Control of Parts
Parts Making in the Building Industry

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PhD Dissertation
Department of Architecture
Massachusetts Institute of Technology
July, 1990

CONTROL OF PARTS:
Parts Making in the Building Industry

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SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE DEGREE
DOCTOR OF PHILOSOPHY
IN THE FIELD OF DESIGN THEORY AND METHODS
AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SEPTEMBER, 1990

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Submitted to the Department of Architecture on July 3, 1990 in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in the Field of Design Theory and Methods

ABSTRACT

The thesis advances a diagramming tool called PAct. Each diagram is a model of a "value adding" enterprise, representing materials processing, parts manipulation and assembly, and the agents involved. Its purpose is to support analysis of the interactions of agents and parts in production flows which are too complex to be held intuitively in mind.

In exercising the tool in simple demonstrations of both conventional and "innovative" instances of parts production, two basic diagram patterns appear: "dispersed" patterns in which agents control (make) parts independently, and "nested" or "overlapping" patterns where some agents control and others indirectly control (design). Descriptive power of complex making processes is increased by putting both "processes" (changes made by agents) and "products" (parts) together in the same diagrams. Designing is found to be vital but not the only or even the dominant relation between agents in value added flows.

PAct grew out of questions regarding difficulties the design professions often have, when trying to improve conventional house building practices. However, the tool is more generally useful to product manufacturers, building industry researchers, historians of technology, and designers who need accurate descriptions of value added flows of any parts making enterprise, to supplement present analysis tools.

Thesis Supervisor: N. John Habraken
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Acknowledgements:

I am grateful to many people:

My parents, John and Catherine Kendall, for sustaining support of all kinds, and for helping me from an early age to appreciate beautiful things, the practicality of ideas, and the value of reflection;

My wife Yoshiko for being a tolerant and loving partner in the changes that this undertaking brought to our family;

My children Nicolas and Yumi for their loving spirits, their music, and their being there to bring me back frequently from the solitary work of thinking and writing a disseration;

My dissertation committe:

John Habraken, a friend and guide for over a decade and a half, who helped me to look into the making of the ordinary built environment in a profoundly new way;

Donald Schön, for coaching me in the art of active listening and presentation, for asking hard questions about how I think, and for leading me to new questions;

Eric Dluhosch, for continuing support and colleagial exchange, representing a kind of academic tradition that is too often forgotten.

Francis Ventre, who was the first person outside my committee who came to understand what my work was about, and was therefore an invaluable intellectual colleague along the way;

Mark Gross, whose early and continuing encouragement to pursue what I felt was right about the thesis was of the utmost importance;

Nabeel Hamdi for encouragement when I had doubts about undertaking a PhD;

Mike Martin, who encouraged me at an important time in my academic career to undertake this Doctoral work;

Seiji Sawada, for pushing me to set goals; and

Age van Randen, for setting an example of how to work out of a vision toward practical results.

Table of Contents

1.0 Introduction: The Control of Parts

The thesis puts forward and demonstrates a new graphic diagramming tool for the study of parts making in the building industry.

In the chapters that follow, some of the tool's uses are demonstrated on practices in parts manufacturing, assembly and construction. Housebuilding has a prominent place among the demonstrations of the tool for reasons I explain further. Methodological and intellectual issues that arose in developing the tool are discussed, and next stages of the tool's development are sketched.

Each use of the tool found in what follows represents a "model" of a highly complex "parts making" enterprise, which may include materials processing, parts manufacturing, building construction or assembly, and certainly includes many people. These phenomena which I call "making processes" are a kind of value chain or value system, terms in currency in the business literature (Porter, 1985). However, unlike in business analyses of value chains, this tool makes explicit both the specific physical parts of interest, and the people or agents changing them. That is, both agents and the parts they change appear in the tool, in relation to each other.

The position I take in the thesis, and a position instantiated in the tool, is that the three-fold order of parts, people's domains of action, and parts changes constitutes an essential core of all making processes, and that ignoring what these three variables have to do with each other impedes the kind of accurate analysis of the dynamics of parts making that is now needed.

From that position, my task in the thesis research has been to look into ordinary parts making processes from the point of view of control, or the actual manipulation of parts by people. The central objective of the tool is to help bring control, in the sense used here, into the discourse on parts making and building construction, among architects, building researchers, and parts makers of various kinds in the building industry.

A review of literature on parts making, building construction and adaptation - and of particular interest to this author, housing production - shows that control as the term is used here has been largely ignored, or has remained implicit, for reasons I discuss in §5.4. Particulary among analytical tools used to describe parts manufacturing, assembly and construction, control as used here has been absent, as we see, in §5.3, in a review of a number of extant tools with graphical and conceptual structures somewhat

similar to the tool I present.

Several intellectual traditions have stood behind other examinations of parts making that have supported the present study. Briefly, we see that there are many insightful efforts of a broad, contextualist orientation in the history of technology (see e.g. Mumford, 1961; Daniels, 1970, Staudenmeier, 1989) which come close to the views taken here. Yet these are still some distance from where we need to be. These studies are, finally, well wrought critiques but are not ultimately driven by the professional necessity of acting on and actually crafting artifacts.

On the other hand there are many highly detailed and accurate examinations of parts making grounded in the physical sciences. These studies have little to say, as could be expected, about the social or organizational ambiance in which parts find themselves, and remarkably little to say about the actual continuum of parts changes in value added processes. (see §5.3).

Some of the closest work to what I present seems to be in studies of labor jurisdiction disputes, in the legal field (Bartosic, 1986), in construction management (Paulson and Fondahl, 1983), and again in the history of technology (Scranton, 1988). In these studies, "who does what to what part" and the mutation of such transactions, constitute central issues of interest.

Another place where we can find efforts to untangle and rethink the complexes of parts making processes has been in the work grounded in systems theory. Systems thinking has been a strong intellectual tradition in the building industry in the past 40 years, at least in academic circles, but a discourse which, after great expectations, has yielded up meager results so far. In part, this meagerness of results may be attributable to the separation of control from the conception of parts making in systems thinking. After years of systems thinking which presumably has taught us to view process and product as inextricably interactive, the commissioning of separate "process" and "product" studies continues, evidence of the maintenance of a conceptual vantage point to which this thesis offers an alternative. (e.g. NAHB National Research Center's Advanced Housing Technology Program reports, 1989)

Much academic work in the study of artifact making, reviewed in the research, has been hampered by what I see to be the difficulty of distinguishing between intentionality and what actually happens in parts making. I believe that this problem is significant, and has appeared for the most part in the efforts in the social sciences to contribute to the understanding of designing and the production of the built environment. The problem comes in part, I think, from a healthy conviction on the part of many

researchers that technology is not value free, and therefore human values expressed in intentions, motives, drives and so on cannot be ignored in its study. But it is one thing to make intentions intrinsic or integral to a study of technology, and another to make a way of studying and describing technology that enables us to discern where particular intentions may be at work in the enterprises we want to understand.

I've aimed for the latter, to uncouple what could be called the psychology of makers from the actual making, so that the variety of their relations could be better understood. For example, the simple demonstrations of the tool I present show that changing parts in value added flows open lines of communication between the people working. People take action directly on parts, sometimes ask others to make parts for them, seek help, make parts for others, and in so doing establish complex and fascinating networks of interactions between parts and people which are the main subject of the tool. This discussion is taken up again in §4.1 and §4.4, but is found also throughout the study.

This view of making - that it is minimally described as people manipulating parts, distinguished from intentions - seems on its face to be trivial. But the entwined complexity of such "making" processes as I focus on has contributed to making such explicit accounting as proposed here difficult to accomplish. Deciding traditions, constraints, and geography, and how to organize it, are themselves important difficulties that must be surmounted.

A study of parts making is especially interesting when we recognize that many "making" activities are shared between experts and non-experts and are not exclusively the property of any professional group. Housebuilding is one such field, an important reason that it is used as the subject for several of the demonstrations of the tool I present in following chapters. Interestingly, the convergence in housebuilding of experts and laymen seems to accompany a tendency to shun the issue of control, perhaps since knowledge of housebuilding is not the sort that can easily be maintained as exclusively professional knowledge. This interchange between professionals and non-professionals is discussed more fully in §4.1, with reference to the observation that housebuilding in particular has been a field in which notable efforts by architects to organize comprehensive changes in housing production have been routinely attempted and just as routinely rebuffed.

Many may argue that an accounting of parts making's complex and apparently seamless cultural enterprise in the way I present it only impoverishes it. That is not easily argued, however, since an accounting is not to be mistaken for reality.

1.1 PAct: Overview of the Tool

The tool presented here, called PAct from Parts and Action, places agents (individuals or organizations), their work (operations to change parts), and the parts manipulated (building parts like windows, pipes, etc) in view together by the use of graphic notation, so that their mutual interactions can be observed and studied. A simple example of a PAct diagram follows:

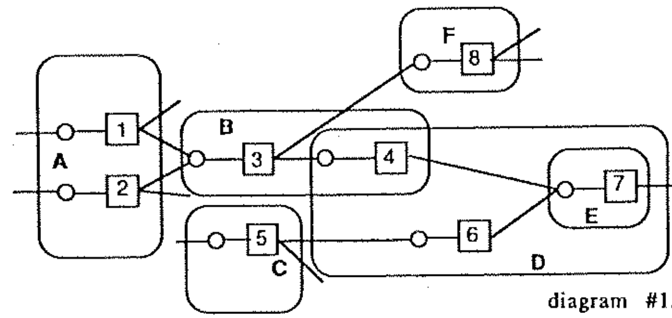


diagram #1.0

Agents are represented by the bubbles, parts by the boxes, and operations by the circles. The lines connecting boxes and circles indicate the lineage of parts, read from left to right in the order of precedence. Looking at the elements of the diagrams, agents can be seen in relationship to other agents, parts relating to parts, and parts relating to agents. These are the principle interactions which PAct diagrams help us identify, account for, and ask questions about.

In the diagram notation, agents A, C, and F have independant bubbles making a pattern of dispersal, while agents B, D and E have nested or overlapping bubbles. From where agent B stands, parts 1 and 2 are parts which are there but which agent B did not have to think about making. On the other hand, agent B makes part 3, one instance of which goes to another agent (e.g. agent F) while also making part 4 because agent D bas asked for it. Agent D makes part 6, but has agent E making part 7. Agent E only works upon demand of agent D. Parts 1, 2, 5, and 8 also go to other agents not identified in the diagram.

The agent which makes or changes a part is said to **control** that part. The agent which asks someone else to make a part has **indirect control** of that part, while the control of the part rests with the agent actually manipulating or changing the part. The distinction between these two roles is crucial and appears as a thread throughout the thesis. It is important to note that agents do not control other agents; agents control parts. Here, control is a concept with a narrow definition, applying to the relations of agents to parts, not, as it is used in management literature, to refer to human relations or the relations of people to things. (e.g. Merchant, 1985)

1.2 What PAct Is For and Who May Find It Useful

In the sections which follow, the PAct tool is used to describe a number of value added processes. One set of demonstrations of the use of PAct will be in comparing several ways of building houses. I construct diagrams of principle features of a major post World War II effort to change conventional housing production practice by wholesale introduction of new hardware and agent relations. I refer to the Lustron House initiative. Other diagrams of the value added flows of "conventional" housing technology under a variety of organizational forms will be presented. Discussions about the difficulties faced by Lustron and other cases will be presented by way of comparisons to conventional practices. (see §3.2)

Doing this comparative work with the assistance of the graphic notation, we can literally see where in the diagrams of value added flows certain kinds of interactions occur. We know, for example, that Lustron's efforts eventually failed. Looking into the diagram of that initiative, with many agents and parts-making flows under Lustron's roof (literally and figuratively), and comparing patterns we see there with patterns in the other cases which remain alive, we can come closer than before to accounting for the conditions which accompany stability or instability in housebuilding practices.

For example, a conventionally built house is diagrammed, showing patterns of relations which are apparently congruent with stable and enduring value added flows in the large sense. Discussion about what this means follows, using PAct diagrams to illustrate points (§3.3). The diagrams reveal information flows in various directions between agents, patterns of hardware flows, kinds of agents doing particular work, numbers of steps in making, in whose domain these actions are taken and other important aspects of making processes.

Making a number of diagrams, we can then scan them in successive "diagram sweeps" for particular attributes or characteristics, such as:

- which part (and kind of part) is controlled by which agent, employing which operations (cutting with saws, or lasers; bending by hand or by special equipment, etc);
- which kind of agents (e.g. expert or layman) appear in which parts of the diagrams;
- which parts of value added flows are characterized by diagrams with many independant agents and which with nested or included agents.

These kinds of questions will be discussed throughout the thesis.

The PAct diagrams are also used throughout to discuss issues

of theory and methodology, definitions and distinctions found by using the tool but usually not found in normal discourse or practice, and comparison of PAct with other models and tools which appear to have similar structures.

PAct has been invented first of all to assist its users in the architectural, construction and manufacturing fields to better understand conventional practice in parts making, that is, what is actually going on in parts manipulation. I have sought to build a way of giving us more descriptive power of parts making than is currently available. This may put us in a better position for making good explanations of "why" some process, part or control pattern is working well or not, or why some alternative practice or value added flow should be put into use. Comparing alternative practices with the tool is one of its most important methodological contributions.

This is important because a careful reading of the literature on the history of technology, product innovation, and the development of "new building systems" in the building and housing industries shows repeatedly the difficulty of drawing the important lessons from the experiences of others who have explored the same territory before. Books, technical reports and other studies are replete with stories of comprehensive programs such as Operation Breakthrough, General Panel House, Lustron, and other less dramatic initiatives, which have failed to bring about the changes envisioned, despite long and costly planning efforts using both private and public funds.

In addition, use of the tool moves us closer to understanding that building "systems" are not invented or designed, but are instead cultivated over relatively long periods of time in the ground of conventional practice, by the work of many independant actors. For example, if we admit conventional wood housebuilding practice into the lexicon of "Systems" (notice the designation of this practice in Japan as "the 2x4 system"), then we will be forced to note that no one, no inventor, and no research program produced this "system", but we will also recognize its pervasive influence. If we do recognize this, why then do we hear frequent reference to the introduction of new systems in normal discourse in building technology?

PAct will also be useful in the discussions about making buildings and parts used in buildings, within those disciplines whose professional identities depend on the continual development of new knowledge and insights such discourse offers. Architecture certainly is one such field. While scholarly investigations of the sort engaged in here have not easily found a place among the inquiries in universities bound to the normal divisions of knowledge along classic lines, it is my conviction that

architecture is one of the proper homes of such studies as this one. Architecture, and parts making in the large sense, are endeavors which in practice focus hard on action, but which in study may well seek to understand the parts its practitioners change and the patterns of control in which the parts move.

But, if a place has not been found in traditional university - and architectural - inquiry for this sort of discourse, and if sheer complexity has made parts making analysis difficult and inaccessible, apparently these are not the only impediments to precise and accurate descriptions of the kind needed. There is also the issue of how people in the parts making business, including manufacturers, designers, and contractors, craftsmen, regulatory officials, and other practitioners conceive their field of work in intellectual terms: the points of view or "theses" out of which they work.

This question of how the "making enterprise" is conceived is critical especially for those who, for whatever reason, act on the parts repertoire to change it or to alter the practices employed in manipulating parts. The same is true for those who wish to maintain or sustain conventional ways of working or parts flows in the face of changing circumstances.

In that regard, managers of building product (and project) value added processes need accurate maps to locate possible impediments and snags to proposed changes in conventional practice; their own, their competitors, or their collaborators. These changes in practice can be in the parts hierarchy (e.g. materials, or materials processing substitutions, changes in assembly sequence, location, etc.) or the deployment of agents (e.g. backward integration, vertical integration, out-sourcing, buying stock, improved supplier/user links, etc.), or, as is usually the case, both agents and parts as they interact.

Because PAct introduces control in parts making via a graphic notation tool, these questions of practice are now more accessible to mapping and analysis by ordinary visual means, and, in the future, with computer support (see §4.6). Simple and varied examples of such mapping and comparisons are given throughout the thesis as illustrations of what will in time become more sophisticated and thorough analyses.

PAct is also designed with historians of technology in mind. Scholars who study artifact production need accurate descriptions of many value added flows, for the purposes of comparison and analysis. Processing and comparing many diagrams will enable researchers to study patterns of parts flows among complex agent domains with the result that specific kinds of interactions will be easier to spot and study, and meanings of such interactions imputed. PAct can also be of value to the new field of

sociotechnology (Bijker, 1987), which redraws intellectual boundaries in the social sciences by demanding a serious study of the social construction of technological systems.

PAct has been built so far with these constituencies in mind, and with the idea that those who wish to innovate should know what it is they work to change: the control of parts. While the questions that motivated the study at the outset were and remain interesting (see §5.1), building and demonstrating the tool has been the objective of the research. The tool is now available in its rudimentary form for exploring an array of questions beyond those which informed its invention in the first place, and more accurately than we can by normal discourse.

Studying parts making this way, we can learn what to leave alone, and what may be changed in light of the control people exercise.

2.0 Parts Making up PAct Diagrams

PAct diagrams are made up of graphic symbols organized in particular ways. Each symbol and relationship between them is assigned a specific meaning. The main elements are

Parts

Operations

Parts liasons

Agents

These four basic elements of the diagrams will be described in detail in this section by use in simple examples in which relations between these symbols will also be described.

Traditions of diagramming are recognized in the construction of PAct (see also §4.5). (Martin and McClure, 1985)

2.1 Parts

Parts include such things as fasteners, boards, hinges, windows, walls, houses or any other part or grouping of parts that is named, regardless of its complexity. A part can be shown as such whether it is understood to be composed of many other

parts (e.g. a window or tenant improvement package) or understood as having no individual parts we want to identify (e.g. a pipe).

I limit the kind of parts used in the diagrams which follow to those parts which are normally found in a building materials supply depot, parts supply center, manufacturing plant, or prefabrication shop; generally, parts we can pick up and hold or which are normally manipulated by machines or equipment in building construction work.

A part is displayed in PAct diagrams and in the following text by the use of the symbol

□ diagram #2.1

Every part is assigned a name or identity code, for example a "casement window", part "#45B", "[parts 3 + 4]", "Honeywell Heat Pump model #4452N", or whatever coding convention or designation is desired. $\square_{17}$ is one way to signify the number of instances of a part.

2.2 Operations

Parts change as they make their way along a value added chain. This is the definition of value added used here: physically changing a part. Values, including costs, can certainly be assigned to these physical changes, but such values are different from, though not unrelated to, such physical manipulations as the tool accounts for.

These changes are the result of operations of one kind or another, or some combination of operations. In PAct diagrams and in the text , an operation is shown by the symbol

0 diagram#2.2

There are four principle kinds of operations:

assembly:

in which several parts are brought together into a new part; for example, a window sash is brought together with a window frame, or veneers are laminated to make a piece of Microlam engineered lumber, or a wall is brought into place on a platform. Of course, there are many kinds of assemblies. Four are of particular note in terms of the relation of their parts: parts are 1)

fixed but removable, 2) fixed but not removable without destruction of the parts, 3) adjacent and removable, and 4) adjacent but removable only by disturbing one of the associated parts.

removal:

a part is taken away, or material removed; e.g. holes are drilled in joists for wiring and piping runs; or a piece of sheet plastic is cut into pieces each of which has a planned use producing no waste;

disassembly:

this operation is one in which a part is detached from another part in a reversal of a prior assembly operation; for example, the door in a prehung door unit is removed after the unit is installed in the wall, for ease of painting; disassembly occurs as a reversal of an earlier assembly process, but not always in the same order. That is, an object with an assembly process involving four parts may be disassembled into two parts.

deformation:

in which the form of a part is changed without adding or removing anything; for example, a copper pipe is bent; or a gasket is compressed into a slot. (casting a material such as concrete is here classed as a kind of deformation; first, the aggregate, sand, and cement are assembled; then cast into a form, without adding or removing anything; here are two operations).

These operations can be complex, employing a number of secondary operations and procedures. For example, assembly may require certain clamps, jigs, alignments, and rotations. Studies in product manufacturing discuss these procedures (e.g. Andreasen, 1983; Hounshell, 1984).

In the PAct diagrams in this study, I limit the operations diagrammed to those which alter a part in a visible way. There are many important changes to parts which are invisible to the naked eye and which add value, such as the work General Electric does in developing a new plastic resin, or Weyerhaeuser's development of a new hybrid tree that exhibits improved growth and fiber strength characteristics. These changes can also be mapped using PAct principles, if we consider cells, molecules and other microcellular elements as parts, but examples of this sort are not in this study. It would be interesting, for example, to use PAct to diagram "designer genes", or other projects in microcellular developmental biology.

An operation is generally not "tool" specific in the long run, in the same way that a design method is not tool specific. A given tool can be found in more than one method, and a method can employ various tools. Someone always seems to be inventing another way to do an operation, not at random, but accompanying

other activities in parts making. An operation of assembly can utilize an assortment of tools or devices, depending on the way an agent wants to or knows how to work, or in some cases by specification from another agent ordering the part. Substituting tools often accompanies other shifts in social relations, economics, new materials, in making the same kind of things. Historical studies of mass production in American woodworking industries show this. (Hounshell, 1984)

But particular tools can also remain a constant while other conditions change. For example, Japanese carpenters still employ tools with ancient lineages, in projects whose designs and off-site production are accomplished with sophisticated computer assistance. Or, an operation of removal can use an assortment of devices. Cutting can be done by saws, knives, tearing, or lasers, but the operation is still classed as a removal operation. Sometimes, operations of a kind become so frequent that the part being changed experiences a basic alteration, eliminating the operations. For example, floor framing in houses was almost always of 2x10's or 2x12's, normal "made for stock" dimension lumber. Now, a widely observed convention is the use of open web wood floor trusses, always "made to order", of the same or even greater nominal height dimensions. With the new part, no holes have to be cut, through which to run pipes, ducts, wires, sprinkler lines, now required in many wooden house projects. So many holes were being required in the solid 2x12's to accommodate the tremendous increase in resource distribution lines, or the reduction of ceiling height by routing these subsystems below the joists, that eventually it became easier to have special deeper trusses made, higher on the value added chain and designed for each house, and no longer stock items like 2x12's.

The PAct diagrams focus on actual changes to parts. Therefore, the O symbol will not be used to identify such actions as selling, buying, transportation or warehousing. Such influences on the control of parts may be accounted for in other tools.

2.3 Parts Liasons

Parts in the built environments we make and change - the kind studied here - have histories and futures. Even parts found in museum displays are only temporarily denied a future of the sort this tool maps. The parts accounted for in PAct exist somewhere in a continuum starting with a substance in nature, returning in time to some basic substance. To show a part of this continuum in a PAct diagram, I use

diagram #2.3

to represent parts liasons. Parts exist in part/whole hierarchies in value added chains; the lines of parts liasons are those which can be followed to find out where a part goes and where it comes from in a value added flow; what it is made of and what it will become part of.

2.4 Agents

Agents in PAct diagrams are those who change parts, or act to cause another agent to change a part. "Agents" is a general term, to be specified as needed in each diagram. An agent can be an individual, a group, a company, a division of a company, or any other actor who engages in a value added flow. An agent is shown in the diagrams by

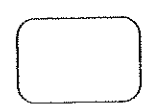


diagram #2.4

The shape surrounds a domain of action with which an agent is identified. In the text discussion of diagrams, agents will be designated both by the word "agent" and by the symbol ©.

Agents in PAct diagrams who manipulate parts perform "work", as contractors think of it, as distinguished from providing a "service" such as designing. This is also the language in normal professional contracts in construction practice. The general term used for this work is control. An agent who changes a part controls that part.

Control = physical change of a part by a human agent.

Only one agent can control a part at one time. For example, a single craftsman, using a routing tool, shapes a wooden piece for use in a window frame. Or, a team of two workers tilts a stud wall into place. Here, the "agent" is understood to be the collective of both workers acting together on the "part" called a stud wall frame. Or, a company makes doors. The collective of workers actually doing the work constitutes the agent in this case, and the parts are doors. Of course, we can look into the company and find many agents. How many agents we see in the PAct diagrams we make depends on the detail we want to examine.

