MAPPING CONTROL IN PRODUCTION CHAINS

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ABSTRACT

(This essay is drawn from my PhD dissertation titled "CONTROL OF PARTS: Parts Making in the Building Industry", completed as part of my doctoral studies at MIT, 1990)

When we examine the production of artifacts, we notice that parts change from rudimentary states to complex artifacts such as building systems and buildings. Parts are deformed, have elements removed, and are assembled and disassembled. In such processes, production operations, their sequences and their locations in space are of significant interest, since some are more efficient than others, lead to fewer mistakes and produce higher quality. The operations we observe in manufacturing and construction are also of interest because they are conducted by human agents acting in many overlapping networks or constellations. Among the many agents, it is conventional for one family of agents to manufacture or construct (producers) and another to specify what is to be made (designers).

This paper focuses on the place these agents take in production flows leading to buildings. We will discover, upon examination, complex webs of interaction in which agents act in relation to each other, through the parts with which they are concerned. These relations can be graphically mapped. In studying such maps, we can see various patterns of control or actions which become palpable in the diagramming tool discussed here, called **Pact**. The paper suggests how this perspective is important to building industry research, and comments on its relations to studies in other fields.

THE ECOLOGY OF PRODUCTION

The broader subject in which this essay may finds its place is called the ecology of production. It cuts across several traditional academic domains, and offers a perspective with roots in production theory and the physical characteristics of building systems, understood in terms of the actions human agents take in their production. As such, the perspective enables us to position, and understand, production, designing and other decision activities in production constellations.

The central principle proposed in this essay is that the study of physical parts and their alterations, and the study of organizational activities involved in physical value creation are incomplete without studying their direct interrelationships. This is accomplished by way of the concept of control, or the physical manipulation of parts. These interactions are presented in the discussion that follows by the use of a diagramming tool called ***Pact.*** Its visual "forms of reference" supplement and clarify many of the verbal and terminological references on which we have become dependent.

This perspective offers several opportunities. It enables us to compare the impact building systematization has on the constellation of the many parties involved in the building process. It also allows us to study the logistics, information flows, boundary conditions, and procedural aspects of building systems and the way such systems alter the modes of interaction of the parties involved. The perspective thus gained can explain, among other things, why building systems that are perfectly rational and efficient on paper sometimes fail when applied in practice, because they require the adjustment of interrelations in the building and manufacturing worlds.

A DIAGRAMMING TOOL

To assist in coming to terms with the ecology of production, we can abstract from the complex reality of production to focus on three core aspects. Of the many conditions of production, and the many kinds of agents, influences and contexts that can be discussed, the first set of diagrams below show three sorts of constituents: 1) the agents who control or change parts, 2) the physical elements subject to control, and 3) the operations used to control the parts.

When the term "control" is used in what follows, it does not mean "manage", "regulate", or "inspect". Rather, "control" here refers to the actual physical alteration or manipulation of a part, such as adding or removing parts, changing a part's shape, or otherwise modifying a part's physical form.

When the term "agent" is used, it is not meant to suggest a focus on human psychology, motives, or broader cultural meanings. While interesting, they are not studied here. A "control agent" is thus any individual or organization that controls parts, or whose identity is associated with "work". Specifically, we refer to such parties as carpenters, manufacturing concerns, or contractors, or others who, for the purposes of this accounting, physically alter parts.

We will also refer later to "design agents", those who specify what is to be made. The various ways these agents relate to parts flows and other agents is of interest. In this discussion, we will not discuss the many other agents involved in design and production such as suppliers, financing parties, regulatory agencies, and so on.

In the diagrams, the term "part" is used to mean any physical object that is identifies as such. A part can be a pipe, a door frame, a wall, or a house, that is any object we can identify and which we can manipulate in making buildings.

1.0 Parts and Wholes

1.1 A standard Pella Casement Window produced by the US firm Rollscreen Company has over 75 named parts. In its simplest representation, we would see

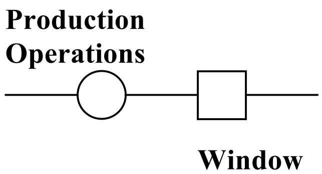

Diagram 1.1

where represents all production operations and represents the part “window”.

