total cost from a systems perspective; in some cases it may be advisable for one firm to bear all the costs of a change, in other cases it may be best to distribute costs. In principle, there is some best alternative (least total cost or most efficient) and some worst alternative (highest total cost or least efficient). Alternatives in between the best and worst case can be ordered along a line, as shown in **figure 6**. Experience allows decision makers to avoid selection of very expensive alternatives. It is less clear that experience allows decision makers to pick a good alternative among the many remaining alternatives. This is where a price mechanism for coordination has difficulty: each alternative must be priced separately by each affected firm and then compared. This is an iterative and time consuming process that is not carried out. In practice, a general contractor will pick one of the many alternatives and live with the cost. But without the knowledge of the costs of alternatives, the general contractor has no assurance that it has picked the best or even a good alternative.

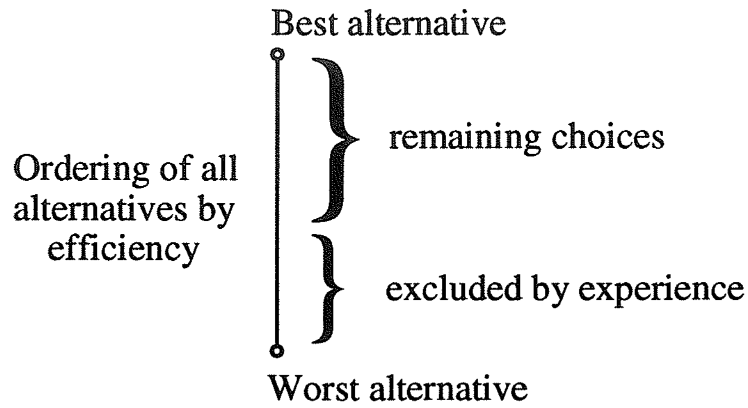

Figure 6: Ordering of Alternatives, Efficiency Defined as Lowest Cost for Entire System of Firms

Centralization as an Alternate Approach to Coordination Policy

It may come as something of a surprise to researchers and practitioners that coordination through a market or price mechanism is inefficient. The problem comes from the shift from award of contracts to construction operations. When bidding for a project, there are multiple firms competing for each trade specialty. Under a cost-time-capacity model, the low bidder is the firm with the least expected capacity-costs for the given project. Of course, there are complexities in bidding, but a related capacity-cost model has been successfully used and tested by Griffis (1992) in an empirical setting. Certain strategic behavior by firms aside, bidding can be said to be an effective way to search the market of subcontractors for the lowest prices. However, once firms enter a project organization, they create asset-specific investments and cannot easily leave the project; likewise, it is difficult for other firms to enter the project organization (Williamson, 1985). Under a price mechanism, an efficient response to changes would involve bidding by the construction community at large. Because the asset-specificity of the investments firms have made to the project effectively limits the number of new entrants to the project, responding to a change requires coordination among the current project participants. In this case, it is no longer clear that market coordination is efficient.

As mentioned above, any coordination system can achieve an efficient allocation with differing amounts of information. We criticize coordination through a price mechanism as ineffective because it necessitates an awkward and time consuming search of alternatives that is not carried out. However, it is not immediately clear what other systems of communication make it easier to find the least cost solution to a changed condition. For example, there exists cost-plus and negotiated contracts that circumvent the bidding process. While these contractual forms may make paying for changes a less acrimonious event, there is little evidence to suggest that a directed comparison of many alternative responses to a change takes place. Similarly, informal agreements that supplement fixed price contracts, such as partnering, are designed to facilitate quick agreement on a solution to a problem rather than to explore alternatives. Cost plus and related forms still coordinate changes through a price mechanism despite their different contractual trappings.