2.5 Simple PAct Diagrams as Illustrations

Summarizing, PAct diagrams include representations of:

* Parts, in part/whole hierarchies, linked by liason lines;
* Between parts are operations, indicating the change that occurs to make the new part in the value chain;
* and agents, those who control or physically change the part.

2.5.1. Parts and Operations

The following series gives some basic arrangements of the elements of PAct diagrams.

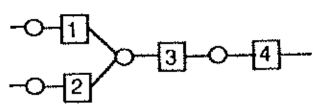
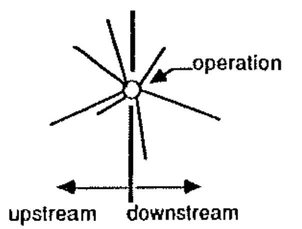


diagram #2.5

□1 and □2 are assembled to make □3, which is then subject to an operation of deformation to make □4. An example might be the assembly of a flexible gas pipe used to hook up a gas appliance to the house gas line. The pipe is assembled with its coupling parts, then bent to fit the specific requirements of the appliance's installation. The lines are the liasons between parts; the O's are operations.

This diagram, like all PAct diagrams, is read by following the liason lines linking parts in part/whole hierarchies. Reading right to left, we see a part's history; left to right we see its future.

In a value added flow, we will call "upstream" parts those whose liason lines attach to an operation to the left of a hidden vertical line through it (see diagram below). This means looking in the direction of sources. We will call "downstream" parts those that are found by looking in the direction of use, or whose liason lines attach to an operation to the right of a hidden vertical line through the operation (see below).



diagram#2.6

The relation of parts in a specific value added chain can be topologically constant but variable in arrangement. Liason lines in a specific chain can remain attached to their parts and operations in specific places. Any given diagram is free to be arranged in any pattern, however. For example, if scheduling is of interest,

"stages" can be organized (see e.g. diagram #3.29, and #4.25). If the entry of a part into a chain is to be moved, the point of attachment can be altered without changing the upstream or downstream portions of the diagram. For example, if a house is assembled off-site, and brought onto the foundation late in the value added chain, that is one situation (see §3.2.4). We can alter the place in the diagram at which the house is brought together with the foundation, by changing only that part of the diagram effected by that shift. This may impose other changes to the value chain, producing still another diagram.

So far, operations of assembly and deformation have been shown. An operation of disassembly is shown next:

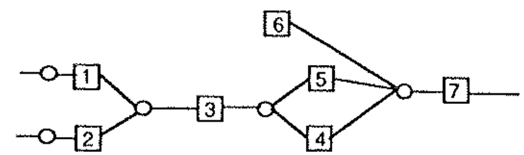


diagram #2.7

In this diagram, parts are assembled, and also a part is disassembled, and then assembled with another part. An example is a Pella window. □1 represents the glass parts, □2 the wooden sash assembly. The glass is installed in the sash to make □3. The next operation shows that this assembly is disassembled (we know it is only partly disassembled, but the details do not show up here), and □6 (the slim-line shade that fits between the double glazing panel) is installed with □4 and □5, to make the finished unit. □4 and □5 are different than parts □1 and □2.

It may be that a part will not be disassembled into the same parts from which it was assembled in a prior stage.

To summarize so far, in a value added chain we start with an operation making a part, and end with a part and a liason line leading to a future state. To the left of a part there is an operation, and to its left a line indicating some lineage. Operations are either assembly, disassembly, removal, deformation or some combination.

PAct diagrams are read from left to right, from making to using; from upstream to downstream; from "lower value added" to "higher value added".

In order to handle the complexity of value added chains, PAct diagrams use the principles of abstraction and specification. This means that a complex chain of parts and operations can be represented compactly without loosing information, but can be "opened" to find out more. For example, the chain making a Pella window, composed of over 150 discrete parts and their accompanying operations, can be represented by a simple diagram

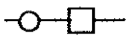


diagram #2.8

in which all operations are "in" the one O symbol, and all parts are "in" the single □ symbol. (A reason to distinguish between O and □ is discussed, for example, in §3.1). This is particulary useful when we want to show a Pella window in a downstream chain, but are not interested to display all that makes up the window, as in

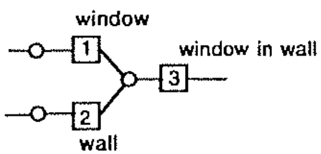


diagram #2.9

where a window and a wall come together to make a new assembly.

If we then choose to find out more about what makes the window, or the wall, or if we wish to find out more about what operations are "in" the O symbol, we then "open" the part or operation.

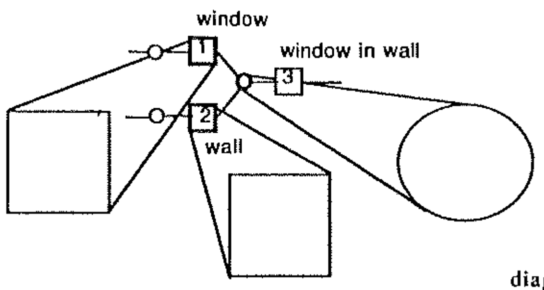


diagram #2.10

In this way, we can manage the complexity of value added chains according to the need to display elements of the parts making. This also suggests the need for data sets 'held' by a computer for specifying any part of a PAct diagram. (see §4.6)

When we open a □ symbol and/or an O symbol, we follow certain diagramming rules as indicated here:

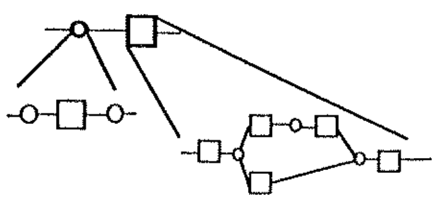


diagram #2.11

where opening an O we see a new string of O and □ but always beginning and ending in an O; and where we open a □, we see a new string always beginning and ending with a □.

2.5.2 Agents

We now bring in agents. An **agent** (©) controls (changes) a part:

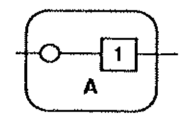


diagram #2.12

This is the most simple designation of control. ©A controls □1. An operation is involved. For example, ©A bends a wire the result of which is □1. The part has come from some upstream source and is going to some downstream use. The agent in whose bubble O_1 occurs is the agent controlling the next downstream part, in this case □1.

When several agents are in view in one diagram, we can see a situation such as this one, characterized as a "dispersed" pattern:

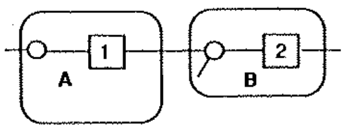


diagram #2.13

where two agents each control a part. ©A controls □1, and ©B controls □2. These agents control independently. ©B uses □1 to make □2. For example, Pella is ©B, controlling □2, and Acme Screw Company, ©A, controls □1, wood screws. This diagram shows that Pella uses wood screws, but that Pella controls the use of, not the making of the wood screws.

More than one © can also appear in a diagram in another way, characterized as a "nested" pattern:

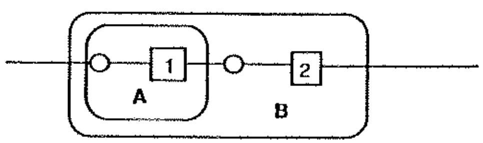


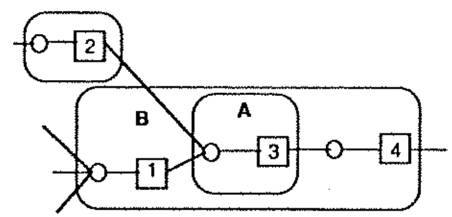
diagram #2.14

in which ©A controls □1, ©B controls □2, but where ©B has what I shall call **indirect control** of □1. The diagram shows that the agents are interdependent by virtue of the postions the bubbles take relative to each other: they overlap. ©B needs to have □1 in order to make □2, and gets it by exercising indirect control. In

this diagram, ©B specifies □1 and ©A controls it. ©B is in need of ©A's work contribution.

For example, if ©B is Pella, and ©A is its sash production group, Pella gives a specification to its sash group, which controls the various parts making a sash. The sash then finds itself put into a Pella window. This diagram abstracts many complex operations in a simple diagram for the purpose of showing another way agents can be shown in PAct diagrams.

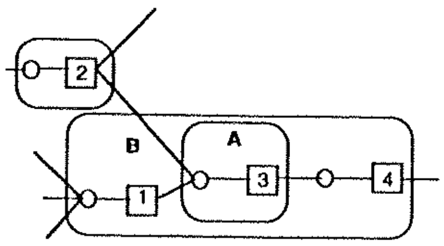
Another way ©'s appear is:



diagram#2.15

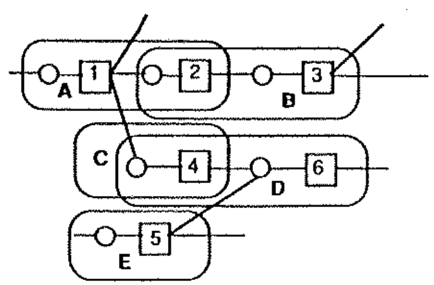
in which the sash group controls □3 by assembling it from □2 and □1. □2 (rubber gasketing) comes from a third independant ©C which controls □2, outside Pella. It is not specified by Pella. ©B (Pella) controls □1, which is an assembly of three parts coming from the upstream side, and □4 which is the finished window. ©B has indirect control of □3, and ©A controls □3.

A more accurate diagram of this situation would show □2 also going to another agent, which means that □2 is a "made for stock" or commodity part:



diagram#2.16

Agents also relate in the way shown here:



diagram#2.17

in which ©A controls □1 and □2, ©B controls □3, and ©C controls □4. Here, ©B has indirect of control of □2. For example, Pella (©B) and Pittsburg Plate Glass (©A) and Silver Spring Glass Company (©C), relate in this way. Pella specifies (indirectly controls) □2, and PPG controls it. This actually happens. Pella orders a certain quantity of glass of a certain kind cut to specified sizes, and as the glass comes off PPG's float line, this quantity is cut and sent out to Pella.

Silver Spring Glass Company, on the other hand, does not have indirect control of any glass in PPG's control, but takes glass as it comes. Silver Spring Glass Company then controls glass for subsequent chains, but characteristically only on order from agent D, which assembles □4 with another □5 to make □6.

I have now laid out the basic diagramming technique, identified the basic relations that PAct diagrams reveal, and have indicated how complex value added chains can be closed (abstracted) or opened up (specified) to see more.

3.0 Demonstrating PAct Use

I now show how PAct diagrams can be organized in more complete ways. First, I show diagrams of a specific part of moderate complexity: an ordinary Pella (aluminum) Clad window made by the Rollscreen Company. These diagrams enable me to specify a number of terms introduced earlier. These include such concepts as control and indirect control, and terms such as prefabricated, industrialized, mass produced, stock or commodity products, made to order parts, vertical integration, and others.

Then, I compare four different value added chains, including both conventional and "unconventional" approaches to building houses. This enables me to go further in discussing and analysing patterns of interactions between parts and between agents, and between parts and agents, newly revealed in PAct diagrams.

Part of what comes from the exercises of comparing four different house production processes is a new way to describe conventional practice in making houses, and by extension, other artifacts. The view we get from "reading" the diagrams engages both the organizational and the technical sides of housebuilding, which helps us to pin down the conditions in the interactions of people and things which accompany stable yet evolving technical practice.

3.1 PAct Diagrams of a Window

This section shows how a series of PAct diagrams can be made of a specific window's value added flow. The diagrams are abstractions of complex processes involving many thousands of agents and many hundreds of parts, spread over a very large part of the globe. These are subject to a large (and changing) number of influences, including design, cost, regulations, transportation and so on.

First, an overall picture of the "basic" complete unit, showing 10 parts:

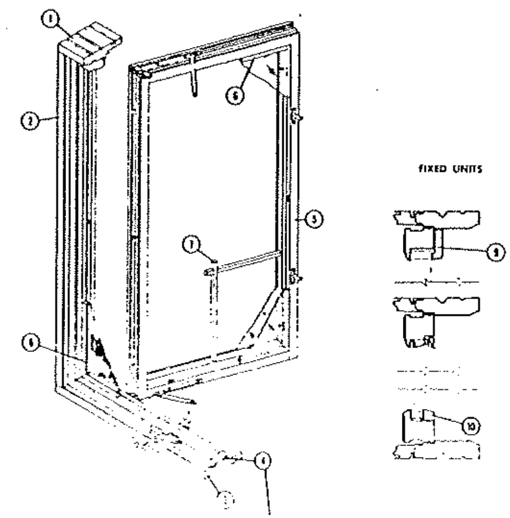


diagram #3.1

I begin with a highly abstract diagram, then give other diagrams that open up to show what actually happens in making the window.'

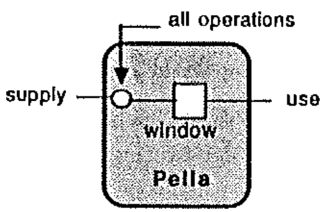


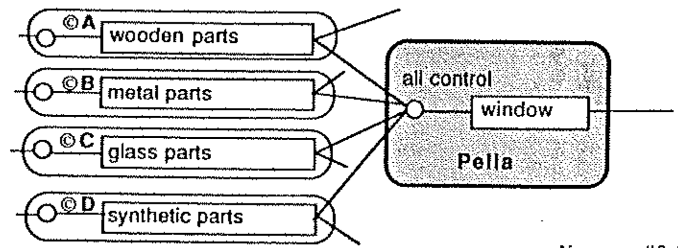
diagram #3.2

where the entire work of making the window is compressed into the single part box and all operations into the single operations box. Supply is to the left, and use to the right. The only agent shown is "Pella."

The next thing I show is more detail on the supply side. This means that parts controlled (again, physically changed) by suppliers will show up in the diagram.

For simplicity, I will show suppliers according to the materials they control: wood, metal (e.g. found in parts #1, 2, 3, 5, 6, 7, 8, in diagram #3.1 above), , glass (one element of part #6 in diagram #3.1 above) and synthetics (e.g part #4 in diagram #3.1 above).

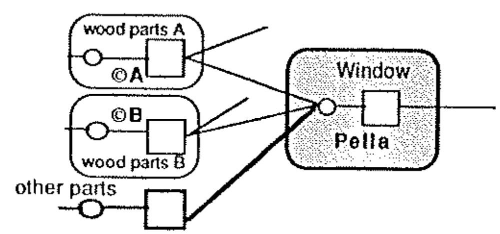
The following diagram shows these:



diagram#3.3

where there are also four new agents, each associated with a kind of part supplied to Pella for its use. The above diagram indicates that each of the agents supplying Pella is independent, and controls parts. The stub lines coming out of each of these independent domains tells that these parts also go to other (unidentified) downstream agents other than Pella.

A more accurate view of the "supply" or upstream side related to Pella is the following:

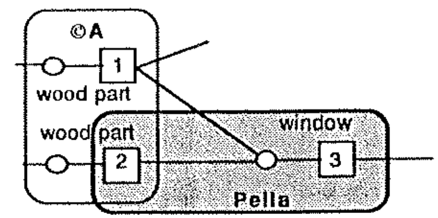


diagram#3.4

where we see that Pella is bringing in parts of the same material from more than one supplier. □1 and □2 are interchangable from Pella's point of view. This may happen when a user does not want to become dependent on only one supplier. For example, Pella may obtain kiln dried cabinet grade white pine from several producers for use in making the window frame and operable sash of the window we saw above (wood parts in parts #1, 2, 3, 5, and parts # 7, 9, and 10).

This means that ©A and ©B control parts suited to Pella's use; the producers act for their own reasons. An interesting question is whether Pella's operations are identical when accommodating the incoming supplies from more than one supplier of the same parts. It seems that a condition for having more than one supplier of a part is that operations under the control of the user must not be different because of the multi-agent stream of supplied parts. For example, one supplier may offer straight grain stock, while another may offer finger-jointed stock. They are interchangable parts from Pella's place in the value added flow, because Pella will paint the product so the finger joints will not show, but from the producer's side, they each have their special production stream.

In addition we can see a situation as in the following pair of diagrams:



diagram#3.5

where one ©A controls both wood parts □1 and □2, but □2 is indirectly controlled by Pella. The Pella domain indicator includes □2 (but notice it does not include the operation making it). **Note:** the way to know which agent controls in situations of domain overlap is to determine to which side of the diagram (left or right) that agent is connected. Here, ©A controls □2, while Pella controls □3window.

An example of this situation occurs when Pella is supplied with two shapes of wood which both find themselves in our window: □1 which is 'standard' size, and 2 which Pella specifies, both from ©A.

Meanwhile, □1, controlled by ©A also goes to another unspecified agent. This is indicated by the stub line.

The next diagram is similar to the last one:

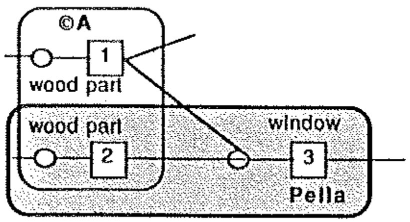


diagram #3.6

except that here, both the operation making □2 and □2 are indirectly controlled by Pella, and controlled by ©A. This indicates that Pella specifies not only □2 but <u>how</u> it should be controlled. This would occur when certain characteristics of □2 could only be achieved, from the point of view of Pella, by using a particular process or tool. The previous diagram (#3.5) indicated that only □2 was specified by Pella, meaning that Pella agreed to have ©A use whatever kind of operation it chooses among all possible tools, processes, jigs, location, and so on, as long as □2 is the result as specified.

©A is, however, an unlikely kind of agent as diagrammed. One agent would be hard pressed to do what is shown, since each kind of control is connected to different kinds of downstream activities and information flows. A more likely situation would be one diagrammed here

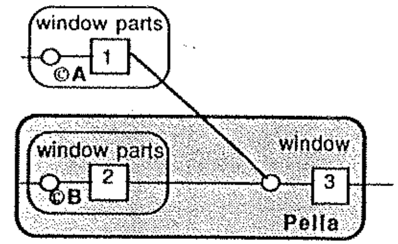
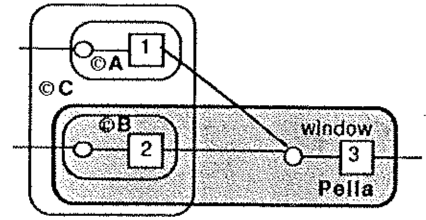


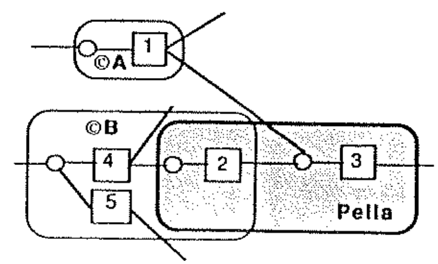
diagram #3.7

where □1 and □2 are associated with distinct and independent ©A and ©B. Or, ©A and ©B can be agents within a larger organization ©C as shown here:



diagram#3.8

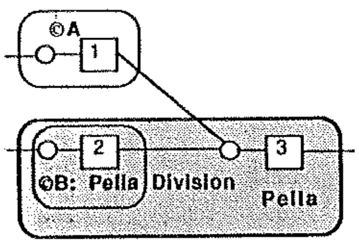
A variation on diagram 3.7, with independent agents controlling □1 and □2 would be:



diagram#3.9

where ©B also serves other downstream users by making more than one part, with more than one user. □4 and □5 go to other agents.

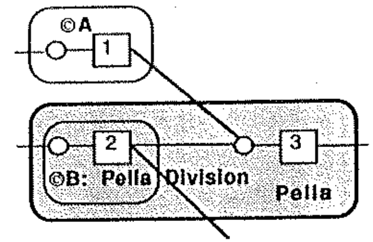
On the other hand, if an ©B makes only one part, that agent can more commonly appear in a diagram like this:



diagram#3.10

in which ©B is now a division of Pella, and not an independant entity.

In the following diagram, which appears to be just like diagram #3.10, we see an ©B making only one kind of part, supplying both Pella's □3 and also unidentified agents and parts flows indicated by the stub line.



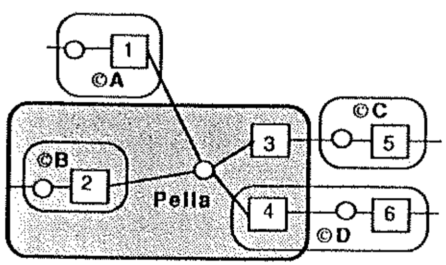
diagram#3.11

This situation, however, may be unusual in practice. I do know of a division of a large Dutch construction company which is interested in making parts of a kind both for its own projects and for trade. If they are considering this, it must be a practice with precedents. However, there is also the logic that this practice would put a supplier into competition with its market, a situation which is apparently not advisable in certain circumstances.

This is an example of an important use of PAct diagrams: to map a situation which works in the logic of the diagramming but may not work, or work often, in reality, or may only occur in practice under certain very specific conditions. That is to say, by following a line of "diagram thinking" that makes sense in its own right we make patterns which, if we ask what they may represent in reality, can cause us to look with fresh insight on practices we take for granted or have never thought about. Making PAct patterns in this way, as in exploratory sketching during the designing of a building, can lead to new ideas that may not have emerged at all, or in the same way without visualization.

If we now move into Pella's territory itself more fully and open up □3, other parts, operations and agents come into view. In fact, exactly the same kinds of diagram forms will appear, but with more complexity when we keep widening the net of supply and use sides of the diagram.

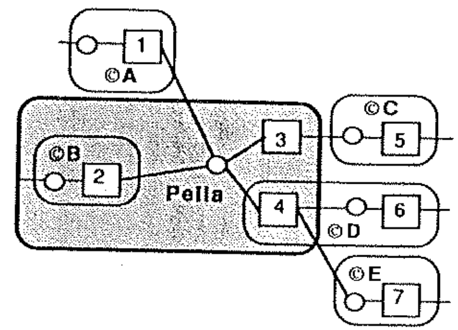
If we open the use side of the diagram, we will see exactly the same kinds of diagram forms as we have seen on the supply side. For example, a user of Pella windows may relate to Pella in one of two ways, or both:



diagram#3.12

where ©C takes □3 (a standard window also available to any other downstream agent), and ©D bas indirect control of □4, which Pella controls. □4 is, for example, a custom shape unit using the same parts that go into a "stock" shape unit.

In some circumstances, Pella may in time decide to operate in a way described in this diagram:



diagram#3.13

in which Pella may find it useful to supply □4 to other downstream agents such as ©E. If agent D were to protest by declaring copyright infringement, would it have a basis, since Pella controls the part? Had ©D wished to claim a patent on □4 (e.g a special window), could it restrict Pella from supplying the □4 window to ©E? In order for Pella to supply both ©D and ©E, does ©D have to withdraw its indirect control of □4?

This concludes the basic examination of a value added chain using **PAct**. Additional questions will be addressed in the next section when comparing different chains for making houses in four different ways.

3.2 Comparing Four Value Added Chains

By comparing a number of PAct diagrams, the patterns of relations between parts, and between agents can be examined. Some of that has been done above with the sample window. More examples follow here, and additional comparisons will be given in §4.3.

One of the more interesting and important controversies in the disciplines engaged in technical innovation has to do with the role of convention as either an impediment to or as a basis for improvements in technical practice or the technical parts we use. Should we "break from tradition" or "build upon what is there"?

A controversy couched in such either-or terms may from the beginning be of diminishing interest since a practical view would suggest that improvements must have to do with both in some pattern of intricate interplay. (e.g. Weisberg's, 1986; G. Daniels, 1970).

We can look into this controversy with added clarity by comparing PAct diagrams. An examination of the patterns in many PAct diagrams give us a basis for inferring what it is that makes conventional practice in complex parts making enterprises persist, or what about conventional practice makes it a good basis for innovation. The other competing perspective which has been

in currency - that convention is a major drag on innovation - can also be examined. We can begin to see more exactly what conditions in value added chains accompany the stagnation of hardware and software.

PAct diagrams help advocates of each of these viewpoints see what their positions mean in a larger context, but the very act of making successive diagrams to represent value chain states argues for convention as the basis of innovation. What is of interest is to discern exactly what conditions preceed and follow change of a part or process or agents relations. PAct is tooled to help us with this.