1.2 The window is, we know, non-homogeneous. It is made of discrete parts each with a name. A simplified part-whole diagram of one possible decomposition of a window would show

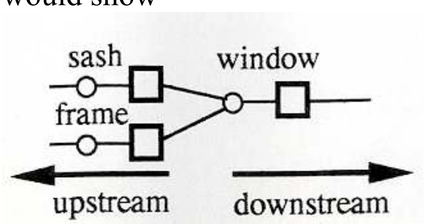

Diagram 1.2

where a sash and a frame are produced and together make a window. The whole is shown by convention “downstream” of the parts of which it is made.

1.3 By way of this decomposition, we can specify the stages of production by successively “opening” upstream representations of a part ( ) or operation (O) to see more. There are many ways in which the window can be decomposed or specified. For example, diagram 1.2 distinguishes the non-operable part (the frame) and the operable part (the sash) but we could have others, such as:

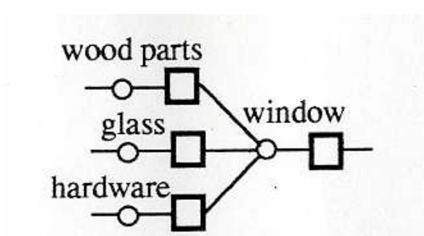

Diagram 1.4

based on material distinctions. We could also distinguish by kinds of operations, and so on. However, for our purposes, we limit ourselves to decompositions corresponding to feasible production sequences.

2.0 Operations

2.1 In the diagrams following, the O symbol is a general notation for technical operations. The number of discrete operations to make the window and its parts are in the thousands, but are of four basic kinds:

2.1.1 *deformation*, or change of form without adding or removing material (e.g. compression of a gasket), shown as:

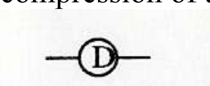

Diagram 2.1.1

2.1.1 *removal*, or taking away a part that was not previously added (e.g. cutting or milling a material), shown as:

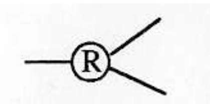

Diagram 2.1.2

2.1.3 *assembly*, or putting parts together (e.g. attaching the glass to the window sash), shown as:

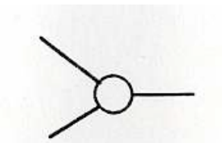

Diagram 2.1.3

2.1.4 *disassembly*, or reversing an assembly operation (e.g. removing the sash from the frame), shown as:

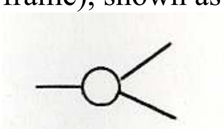

Diagram 2.1.4

2.1.5 *unspecified operation*, for use when an operation occurs but is not yet specified. Such an operation may be shown as:

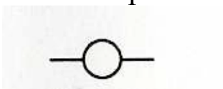

Diagram 2.1.5

2.2 Operation Sequences

The sequence of operations may be organized in different ways, for making the same object, for reasons of convenience, convention, functionality, cost control, as shown in:

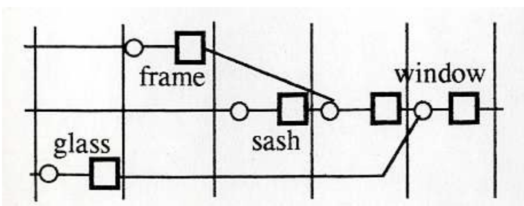

Diagram 2.2.1

or in a variation:

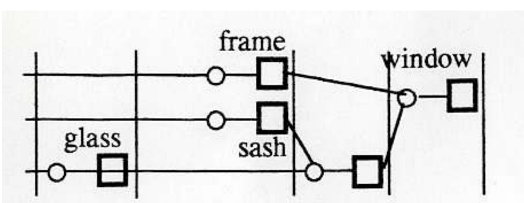

Diagram 2.2.2

in which the same parts are subjected to a different sequence of operations, with some of the operations occurring simultaneously (shown as vertically stacked), producing four stages compared to the five stages shown in diagram 2.2.1.

3.0 Site

3.1 All making occurs on a site. The site may be an assembly table in a factory, a space in an office building being "fitted-out", or a hillside where a house is being built. However, the decision to couple a site and work is subject to controversy because there are economic, logistical and technical consequences to this decision. The notation thus includes a way to represent the distinction between sites. For example, the assembly of the sash and frame can be shown:

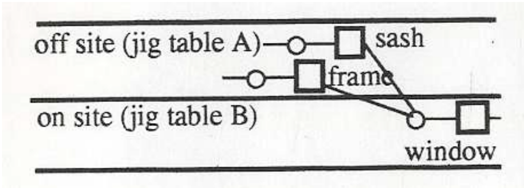

Diagram 3.1

Where an "off-site" distinction (relative to the house in which the window will be installed) is cast in two locations (sites), showing that both sash and frame are made in one place (site) and assembled in another (site).
3.2 We can also see that the disposition of production to different locations or sites can be different for the same production chain, as in