Fortunately, coordination economics does provide an alternate view of efficient coordination. Bolton & Farrell (1990) note that decentralized or market modes of coordination perform very poorly when reacting to a crisis. Although there is an urgent need for coordination, market coordination tends to foster delays. A centralized system is much better at reacting to crises quickly and with less duplication of effort. This is like ambulance dispatching: there is a centralized command center that dispatches an ambulance to an emergency with knowledge of which ambulances are available and where they are located (non-price information). It is almost unthinkable that a decentralized system of prices would be used to coordinate ambulances. However, construction attempts to accomplish coordination in such a manner. The resolution of a problem or change requiring the coordination of multiple contractors can be slow, even for a single alternative. While the Bolton and Farrell model describes the ability of a centralized system to react quickly to a crisis compared with a decentralized system, it does not necessarily say much about the goodness of the solution. However, in a model of production planning, Milgrom & Roberts (1992) show that coordination problems with design attributes can be optimally solved with the least transfer of information between agents by a centralized coordination mechanism, whereas a price-mechanism fares badly on this metric. Problems with design attributes involve situations where there is prior knowledge about the form of the desired solution, and small errors of fit are costly. Construction meets these criteria as there is foreknowledge of the rough sequence and time requirements of any plan, and errors in fit (particularly timing) are generally costly.

Technical Vision for Improved Coordination

For construction, this view of coordination presents an alternative paradigm: Rather than coordinating through an exchange of prices, a single decision maker (perhaps the general contractor) should collect information about costs and capacities from each of the subcontractors and vendors and decide the best response; this response would be imposed by the general contractor and firms would be compensated for their costs. In principle, this mode of coordination minimizes the amount of information that must be shared for selection of an optimal (least cost or efficient) response to a changed condition.

The Milgrom and Roberts model supposes that there is foreknowledge of the form of the optimal structure of the response. Some of this foreknowledge exists for construction but we do not at present have a clear understanding of how to construct an optimal solution or what information must be shared to determine the solution. While the details are beyond the scope of this paper, the author is currently developing cost models for firms and optimization techniques to support centralized coordination; other researchers are also beginning to investigate aspects of this problem. In essence, each firm has a cost-time-capacity structure such as that shown in **figure 5**. With knowledge of the cost-time-capacity structure of the firms affected by a change, the interactions between firms' costs can be explored. With a directed search or optimization technique, the most efficient or least cost solution can be found. Thus centralization becomes theoretically attractive.

Of course, such a vision of firms sharing information about costs , capacities, etc. requires considerably more information sharing than what is currently done on projects. To collect and process information in a timely manner will require the use of information technology — computers, networking, etc. — across the network of firms involved. Certainly there are many technical issues concerning the sharing and manipulation of information that remain to be solved, but considerable research has been done is this field (see for example (Aouad, et al., 1993; Björk, 1991; Böhms, 1991; Eastman, 1994; Fischer & Froese, 1992; Fruchter, et al., 1993; Reed, 1994; Teicholz & Fischer, 1994)). Some more central issues involve incentives to share information, which we turn to in the next section.

Beyond Partnering — Organizational Concerns

It is important to note that the theory presented above is not based on consideration of incentive issues. This has two implications: First, incentives can act to constrain the action of firms. Second, the critique of current practice is fundamental; this is to say that any organizational structure that promotes coordination of changes through a price mechanism or similar structure will suffer difficulty in achieving quick and optimal coordination. Thus traditional incentive schemes that encourage or penalize based on performance but do not change the fundamental mode of coordination will not work well in an environment characterized by changes in schedule and scope that affect multiple parties.