The examples I use next for the purposes of comparison and lesson drawing, like the window demonstration in the last section, also come from the housing industry. I show three variations of a kind of house production practice using conventional wooden housebuilding technology.

First, I diagram a "conventional wooden" house, built on site, first as a house built speculatively for sale, second as a house built to order. This way of building, which should be called the 2x4 system, is used throughout North America for most of the normal residential developments of detached and low rise construction.

Second, I diagram a house built by Acorn Structures, a house prefabricator, most parts for which are prepared in an off-site plant leaving significantly fewer operations for direct site work than the "site built" example. Acorn Structures houses nonetheless fall within the technical vernacular of the site built house: the parts supplied to Acorn and the operations performed are in the main identical to that of the site built house. Acorn works only on the basis of orders from customers. It does not make house packages speculatively.

A third, contrasting example is from a house differing in many ways from what was at the time and still is conventional practice. This is the Lustron House, conceived in1946 by Mr. C.G. Strandlund, then executive vice president of the Chicago Vitreous Enamel Product Company. At that time, Strandlund sought federal government allocations of steel for use in constructing vitreous enameled gasoline stations. The Lustron house, largely known as a steel house came about in the post WWII enthusiasm about "mass produced housing".

Fourth, I diagram a house module produced by Cardinal Industries, also fully within the conventional wooden housebuilding technology. Cardinal's production division only produced modules on order, but as it turns out orders which only came from other divisions of Cardinal.

3.2.1 A Conventional Site Built House

Descriptions of this approach to housebuilding are widespread in professional, scholarly and popular literature (e.g. Dietz, 1974; Eichler, 1982; Allen, 1985; Habraken, 1983, chapter 3.2; Fine Homebuilding, etc). The best evidence of what I refer to is to be found in any local lumber company and any North American residential development under construction.

The concept of dispersed and nested diagram patterns has been mentioned. We will see in the diagrams that follow that a conventional housebuilding value added chain in the large sense is characterized by a highly dispersed pattern of agents controlling parts. Of course there are patterns of nested and overlapping relations, but in the large, "dispersal patterns" dominate in healthy conventional practice.

The term "highly fragmented" has been commonly used in reports, evaluations, and assessments of the housing and building industries to represent what I call patterns of dispersal. These reports have been written by experts who seem to carry highly centralized industrial and organizational models as referents of what housebuilding ought to be, often modeled on value added flows in other industrial sectors. This attribution of "fragmented" to the building industry has almost without exception been perjorative, suggesting that a less "fragmented" condition would be better. (e.g. Econ. Inc., 1983).

What does a house with a "fragmented" or "dispersed" diagram pattern look like? A picture of a "conventional" site built house under construction, whose PAct diagrams we will see follows here:

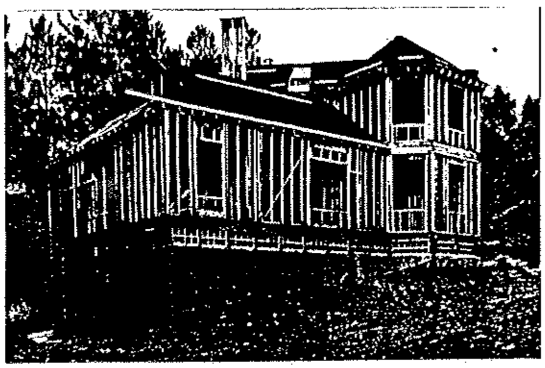


diagram #3.14

Next, I make an abstract diagram of a conventionally framed wall of such a house, and build up a series of diagrams:

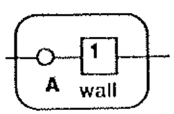


diagram #3.15

where the wall is shown as a single part, in one agent's domain, with a line indicating that it came from an upstream agent and goes into a downstream agent's domain.

The wall we examine is part of a house. It could be a wall enclosing a back porch. The next diagram shows:

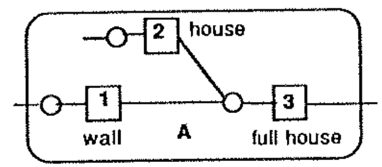


diagram #3.16

where the □ wall is joined with the □house to make □3. The same ©A includes all parts and operations so far.

We can organize the diagram to match the actual staging or scheduling of operations by redrawing diagram #3.16 to appear like this:

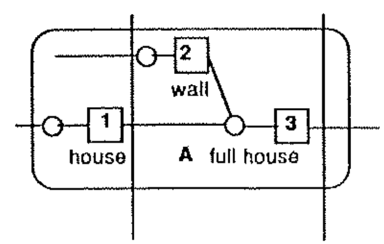


diagram #3.17

where only the staging changes: the house comes before the wall.

In the Pella example, I first stretched the diagram in the direction of the supply or upstream side. In this following, I stretch it toward the use or downstream side. In the first instance, a situation of speculative house building is diagrammed:

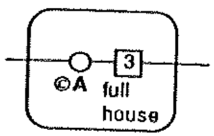
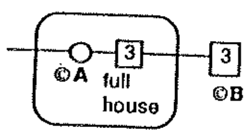


diagram #3.18a

where □3 is what some builders call a "merchandise item" ready to be purchased. In the second instance, we see that another agent has obtained ownership but not control of □3:



diagram#3.18b

For example, an ©B may purchase the house □3, but not physically manipulate it. So no control bubble appears in the diagram.

When, however, ©B controls (which may or may not coincide with ownership), we may see:

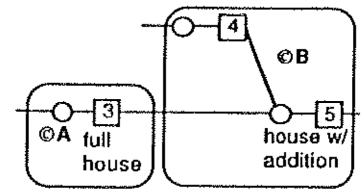


diagram #3.19

in which ©B adds a wall (□4)to the spec house. The result is a new □5.

What goes on inside ©A's and ©B's domains is of course much more complex than what is shown so far. Instead of going inside these agent's domains, which I do shortly, the next diagram shows that in this value added flow, both ©A and ©B are supplied by the same ©C.

Let's say for simplicity of diagramming that ©C controls all the necessary parts for the wall: studs, plywood, nails, drywall, electrical parts, Tyvec™, wood siding, insulation, and so on. (Of course this is <u>not</u> the way things work in conventional housebuilding.

Each of these parts is found in the control of individual agents, but this begins to build a basis for comparison with the subsequent example of Lustron).

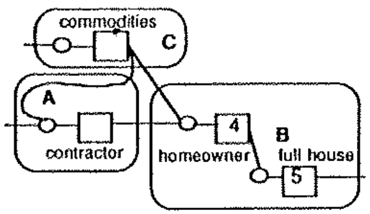


diagram #3.20

The products ©C controls are shared by ©A and ©B. Neither ©A nor ©B specify anything controlled by ©C. Perhaps ©A is a professional builder, and ©B is a non-professional homeowner. This is a familiar situation, just as it would be familiar if ©B were another contractor. ©C is a "class" of agent associated with commodity producers. Lets specify ©C to bring it closer to reality in conventional practice. Modifying the above diagram, we get

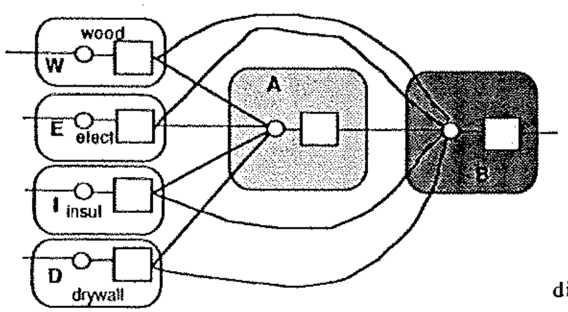


diagram #3.21

in which each of the four (out of many) supply agents controls

parts going to both the speculative house builder (©A) and the new owner (©B) who in this case also builds a new wall.

Now, we repeat diagram #3.17

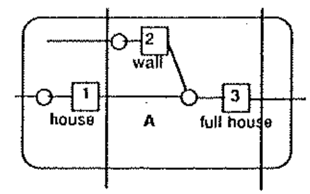


diagram #3.22

and open ©A and □1. Lets keep the supply agents found in diagram #3.21 in the new diagram, and call ©A the general contractor (©GC). We will also now add the "improved site", with services in the street, already several stages above raw land in its value chain. This makes:

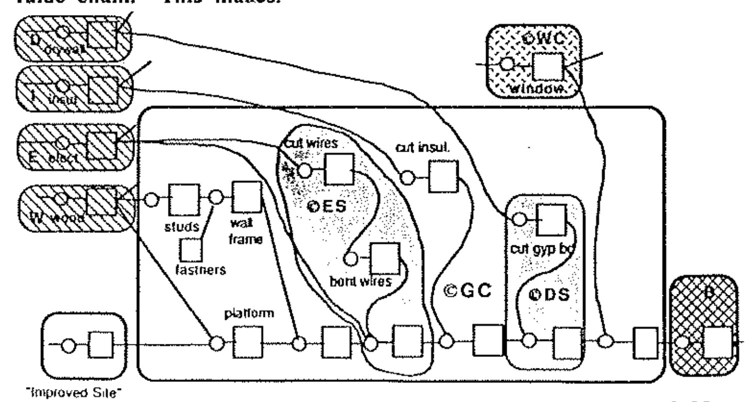


diagram #3.23

where ©GC, ©ES and ©DS are all single individual craftsmen, and the supply agents ©W©E©I©D©WC are all stock or commodity producers who also supply other agents as indicated by the stub lines coming from each.

We see that ©GC controls some operations including the cutting and assembly of studs and the cutting and installation of the insulation. ©ES and ©DS control their parts, indirectly controlled by ©GC.

Lets now look more closely at a part of the diagram, including ©W, ©E, ©D, and ©WC, and part of ©GC's domain and all of ©ES's and ©DS's domain:

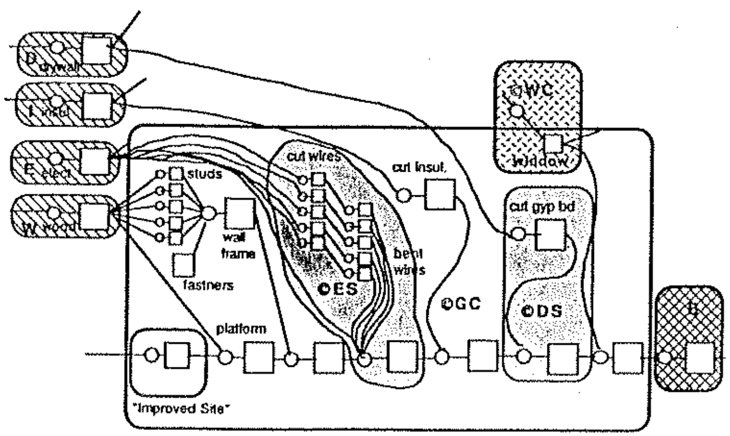


diagram #3.24

So far, we have seen the ©B - homebuyer - as an agent who purchases a house already available, a house built on the initiative of the ©GC. This is known as a "spec. house", or a house built on risk. ©B has done nothing to indirectly control this house.

©B and ©GC are independent. Notice that some call what ©GC makes in diagram 3.24 a "production house", or "merchandise", as distinguished from "custom". The diagram for the relation of a commodity product such as a 2x4 board to its downstream user has the same dispersed pattern as the diagram of the production house to its buyer. This is taken up further in §4.3 and in diagram #4.18.

This independent relation is indicated in the abstracted diagram here:

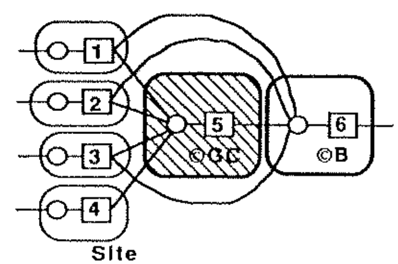


diagram #3.25

From this diagram dominated by dispersed agent relations, we can move to another situation in which ©B has indirect control of the house, as in

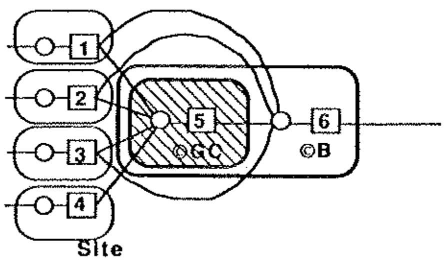


diagram #3.26

in which the house is ordered by ©B. Here, ©GC controls the housemaking under the indirect control of a downstream agent. ©B is called a downstream agent because subsequent additions to the value chain occur by the control of that agent. In this diagram, we see the site which, as in the previous diagram, is already improved by some other agent and is purchased in its improved condition by ©B.

This diagram has both nested and dispersed patterns.

If we look further, we see deeper nesting, when subcontractors appear inside ©GC's domain, and also inside ©B's domain who, the diagram shows, does not control but rather

indirectly controls parts via other agents to whom specifications are given:

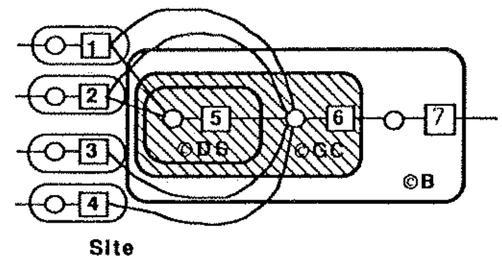


diagram #3.27

But it may be rare, if not actually impossible, to find a situation in which an agent will have such extensive indirect control as in the above diagram, or, on the other hand, that an ©GC will be so completely included.

This question is pursued further in §4.0, but in terms of the present discussion, we can reasonably declare that ©B indirectly controls □4, but not the operations making it.

This means that ©GC is free to specify the way to make □5; to employ tools and procedures for reasons he need not discuss or negotiate.

We see this in the following diagram:

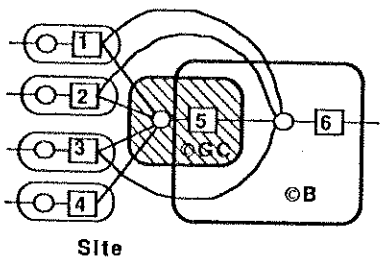


diagram 3.28

When we look further and seek more complexity matching reality, we find a dispersed pattern of indirect control of ©B inside ©GC's control domain:

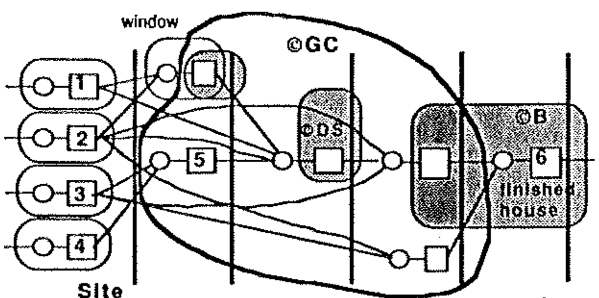


diagram #3.29

Here, we see the concept of stages of production introduced (see more in §3.2 and 4.3). We also see a dispersed pattern of indirect control. For example, we see ©B, perhaps through an architect, specifying only certain parts or features of the house,

but not the construction technique.

The more influence on details of both operations and parts a downstream agent wishes - the more "customized" - the closer we come to a diagram like #3.27 or #3.28. But there is reason to believe that we never really reach fully nested patterns.

The more limited the scope of indirect control by the "buyer" - the more "convention" is accepted, as in make the living room "in a colonial style like Williamsburg" - the further ©B recedes out of ©GC's control domain, while never entirely leaving it.

In these discussions of conventional practice, there are two kinds of agents indicated: independent agents (e.g. ©W, ©E, ©I, ©D, ©B and ©GC); and included agents (©ES and ©DS). We know that there are many more inside the suppliers domains. Inside ©GC, there are actually only two individuals shown here; a typical small homebuilder will have a diagram like this; this builder is both the carpenter and general contractor.

What do we call ©WC controlling the window in diagram #3.24? ©WC is an independent agent, such as Rollscreen making Pella Windows, controlling a window for which ©GC has indirect control. That is, ©GC ordered the windows for the house rather than using "stock" windows. But notice that ©GC does not have indirect control of the operations making the window.

The general contractor and agents making the commodity independent agents. ©GC can be supplied by other agents, and wants the freedom to choose to do so, and the supply agents can serve other ©GC's. An ©GC will not want to be trapped into a situation of only one possible liason line to its supply side.

It is only under special circumstances that a contractor will want to use a part for which there is no competitive substitute. Also, a commodity producer like ©D will not want to become dependent on the demand or use side on only one agent, since when that agent disappears, it is too much trouble to find another in time.

Parts entering ©GC's domain are either assembled directly (electric boxes or whole sheets of drywall) or are first cut and/or bent prior to assembly (e.g. studs, wires, or drywall). If the ©GC thinks ahead, he may cut more studs of a certain specification than this particular flow requires, thus stocking them for another similar wall. That would be diagrammed:

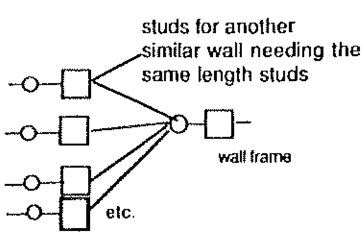


diagram #3.30

We also know that in due course, a commodity producer will make stock parts (e.g. 8'-0" studs) of a kind suited to downstream agents' control, so that only assembly is required for a "normal" height wall, and no removal or deformation is required on site.

By examination of each commodity producers' control, we would see very extended value added chains of a predominantly but not exclusively "nested" form. The activity of making the parts which enter the general contractor's domain is often quite complex, with many operations and many included agents. For example, Weyerhaeuser's control diagrams are complex. A PAct diagram of the value added chain of a piece of plywood would show both nested and dispersed diagram forms.

The diagram of an ordinary airconditioning unit produced by the Trane Company would be even larger, and also have nested and dispersed forms.

We see over time expansions and contractions of the complexity and diagram form of a given commodity producer's control.

For example, electrical boxes which were once available only as metal objects made of over ten parts are now available as one piece plastic objects of the same dimensions and "capacities" to receive a variety of electrical parts, and the same assembly interface conditions. On the other hand, bathroom lavatory faucets now have more parts than before, e.g one piece handles are now made of several parts, to offer "choices" of handles to downstream agents.

We know from examination of conventional building processes downstream of the domains of the commodity producers, that the number of operations each agent does in a conventional value added flow - with each part - is small relative to all the operations that a part goes through before-hand. Studs are usually cut once before being assembled; the same with the other parts.

The value added contribution of each individual agent downstream of the mass production agents is therefore small. We see a large number of parts but comparatively few operations between that which enters the domain of the general contractor and what leaves it as a finished house. In the long history of these parts, ©GC only comes in during a small but vital section of an overall PAct diagram of housemaking and its parts lineage.

But the number of operations for the ©GC is not tending toward zero. Also, the <u>kinds of operations within the ©GC domain</u> remain a mix of the four kinds of basic operations. While dreams of limiting ©GC operations to assembly have been passionately argued, the other kinds of work seem to be an important, perhaps

essential part of what happens to parts after they leave the kinds of agents we call commodity producers and join a site.

If we identify ©GC as a kind of agent which controls a site for a time - e.g. a piece of real estate - and the commodity producer as a kind of agent who <u>never</u> controls the site in which the mass produced part is used, we begin to understand the important distinction between what has been called a "territorial power" and a "non-territorial power". (Habraken, 1988) (also see ©4.3)

We also notice that when ©B (homeowner) controls the house after the contractor leaves (an example of a transfer of control for a given part), parts are brought in from the same agents supplying the general contractor and subcontractors.

An examination of the pattern of agent domains in diagram #3.24 shows that the general contractor exercises indirect control of the window (it is a special order), but of the other parts coming into its control, it does not have any indirect control. Indirect control is more work, and an agent will, other things being eqnal, try not to do more than necessary.

These patterns show a heavy reliance of each agent on the control of other agents. <u>Again, no one party controls very much.</u> Indirect control is strictly limited, which is a good thing since indirect control takes time and carries responsibilities even when the situation is conventional, stable and certain. When a break from convention occurs, and situations of designing become ambiguous and uncertain, we take note and want to learn what did not change as well as what did.

3.2.2 Acorn Structures House

Acorn Structures is a residential design and construction company in Acton, Massachusetts, with a long and illustrious tradition, including the participation of some of the major architects in the post World War II era, who worked so hard to push forward innovations in housing production (Kelly, 1959).

Acorn now makes "conventional" wooden stick built houses of a distinctive style, recognizable to a discerning eye. Part of Acorn's trademark is a contemporary New England appearance, large solar oriented windows, and the use of an exposed interior post and beam framing technique for the large spaces, and wood stud bearing walls for the exterior.

Pictures of an Acorn house from their promotion catalogue follow:

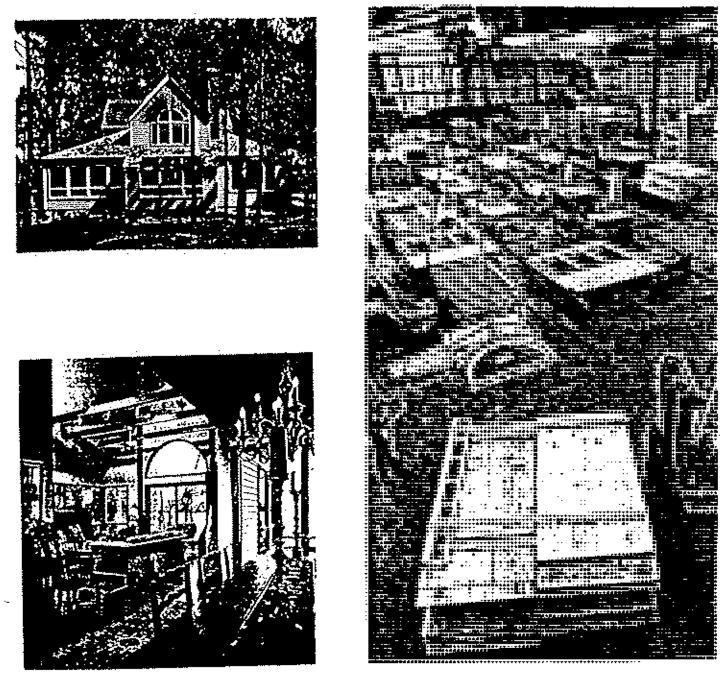


diagram #3.31

Acorn provides design services to homebuyers or general contractors who want to purchase an Acorn house package. A buyer may come directly to Acorn, which may recommend an experienced builder in the vicinity of the owner's site. Or a builder may come to Acorn, purchase a package and erect it speculatively on her own site.

In no case does Acorn build houses. It only undertakes to produce a house package "just-in-time" by order as we see here:

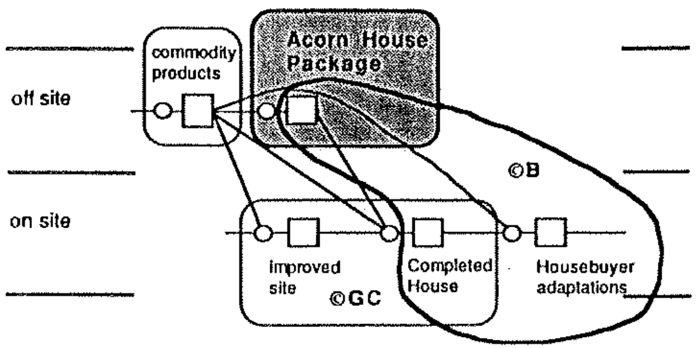


diagram #3.32

In this diagram, we see the indirect control of the house package is by the homebuyer (©B). We see also that the package is produced off-site.