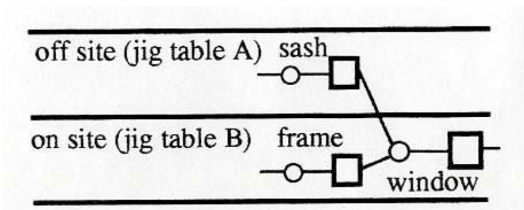

Diagram 3.2.1

where "on site" means the location where the window is finally assembled.

or alternatively,

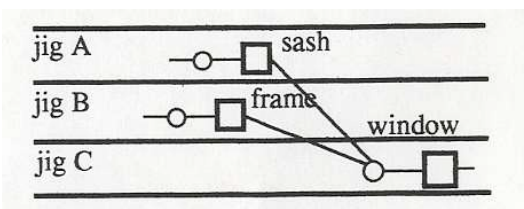

Diagram 3.2.2

4.0 Agents and Control

4.1 The window we have been using as a demonstration, and its parts, feel the imprint of many hands (and machines) during its production. While a window may once have been produced in its entirety by one pair of hands, belonging to one skilled craftsman using simple tools, we are today used to a process whereby a number of agents are engaged in the many tasks using sophisticated computer driven machines.

We will call the agent doing the "work" of physically manipulating a part the CONTROL AGENT. Having identified such agents, we may observe their various deployments relative to the operations involved in making the window.

4.2 We may see a single control agent in the following way:

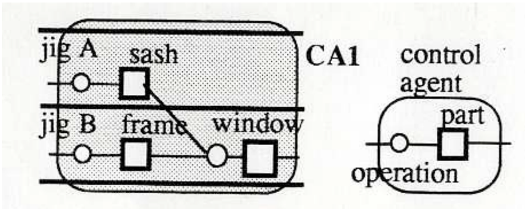

Diagram 4.2

where CA1 controls all parts and operations exclusively.

4.3 If, however, a situation of distributed control is observed relative to the same part-whole diagram, several possible arrangements are possible for the same value-adding process, for instance

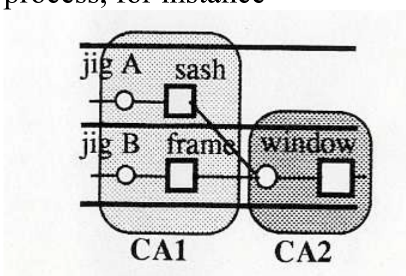

Diagram 4.3.1
or

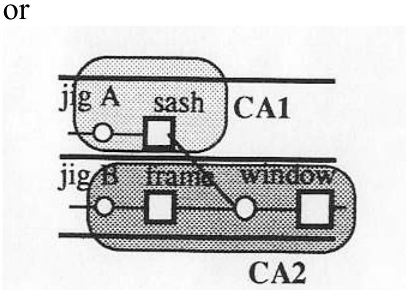

Diagram 4.3.2
or

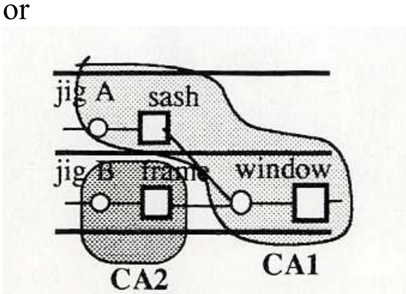

Diagram 4.3.3

and, the identity of the control agents can change without altering the arrangement or pattern of control, e.g.:

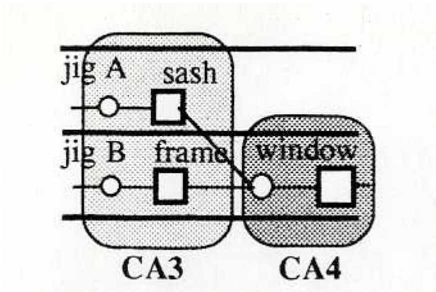

Diagram 4.3.4

These diagrams show that a DISPERSED PATTERN OF CONTROL exists. Drawing control agent boundaries in this way shows the independence of each agent. For instance, CA3 takes initiative to produce the sash and frame independent of CA4. CA4, for its part, makes the window independent of CA3, but uses the sash and frame made by CA3. Presumably, CA4 could also acquire sash and frame from another CAX, producing a competitive situation with CA3.