In this sense we can see the limitations of partnering, which can be defined as an informal agreement among different parties in the construction process to work together in a cooperative manner to solve problems quickly and to avoid lingering disputes. As an extra-contractual agreement, partnering does not fundamentally change the coordination mode from a price mechanism (that is, negotiation of work to be performed through an iteration of prices for various scenarios). Certainly, partnering does improve the construction process by aiding the speedy resolution of problems, and by reducing disputes makes working in the construction environment more enjoyable for all parties. But partnering does not help to solve problems optimally as there is no mechanism for firms to come together, truthfully share information, arrive at a lowest cost solution, and equitably pay each firm for its expenses. Returning to the Durand Centre case, suppose that the least cost solution to make-up the delay was for the concrete subcontractor to speed its work as much as physically possible. This may be very expensive for the concrete subcontractor, and, in a traditional round of negotiation by examining scenarios and prices, the concrete sub may shy away from this option for fear of getting paid the amount it is owed for the work. Similarly, the general contractor may see the cost of this option for the concrete subcontractor and decide to explore a solution that is apparently not so expensive. Thus, without a centralized information sharing mechanism there is only a limited ability to search the possible range of actions and determine the optimal solution. Partnering does not aid this search in a significant way as even if firms choose to cooperate, they have little means of determining what is best for the project as a whole rather than what is best for each individual firm.

The difficulty of moving from an environment where firms work to add value to the project rather than just to themselves stems not only from a limited ability to determine what is best for the project but also from the structure of incentives. The steel erection subcontractor that caused the delay on the Durand Centre project worked under a fixed price contract that made it responsible for pay for the effects of the delay. As such, the steel subcontractor had little incentive to acknowledge any responsibility for the delay and had every incentive to pass the blame to some other party (late receipt of design drawings, delay from suppliers, etc.). In general, changes in schedule and scope are seldom the sole fault of any single party and it is difficult to fully recover damages. In this sense, there is a disincentive to share information in a truthful manner (e.g., whether to give advance notice of a problem or to accurately represent costs). Penalty contracts retard the ability of firms to share information and to determine and implement optimal solutions. Partnering, which as an extra-contractual agreement does not replace this common incentive structure, does little to help this problem. Current contractual agreements act to reinforce coordination through a slow and cumbersome price-mechanism — a wheel which partnering oils but does not replace.

What is needed in construction is a means to share and act on information (using information technology and capacity based tools described above) and a means of jointly sharing risk to provide incentives for optimal responses to changes in schedule and scope. What such an incentive and information sharing structure will be for construction is yet to be determined; partnering is probably a good evolutionary steps towards such a structure. It is worthwhile to compare construction with current best practice in manufacturing. For example, lean production developed within the Japanese automobile industry is a highly effective and cost efficient method that has spread to much of western manufacturing industry. Of this paradigm, Womack, et al. (1990) of MIT write:

> We find no evidence that Japanese suppliers love their assembler customers any more than suppliers do in the West. Instead, they operate in a completely different framework that channels the efforts of both parties toward mutually beneficial ends with a minimum of wasted effort. By abandoning power based bargaining and substituting an agreed upon rational structure for jointly analyzing costs, determining prices, and sharing profits, adversarial relationships give way to cooperative ones. (pp. 167-8)

This structure has evolved over a considerable time period — it was at least 20 years before Toyota had developed a clear paradigm for production and spread it to supplier firms and distribution outlets (Cusumano, 1985). Other current approaches in manufacturing organization have not been overnight efforts and have often started within the auspices of a single firm (see for example Davis (1993), Drucker (1990) for perspectives on inter- and intra-firm management and coordination).

But some aspects of new manufacturing paradigms are becoming clear. First, there must be a clear model of efficient production (e.g., Just-In-Time Production, supply-chain management). Second, this model is used to determine a rational structure for firms to jointly analyze costs and to determine prices. Third, with a view of efficient production, firms develop an organizational and contractual structure that provides a set of aligned goals and interlocking incentives. For example, firms involved in a joint production activity may own each other's stock. Fourth, the creation of interlocking incentives and the learning that takes place by working together tends to promote long-term, exclusive relationships. Fifth, these long-term relationships allow firms to jointly invest in computerized, integrated logistics systems to better react to market conditions, manage inventory, etc. In turn, these logistic systems support and refine the production paradigm, which provides an even greater rationale for joint cost analysis and so on. Thus current best practice in manufacturing creates a self-reinforcing system that promotes cooperation and efficient production at a system rather than firm level. No such paradigm yet exists for construction.