In the situation of a contractor ordering a house package and building it speculatively, we see the following diagram:

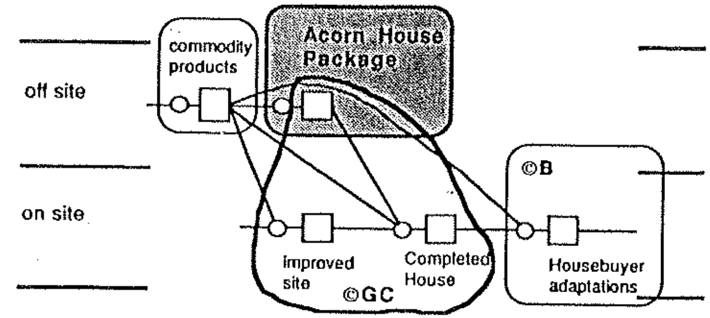


diagram #3.33

In 1989, 30% of Acorn's clients were speculative builders, including a Japanese builder, to whom Acorn delivered nine house packages including furniture, lighting fixtures, and all other 'appearance' items. In this case, piping, wiring, heating and airconditioning parts were not part of the package ordered from Acorn, but were provided locally in Japan to meet Japanese code requirements.

Acorn's wooden housebuilding technical repertoire, identical to an equivalent site built house in its technical interfaces and production sequences, is organized primarily off-site. Commodity products enter the supply side of the facility, are warehoused, moved through a processing, cutting and assembly process, and leave on trucks from the plant's other side. In between supply and delivery, some parts are "worked" (the production plant is largely a carpentry shop indoors), and other parts such as roofing shingles, cabinets, plumbing fixtures, and even the furniture in the packages delivered to Japan, are unloaded, warehoused, and reloaded with the house package.

We can now draw a more complete map of the production of an Acorn house.

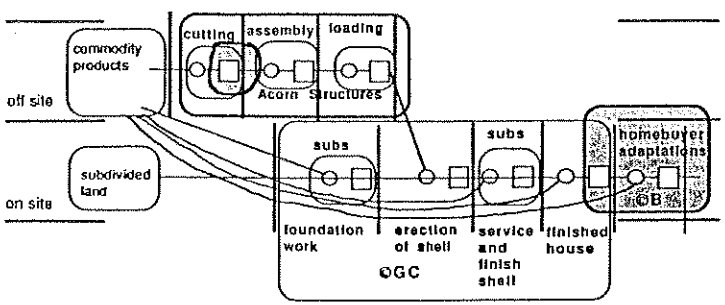


diagram #3.34

A prominent feature of this map is the placement off-site of Acorn's control.

The initiation of Acorn's control of parts follows the instructions of a downstream agent. Acorn's control appears in

both situations of overlap and nesting. It is not independent relative to a downstream agent, but is a just-in-time producer based on orders.

The fact that Acorn's control occurs off-site is independent of its control pattern. Here, we see that Acorn's diagram is identical in terms of control patterns to the general contractor's diagram who also built by order. (see ©3.29, in which the ©GC in that diagram becomes Acorn here).

However, Acorn does control one part independent of downstream agents, in one case, as the following diagram has come to represent:

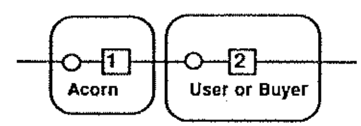
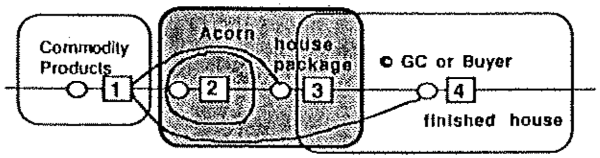


diagram #3.35

□1 represents a "standard" eave/soffit vent part, which helps the roof "breathe" and thus serves as a part contributing to one of Acorn's sales points - energy efficiency. This part is accurately made by the dozens and is stocked for Acorn's use on all, or nearly all its packages. It is an internally mass-produced part, fabricated from the same commodity products used to make other house parts. Its diagram has the following shape:



Part #2 is the part made independent of downstream control

diagram #3.36

Acorn is a prefabricator. Diagrams in which overlap occur signify a situation of prefabrication. (see also §4.3) A downstream agent specifies a part controlled by the upstream agent whose diagram joins in the overlap with the specifying agent. Designing is occuring. The prefabricator controls what is designed by the next agent.

Acorn uses commodity products but does not manipulate them until an order is placed, or a design is agreed upon. It is fully responsive to the "market" in terms of its parts making. However, it has a production facility and a design department with substantial carry-over of processes and know-how from one job to another, giving Acorn its identity. These standard operations appear outside the overlap with each respective client.

3.2.3 Lustron House

The Lustron story has been reported in a number of studies. (e.g. in the Booz, Allen and Hamilton Report to the US Government Reconstruction Finance Corporation, 1949 ; Bender, 1973; Russell, 1981; Herbert, 1984).

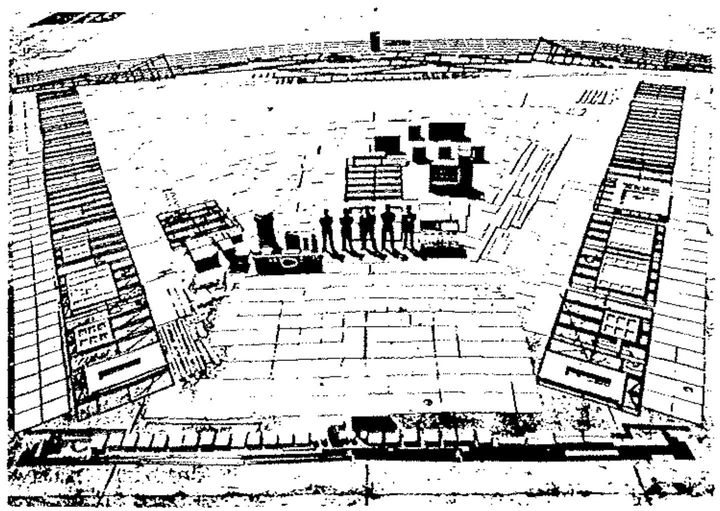
Like some other well documented efforts, for example the General Panel House (e.g. Herbert, 1984), Lustron's initiative departed in substantial ways from conventional value added flows, substituting materials and organizational patterns for its competitor's conventional ways of working in bringing a new house to the American market.

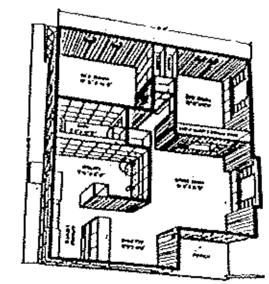
The Lustron factory was modeled on the automobile mass production assembly line concept as it operated at that time. The objective of the United States Government Reconstruction Finance Corp was to "aid the housing situation by bringing about a reduction of housing prices through mass production," (Booz, Allen and Hamilton, 1949) without, however, specifying what was to be mass produced.

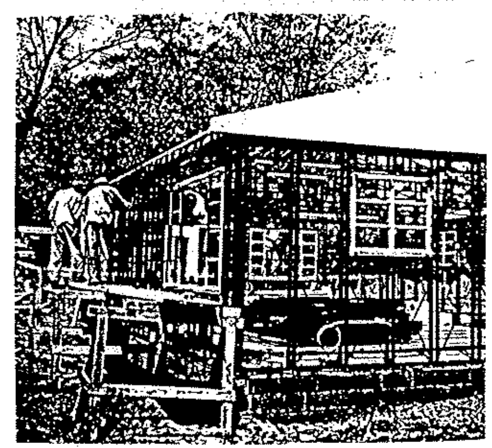
Lustron designed two house models (a two and three bedroom house) and tooled its production lines to making parts for them, many "normally" produced by commodity production companies (e.g. cabinets, structural framing members, bathtubs, exterior and interior wall surfaces, roofing). Approximately 3000 house packages were actually assembled and left Lustron's plant in the 18 months the company operated, compared to the capacity of producing 19,000 dwelling packages each year.

The Strandlund Corporation's initiative was so popular that picture postcards were produced, showing a Lustron house "package of components" arrayed on the concrete apron of the airplane manufacturing facility in Columbus Ohio, obtained for the company's use immediately following World War II, in 1949.

Following are views of a Lustron house.







diagram#3.37

A series of diagrams of the Lustron case will shed light on both this particular initiative and the larger issues in the ideology in which the Lustron house tried to grow: <u>that houses can be mass produced</u>. As far as I can tell from the literature, the following diagram is correct:

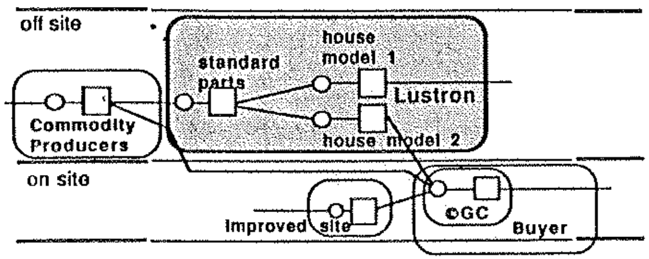


diagram #3.38

This shows that Lustron delivers house packages on receipt of orders. However, all parts for the "Lustron packages" were produced on an assembly line basis, mass produced for use in the two house models Lustron had decided to market. That is, the two house models and the <u>parts</u> of a Lustron house package were not subject to downstream indirect control. A downstream agent's relation to Lustron had only to do with a selection between House Model 1 or House Model 2. The question of the <u>timing</u> of production apparently is not evident in the published literature. That is, would Lustron wait for an order from a downstream agent to produce, or run its production to keep its available warehouse space full in anticipation of orders? To see more, I open up more of the "mass-produced parts" in Lustron's domain and the commodity producers supplying Lustron.

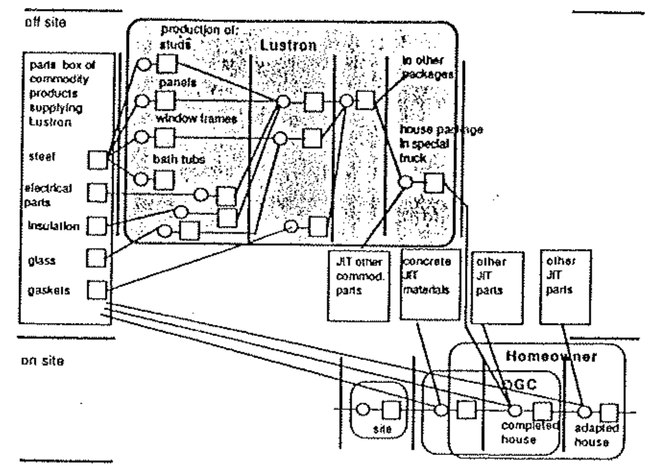


diagram #3.39

where, within Lustron's domain, we see an extensive number of operations and parts. Once the selection of a model was made, a package was assembled from the internal stockpile of parts, loaded onto the specially designed truck, and delivered to the site where it was assembled by a contractor with parts supplied by the contractor as "out-of-package" parts.

If we open up the parts box called "studs", we see the extent and the number of operations and parts in Lustron's control of the parts it decided to mass produce, corresponding to the two house "models" it had prepared:

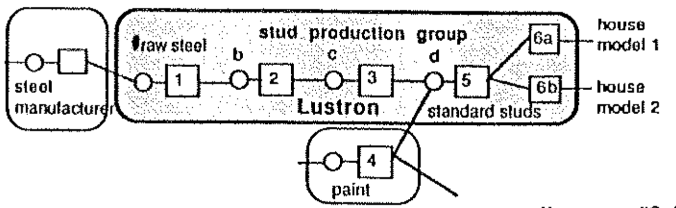


diagram #3.40

where a "stud production group" controls a number of parts and operations making them, such as rolling, cutting, punching, rustproofing, painting, each operation followed by a part to be handled. At the end of the assembly line, the finished part would be stocked, ready to be grouped with other parts for a specific house order, loaded in a truck trailer assigned to each house package. Over 800 specially designed trailers were prepared for this purpose, with assigned slots and racks in each, made to accommodate the specific house parts, loaded in reverse order of their installation sequence on-site.

Lustron made high value added parts with very limited applications: their two house models. Both the houses and the parts had been "standardized" for purposes of mass production. Had Lustron standardized parts that could be used in both their house models and models of other agents, their story would have been different. Then, the diagram of their control would have appeared as any other commodity producer.

But we can see that this was not the case. The production of parts in Lustron has a diagram form different from the production of parts by a stable mass producer such as Weyerhaeuser or US Gypsum (USG). The parts produced by USG necessarily leave their domain as independent, comparatively low value added parts moving into a huge variety of downstream control situations with other parties. Some of the production goes to other divisions of USG to make higher value added parts. Lustron's parts, however, never leave their domain as independent parts. They are captive parts for a "long time". They are not traded or sold, in any case, so never have to submit to the laws of commercial enterprise.

The contrast can be clearly diagrammed by reading a diagram of what USG seems to do:

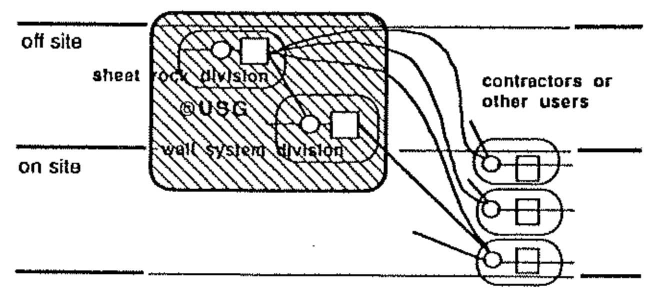


diagram #3.41

where sheet rock, relatively low on the value added chains in which it eventually finds itself, is produced and leaves USG's control to enter the independant domains of large numbers of agents who subsequently control the sheet rock parts to their own needs. Sheet rock is also used by another USG division to make "System wall" elements.

The lesson, well learned if not well understood, is that commodity products at whatever stage on a value chain must correspond to the situations of control of territorial powers. Such territorial powers are those agents who, from time to time, actually control (physically change) a site, (a piece of real estate, a building, a part of a building, a piece of equipment as the site for the parts making it) as distinct from those agents who control parts used in a site. In contrast, the parts Lustron made as:

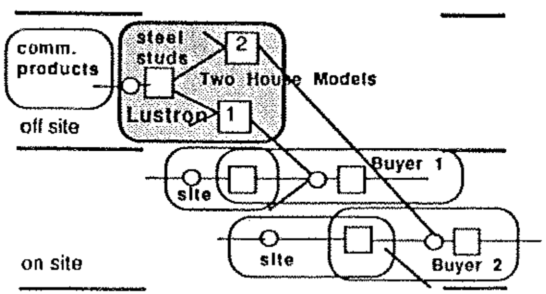


diagram #3.42

where the mass produced parts only find themselves in downstream Lustron parts: the two model houses. They were "captive" parts.

The final Booze, Allen and Hamilton report recommended that Lustron should "approach fleet sales from the point of view of determining what is wanted and then try to meet the demand exactly. Lustron should work with prospective purchasers (as it did in some cases) to get initial specifications as favorable to Lustron as possible. Then it should, as far as is practical, offer a house that just meets these specifications." Lustron went bankrupt before this strategy could be attempted.

If it had done what the report suggested, Lustron would have been approaching a just-in-time model in which its parts would have been diagrammed inside situations of overlap, as follows:

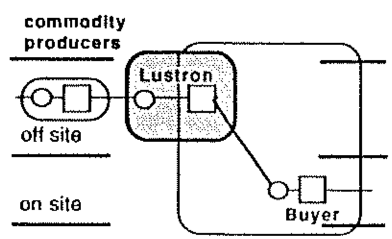


diagram #3.43

On the other hand, had Lustron wished to follow the pattern of a stable mass production agent, it would have worked out of a diagram such as this:

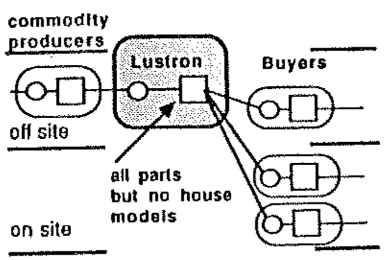


diagram #3.44

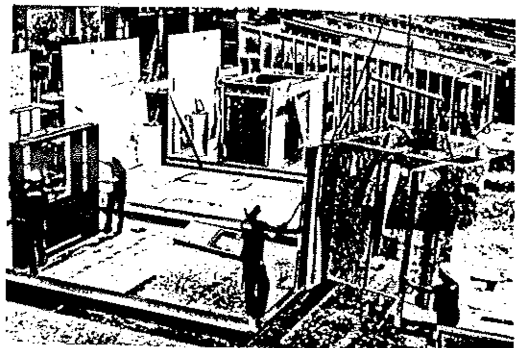
The post card of the parts of a Lustron house, laid out on the apron outside the Lustron factroy, shows parts Lustron controlled going into a finished house, and presumably parts it also handled (but did not control or change) for the convenience of the contractor. I am not aware of a similar display of the traditional "2x4 way" of building. Lustron reportedly had "3000 parts, loaded on the special trailer; a group of 37 factory built site assembled elements". A similar sized wooden house had roughly 30,000 site assembled elements. (Bender, 1973)

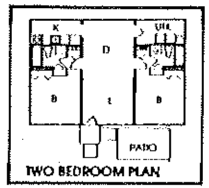
The key questions are: which agents controlled which parts (taking benefits and assuming responsibilities), and which artifacts are being called "parts" in each case? The Lustron house very likely had 30,000 parts, the difference being not so much in parts count, as in which agent's domain the parts were assembled, with which situation of overlapping control if any.

3.2.4. Cardinal Industries House

A fourth demonstration is now presented, that of Cardinal Industries, a company which saw itself as a housing manufacturer, involved in the "industrialization" of housing. This company used the same conventional wood housebuilding technology we found in Acorn Structures and the site built house.

Following are pictures of Cardinal "products": all of their modules were variations on a basic12'x24' unit:





Copyright 1982 Cardinal Industries Inc

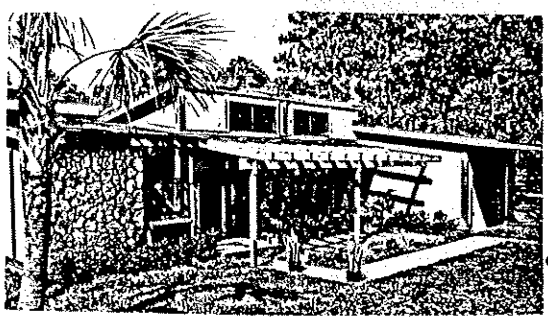


diagram #3.45

An article in a professional journal (Enginering News Record, 1988) represents the difficulty the housing industry has in describing itself and its work vis-a-vis other industrial sectors. Under the heading "Prefabs Aren't "Construction"", the article says

"A company that manufactured modular housing at its factory was not involved in "construction" and thus was not subject to construction safety

standards, a federal court has ruled."

"Cardinal Industries Inc. mass produces modular housing at a factory in Ohio. The units come off an assembly line as finished houses, needing only to be transported to their destinatioos and set in place. Cardinal employees do not transport or install the units."

"In 1982, the Occupational Safety and Health Administration (OSHA) conducted an inspection of Cardinal's factory in response to an employee complaint and the report of a fatal accident. After that inspection, the Secretary of Labor cited Cardinal for failing to install guardrails on raised platforms and failing to require employees working on roofs to use fall protection."

The company was cited under OSHA's "general industry" standards, which apply to all industries except those covered by more specific standards. Cardinal contested the citations, saying its construction-type work was governed by OSHA's "construction" standards." OSHA's Review Commission agreed with Cardinal and vacated the citations against it. According to the commission, the tasks performed by Cardinal employees were characteristic of construction work, not of manufacturing."

"The Secretary of Labor appealed to the US Court of Appeals for the Sixth Circuit, which concluded that Cardinal was engaged in manufacturing and not construction. The court noted that the Occupational Safety and Health Act, in defining the term "construction", refers to the Davis-Bacon Act. Davis-Bacon regulations define construction to mean "work done on a particular building or work at the site thereof." Cardinal did no work at a building site and therefore was not engaged in construction, the court said." [Brock v. Cardinal Industries Inc., 828 F.2d 373 (6th Cir. 1987)].

A PAct diagram helps to clarify this text:

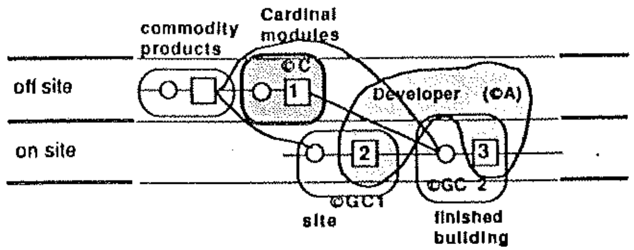


diagram #3.46

where ©C is Cardinal, ©GC1 is an agent which controls the site preparation, pours the foundation, installs utilities, roads, grades the earth, and so on, ©GC2 is the general contractor which controls the assembly of the Cardinal module with the site, and ©A is the developer who indirectly controls □2 and □3. This diagram shows Cardinal acting speculatively. <u>In fact, this is not what Cardinal actually did</u>.

If Cardinal did not act speculatively, is the following more accurate?:

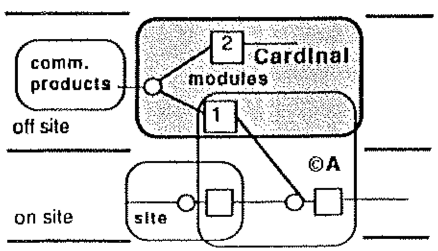


diagram #3.47

where ©A indirectly controls the module □1. □2 is another module which is stock. It turns out that this is not fully accurate, either, and should be replaced by:

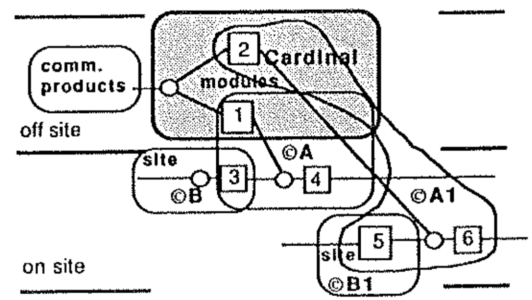


diagram #3.48

where no module was made except by the indirect control of a downstream agent. Sometimes a downstream agent canceled an order, leaving modules "on the lot", but this was an exception, and was certainly not intentional. In these diagrams ©A and ©A1 are involved in construction according to the Davis-Bacon Act definition. OSHA's Review Commission, however, saw it differently as the text shows.

It seems clear that the control of a building site makes an agent involved in construction, whatever else it may do in addition. In fact, Cardinal operated in a diagram like this:

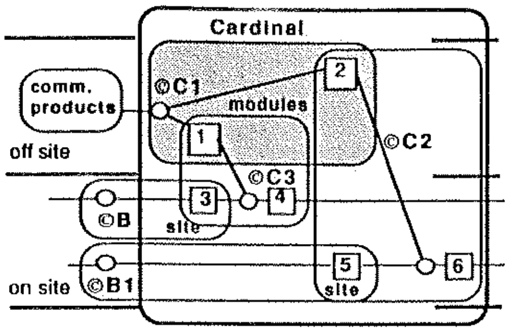


diagram #3.49

in which Cardinal controls the modules and indirectly controls the sites. ©C was Cardinal, ©C^1 was the production division, and ©C^2 and ©C^3 were two of its development divisions. These two divisions engaged in <u>construction</u>.

Cardinal had many development divisions: motels, apartments, student housing, retirement housing, office parks (for its own offices), each with its own specifications. No complete module would suit all these divisions requirements. Virtually all of Cardinal's production of modules was for its own account. The reason for the low rate of trade outside Cardinal was that its "product" was very expensive relative to the competition.

Cardinal's founder was interested in the "manufacturing" and "mass production" of houses. However, Cardinal did not engage in mass production as we saw in diagrams #3.46 and 3.47. It was in fact a prefabricator like Acorn, but a prefabricator for other divisions of its parent company, not for independent agents.

3.3 Summary of Cases

The Lustron "system" was promoted as a new way to mass produce houses, gained the support of labor, the federal government, architects and engineers, and materials suppliers, but failed anyway despite very substantial infusions of know-how and finances.

Cardinal Industries, operating with conventional technology and construction practices under the assumption that it was involved in "industrialization" of housing, filed for bankruptsy and was reorganized by court order.