4.4 The same agents may, on the other hand, be arranged in another way over the same assembly hierarchy, in an overlapping form, as shown here:

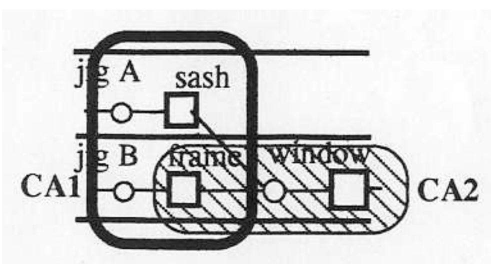

Diagram 4.4.1

or

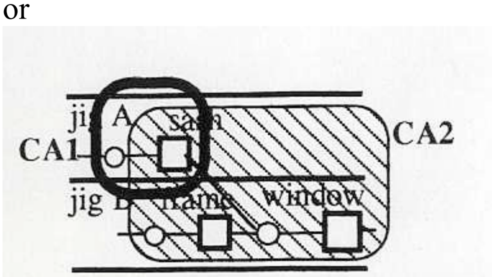

Diagram 4.4.2

or

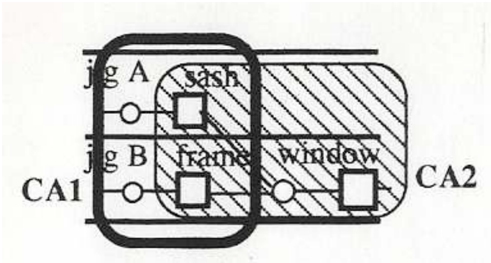

Diagram 4.4.3

and again, the identity of agents may change without altering the arrangement of control. We may, of course, never find in practice what can be diagrammed, an important benefit of diagramming.

The examples in 4.4 show situations of OVERLAPPING CONTROL. Drawing control agent boundaries in this arrangement shows, for example, that in 4.4.1, CA2 controls the window and has what we will call INDIRECT CONTROL of the frame, which is controlled by CA1 along with the sash. CA1 and CA2 share the frame, but have different relations to it. CA1 controls or physically alters it, but we read the diagram to show that CA2 INSTRUCTS CA1 to make the frame, since it needs it for the window but does not choose to make it. CA1 can, in this diagram, select operations to make the sash and frame, since these operations are not within the boundary of CA2.

4.5 Putting diagrams 4.3.1 and 4.4.1 adjacent to each other, we see in the two different control patterns here two ways control agents may interact over a given part-whole hierarchy:

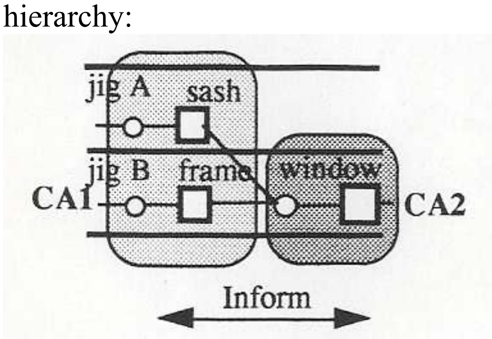

Diagram 4.5.1

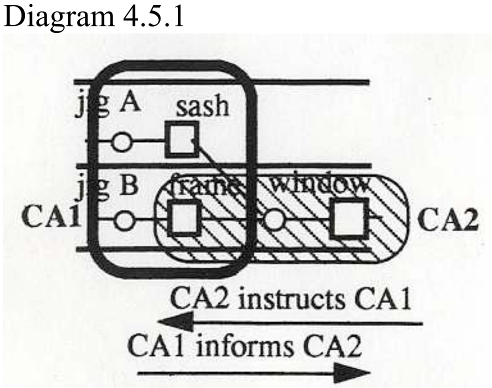

Diagram 4.5.2

In diagram 4.5.1, we associate CA1 with a kind of agent who makes parts independent of any "downstream" agent; CA1 takes the initiative. That is, CA1 produces "on speculation", "for stock", or "for the market". CA2 is shown assembling the sash and frame to make the window. One of two conditions must then exist: CA1 has studied CA2's control situation, and perhaps those of other CA's making windows, and decides to produce parts attractive to CA2 and other window producers; or, CA2 finds CA1 making parts and adjusts its operations to efficiently use what is already available from CA1. The two agents need not communicate directly or share information for either condition to exist, but communicate by way of the open market. The only information exchanged is in the part itself (or its representations) and about cost. This diagram does not represent, for example, the Pella window.