What about construction is different from manufacturing? Certainly, projects are short term and there is less ability for firms to develop long-term relationships, although there is evidence that construction firms do cooperate over the long-term (Eccles, 1981). Relationships between firms may be less exclusive than in manufacturing, and there is a question of the strategic value of information — what information can be shared with a firm's partners on one project without giving away valuable information that may reach a competitor. Within the project, information and production needs are also different than manufacturing. Using a '3I': Inventory, Information, and Incentives view of the world (O'Brien & Fischer, 1993), we can highlight these differences. As shown in **figure 7**, the construction organization can be seen as a general contractor working above subcontractors working above suppliers in a chain-like structure; this matches the traditional contractual structure. Inventory or materials flow up from vendors to subcontractors, and then across from one subcontractor to another as each sub inherits the site work of those who proceed it. Information flows both up and down and across chains as needed (design coordination of mechanical systems by vendors may be cross chain while overall schedule established by the general contractor is up and down chains). Incentives correspond closely to payment and contractual obligations; these largely run down the chains.

A 3I view of construction highlights a mismatch between incentives and work flow. Subcontractors who inherit the work of others have little control of preceding contractors as incentives flow from the general contractor, who is principally concerned with schedule and less with the needs of individual subcontractors. As an example, we have observed concrete subcontractors pour mats and then embed anchor bolts in the mat in a haphazard manner (the bolts don't line up, aren't straight, etc.). A framing subcontractor who follows the concrete subcontractor on-site must then erect its frames on the poorly aligned anchor bolts. This slows the erection process and prevents off-site prefabrication of mudsills and frames. This represents added expense to the framing subcontractor (and to the project as a whole as the framing sub has likely allowed for this situation in its bid, although this represents a hidden cost). As the framing sub has little ability to control the incentives for the concrete sub, the concrete sub has a strong interest to complete its work as rapidly as possible with only limited regard for the following subs. A similar situation exists for information flow; Fischer, et al. (1994) note that "a team responsible for a specific task has interest but no control over the information flowing into its task, and control but no interest in the information flowing out of its task." For teams that share information both horizontally (away from incentives) and sequentially (the information won't come back), a 3I model highlights these information problems.

Manufacturing organization is similar to construction but, in contrast to construction, information, incentives, and inventory run up and down the chains but seldom across. All horizontal or cross chain work is down within the firm in manufacturing whereas cross chain coordination is a primary characteristic of construction or project production. These differences make direct importation of manufacturing techniques impossible for construction and care must be taken in using manufacturing as an example. Nonetheless, the example and potential demonstrated by current best practice in manufacturing is compelling; development