In the hands of Acorn Structures and any site builder, conventional wooden housebuilding or the vernacular building technology we use as the standard against which to measure other practices is apparently not deserving of postcard promotion. This true system has, with only a few exceptions (Habraken, 1983), not been understood as a system, making it unsupportable as such. No single agent can claim benefit of its existence and evolution, which is both its strength and its vulnerability to being overlooked and bypassed in private and public research agenda, and as such it has been ignored as the subject of development and improvement. Only some of its parts are now identified as "systems" and they of course are the parts developed and promoted by the commercial interests who make them.

In the United States, the Lustron effort, like the famous General Panel House initiative of Gropius and Wachsmann in approximately the same period just before and following WWII (Herbert, 1984), was one of a family of initiatives which shared the idea that houses could be mass produced. The belief in the "industrialized, mass produced house" was very strong (Kelly, 1959) and remains so (Bernhardt, 1980; Russell, 1981; Herbert, 1984, etc).

At approximately 20 year cycles, progress talk converges on mass production of houses as the key to lowering costs, increasing efficiency, and meeting the social goals of a house for every household. In 1948, General Panel, Lustron, and a number of others tried and failed (Herbert, 1984; Hounshell, 1984; Bruce and Sandbank, 1972; Russell, 1981).

In 1968, the United States Government's Operation Breakthrough attempted to move the production of housing toward the automobile model of mass production with notable lack of success (Bender, 1973).

In 1988, with serious problems again surfacing in the ability of housing production to meet social needs, progress talk

returned again to discussions of mass production, industrialization, prefabrication and systems talk, again with confusing interchangably. In the meantime, confidence in the possibility of technical innovation in "total housing systems" seems to have declined, perhaps most notably evident in the withdrawl of Federal initiatives from housing research and production, but also by the lack of private sector initiatives outside "normal" hardware advances. One exception was General Electric's "Living Environments" program in 1988-90, an industry initiative to build alliances among materials suppliers, builders and other agents to speed the introduction of new products in the housing market, which perhaps more accurately than other efforts began to understand the significance of dispersed control patterns on housing innovation.

During and between these periods of interest in mass production of houses, an ambivalence could be detected toward the belief in technical fixes (e.g. Nelkin, 1971) in discussions about housing innovation and in funding patterns for government sponsored research. For example, the line item budget for building technology research in housing at the US Department of Housing and Urban Development has fluctuated and declined between 1970 and 1990 from $3.5 million to $1 million, with a low point of $224,000 in 1984, and a high in 1973 at $18 million with a temporary infusion of funds from the US Department of Energy, which dropped by 1976 to $10 million. (HUD, 1989)

In addition, at the end of the 20th century, there certainly seemed to be a diminished number of people thinking about the subject, and an equally small number of people who were trying to take stock of the lessons from past efforts.

From the examination of the four cases: Site built house; Acorn Structures house; Lustron house; Cardinal Industries house, several summary remarks are in order.

1. The technical repertoire of the houses made by the site builder, Acorn, and Cardinal was identical: the conventional "2x4" system. The suppliers, crafts, building practices and commodity parts were interchangable among them. Lustron, while sharing some parts (e.g. plumbing, electrical, heating systems, glass, paints) essentially disassociated itself from or tried to replace a number of conventional suppliers and materials, while maintaining agreements with the carpentry, electrical and plumbing unions that also built wooden houses, to work in the Lustron factory and construct the packages on site.

2. One of Lustron's objectives was to increase its control of the value chains of parts production of, e.g. framing members for walls and roofs, finish wall/ceiling/roof surfaces, and bathtubs. The objective was to profit from this added work, guarantee supply and quality, and cut costs. A diagram shows this pattern in contrast to the other three cases:

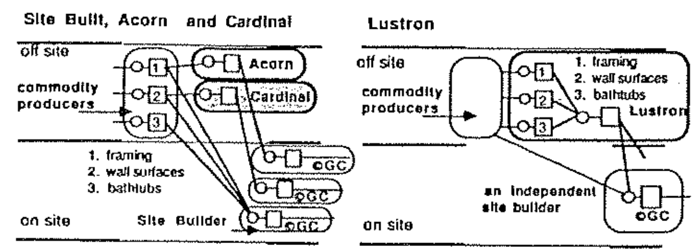
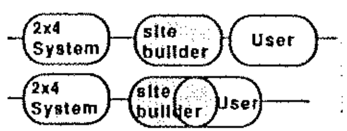


diagram #3.50

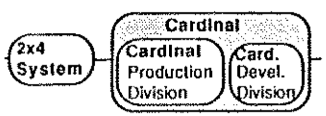
When the three "2x4" builders are used as a reference, we see that Lustron exhibits an effort at backward integration, in which the control of Lustron extends leftward of its final product (the house models) into work which the other three accept as the independent control of their suppliers. (see more on integration in §4.3)

3. Adding the information in the above point to the next, in terms of the relations of the four cases to the next nearest downstream agent or users, we see that



A site builder can operate in either a dispersed or overlap diagram.

Acorn is entirely (with the exception of the standard eave vent) organized in an overlap diagram form. It works on orders.



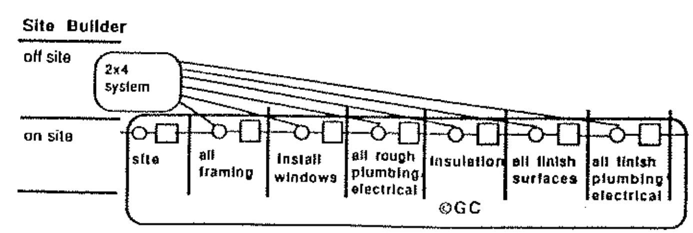
Cardinal operated in an overlap diagram. But those agents whose control overlap are other Cardinal Divisions.

Lustron organized itself for mass-production of house packages, which has a dispersed diagram form. Its control was independent of downstream agents

diagram #3.51

The issue of which agent "switches on" production of which specific house parts is very interesting. More precisely, the question is which operations can proceed independant of the insertion of indirect control of a downstream agent. This is the central concern of Just-in-Time (JIT) production, and should be considered seriously in housing production, as it has become conventional practice in commercial office building production and "exploitation". This is discussed further in §4.3

4. The sequencing of operations in the house building demonstrations are similar in some respects. The similarities have a great deal to do with the actual technical position of parts relative to each other. In all four cases, resourse distribution systems are threaded within and through the floor and wall framing of the houses. The framing is identical in principle, Lustron's being steel, the others wood, with no difference in principle in parts' positional relations to each other. We see:



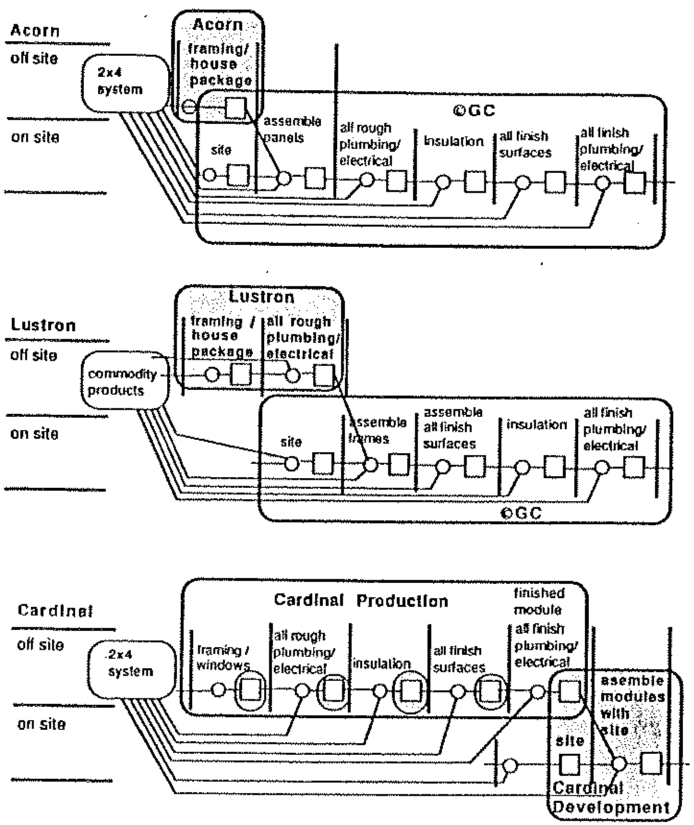


diagram #3.52

In respect to the physical positioning of the parts diagrammed in #3.53, none of these cases deviated from the "norm". Architectural style differed as we have seen, materials substitutions were made for some parts, and differences appear in the location of operations and control patterns, but what is shared are the parts postion rules leading to basic similarity in staging of operations.

Following these detailed case studies, some general comments can be made.

First, all the cases diagrammed so far, whether "conventional" practice or "innovative", have "dispersed" diagram forms in them. There apparently is no escape from the situation that "fragmentation" among agents, as many call dispersal, is in the nature of these cases. Second, in the demonstrations, there is always an agent making something, and another agent using it. Apparently, we do not find a situation in which one agent controls everything.

The PAct diagrams made so far confirm the prevalence of patterns of dispersal, and begin to distinguish the details of "which agents control which parts" in the various demonstrations.

This lets us declare that the concept of "integration" does not suit housebuilding practice in the large. A diagram like this:

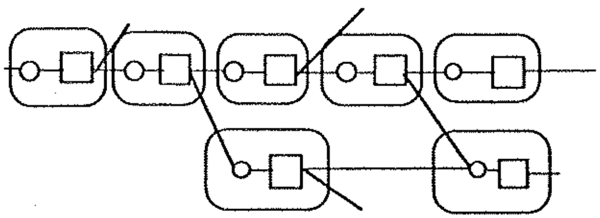


diagram #3.53

is suited as a general model of these four demonstrations, and any complex making process in which more than one agent is involved, and in which parts change as they change hands.

But having said this, it is also clear from the examples given that "nested" diagram patterns also appear in all cases. We have seen two kinds of nesting. In one, the nested patterns occur in situations of partial overlap between adjacent agents. There, a given agent's control is observed to occur in relation to the control of the next agent in such a way that each agent also retains some independence of action.

The second form of nesting we have seen is one in which an

agent is entirely included within another agent's domain. Both of these situations of "nesting" are situations we call **indirect control**, or designing. The following diagram has such nesting patterns as well as patterns of dispersal:

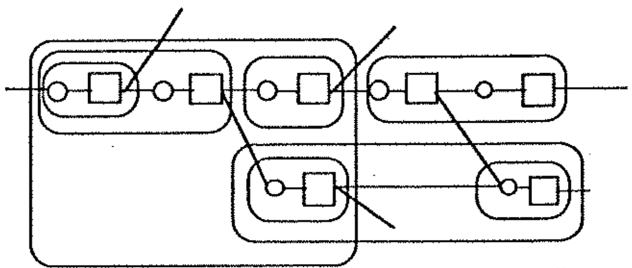


diagram #3.54

The demonstrations so far show that the last agent to the right in a PAct diagram does not control very much of the value system in which it plays a part.

Understanding what to control is precisely the question to answer each time a change is contemplated by any agent. Because we see that any housebuilding strategy has at least some dispersed patterns, it makes sense to take just as seriously the practices that make such patterns strong as it does to pay attention to forms of nesting. We take this up further in §4.0.

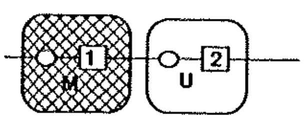
4.0 More About Organizing PAct Diagrams

4.1 Kinds of Agents and Their Relations

One of the very interesting things "reading" a value added chain enables is identification of the kinds of agents controlling parts at different "positions" in the diagrams.

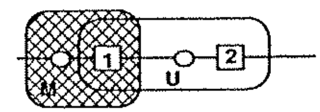
There are many kinds of agents, but the first distinction we read in a PAct diagram is one between maker and user. User is a general term applying to anyone downstream of a part, independent of the identity or affiliation. User is not to be limited to layman.

We have seen these two roles taking three basic forms so far:



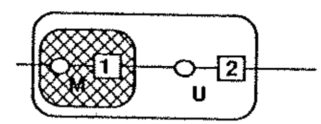
Here the maker and the user are independent, their relationship being formed by the liason □1 has with □2. Their relation is by means of □1.

diagram #4.1a



Here, maker and user have overlapping control, signaling a situation of specification or designing, noted in §3.2.

diagram 4.1b



Here, maker and user have nested control. ©M is a captive of ©U. Their control overlaps, giving us a situation of design and agreement about □1. Here, all of ©M is subject to ©U, but that in ©U's diagram outside the overlap is of no concern to ©M.

diagram #4.1c

What agents do to make their products need not be included in the control that users have. This is literally to be seen in the situation of the dispersed diagram form, in diagram in #4.1a above, where maker and user are independent and relate only through the parts liason line. The user needs the part; the user need not become the maker or enter the control domain of the maker. Such is the situation we understand when we use a piece of plywood, install a replacement cylinder in our leaking faucet, or build our own house. We are just happy to have the parts we need.

Once the maker enters the control domain of the user to take part in it, as in the second "overlap" diagram in #4.1, the maker has to become more like the user, until the maker becomes entirely subsumed to use and has no autonomy, which we see in the third, nested diagram in #4.1.

We understand that a maker enters the control domain of a user - giving us the overlap pattern in our diagrams - when we look into the relation of Pella to the general contractor. This is what diagram #3.12 showed us. We read that Pella opens its control to the contractor to take part in it, when the contractor ordered a window just to fit the opening in the wall which his drawings indicated.

In the nested diagram, we see that the maker fully enters the control of the user and is exclusively dedicated to the control that serves the use surrounding it.

Examination of these diagram forms and their meanings lead to consideration of kinds of agents whose relations are interesting to consider in the PAct diagrams of housing production we have seen so far. Experts can and do find themselves as both makers and users in diagrams 4.1a, b,c above.

In addition, there is the important distinction between expert and layman which I will diagram. In the complex "making"

processes which are the subject here, there is probably little argument about a differentiation of roles along the lines of expert and layman, or specialist and generalist. For instance, what General Electric Plastics, Rollscreen Company, Acorn Structures, or a general contractor do as **makers** certainly requires sophisticated management and equipment. These agents are experts who command special knowledge or experience in their work, which sets them apart from those who do not have that authority, or from other agents who are expert about some other value process.

This "setting apart from" is literally what a dispersed diagram shows: specialist agents and the parts they control are in some cases at a distance from other agents who use them, connected only by the liason lines. We know, for example, that agents in a dispersed form can be both experts, as when

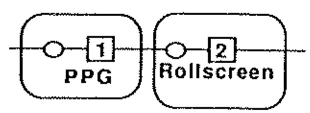
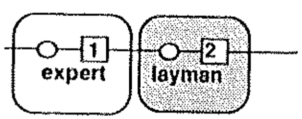


diagram #4.2

where Pittsburg Plate Glass makes glass which Rollscreen Company acquires, to use in its Pella windows. Experts certainly relate directly to other experts this way, as well as in overlap diagram forms we have already seen.

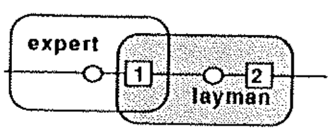
But when the two kinds of agents in view are experts and laymen, and when we recognize that both "species" of agents do control parts in reality, and if there is interest in understanding the relation of laymen to expert in value added flows, then reading their positions in PAct diagrams will be instructive, as the following shows.

Four PAct diagrams focus on the "place" of experts and laymen:



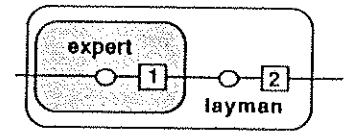
A normal relationship in which a specialist agent, e.g. Weyerhaeuser, controls a part (plywood) which goes to a layman.

diagram 4.3a



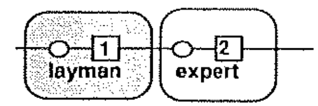
Here, we find a relation which is found in all vernacular technology and making, in which the layman can share knowledge with an expert but will recognize that an expert is needed to make what is in mind.

diagram 4.3b



Here, we may declare in this diagram that when we see a layman telling not only what to make but how to make it, the layman becomes an expert.

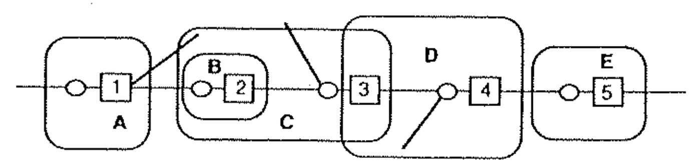
diagram 4.3c



This may be a situation that in reality never occurs.

diagram 4.3d

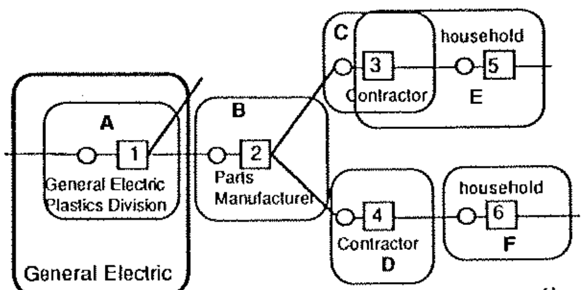
In the case of the fourth diagram in the above set (#4.3), a great part of the relation of expert maker to layman user has to do with the maker's ability to identify the situations of control of the layman. Does a producer have to teach the user? Is there need for maintenance follow-up? Does a producer have to provide tools, or do the needed tools already exist by some other agent's control? What are the conditions in which the user controls the part? For example, in this diagram:



diagram#4.4

what can ©A find out about ©D in order to provide □1 to ©B to make ©C's work easier, thus encouraging ©C or ©B to specify □1?

This is one of General Electric's jobs in its Living Environments project, a prototype house for exploring uses of engineered thermoplastics in house construction, by a process of discussions with potential downstream users of GE's plastic resins. It seeks to understand what builders and homebuyers need, so that GE can produce plactic resins suitable for building product manufacturers to make plastic shapes that will be specified and purchased by contractors to build houses. This is diagrammed like this:



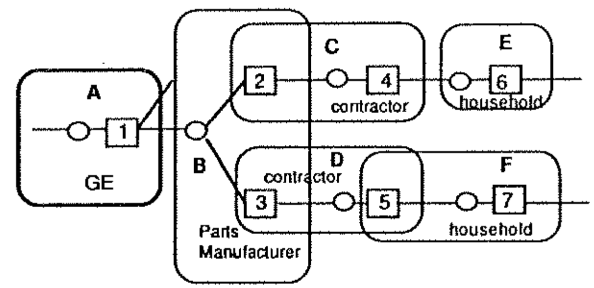
diagram#4.5

GE would like to know as much as possible about ©C, ©D, ©E and ©F in order to advocate successfully to ©B to mass produce

□2 using □1.

On the other hand, from looking at other diagrams, we would have to say that ©B should not become dependant on □1 in controlling □2, which means being independant of GE; there must be another supplier than GE. In the long run this is also of benefit to General Electric and other agents in the diagram.

General Electric is also interested in the information flow and agent relations that would support the following diagram form:



diagram#4.6

where manufacturers begin to relate to contractors in the relation of prefabricators, a relation of expert to expert.

We found situations of independence in dispersed diagrams in relations of experts, and relations of experts and laymen. But in the latter, the relation is directional: experts make and laymen use. Situations of overlap also appear, between experts and between experts and laymen, again in a directional way as diagrams 4.3 show.

PAct diagrams show that parts themselves are the basis for exchange between experts and laymen in dispersed diagrams.

In fact, parts are the basis for exchange in any dispersed diagram, independant of the kinds of agents on each end of a liason line: experts and experts, laymen and laymen, or experts and laymen.

How then are making and using to be "read" as relating in situations of <u>control overlap or nesting</u>? We should understand by this diagram form that using instructs making in situations of control overlap.

In other words, the contractor controlling the use of the Pella window specifies the window Pella is to control (make) for the house the contractor is building:

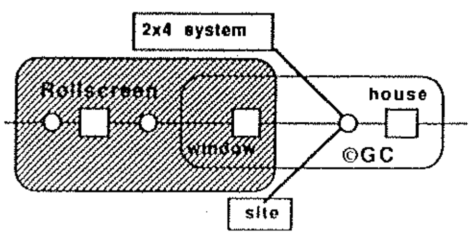


diagram #4.7

The diagram shows that a design or specification must be made for the window, either by the ©GC or by someone the GC hires. Whether another agent is brought in or not, the contractor appears in this PAct diagram as the agent of indirect control of the window.

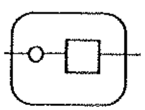
We recognize now that designing occurs when we see overlap or nesting, and we recognize experts as one kind of agent at work in these diagram forms. It then becomes interesting to ask the professional identity of the experts. Do we find an architect, engineer, contractor? When an agent has only indirect control as we saw, for example, in diagrams #3.28 and #3.49, and no control, we can read this situation and infer from it the basis from which the instructions - which are indirect control - actually come.

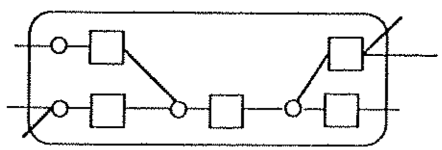
What I want to say by way reference to the housebuilding demonstratons in §3.2 is that the continuity of the vernacular "2x4" housebuilding technology found in diagrams of Acorn, Cardinal and the Site Builder has a great deal to do with the compatability of the roles expert and laymen take in value added processes. The diagrams show that this is the case. While often set apart, they both appear in PAct diagrams of housebuilding value chains that have stability and some evidence of renewability. So while the relation of experts in both dispersed and overlapping diagrams is also clearly present in the demonstrations given here, and is critical as we have seen, experts do not constitute the whole story.

Therefore, when we account for experts and laymen in PAct diagrams, we find them in situations of both nested and dispersed control. But it is important to note also that we must pay close attention to the position and direction of these relations in the diagrams we make and study.

4.2 PAct Chains

A PAct chain is what an agent controls.





diagram#4.8

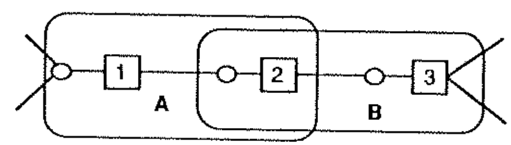
We can have very short chains as in the left hand diagram, or long chains as in the right. We could say that an agent's

diagram - for example a general contractor's - is very long, including many parts and operations. Upon specifying the contractor's domain in terms of agents, however, many individuals may appear, each doing a piece of work, each, including the general contractor's, with a relatively small chain.

This makes us realize that when a long chain is evident in a diagram, it means that an individual agent controls many parts and operations without delegation. That is what we see when we view the diagram of someone building a whole house by herself: the master craftsperson assigning no division of labor. When we have many agents in a diagram, we see division of labor to that extent.

When we have a situation of indirect control, a chain is still what an individual agent controls.

Thus, a part indirectly controlled by ©B is not in ©B's chain, since ©B is not making it:



diagram#4.9

where □1 and □2 are in ©A's chain, and □3 is in ©B's chain. This lets us see in the diagrams which chains are literally pulled by the market (e.g. □2: made to order) and which are "supply driven" (e.g. □1: made to stock). For example, all output of modular house factories are of the □2 sort; or to say it another way, all control in a modular factory is market or "downstream" driven.

We also know that many agents who know how to control parts like □1 and □3, e.g. commodity products, are also trying to control parts like □2, that is "made to order" parts, on a very small batch basis and even on a one of a kind basis. Pella was such a company.

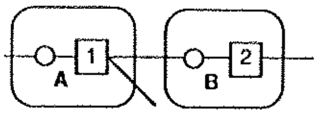
Peters (1987) suggests that to survive today, American companies are rapidly moving to de-integrate, toward smaller scale enterprises, and toward greater flexibility in responding to highly fragmented and quickly changing market niches. Listening to users, listening to the people on the front line of the company closest to the market, small batch production and reduced dependance on commodity production (does he therefore mean more dependence on prefabrication or overlapping control?) are all keys to the future corporation, he suggests.

Perhaps Weyerhaeuser's efforts within the past few years to move from 80% commodity products orientation and 20% higher value added production, to a reversal of that mix is a sign of what Peters suggests.

But, if an agent moves to control more of a downstream value flow, that does not necessarily mean moving out of the role of commodity production. It may mean that the agent's risk increases. However, if the agent moves to control more of a downstream flow in a situation of control overlap (design and agreement making) with a downstream agent, that does not seem to pose a risk and is in fact the kind of "flexibility" in production that Peters suggests.