This decoupling of maker and user has its own efficiencies, opportunities and risks. This may be a basis on which a maker may innovate and compete independently, and by virtue of market generalization, seek wider markets because of its independence.

We associate CA1 in diagram 4.5.2 with an agent who makes parts indirectly controlled by or ordered by the downstream agent CA2. CA1 produces, in this instance, "by order" "on requisition" of CA2. The upstream or "producing" agent's work here depends on the indirect control of the "user". Direct communication therefore occurs concerning what is required, its physical characteristics, price, intellectual property rights, boundary conditions, and agreements are reached concerning the producer's capacity to meet the user's requirements.

The coupling of maker and user indicated in overlapping control increases negotiation, exerts significant pressure on the skill of the design agents involved, but may also result in a decrease in later stages of work, and an improvement in quality, a reduction in waste, and more speed in downstream operations. The weakest link in a complex chain of overlapping agents may be in the ability of those specifying the parts to understand the larger value chain, clarify responsibilities and specify unambiguously.

4.6 A PATTERN OF INCLUSION is indicated in a variant of diagram 4.5.1, where we see:

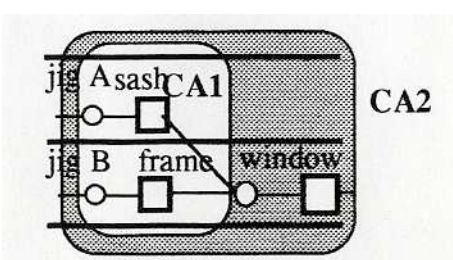

Diagram 4.6.1

in which CA1 controls sash and frame as well as associated operations, all of which are indirectly controlled by CA2, which makes the window, as shown. CA1 has no independence. CA2 assumes responsibility for instructing CA1 both on parts and operations.

Making a diagram this way lets us consider what CA1 is. With no action aside from what is indirectly controlled by CA2, we can say that CA1 is an automaton or programmed machine, capable of no independent activities.

5.0 Specification Agents

5.1 In the diagrams so far, the task of specification has been assumed, if it exists as a distinct task, by the control agent. It may be that further division of roles serving production is evident. A distinct SPECIFICATIN AGENT, who specifies what is to be made, may appear, and be diagrammed as follows:

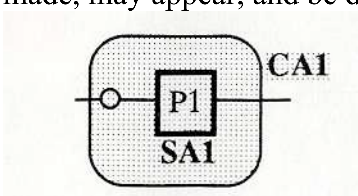

Diagram 5.1

where SA1 serves P1 by formulating its physical properties in such a way that CA1 can control it by operations of its own selection.

5.2 We can also make a diagram of another situation such as

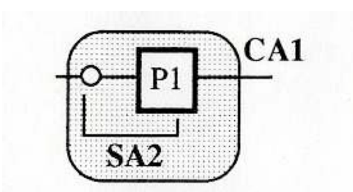

Diagram 5.2

where SA2 formulates specifications about both O and . This situation is close to what is called “concurrent engineering or design”, in which issues in production are closely considered in the part’s specification by a single team (SA2) incorporating parties involved in all steps of a product P1’s value chain. This process is made easier now with computer driven machines.

5.3 A variant on diagram 5.2 is one in which two separate SA’s (specialized teams, for instance) operate in the same control situation, as in:

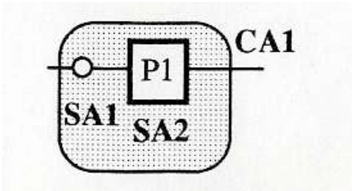

Diagram 5.3

suggesting the need for coordination and collaboration. This diagram respects, however, the reality that some individuals (or teams) have specialized knowledge about production operations, and others may understand the questions of parts structure and form, style, and marketability.

5.4 If we "open" an abstract situation of control and show a more complex role distribution, SA's may appear with various scopes of responsibility in a situation of DISPERSED CONTROL, such as:

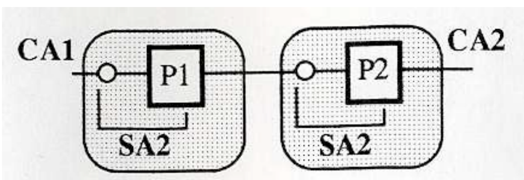

Diagram 5.4

in which the same SA2 is engaged for two separate control agents CA1 and CA2.