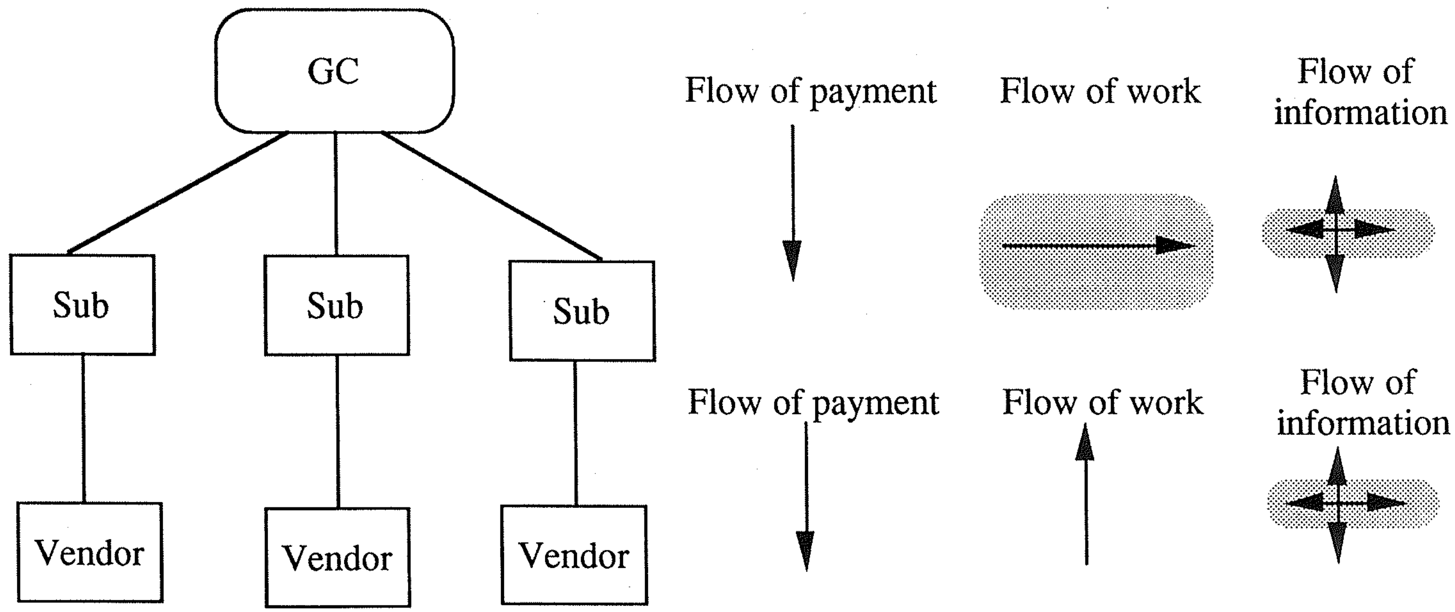

Figure 7: Inventory, Information, and Incentives (3I)

of a similar self-reinforcing production-incentive system is needed for construction firms to truly improve their collaborative abilities.

Conclusions

In this paper we have presented a view of efficient production for construction, where changes in schedule and scope have been seen as a common and recurring problem that makes construction a messy and expensive undertaking. New tools need to be developed to facilitate the sharing of information and to accurately determine costs for optimization at a systems level. Certainly, much work needs to be done to develop these tools, but in the long-term it is willingness to share information that may be a more difficult proposition; given the current climate in construction, firms are generally more comfortable sharing as little information as possible. Partnering and similar approaches have demonstrated a more cooperative framework for project coordination (although not with centralization in mind) and can be considered an evolutionary step towards a centralized coordination regime. Complete transition to a centralized regime involves careful consideration of incentive issues and boundaries between firms; we have discussed dimensions of this problem above and further discussion can be found in sociological (O'Brien, 1994; Powell, 1990) and economic (Laffont & Tirole, 1993) perspectives. In principle, centralization becomes possible with an equitable way to distribute its benefits. Firms that share information about costs and capacities can be equitably compensated for their expenses through an agreed upon payment and profit rule like cost-plus contracts; this approach has been advocated by (Miles & Snow, 1986). Of course, there are problems of opportunistic behavior as firms can be dishonest about their costs. But this problem also exists under a price-mechanism regime; at least under a centralized regime a decision maker has more knowledge about a firm's operations and claimed costs and thus may act as a check against opportunistic behavior.

For the moment, individual firms can take the lead in construction by doing a number of things: First, consider the capacity needs and constraints of the firms working on a project; similarly, consider the capabilities of supply-chains. Second, when negotiating a response to a problem of schedule and scope, think broadly about solutions; consider a broader range of interactions involving a larger number of firms. Third, pay close attention to contracts and incentive issues. Does the current incentive structure retard information sharing? Fourth, consider the nature and value of information that the firm would like to get from other firms; look for reciprocity. Use this assessment to develop better relations, different contractual structures, long-term relationships, etc. Fifth, consider the strategic value of information. What information can be shared without exposing a firm to risk? What is the minimal amount of information a firm needs to share or receive? Finally, do move forward with partnering as this technique does add value, but be sensitive to its limitations.

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