High value added means, to Peters, active listening to customers and tailoring production to users, linking products and service in new ways. Will this produce more independent agents who can adjust quickly to changes in the situation both from the supply end and the demand end? It means organizatious can be smaller, with more people in organizations involved all the time in improving the products and services.

In situations of independent agents having diagram forms as in the following very simple diagram:



diagram#4.10

©A and ©B are independent, each having its own chain. This is still the diagram of the most efficient, but most risk-prone kind of chaining. It is efficient because negotiation between ©A and ©B are eliminated, and risky because a change of one ©'s control will only be indirectly felt by the other, who may not react adequately to maintain the liason.

But if Peters is correct in his assessment that producers are moving toward postures whose diagrams look like diagram#4.9 (overlap), this is important to consider, since the relation of indirect control (designing) we discussed in §4.1 becomes more prevalent and more demanding. It means more negotiation and less implicit integration. We need to have confidence that design expertise is ready for these increased and more complex requirements.

The question that will be asked is which agents will prosper from an overlap or nested form, and which will prosper from a dispersed form. If the answer is the first, that is a subject of work in the field of design theory and practice. If the answer is the second, the next question will be how to foster value added processes whose diagrams have that form.

4.3 More About Comparing Value Added Chains

So far, I have given a number of comparisons: the Pella window and the four housebuilding strategies in presented in §3.2. In §4.1, I compared a number of PAct diagrams in discussing the relations of agents of different kinds.

The demonstrations discussed thus far accompany the use of the technique of "opening" (specifying) a diagram to bring more information into view, or "closing" (abstracting) a diagram element to hold data behind the scenes. In §4.6 on Computational Support, I discuss this further.

These comparisons are possible because the same principles of interaction between agent and part hold in PAct diagrams at all levels of specification and across technical lines. What is accounted for is not idiosyncratic to any particular organization structure or hardware, but is in fact common to all parts making.

From a methodological standpoint, these comparisons are an important part of what I present: they show how the PAct tool can be used.

In this section, I present additional comparisons with PAct, to reiterate in principle how comparisons can be made, and to tie together points introduced so far about the control of parts.

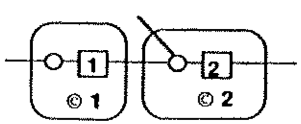
4.3.1 Autonomy, Coordination and Integration

The third of these three terms represents a major goal in much of the building products industry. Integrated systems and integrated delivery processes are both familiar terms of reference. On the other hand, coordination, meaning much more than alignment of parts, is an important practice among architects and construction managers. Autonomy is not a term used to describe parts production and construction, but represents an important third concept in the relations of agents in value chains.

We visualize these terms in the following PAct diagrams:

The basis for the comparisons is a chain of two parts with their operations. Let us call □1 "parts making a house" and □2 "a completed house" having been assembled with a site.

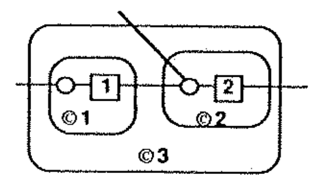
diagram 4.11a



Let us assign an agent to each part, making a PAct diagram with two agents ©1 and ©2. In this diagram we say that there are two autonomous

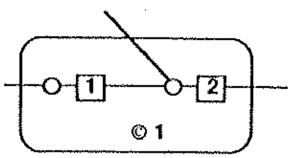
agents acting independently of each other. This is what a situation of autonomy looks like. Neither agent need talk with the other about the control they exercise.

diagram 4.11b



Next, for the same parts, let us again assign agents as before, but in this case let us introduce a third agent, ©3, whose place is one of coordination of the other two agents. Having such a third agent means that there is a plan in which both ©1 and ©2 have a part (literally) to play. Without a plan, ©3 is not needed. ©3 comes into the diagram with the introduction of a plan. It turns out that ©3 may be the same actual person or organization as either ©1 or ©2, but the role will be distinguished. Coordination happens when there are two or more autonomous agents whose control should be "lined up" by a third agent.

diagram 4.11c

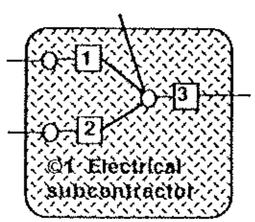


In the fourth case, let us start with the same parts: □1 "parts making a house" and □2 "a completed house". This time, we introduce one ©1 who includes both parts. This is a situation of integration.

diagram 4.11d

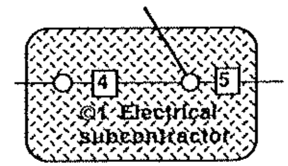
As long as we discuss control of parts, and not design, it is correct to use these terms in reference to these diagrams. We have shown control integration. It may be considered, however, that integration has the meaning of making many parts one, or eliminating parts. This is a change of design which is something different from a change in control as we see here.

Parts integration can be shown in the following series:



Let us begin with an ©1, for example an electrical sub-contractor, controlling two parts: □1 "power distribution lines and terminations", and □2 "data lines and terminations" which when assembled makes □3 "completed data and power installation" when installed in a house.

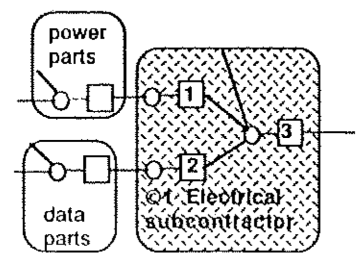
diagram 4.12a



We now "integrate" the two parts to make a new □4, which is what the Smart House ™ Venture proposes for improving safety and convenience in houses. The separate cables are now combined into a single cable, and single termination boxes are now used instead of separate ones for each kind of signal (power and data). Parts have been eliminated in a design change. The agent has not changed: the design change has not reduced or increased the agents we started with.

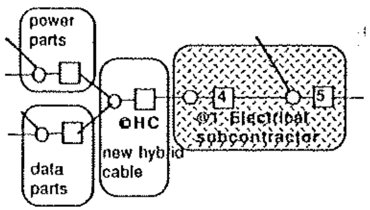
diagram 4.12b

However, upon further examination, we may find adjustments in agents upstream of the electrical subcontractor.



By examining upstream control in diagram 4.12a, we may see two independent suppliers making parts entering the electrical subcontractor's domain to be further adapted in □3.

diagram 4.12c



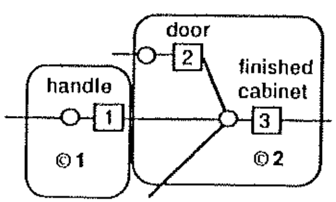
Eliminating a part the electrical subcontractor controls, for example □1 or □2 in diagram 4.12a may mean the introduction of a new agent upstream as we see here.

diagram 4.12d

We can say from this that reduction in parts at a certain place in a value chain may have its consequences upstream and perhaps downstream in terms of the agents who control parts.

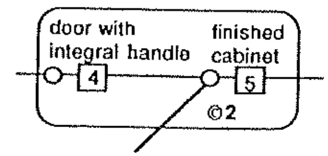
Since complex value chains normally have many agents as we have seen, tracking these changes may be of significance in planning changes to conventional practice.

An example of what may occur when parts integration occurs is diagrammed here:



Let us begin with two agents: ©1 with its □1 "handle", and ©2 with its □2 "door" and "completed cabinet". ©2 assembles the door with its handle and the cabinet.

diagram 4.13a



Let us redesign the cabinet door to make the handle integral to it. The door must still be assembled with the base cabinet, but in this diagram the separate handle drops out of the diagram, and with it the agent controlling it. Here, a design change in the direction of parts integration has accompanied a change in the control pattern.

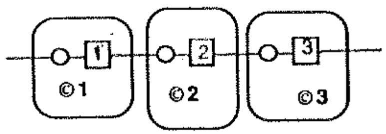
diagram 4.13b

Two other uses of the term integration can be made in PAct diagrams. These are vertical integration and horizontal integration, both familiar terms having to do with theory of business organizations but also relating to the parts agents control.

The following series pins down several related terms and lets us raise questions having to do with the evolution of such control patterns.

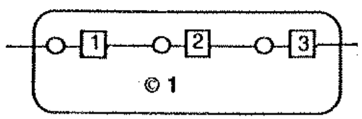
Here again we fix a pattern - in this case the pattern of three parts - impose a series of control patterns, assign a name to each, and raise a series of questions that the diagrams forms themselves help us make more sharply than we can with words.

<u>Vertical Integration:</u> the control by one agent of more than one part of a "system".



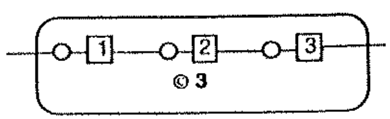
Begin with three parts: □1 compressor; □2 refrigerator; □3 "system" unit kitchen. Each appears in the diagram with its own agent.

diagram 4.14a



forward integration

A situation of vertical integration is diagrammed here. ©1 has vertically integrated the control of three parts. This occurred in reality when a company making refrigerant unit compressors started making refrigerators, then the unit kitchens in which its refrigerators go. This is also called forward integration when ©1's control moves downstream.

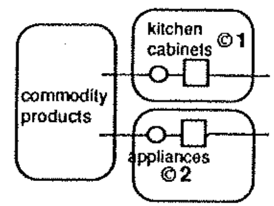


backward integration

In the same parts hierarchy, had an agent starting in the position of ©3 shifted into a position of control of all three parts, we would say that this is a situation of backward integration.

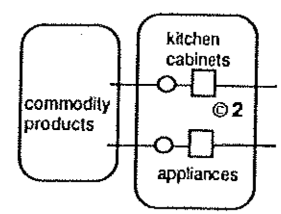
diagram 4.14b

<u>Horizontal Integration:</u> the control by one agent of parts that are not part of a "system."



We begin this series with a parts box full of commodity products, similar to the one we saw in the diagrams of Acorn Structures and the site built house,. To this we add □1 kitchen cabinets and □2 large appliances. □1 has its agent, and □2 has its, each operating in autonomy.

diagram 4.15a



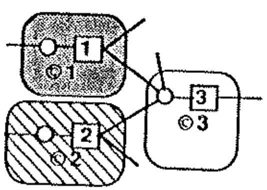
We next move to a diagram of this parts flow in a situation of horizontal integration. This series depicts what actually happened when Westinghouse Applicances bought a large Denver based wooden kitchen cabinet company.

diagram 4.15b

I purposefully selected two very similar things to distinguish vertical and horizontal integration. I could also have selected quite different things: a given agent, Westinghouse, controls nuclear power plants and makes residential appliances, two artifacts that no one would seriously argue are part of a system; Westinghouse would, on the strength of the control of these two distinct systems, be classed an horizontally integrated agent.

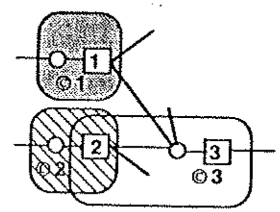
But it is interesting to note that we do not say Westinghouse is vertically integrated when it controls both refrigerators and kitchen cabinets, even when appliances and kitchens clearly go together in general and the same would hold with Westinghouses products. What Westinghouse controls in this case is not recognized as a "system".

<u>Horizontal and Vertical Integration</u>:



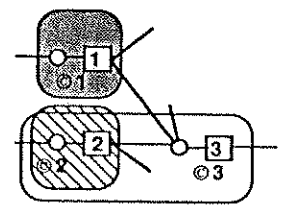
Let us begin with the same parts hierarchy we had in diagram #4.12. Let us assign different parts names: □1 is a hollow core door, □2 is cabinet grade trim for door jambs and trim, and □3 is a spec built house with a door installed in it. ©1 and ©2 are mass producers, and ©3 is a merchant builder building a speculative house.

diagram 4.16a



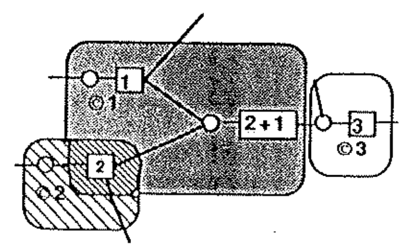
First, I extend ©3's control to the left, to include □2. The builder is shown ordering her owndoor frame and trim material.

diagram 4.16b



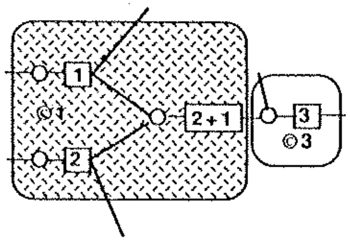
Next, ©3 controls □2, meaning that ©2 is now making parts only for ©3.

diagram 4.16c



Next, we see another situation in which ©1 the door manufacturer has indirect control of a □2, and makes a new part □2+1, which is a new part we call a pre-hung door. Notice that both □1 and □2 have stub lines: they are both available independently of the new □ 2+1.

diagram 4.16d



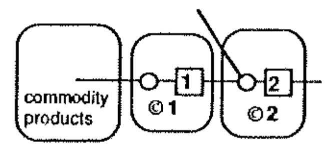
Finally, we see a situation of horizontal integration which represents the current way that a pre-hung door manufacturer operates in a PAct diagram. But the parts repertoire has increased by the introduction of the new part □2+1, but both □1 and □2 are still available independently.

diagram 4.16c

4.3.2 Industrialization and Prefabrication

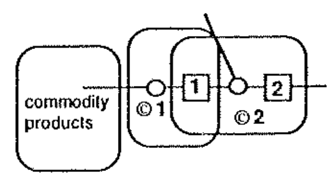
The distinction between the concepts and practice of industrialization and prefabrication has been the subject of controversy for some time. (e.g. Kelly, 1959; Russell, 1981; Habraken, 1983; Herbert, 1984; Industrialization Forum, various issues) It is not a purely academic concern, since we know that concepts powerfully impact action (Rosenthal, 1984). The controversy over this set of terms has been difficult to discuss and settle, because it has continued for so long without considering control. The terms remain loose and distinctions blurred. Dependence on words alone has inhibited the kind of unambiguous references that help us agree on the actions we want to take in common with other agents.

The following series of diagrams helps us discuss these terms:



Consider □1 and □2. □1 is made from commodity products. ©1 and ©2 are independent. We may, as before, call both parts "made for stock" (MS) parts. If so, then we may agree that MS parts are those made by an agent independent of the control of any downstream agent. This also seems to be how "industrialized" parts would appear in a diagram.

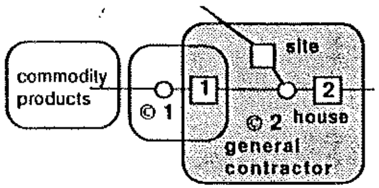
diagram 4.17a



A small shift in the diagram moves us to a situation in which □1 is made by order of ©2. We may then say that □1 is "made on demand". This is often what pre-fabrication has meant. In that definition, prefabrication seems to have to do with the control of a part by one agent and its indirect control by a downstream agent. But is this always the case? See 4.18a.

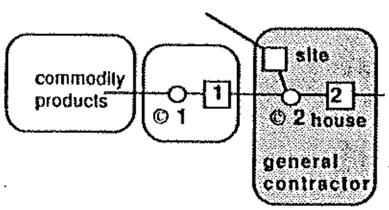
diagram 4.17b

A second series introduces a site.



In a diagram of prefabrication, such as Acorn Structures, a site appears in the control of the agent downstream of the agent doing the prefabrication. <u>But the important thing to see is that the prefabricator's control has to do with a site</u>.

diagram 4.17c



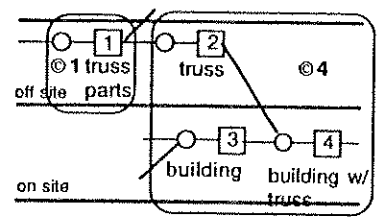
In a diagram of MS, a site appears also in the control of the agent downstream of the MS agent. But because the MS and the downstream agent (e.g. a general contractor) are independent, <u>the site does not have to do with MS' control.</u>

diagram 4.17d

However, it should be pointed out that prefabrication, as mentioned previously, has also been associated with off-site production, to be contrasted with "fabrication-in-place". Site is a general term, and is not meant to refer only to a piece of real estate. For example, the site of a bathroom is the dwelling unit it

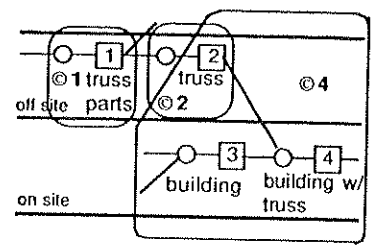
goes with; a wall stud is the "site" of an electrical box.

Are off-site and on-site fabrication linked with a particular control pattern? The following set of diagrams lets us look into that question:



Here, a truss □2 is made off site and brought together with a building. The building is the site of the truss. One agent controls both the building, the truss, and its assembly with the building. Another agent controls the parts making the truss. Is □2 prefabricated, when there is no indirect control but it is nevertheless made off-site?

diagram 4.18a

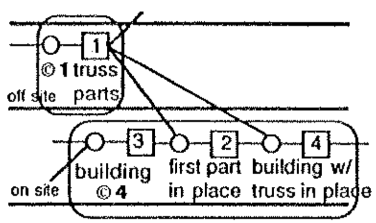


Here, we see the same parts hierarchy, but a shift in control. The □2 is still made off-site, but we see a new agent, ©2, actually controlling it under the indirect control of ©4. Would we declare that the truss is prefabricated in this diagram?

diagram 4.18b

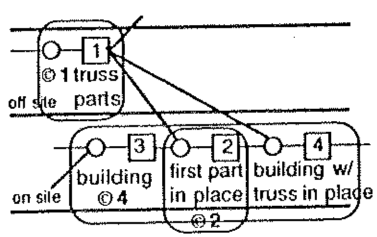
From these diagrams, we see that if prefabrication is meant to be what is done off-site, that this can happen under different control patterns: under conditions of nested or overlapping control or completely within the control of a single agent.

To finish the discussion about fabrication and its location relative to a site, diagrams of truss making-in-place can be made:



In the first diagram, we see that parts of the truss are installed in the building one at a time. The truss parts are still commodity products, and there is still a building in which the truss will be found. We see one agent assembling the truss in-place.

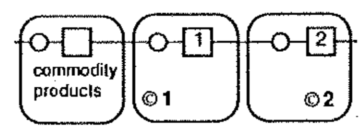
diagram 4.18c



In the second diagram, we see that with the same parts tree, a different control pattern is diagrammed. ©2 controls the installation of the first truss part. ©4 indirectly controls □2, and ©2 controls it. For example, ©4 may ask a company with heavy equipment to lift the heavy bottom cord of the truss in place. Then, ©4 finishes the job. Is □2 a prefabricated part, even if it is made on-site?

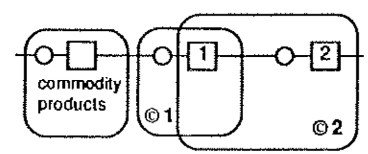
diagram 4.18d

Finally, the term mass production (MP) has been used in association with industrialization, commodity production, made for stock. PAct diagrams made so far show that these terms also can be seen in terms of control patterns. In the following familiar diagrams, what lets us declare that a part is mass produced?



May we say that both □1 and □2 can be mass-produced? Can either or both also be one-of-a kind or produced in small batches?

diagram 4.18e



In this familiar diagram, can either or both parts be mass-produced, one-of-a-kind or batch produced?

diagram 4.18f

The point must be made that it is not my intention to declare that a particular definition of a term is right or wrong, but that the diagrams can clarify different meanings of the same terms by means not of words but of the diagrams themselves. This is advantageous because the conventions we agree to can be less ambiguous, and less bound to words, while not separated from them. (see more about this in §5.2)

4.3.3 Control Sequences

The introduction of Wiremold's wiring raceway has influenced control in conventional value chains. The influence has been in the sequence of control.

The first diagram is of a conventional wall with normal wiring in the wall cavity.

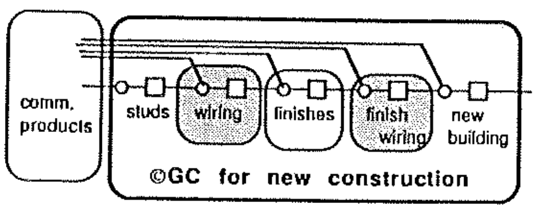
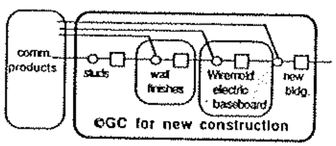


diagram #4.19

Here, we see a sequence of control in which the agent controlling wiring is located between three others. Traditionally, the electrician drills holes through the parts installed by the previous agent to install wiring and boxes, (although metal studs have holes provided).



Here, sequences are altered. The control of the wall occurs independent of the electrician, reflecting the repositioning and consolidation of the electrician's control of the part. Wiremold's part goes along with this shift in control pattern.

diagram #4.20

The ©GC is the coordinating agent in both the above diagrams. In the first diagram there are four agent interfaces to organize. In the second diagram, there are three agent interfaces, making it, other things being equal, more attractive to the coordinator.

A vital consequence of these two alternative PAct diagrams can be seen when the question of renovation is introduced, that is when the value added chain extends downstream beyond the end of the diagrams I have made above.

First, a diagram of the alteration of wiring in the conventional control pattern. We can read the number of parts liasons and agent changes. One agent cannot control before the previous one has finished.

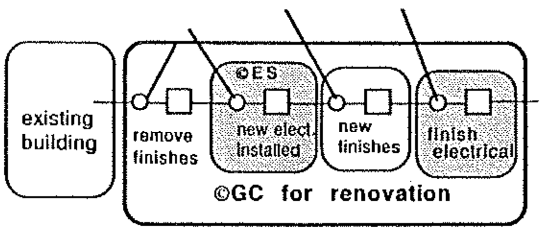


diagram #4.21

In comparison, a diagram of the adaptation of the second diagram has a value added process in which only one agent takes part. This diagram eliminates an agent that we saw in diagram #4.21: the GC and several operations.

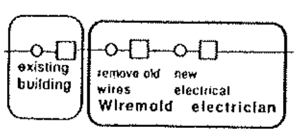


diagram #4.22

The experimentation with new technical parts and coordination practices whose diagrams approach #4.20 and #4.22 is now very aggressive. Solving wire management problems is now recognized as vital to satisfactory building procurement and facility management in "flexible" (not meaning elastic, but adaptable) office buildings in both the private and public sectors.

4.3.4 Base Building/Infill

A refinement in conventional office building construction is now compared with conventional practice in residential building construction by using PAct diagrams.

Complex building projects have for some time used a "fast-track" construction approach. "Packages" of technical decisions are prepared in phases, based on technical distinctions between, e.g., building structure, environmental and resource systems, and finishes. Each package concerns the entire building in one of these specific technical arenas. Their implementation also proceeds in phases. The structural package is one of the first: all decisions about a building's structural design are fixed, and construction begun. While construction of the structure is occurring, the mechanical systems package design is begun, and construction is undertaken of this part of the job; it is followed by other packages, including the finish package. These define phases which overlap during both designing and constructing to speed up completion of the project diagrammed as follows.

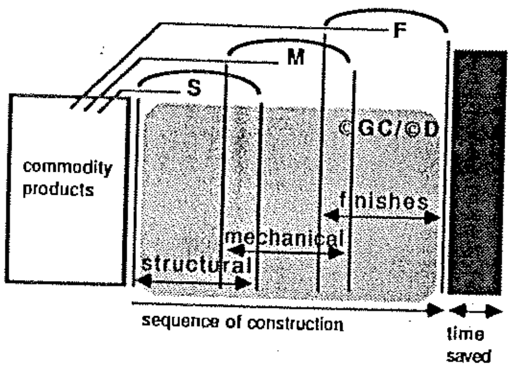


diagram #4.23a

For some time, this phased approach was associated with a PAct diagram of the following control patterns:

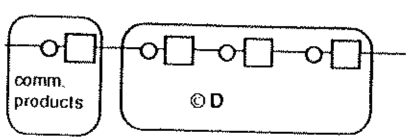


diagram #4.23b

in which one chain could be observed. This means that one agent, ©D, had to do with both the control and indirect control of the entire process. An architect would be hired, and a contractor brought in, but characteristically one agent's domain enclosed the others.