5.5 In the context of an OVERLAPPING CONTROL PATTERN, a situation may exist in which the same SA serves both P1 and P2 and their associated operations, as in

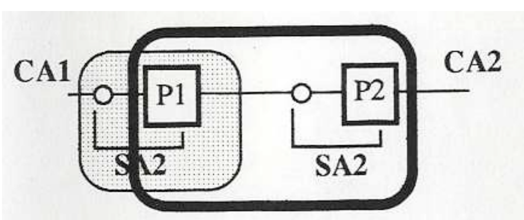

Diagram 5.5

RESEARCH WITH **PAct**

The purpose of developing **PAct** has been to support description of interwoven organizational and technical forces at work in multi-agent production activities. The present "visual language" is therefore not an end in itself, but a means to bring the concept of control into the technical discourse. Using **PAct**, we may therefore sharpen our understanding of the ecology of production, in order to detect problems and opportunities for improvement in the process of value creation. Such a capacity is vital to effect improvements in quality and utility of products, the identification of points of friction and needs for new knowledge, and the well-being of individuals and organizations engaged in manufacturing and construction.

A number of areas of research may benefit by mapping value chains with PAct. Several are noted below.

UNDERSTANDING SYSTEMS

The term "system" is used in the building industry to describe any set of interrelated parts. Such terms as "systems building," "open systems," or "closed system" are found. Most definitions are given in technical terms, such as product compatibility, technical interfaces, interchangeability, and so on. But since any system is first of all an agreement among a group of people to designate a set of parts as such, any definition of a "system" must recognize its social or organizational dimension. **PAct** diagrams make this designation possible in an unambiguous way.

Not only are systems concerned with both parts and people, but they evolve. Such evolution can reveal important characteristics of both the technical repertoire and the agreements needed to let the "system" evolve as such. Studying the evolution of systems will help us understand and improve them.
Given an interest in the development of a particular system, such as "partition systems," "plumbing systems," "façade systems," or "infill systems", we may want to delineate their evolving jurisdictional boundaries. This has been of interest in the field of the law and trade jurisdiction disputes.

What, over time, is understood to be included in each of these "systems?" If, in the interest of comparison, we represent the evolution of a given "system" in a serious of diagrams, we can examine what perturbations are observed in each diagram, inside and outside the system's boundaries. For instance:

• Have operations changed with no change of the control pattern?
• Have certain agents been replaced by others in the same control pattern, or have changes in agent identities (e.g. laymen vs. professionals; union vs. non-union; carpenters vs. another trade, etc) accompanied changes in control patterns?
• Concerning which technical operations has the system remained stable as its environment changed?

In this way, we can also represent the evolution of a given "system" juxtaposed against the demise of a competing system which failed to mature. In so doing, we are in a position to identify key attributes of successfully evolving systems in terms of both hardware and the organizations in whose boundaries they exist.

TERMINOLOGY AND DEFINITIONS

The ASTM (American Society for Testing and Materials) Committee on Terminology meets regularly to resolve disputed definitions and concepts, and to improve the terminology used in the standards community and those constituencies affected by standards. Terminologies are aggregates of terms, representing concepts of importance to various fields, and are important tools for classification, knowledge transfer, and translations. Terminologists, those who prescribe terminology for general usage, are the creators of terminology.

In the development of terminology, concepts are fundamental. They serve as the basis of terminology, referring to objects of the world observed. Concepts can refer to objects, properties, and relations as diverse as "a brick," "pain," or "manufacturing." A concept, however, is only a mental construct derived from objects, properties or relations. In order to communicate that mental picture, a symbol is assigned to represent it. (Felber 1993)

In a culture dominated by the written and spoken word, it is not surprising that written text is the accepted symbolic mode for conveying mental pictures or concepts, particularly in relation to legal agreement. However, discursive means of conveying information can be supported and in some cases supplanted by pictorial means.

An example of the difficulty of strict reliance on the written word in developing definitions of terms comes from the following partial soliloquy from an ASTM meeting of the subcommittee considerations of voter comments relative to E-6.94 on Terminology and Editorial. (October 21, 1987 meeting)

"Item 2, building assembly – 1) fitting together of manufactured parts into a complete structure. 2) the structure so formed. Voting tally: 90% affirmative.

Negative comment:
Schuman: Is written to answer "building an assembly." As an entity it should read: manufactured parts fitting together into a complete structure.
Ventre (non-voting): why restrict to "manufactured?" This eliminates a large class of parts: e.g. those hand fabricated.
Affirmative comment:
Ellis: change "parts" to "components"
Action by Subcommittee:
Item withdrawn from ballot for review of interrelationship of Items 2 through 7.