Combining diagrams 4.23 and 4.23a, we see one kind of practice.

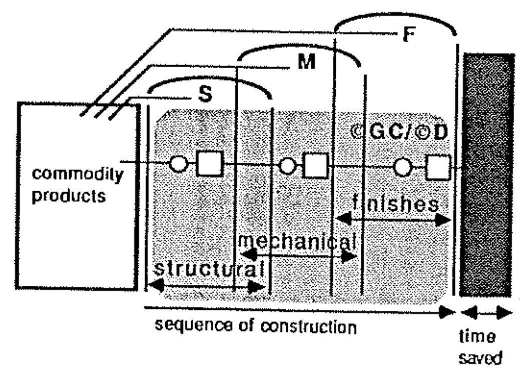


diagram #4.23c

This practice, however, has seen an important refinement for which the following PAct diagram applies:

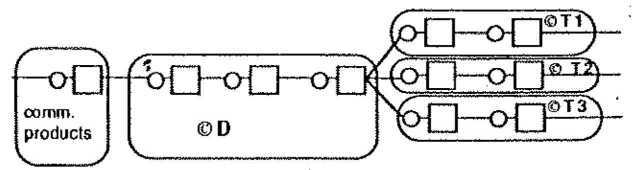


diagram #4.24a

where there are several chains - meaning several agents - appearing where there was one. The significance of this shift in control patterns having to do with a single building project is interesting to map on the diagram of phasing we saw in diagram 4.23a above.

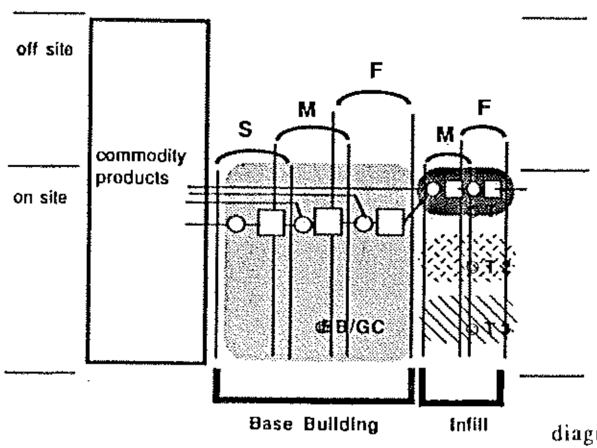


diagram #4.24b

This diagram is based on the diagram of "fast-track" project administration, but shows a dispersal of control in the production of the building.

We now see three new agents: ©T1, T2, and T3 (of which there can be many more). We focus on one of them. Each controls parts which are assembled with the Base Building (BB). The result is an "improved" BB with "fitted out" offices. The BB part is essentially a "site" for the parts T1, put there ("improved with sewer, water and electricity in the street in front") by the control of an independent agent.

Turner Construction Company, for example, seems to be doing what is diagrammed here. Turner can be ©BB and/or ©T1. Turner may do what ©BB does, and another agent may take the control indicated by ©T1. Or one agent can be both ©BB and ©T1. Turner has developed Special Project Groups (SPG) in each of its "territories" or regional offices, which specialize in working as ©T1 does.

The parts controlled by ©T1 are observed to change at a faster rate, and by different agents, than the parts controlled by ©BB. T1 parts are those which can be removed or installed without making BB parts change, and many T1 parts change as occupancy of a tenant space changes.

The TI work is different from BB work (it is not subject to the weather in most cases) and the parts usually enter the ©GC's control higher on a value chain than the parts found in the BB.

As this practice evolves, a new ©IS (Infill System Contractor) may now be emerging to control the parts ©TI needs, as the following diagram indicates. This new agent takes orders from ©TI, and produces the correct parts specified for the job, and delivers a "container" to the job site with the parts ©TI needs to complete the job. This diagram has the following pattern:

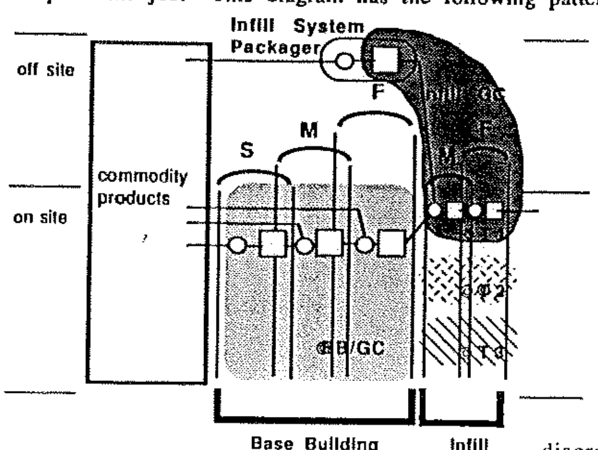


diagram #4.25

where the control of ©TI and ©IS overlap, but remain independent of ©BB and the commodity products manufacturers.

A further refinement is also now being cultivated by consortia of manufacturers and consultants which now takes the following diagram form:

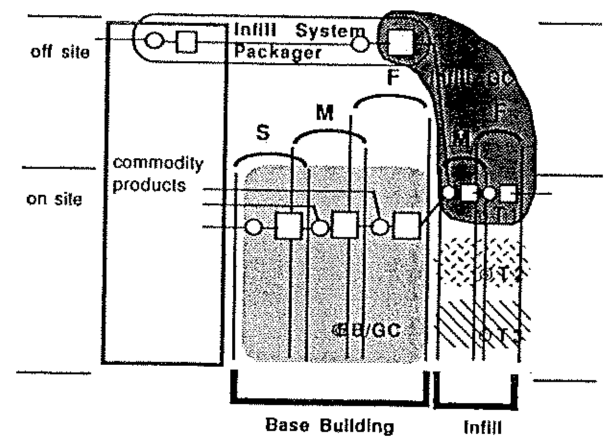


diagram #4.26

in which manufacturers cooperate with downstream agents to prefabricate parts for specific TI packages, a kind of collabortion

Peters has described (1987) but which is only nascent in practice.

Further, some commodity producers provide new parts to ©IS which take account of the special requirements of ©T1. For example, the raised floors manufactured by Tate Systems, or Nello Systems, were developed to assist ©T1 in the work of installing underfloor cabling and cooling lines to computer rooms.

In contrast to this continual evolution in office building practice, we can compare diagrams of <u>residential occupancy</u> construction as conventionally practiced. We find practice diagammed in the following PAct pattern, identical to the diagram #4.23a above:

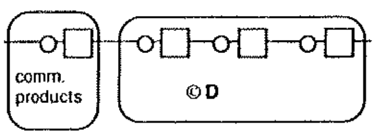


diagram #4.27a

This PAct diagram shows a single agent controlling all operations and parts. This means that, as in the example above, a developer will operate in an "integrated" way, bringing all dwelling units and all technical parts together under one control. In practice this means that if one part changes (a dwelling program or technical systems), that agent must take responsibility to sort out the consequences of those changes in all

other parts under her control.

The following diagram represents a typical floor or section of a residential occupancy building in which the PAct diagram appears.

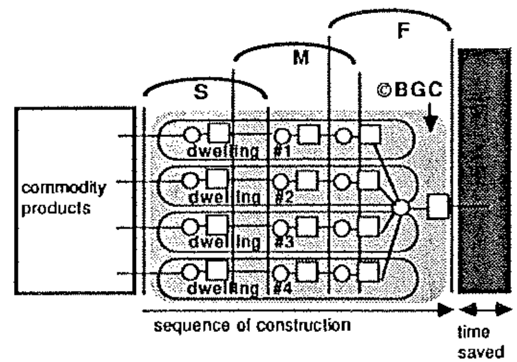


diagram #4.27b

Often, as a floor's structure is completed, other construction begins there on all dwellings, as the structure of floor above is being completed. Each floor acts as a site for the completion of the rest of the work there, as other "sites" above are being prepared.

In the diagram, stages of construction are indicated by vertical bands, corresponding to the deployment of physical systems. The three phases are shown uniformly crossing each dwelling. That is, on a given floor, all piping and wiring are normally installed not so much on a dwelling by dwelling basis, but by order of the logic of the technical systems. For example, all the electrical boxes in all units go in, followed by the wiring, and so on. No dwelling's heating equipment or finishes should go out of phase. Work progresses floor by floor, one system at a time.

The pattern of control shown in the last diagrams shows the undifferentiated planning of the building, in which the building is the sum of the individual dwelling units, and each dwelling is the sum of the spaces and technical systems of that dwelling.

Given the problems faced by residential developers and contractors - who face processes with a high degree of uncertainty brought in large measure by the number of "dispersed" agents controlling parts of the overall development process - the decision deferrment advantages of a construction process diagrammed in #4.24-4.26 would be useful.

These comparisons are rough and abstract, but show readers how comparisons can be made and how they can be used to study alternative value added chains. By now, readers will have come to understand that a series of diagrams building up a picture is often more satisfactory than trying to put too much in one

diagram.

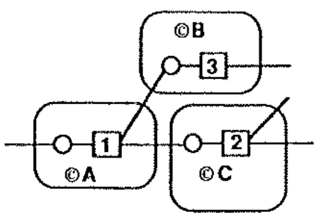
This is especially important to recognize in case we want to identify an agent and study the variety of control situations that agent may have. A separate diagram for each control situation will be more satisfactory, and readable, than a composite one. However, more sophisticated graphic displays may overcome this difficulty.

In any case, building up an understanding one diagram at a time not only gives us time to understand, but in building each picture, we compare what we make with what we change, a process that in itself is important, and goes to the center of the use of PAct as a comparative tool.

4.4 Relations Between Agents Summarized

In all the uses of PAct so far, we have encountered various diagram patterns. The intention in making PAct diagrams is to see what can be "read" in these patterns relative to the relations agents have with one another. The two principle patterns are "dispersed" and "nested" diagram forms having to do with the relations between agents controlling parts.

To reiterate, we have seen situations of independent control:

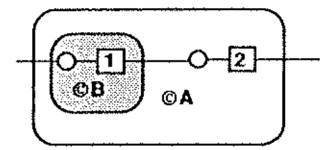


in which neither ©A nor ©B are dependent on the other. ©B is free to use □1 or not. ©A is not dependent on ©B's use of □1. If ©B decides not to use □1, ©A has others who will use it (e.g. ©C). ©A's objective is to persuade ©B to use □1. ©A therefore informs downstream agents.
diagram #4.30

Because ©A is independent, the information flow from each downstream agent toward ©A is also one of **informing**. The sum of information coming to ©A constitutes the synthesis of information ©A needs to be independent. An agent in ©A's

position must generalize to act.

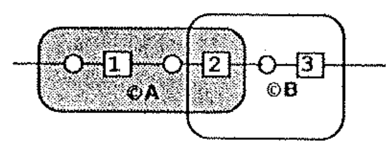
In a **nested** diagram, we have already seen many situations of completely overlapping control as in:



Here, ©B is entirely within ©A's domain. This means that while ©B controls □1, ©A's job is to **instruct** ©B. ©B's control is entirely subject to ©A's instructions.
diagram #4.31

This is the situation we ordinarily call **designing**. ©A is designing □1, while ©B controls or makes □1. We have called ©A's relation to □1 one of **indirect control**. In a situation of **nesting** as in the above diagram, ©B has no choices to make. ©A is entirely responsible for instructing ©B about □1. ©B can **advise** ©A, but is captive.

In a third pattern we have already seen, there is a condition of overlap. An example of this is



in which ©A's control of □2 follows the instructions of ©B. That is, the diagram has ©B designing □1, and ©A controlling it.
diagram #4.32

This diagram differs from the nested diagram form by letting us read that part of ©A's domain is not subject to ©B's instruction, whereas in the nested pattern, ©B's control was <u>entirely</u> dependant on ©A's instructions.

A situation of partial overlap should be read to mean that ©A has organized itself to be instructed by various "©B's". A normal contractor or architect will be organized this way. What is independent about ©A is what is not included in ©B's control bubble.

For example, in Acorn's case that we have reviewed in §3.2.2, the "standard" eave/vent is a part independant of any particular "©B"; also, many of Acorn's operations and processes - jig tables, marking and cutting tools, and technical protocols are independent of any particular ©B. These identify Acorn.

Only part of ©A's control is captive of ©B, and we understand this to be for the duration of the job of producing what ©B has designed. Notice in the following diagram what we have seen before: that O_1 is outside ©B's bubble.

This means that ©B (Buyer) designs □2, but does not specify the operations that adapt it from □1. In Acorn's case, the company provides design services for what it controls.

The diagram of this is:

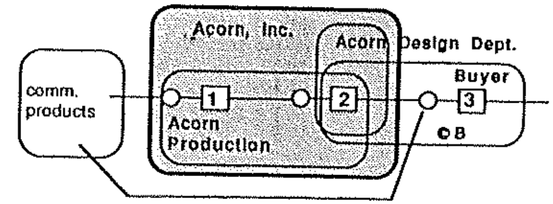


diagram #4.33

in which Acorn's design group controls no building parts, is partially within the bubble of ©B the buyer, is fully within Acorn, Inc. (that is, it does only Acorn work), and Acorn, Inc. per se controls nothing. Those agents who do not control, however, have indirect control. ©B controls the house by bringing in commodity products to build a deck, and is seen indirectly controlling the □2 house package with the participation of the design department of Acorn, ©C. Had the buyer ©B provided design services from an architect independent of Acorn, the diagram would change in the following way:

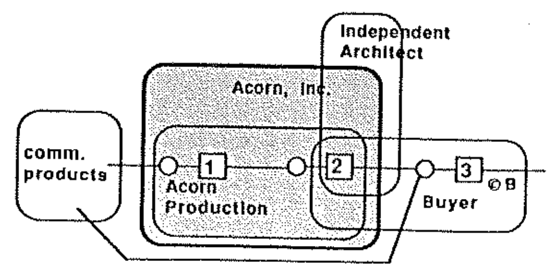


diagram #4.34

My understanding of Acorn is that in this case, Acorn's own architecture department would review the drawings and approve them, providing a diagram:

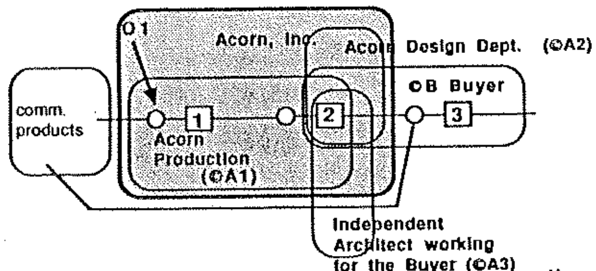


diagram #4.35

In this more complex diagram, we can read the agent controlling □1 by observing the location of the symbol for operation (O_1) associated with □1. The agent in whose bubble O_1 is found is the agent controlling □1. The other agents are in one way or another influencing the control.

Here, four agents (©A1, A2, A3, and B) have to reach coneensus about □2. Acorn has delegated to ©A and ©C its say about □2. Designing □2, in this case involves more

communication and negotiation than the situation of simple overlap we saw in diagram #3.63.

Finally, the diagram form

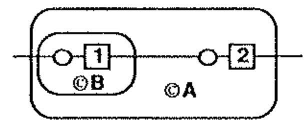


diagram #4.36

raises questions about ©B. What does it "bring" to the control of □1? The diagram form tells us that ©B is wholly dedicated to control of □1. Such would be a single purpose robot. The diagram can be read to say that ©B brings nothing general to the process, but only receives instructions.

On the other hand, if we draw

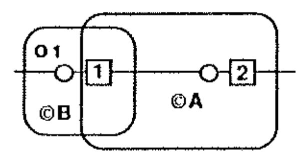


diagram #4.37

we mean that ©B brings "O_1" to the control of □1. O1 appears in the diagram independent of ©A or □1. That is, the diagram form means that ©B is free to make parts other than □1 by way of O1, which is a general operation not limited or specific to □1 or ©A's indirect control. For example, Pella's production operations can turn out custom window shapes or other shapes produced on a stock basis. Or, if ©B is a contractor, we understand that the contractor's practices can be applied to a speculative house or a custom office remodeling.

4.5 Criteria PAct Follows

PAct has been introduced and demonstrated in a number of situations in the building industry. The emphasis has been on making control explicit in the study of parts making.

It makes sense at the conclusion of the more technical section of the thesis to summarize the specifications which should be applied to the tool I have made - what it should be accountable for.

First of all, there is an accountability that any diagramming technique should meet:

1. The diagrams are an aid to clear thinking.
2. The diagrams can be manipulated easily on a computer screen.

3. End users can learn to read, critique, and draw the diagrams quickly, so that the diagrams form a good basis for communication
4. Hand-drawn diagrams are designed for speed of drawing; computer-drawn diagrams can have more lines and claroration.
5. The diagrams use constructs that are obvious in meaning, and avoid mnemonics and symbols that are not explained in the diagram.
6. The diagrams can be printed on normal-sized paper. Wall charts of vast size are to be avoided because they tend to inhibit change and portability.
7. Complex diagrams are structured so that they can be subdivided into easy-to-understand components.
8. The overview diagram can be decomposed into detail; the designer does not necessarily have to resort to a different type of diagram to show the detail.
9. The diagrams reflect the concepts of structured techniques.
(Martin and McClure, 1985)

In addition to these basic diagramming characteristics, I have demonstrated that PAct meets these additional requirements:

10. PAct diagrams are able to represent actual or hypothetical value added or "parts making" chains.
11. PAct diagrams put human agents (individuals, companies, divisions, consortiums) and the parts they control (physically alter) literally into view together, to make their interplay visually accessible, and to aid in the study of what they have to do with each other.
12. The number of variables instantiated in PAct is small, and the notation is simple to understand, to support rapid diagram scanning of many diagrams for comparative purposes. Further, by opening

and closing diagrams, we can manage the complexity of very large value chains. (see more in §4.6)

13. PAct diagrams help users come to grips with a new combination of variables in value added processes, in ways that other tools have not enabled, for practical purposes in support of the building industry, as well as intellectual reasons in support of technological discourse.

I have now demonstrated PAct by "hand made diagrams". Further development of the tool is now possible, computers can be brought to support it, and lesson drawing from using the tool can continue by the application of the tool to many other instances of parts making.

4.6 Computational Support

What has been demonstrated so far by handmade diagrams, as it were, would benefit from the application of computer support in two important respects:

1. Diagram layout and manipulation will go faster;
2. Complex data bases that we want to relate to our studies of control of parts will be easier to use.

First of all, diagram layout is time consuming. The legibility of the diagrams depends on the careful placement of notational elements. Visual clarity of the diagrams is essential to let us "read" them. There are placement rules for the purpose of organizing the diagrams, some of which are basic to the notation and were discussed in §2.5. There are others. For example, in several diagrams I put all off-site making in a band across the top, under which I place a parallel band containing all on-site making. These bands are helpful as we build and work with a diagram. I also introduced stages in a number of diagrams, vertical bands between which parts and operations are positioned.

The more complex diagrams often have crossing lines and alignment difficulties, "fit" problems with too much information in one place, and so on. These and other layout problems can be sorted out by hand, but automated layout procedures would greatly speed the organization of the many diagrams that will be needed to make PAct useful.

Second, once a rough diagram is sketched out for the first time, discussion of the issues and evaluation of what the diagram infers inevitably lead to the need to alter something in the diagram, to reorganize it entirely or in part, to bring in or delete some elements or patterns. Handmade paper diagrams become messy, and that media quickly impedes the rapid adjustment and organization of diagrams that is needed to match the speed by which mental images of new patterns appear. Building and working with diagrams on a computer screen would be of significant value.

Third, once a diagram is "ready" and we want to make comparisons, we need to "save" it as a reference diagram. Several people may work independently on their own computers, sharing identical representations of the same diagram as a starting point. We may then begin to make changes on the original. For example, this was what I did in diagrams #3.24 and #3.30. I held the structure of the diagram and moved some of its parts, brought in new ones, and deleted others. To do the kind of comparisons I have discussed, rapidly and in consultation with other people, it is essential to have the ability to select from a diagram the elements and arrangements which should consititute "structure" or a "fixed" configuration, to save and copy it, and tben place variable elements as needed in that "fixed" diagram form; to then select another "fixed" pattern based on what was learned from the last exploration, and work with it, and so on.

Fourth, the limitations of working on paper with outline shapes and lines and simple text so far is constraining. Color, line weight, tones, and the use of information layers are graphic capabilities that are key to full usefulness of the tool. For

example, we can overlay diagrams of the same structure of stages, but with different on-site and off-site distributions. Second, I have briefly discussed the value of identifying the patterns in which craft trades alternate with each other in conventional practice, in contrast to the bunching of operations to reduce dependencies in the use of the Wiremold baseboard wiring raceway. Using color to identify trades in diagrams would be helpful: electricians denoted as blue, carpenters as red, plumbers as brown, and so on.

The second major respect in which computational support is essential is for handling the very large (and changing) information content of complex value chains, while keeping diagrams of a size that they can be organized on normal sizes of paper.

Part of this difficulty will be managed by the use of graphic information layers mentioned above. For example, the information contained in the deployment of stages may be distinguished as a layer from the information about the parts hierarchy, and further distinguished in another layer from the agent domains, and so on.

That is, the computer can be used to "select" certain data or diagram elements or relations, and highlight or bring them forward to more clearly show some aspect. For example, we may want to know more about agents of a kind, sequences of one kind or another, situations of control overlap between particular agents, the occurance of certain operations, and so on. By selecting only some data or patterns, we can "track" a part's journey in downstream chains, a task which is apparently of interest to manufacturers such as Weyerhaeuser, who so far have no explicit map making technique to see the downstream control patterns or chains in which their products find themselves.

But more than that, the operation of "opening" and "closing", discussed briefly in diagrams #2.10 and #2.11 is vital. "Opening" is a procedure in which we look into either a PAct part or PAct operation to see more: more information, more specification, more detail. "Closing" is a procedure in which we decide to simplify or abstract a selection of PAct parts and PAct operations in a PAct diagram.

We have "opened" a number of simple diagrams in this way in the study. Diagrams # 3.20 was "opened" to become diagram #3.21, and subsequently, diagram #3.21 was further "opened" to become diagram #3.23.

Reversing these operations produces "closing" or abstracting of a PAct diagram.

In addition, "opening" can be imagined if we have a part box in the notation, with several imaginary "lids", with labels such as "costs", "applicable code limitations", "technical specifications",

"suppliers", "interface rules", and so on. Opening a lid will give us more information that is stored in that compartment. We can change the contents of a compartment when we want, bring information out for study, and return it.

The same procedure that I have discussed briefly regarding "parts" is also needed with PAct "operations". We will need to have rapid access to similar information compartments related to information about operations, such as "tools required for the job", "duration of the operation", relevant codes", "location of work", "alternative agents", "energy requirements", and so on.

Once we can "open" lids to get out data, the computer should assist in "checking" what is pulled out. For example, we may want to find out if certain information about on or off-site production has a correspondence to patterns of nested control, or to situations of dispersed control. Further, we will want to ascertain the conditions in a diagram in which undesirable or "forbidden" relations of data to diagram patterns crop up. For instance, we may know that data on building codes, found by opening an information lid, disallows certain operations or assemblies. The computer can assist by searching for and pointing out where such situations occur in many diagrams which we may be comparing.

Without computer support in this way, the complexity of value chains will render PAct a toy with some heuristic and intellectual value, but without the capacity to serve a real use in the analysis of parts making.

This closes the technical section of the thesis. The discussion now moves into a number of issues concerning the development of the tool, additional comments on the semantic gaps PAct helps to address, a comparison of PAct with a number of other analytical tools, and finally, why control has been neglected in technology studies.

5.0 Developing The PAct Tool: Intellectual and Methodological Issues

5.1 From Explaining to Describing to Explaining

From before this study was undertaken, the impulse has been strong to explain recurrent difficulties that have been encountered in initiatives, many guided by leading architects, to "improve" conventional housing production. "Conventional" technology seemed more enduring than any of the comprehensive programs of "innovation". The distance of so much "innovation" thinking from reality was remarkable. What was actually going on in conventional "making" that rendered so many initiatives useless? How could we take part in the development of the "2x4" system? Accurate probing of some of these difficulties and questions has now been started with the assistance of PAct.