Item 3, Building Element – a building component or part of the simplest nature, such as a wall, a beam, a foundation. Voting tally: 54.4% affirmative.

Negative comment:
Ellis: "of simplest nature" is too general and limiting. Delete. Add "principle" before "building component," so as to include the concept of a major component. Delete "or part" 1; see item 1.

Ferguson: Add “a major” building component. Delete “of the simplest nature;” a wall is not so.
Mather: A building component of the simplest nature is an atom or molecule. “Simplest” is one of those absolute terms that ought to be avoided. If the phrase “of the simplest nature” were deleted, the resulting definition would suit me all right. However, there is a problem of the relationship with item no. 5…
Schuman: what is “simplest nature” to a carpenter, or…?
Verschoor: The phrase “or part of the simplest nature” threw me for a curve. Does “building element” also apply to a nail or a screw? The examples given are components consisting of assemblies of constituent parts. Perhaps the present definition is too close to item 5 for “building member,” which is causing the confusion.
Jones: the use of “component” in items 3 and 5 seems to conflict somewhat with the term “component” as defined in 631. Is not a component more complex than an element? We seem to be making them synonyms.

<u>Action by Subcommittee</u>
Item withdrawn.

There were other efforts in the same committee meeting to pin down terms of reference in addition to “building element” and “building assembly,” including “building material,” “building member,” “building product,” “building system,” and others.

What would these terms look like in a PAct diagram? The search for such definitions as those above can perhaps be supported by reference to diagrams, such as the following:

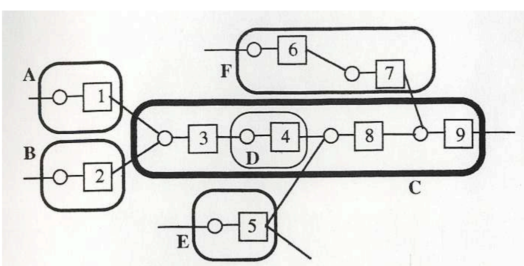

Diagram 5.6

We could conduct the above committee discussion with the assistance of PAct diagramming. If a disagreement about a definition should occur, the members would make diagrams that each thinks best fits the concept they have in mind. If the diagrams which result are the same, the words chosen to describe the concept are the problem, not the concept itself. For example, a dialogue might ensue as follows:

Building Assembly: in this diagram, parts 3, 8, and 9 are assemblies. We could say, then, that a part (3) is an assembly when, from the point of view of the agent controlling it, more than one part is connected to the upstream side of the operation resulting in such a part (3).

Building Element: we might agree that all parts shown are elements; but someone else may declare that only parts 1, 2, 4, 5, 6, and 7 are elements. That is, a building element is defined as such when the operation making it is connected upstream by a single line only.

Building Material: Someone might say, “a building material is what has been made, low on the value chain, with no specific downstream use intended.” Someone could be expected to ask “how low on the value chain?” Are only parts 1 and 2 qualified as building materials in this diagram?

Building System: Is a building system that which a single party controls? If not, how do we recognize a building system?

MAKE VS. BUY DECISIONS

Make vs. buy decisions have non-trivial organizational and resource allocation implications for organizations.

To make a part, whether the actual CONTROL is delegated “upstream” to other agents or not (shown in PAct by overlapping control patterns) means taking responsibility for it. In this process, the interesting question is how far upstream to other agents must the control delegated to achieve the required result. Making a part is burdensome, time consuming, and complex, and is only needed when parts on the open market are unsatisfactory.

In buying a part, the boundaries of responsibility are quite different. Then, we are not responsible for the part we buy as such, but are responsible for it when we control or modify it – when it comes into our control domain. Using PAct, we can study the implications of the make vs. buy decision in the context of the patterns of control associated with each.

In the large sense, the building industry seems to thrive on situations of control shown as DISPERSED CONTROL PATTERNS. It is normally the case that any given building project “reaches” only a very short distance upstream to control production, soon moving into the constellation of available parts. Compared, for instance, to the control pattern of an automobile’s value chain, a house’s control pattern is quite different.

STUDIES OF INNOVATION

Studies of innovation stress the stages of emergence, rapid acceleration and adoption, and maturation and leveling off of a technology (Foster, 1986). When products are reconfigured, new ones introduced, new organizational forms created to match the new hardware, and new supply chain constellations formed, there is nevertheless the requirement that the innovation “connect” with existing flows both upstream and downstream. The innovation, in other words, occurs in a field of activity, a socio-technical context, which must be relatively stable.

Exactly what constitutes that stable field is a mystery to managers of innovation. It appears shifting and illusive. That field, is, in PAct terms, the constellation of both OVERLAPPING AND DISPERSED CONTROL PATTERNS within which the innovation is positioned, and can be mapped at successive levels of abstraction. PAct diagrams are a kind of environment in which these patterns of the field can be effectively studied.

BACKGROUND

In the work leading to the development of the accounting tool discussed here, the concept of "CONTROL AGENT" did not appear in existing technical discourse or in existing visual language tools used in the various technical fields studying production (Compton 1988). That meant that existing modeling could show parts and pertinent date about physical characteristics and information embodied in the technical operations, but could not identify the "agents" who actually did the work or specified it.

Because of this, existing diagramming tools could not help identify inter-agent relations in production chains. Without this ability, it was difficult to understand production chains in a way that would make palpable the shifts we know sometimes occur as production and building systematization undergo change. Further, the inability to explicitly associate agents with the parts manipulated, at both a macro and micro level of analysis, was a serious impediment when accounting for organizational and individual action and responsibility.

On the other hand, current thinking on the organizational or management side of production and construction seemed to operate from the perspective that the physical systems under study were "there" in an objective, "a priori" way. Agents as units of analysis were discussed, but their control or manipulation of parts had not yet become part of the discourse, even in the organizational literature dealing with technology (Schön 1967).

Because up to now neither the organizational nor production engineering models address these concepts and interactions, what might be called the ecology of production remains unexplored. This is detrimental to our understanding of the mutual effects of control patterns and the technical repertoire under frequently shifting practices of production.

Most of us will be familiar with the accelerating efforts in the engineering fields to develop theories of design, and to integrate design and manufacturing in what is called "concurrent design and production" (Nevins 1989) or "new strategic aggregated disciplines and processes" (Miller 1994). Most of these efforts have come about in order to make good use of computers and to support better communication between the parties involved in complex, multi-agent, geographically dispersed design and manufacturing processes.

In recent years, we have also seen increased efforts, by colleagues in many fields not normally associated with the design and making of man-made systems, to understand what designing and making activities are and how they can be effectively linked or "integrated".

For instance, it is common knowledge now that the sciences, especially those in biology, are fast becoming members of the design and production establishment. Not only do they try to understand certain biological phenomena, they are actively engaged in changing what they observe, stimulating new observations and new proposals. In actually constructing artifacts such as new genetic structures, these colleagues also enter into a distinct kind of work which serves and supports the production of new artifacts, the activity we know of as "designing". (Aldovini and Yound 1992)

Other fields not traditionally interested in the subjects of designing and production of the built environment are also moving into this milieu. Focusing principally on electronic and automotive engineering, academic colleagues in business management and organizational theory are appropriating language associated with architecture in describing the evolution of technological systems. In this work, we find terms such as "architectural knowledge," "component knowledge," "architectural innovation," and "systems architecture" (Henderson 1990).

In the field of cognitive studies, a prominent author has published a series of books and articles that seek to take stock of how and why some products- designed, manufactured, and marketed by trained experts- satisfy customers and others frustrate them (Norman 1988).

Also, a field called organizational ecology has emerged. Authors track the mortality of industries and technological change, drawing upon terms of reference familiar to designers and manufacturers such as "systemic technologies," "standardizations," and "product differentiation" (Mannan 1989).

The perspective offered by the ecology of organizations seeks to understand the forces that shape the structure of organizations over long time spans. The view seemed close to the one discussed here, since here the focus is on understanding the "structure of production" as a socio-technical enterprise, and the ebb and flow of technical tasks and roles over time. This also led to readings in another emerging field called "socio-technology". (Bijker et al. 1987)

These are positive signs. It shows that the work of designers and producers - engineers, architects, parts producers, builders - is of interest to other fields. Because of the enlargement of the field of explorers, there may be new grounds for building a better understanding of man-made artifacts, and how they come to exist and change by human action. This being the case, however, it is incumbent on those for whom designing and making are central not to stop in their efforts to stretch the limits of what can be made explicit in their activities. The task is made the more difficult, however, because the mundane objects such as pipes, tiles, fixtures, windows, walls and buildings which are the subject of the present interest escape attention because of their very ordinariness.

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