This urge to explain eventually became an impediment to finding out more about actual "making" processes, but I now see the importance of wishing to explain - that is to take a position and come to "conclusions" - as part of a research endeavor. I have also learned that trying constantly to interpret and attribute cause can make description difficult, and that eventually, good descriptions are vital to working out an understanding of things that have heretofore resisted explanation.

What developed out of this study - the PAct tool - can be seen in this light: a means for describing parts making. Describing, we know, cannot be done without "taking a position" from which to view, and thus no tool whose purpose is description can be neutral because of its limits: it looks at some things and not others.

This tool accounts for only a few aspects of parts making: people, parts and parts' changes. It does not account for <u>why</u> people take action on parts, just that they do, despite the obvious fact that regulations, economics, politics, intentions and other influences are surely critical to a full understanding of parts and building production. Therefore, the limitations and strengths of the tool come from the interest that motivated the tool building in the first place and the focus it came to have: combining people and parts by introducing control. In any case, the objective of the thesis has not been to explain, but to develop and give initial demonstrations of a new tool. Making conclusions is interesting but not to be mistaken for the main purpose, which is enlightening description.

The things I have learned about the potential trap of wanting to explain touches close to home on a real problem my "home" profession - architecture - struggles with today, in my

view. My field is possessed by a propensity, and a responsibility, to make judgements: the mark of a good professional in practice is the ability to make informed judgements. But this pressure for judgement is particularly troubling when the object or situation we judge is not well framed or is not well understood, which in complex times is often the case. Too often, it appears that we are driven to make judgements and to confirm our professionalism in the eyes of peers by making and even building "conclusions", when what is called for is quite another thing. Conclusions, when built, can be so difficult to live with.

In principle, making judgements as we are mandated to do is not a bad way to begin framing research questions. It is probably not only a good way, it may be the only way. What follows, however, matters as much if not more in the long run. What follows is working out the question. Objectivity and open minded curiosity are then basic requirements for intelligent discourse and exploration of subjects which abound in our field, all resisting simple explanations. The discourse starts out, however, by taking a position.

In the ensuing discussion, I outline part of the intellectual history of the research reported on here, in order to place the tool and the work of building it in the context of an architectural discourse about building technology.

Trying to explain this phenomenon of diminishing relevance of much architectural and other expert thinking to the cultivation of the 2x4 system meant that evidence was needed. What was really behind this sense? What evidence could be found? Was it shortcomings in the hardware itself? In diminished craftsmanship? In architectural styles that did not suit the times or places or the hardware? In "big" efforts to improve technology which failed, thus drawing intellectual and financial resources from more modest, more sustained, but perhaps more important efforts? Where would such evidence be found? What should I look for?

There was ample evidence to support another contention: that the state of affairs was good in housebuilding. Evidence of this could be found most easily in promotional literature, trade journals, building shows, the local building supply centers and in countless neighborhoods in which countless houses were undergoing transformation in large and small ways, all within the general "2x4 industrialized vernacular". Certainly the technical repertoire was ample to the extreme, and the know-how also appeared to be available, if increasingly costly and at sometimes reduced levels of quality. The "2x4 system" was even being taken up directly and explicitly in Japan, another wood building culture,

and there was evidence of smooth transferability of know-how and technical processes and products, if not whole house packages, between the US, Canada, and Scandanavia, another wood building culture.

A claim that there was a growing distance between what architects were able to contribute to the cultivation of housing production and what housing processes required in contemporary times, was hard to pin down, and perhaps out of line. The "2x4 System" had been gradually evolving for 160 years, and at any one point, it seemed perfectly healthy and whole. It could be found as the way of building in a traditional bungalow, a modernist vacation house, a tract house in a developer's subdivision, an addition to a New England timber framed houses, and a backyard storage shed.

As work continued on the research, the effort to attribute cause to this apparent disparity between contemporary architectural thinking and housing processes gradually worked its way toward an effort to understand the way of building I was interested in. It seemed to me that contemporary thinking in the professional design fields had so separated process and product thinking that their interactions, so vital to real practice, had slipped through the cracks of research.

My interest in the attribution of causes continued, but always there was a kind of circularity, as well as a maddening slipperyness to the subject. Things wouldn't stay pinned down. Not only would the seamlessness of the subject appear to be without end, but as soon as one definition was accomplished, another would seem more crucial and more likely to lead to the "cause" that was being sought.

It was while reading Staudenmeier's Technologies Storytellers (1985) and Bunge's Causality and Modern Science (1979), quite different approaches to the discussion of causes, that a way out of these predicaments was found.

What became clear was that we may choose to, and can usefully start a journey of discovery with a causal/ determinist proposal, but that, once having set out what seem to be the major landmarks, the crucial next stage of the enterprise has to be bent toward good description.

The situation, I gradually found out, was that there is an asymmetry and superimposition of causes to sort out. Attribution of causes could perhaps be accomplished after that. Bunge, in discussing interactionism or functionalism - the view according to which causes and effects must be treated on the same footing - suggests that

" ...the polarization of interaction into cause and effect, and the correlative polarization of interacting objects into agents and patients, is ontologically inadequate; but it is often a hypothesis leading to adequate approximations and, more often than not, it is the sole practical course that can be taken in many cases, owing to a paucity of information and theoretical instruments; hence, it is methodologically justified in many cases. But such a success is not justified in itself; if it is successful, it must be because it is rooted in the nature of things, because in reality most reciprocal actions are not symmetrical." (p 170-171)

and later, Bunge declares that we should recognize that

"...the neat separation and isolation of determiners, while not the *last* stage of research, is a very important preliminary stage, whereas the tenet of the unanalyzability of wholes blocks *ab initio* every advancement of knowledge." (p 172)

This helped me to understand that causal analysis is not, therefore, the sole kind of analysis that we need to know about. That meant to me that searching for causes and explanations was not the only thing that counts, in a thesis or in practice. This took the pressure from a kind of self-imposed forced march toward explaining. I could start by thinking about causes or explanations, but there was more to the research than that. Searching for causes is a good place to start, but it is only the beginning. What follows is sorting out.

This was a relief. What I took from this was that my sense of the systemic characteristics of the conventional way of building was a good place to start. The relations and interactions of phenomena (product and process, hardware and software, local and general, custom made and stock, experts and laymen) was itself a deserving subject for analysis that was not separate from an impulse to attribute cause at some point.

But, interactiveness per se is not a very useful concept. It has to be taken much further. This pointed very clearly to the importance of a good description of the phenomena whose interactions were of interest: in my case, the conventional housebuilding enterprise in the United States, and the relation to architectural thought to its evolution. This insight was crucial because it meant that description was good to do, and finding out how to describe the subject was intellectually not a deadend enterprise. Good descriptions unfold with and enfold the work of attributing cause.

Having been at least temporarily relieved of the need to explain, the work could more freely focus on taking stock of the business of 'simply' describing what was going on in the housebuilding enterprise, without having to apologize for it. Having been in the business of studying accounts of the housing enterprise for over two decades, and architects' exploits in it, and having paid attention to various efforts to describe the important variables in the practice of building houses, and having done

some small amount of building myself, the question was, what could I add to what had already been done to describe the subject?

It was clear from the beginning that the crucial issues had to do with a good whole picture, in which parts we make could be discerned in their relations to each other and the complex of agents who worked with them.

The parts, in the most simple framing of the subject, were certainly the normal artifacts of construction, and the various agents who in one way or another take part in parts production.

The "whole" was the problem. The whole included all these parts, certainly, and also all the people working with the parts. What were the relations people had with the parts they manipulated, and with each other? Weren't these the interactions which, when accounted for, would make for a usefully description of the 2x4 system or any technological system, and would enable me to look more clearly into the thesis?

"Relations" and "interactions" of course is systems talk. (Rosenthal, 1984) But much of systems talk is remarkably devoid of "people talk" in the same breath as "parts talk". For example, in a "Model for an Industrialized Housing Industry in the United States" (Brill et all, 1972) we find

"It is useful to conceive of an IHI (Industrialized Housing Industry), both present and future, as a system. A system is characterized as a set of elements interacting with each other to produce some desired goal. Since a change in any element will reverberate throughout the system, unless all the system's elements are interacting properly, [author's note: of course this is not the case: there are dependencies and relative independencies] any attempt to deal with a sub-system out of this context will have suboptimal results. For instance, attempts to solve transportation problems by designing better house-carrying helicopters won't improve the situation unless you can also arrange for cheap insurance which will permit houses to be carried over populated areas. The IHI is a complex system, and we will present it in its complexity. Attempts to simplify models for "clarity" have invariably led to diminishing the possibilities of solutions to complex problems by diminishing the "solution space". Complex systems are very difficult to understand and to manipulate". (BOSTI Report §B.5)

Given the overly narrow "technical" paradigm that so many portraits of the "making" enterprise spring from, including the one just quoted - and I distinguish this from the historical and critical writings of Mumford, Layton, Rosenburg, and others - couldn't the simple proposal to bring people's actions - actually changing parts - into the picture be a useful addition to the technical discussions?

The description that I sought to make possible was not first of all for "problem solving" purposes which has occupied and ultimately distracted so many thinkers in the fields of designing

and making. It was, therefore, different from the CPM method, or the various graphic tools CAD and CIM developers work on in support of integrated manufacturing, as we will see in §5.3. In appearance, the tool I developed is in the family of network diagrams, graph representations and precedence diagramming familiar in other sectors of industry (Martin and McClure, 1985). Its lineage includes work in manufacturing, materials processing, and design for assembly.

Rather than being a problem solving device, the tool I came to invent was an accounting tool - perhaps we could also say a tool to study making in context - which could be used as part of a problem solving technique, but wasn't one itself. I really wanted to take stock of what was going on in the behavior of parts and people in value added chains in which parts making was the subject. The aim was to describe, not solve, in terms that would make a contribution to architectural discourse.

The largest problem in tackling the description of the subject was that it was both immense and highly detailed. The housing industry constitutes a massive social enterprise and serves as a barometer of the health of a local / regional economy. The number of participants in the housing industry, direct and indirect, is huge. Houses people build are a close measure and mirror of a culture.

Building a house is also highly detailed; the number of parts in a house is very high, no matter if it is "ordinary" or "innovative", the parts count has some relation to the number of people who want to take part in that form of culture-making. One can't take part in a "making" activity without a part to control. The range of parts types is also very large, the operations of cutting, fitting, attaching, are very large in kind and number, and the circumstances in which these operations occur also vary widely. The number of discrete influences on any one act in the making of a building, from its individual parts to the entire artifact, including both "software and hardware", is also very large (e.g. Ventre, 1982; McCue, 1970). Manufacturing the parts of which houses are built is also highly intricate; even a simple casement window has over 150 discrete parts as we have seen, and many suppliers and workers are involved. (refer back to §3.1 for more on window making) Further, the flows of information between both experts and laymen as we described in §4.1, both in "direction" and in "kind" are not easily sorted out.

Parts making (for houses or for any other artifact) constitutes an artificial system, so it quickly became clear that biological analogies would not entirely suffice, despite efforts by many important thinkers (e.g. Alexander, 1986; Fitch, 1972) to make housing, technology, or building production fit that model.

The basic literature of general systems theory, while interesting in its own right, in the end did not provide much leverage, in the main because natural and social systems - the central interest of the original general systems thinkers - and artifactual systems are only partly alike. The social science literature generally saw artifacts as immutable, as given, fixed, passive, and something to be reacted to, not to be changed. Even the engineering literature on systems did not give the insights I felt were needed, principally because the question of agents was left out of their stories; engineers like to neutralize the question of agents by declaring that people don't matter as a variable: the principles of systems engineering should hold across all agent domains, so agents can reasonably be deleted from the analysis.

The many efforts in the 20th century to improve housebuilding by bringing in systems thinking seem to miss the mark too often to be excused any longer. Something is apparently wrong with systems thinking in this context applied to "making". The problem seemed to be that most of these efforts did not go far enough in accounting for complex "system" behavior. For example, conventional building has been repeatedly characterized as "just" a fragmented assortment of skills and building parts. There was and is a well documented belief, as I have mentioned before, that what is current does not constitute a system, a radical stance that has really done substantial damage to sustained cultivation of building practices and intellectual discourse on the subject of "making".

The distinction that had been made between "Support and Infill" (Habraken, 1962, 1972) for the design, construction and adaptation of large housing projects was an example of connecting hardware and people that is so frequently misunderstood by strictly technical thinking. This concept suggested that dwelling was not a passive technical object, but the active working together of households and the physical elements that made a dwelling, in the context of the "common" physical arrangements and that social organization which controlled this physical context. This distinction that now informs new developments in housing practice and technical developments could, however, not have been made and worked out in practice without the introduction of control as the criterium.

The simple basis used in this study for describing the relations of people and artifacts was that people - including the manufacturer, carpenter, and layman - actually do something to the artifacts whose value added flows we want to understand. They actually "lay hands on" and take action. They could not be left out of the story. They literally needed to appear, with their actions, in the same mental and actual pictures with the parts.

So the fulcrum shared by all the actors that came to be described was the action of changing something physically. The description then became one of working out what action was taken by particular actors. Soon, it became possible to discuss what the actors had to do with each other, what they told each other and what information was passed, with more clarity than before. It was interesting and important that designing appeared and could be "located" in the maps of "making", although I began to see that forays into design talk only deflected concentration from the overall descriptions I sought to enable. I wanted to focus on descriptions of making, not designing.

Enlarging the discussion of architectural practice and theory by including studies of control of parts in the building industry is possible and its continuation will be useful for several reasons. First, it will contribute to a reinvigoration of the discussion of technology in architectural thought, a discussion which is now less interesting than it could be. Second, it may contribute to new professional expertise to improve practice, as architects' reacquaint themselves with the realities of contemporary housing production which are so intriguing and important to understand.

5.2 More About Minimizing the Semantic Gap

I have already made reference in previous sections to the issue of the words we use to describe "making processes" and its various aspects. Here I will go further into that subject.

The terms of reference found in the literature on "making" have a fascinating ambiguity which may suit the "making enterprise" in the large in some ways, but enough cases are accumulating to make us want to pin-down the terms of reference to see what we are really working with. Several examples of the gap between practice and semantics will be offered here using PAct.

5.2.1 ASTM E-6 Committee

The work of the ASTM E-6 Committee on Terminology (Designation E-631-85c: Standard Terminology of Building Constructions) impressed me with the difficulty of trying to pin down complex concepts in building processes and products using words. An example of this came from the following part of a soliloqy from an ASTM meeting of the subcommittee considerations of voter comments relative to E-6.94 on

Terminology and Editorial. (Oct 21, 1987 meeting in Bel Harbour)

"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:

Shuman: Is written to answer "building an assembly". As an entity it should read: manufactured parts fitted 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 simplist nature, such as a wall, a beam, a foundation. voting tally: 54.5% affirmative.

Negative comment:

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

Ferguson: Add "a major" building component". Delete "of the simplist nature"; a wall is not so.

Mather: A building component of the simplist nature is an atom or a 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......

Shuman: 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.

Affirmative comment:

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.

Action by Subcommittee

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" included "building material", "building member", "building product", "building system", and others. What would these terms: building element, assembly, material, member, product, system look like in a PAct diagram?

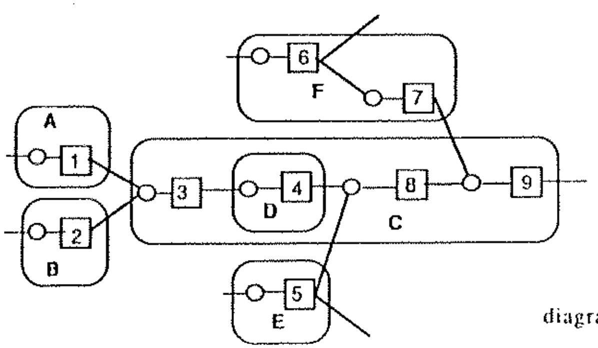


diagram #5.1

Building assembly:

In this diagram, parts 3, 8, 9 could be called assemblies, since they explicitly indicate the parts of which they are made.

Building element:

In this diagram, we might agree that all parts upstream of □9 are building elements from it's "point of view". What in the diagram would not be called an element?

Building material:

Perhaps only □1 and □2 would be called materials by ©C. Perhaps, on the other hand, a building material will be known by the operations which are found to be used to transform it: a part which is only assembled without cutting, for example, might by some not be called a building material.

Building member:

A building member may be what is also known as an element, but some might find it otherwise.

Building product:

From the point of view of ©C, parts 1, 2, 5, 7 may be called products, because of the way these parts appear in the diagram: coming from independant agents. But others may say that a product is a material.

Building system:

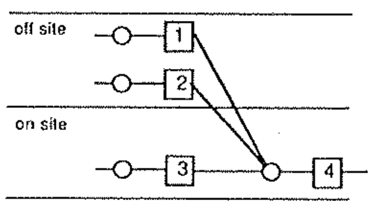
could include all or only some partial configuration of the diagram, depending on what was agreed by all the parties who had to communicate about the parts in question.

The terminology problem is reduced by employing PAct diagrams. The definitions that are suggested may not meet the agreement of others, but the point again is not that one or another definition is correct, but that definitions are possible with reduced uncertainty by means of PAct diagram, compared to sole reliance on verbal constructions. Should a disagreement about a definition occur, we should try to make a diagram that fits the meaning in mind. If the diagrams which result are the same, the words chosen to describe the action are the issue, not the action itself.

The following terms are familiar in the literature on building technology, often used interchangably or in "strings" - e.g "prefabricated, industrialized mass produced parts manufactured in a factory" - in popular, professional and research literature:

* prefabricated
* mass production
* construction
* manufactured
* batch production
* industrialized

The distinctions between them remain fluid, as the following discussion shows using definitions from Webster's dictionary:



Prefabricate: "to fabricate the parts of at a factory so that construction consists mainly of assembling and uniting standardized parts".

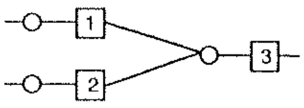
The definition suggests only part of a PAct diagram, where assembly is shown on site or "in construction." The PAct diagrams cannot deal with "mainly".

diagram 5.1a

Construct: "to make or form by combining parts."

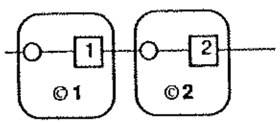
Assemble: "to fit together the parts of."

Fabricate: "Construct, manufacture, specif: to construct from standardized parts".



This parts tree shows combining parts as well as assembling and fabricating. "Standardized cannot be used, apparently, unless agents appear in the diagram. A standard has to do with agents, not just parts.

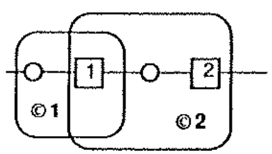
diagram #5.1b



Standardized:"having attributes required by law or established by custom; regularly or widely used."

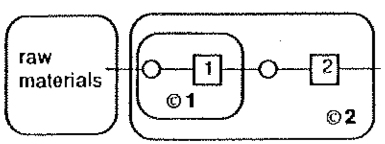
The definition tells us that no one agent has indirect control of a part called "standardized" suggesting the dispersed diagram form. Would we say that both □1 and □2 are standardized?

diagram #5.1c

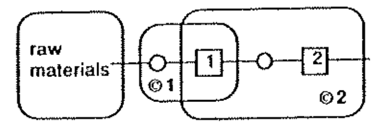


However, for a part such as □1 to become standardized, it may have existed initially in a situation of overlap as in 5.1d, in which ©2 would represent the collective of agents in whose interest it is to have □1 as a "standard" part, and □2 is the collective of all downstream parts using □1.

diagram 5.1d



Manufacture: "to make into a product suitable for use; to make from raw materials by hand or by machinery; to produce according to an organized plan and with division of labor; fabricate."



Both diagrams 5.1e and 5.1f may be useful in asking which parts are manufactured. In both, there is a plan indicated by the appearance of overlapping control, and there is a division of labor, shown by the presence of more than one agent.

diagrams 5.1e and 5.1f

By way of summarizing this section, I would like to present the two main diagram forms and suggest English language equivalents to them. The diagram forms have a power to bridge across disciplines and across languages.

First, there are diagram forms which appear this way:

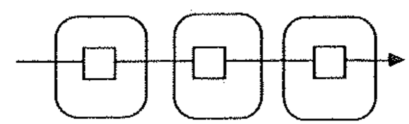


diagram #5.2

in which independent agents are found stringing along liason chains. These I have called **diagram forms of dispersed control**. Such diagrams are characterized by many "synapses" between independent agent domains.

They are what we see most of, when we diagram vernacular value added chains. The characteristic relation between agents is commercial.

I would call this sort of diagram #5.2 one in which **implicit integration** is at work, where a form of "cultural intuition" has evolved to take the place of negotiation. No one agent is to be found whose "bubble" indication surrounds the entirety. There is no "total system control".

What is it that makes for the coherence of such value chains, when the diagram form indicates that designing is not occuring there?

On the other hand, when we see diagrams with this form:

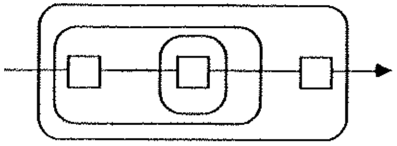


diagram #5.3

we have called these nested diagram forms. The characteristic of this diagram form is that agents relate to each other hierarchically, by inclusion, or by explicit integration.

Shifts from implicit to explicit integration or the reverse are very interesting and need to be studied. For example, what happens to a value chain when we say a technical practice becomes vernacular?

The variety of natural languages in which technical discourse occurs around the world gives its rich texture of meanings and interpretations. Even the highly technical languages that scientists and mathematicians use to exchange findings are nevertheless subject to interpretation, showing us that even with specialized, abstract and symbolic notation, the necessity of interpretation does not disappear.

We should therefore not be reluctant in architectural discourse to supplement natural language rhetoric with new notation tools, in order to bridge semantic gaps, and to describe and communicate among ourselves and with other disciplines involved in making processes.

5.3 Comparing PAct Diagrams with Those of Similar Structure

A number of documents studied in the course of the research included diagramming techniques which in some ways had similar structures to the PAct tool. Others used concepts found in this study, and had graphic ways of representing them which were helpful. These are presented and discussed here.

None of the diagramming techniques found in the literature included control as defined in this research, so the "point of view" taken in this research and in PAct will not appear in any of the tools that follow, nor could they be expected to do what PAct does. Thus the comparisons are limited but nevertheless interesting if for no other reason than to point out in many instances that discussion of control in parts making has been missing.

This issue of the neglect of control is taken up in more detail in §5.4.

5.3.1. Critical Path Method

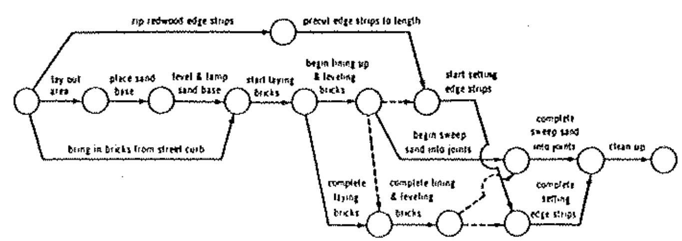
From the outset, when trying to explain what I was doing to others, it was hard to distinguish what I was inventing from a well established technique called the Critical Path Method (CPM).

CPM is a scientific approach to solving the complex problems

of planning, scheduling, and managing production projects. It is a work scheduling management tool utilizing a graphic modeling concept called a network diagram. This concept is in a lineage including the Gantt chart developed by Henry Gantt and Frederick Taylor in the early 1900's. A Gantt chart takes the form of a bar chart (Radcliffe, 1967). The basic logic of the CPM technique emerged in 1957 from work done by Kelly of du Pont and Walker of Remington Rand, concerned about long time lags between completion of research and development on a new product and construction of facilities for manufacturing the new product.

CPM is an application of systems analysis, which is part of operations research, an approach to problem solving having to do with systematic and scientific analysis, evaluation and solution of complex organizational and operational problems.

The following is a simple example of a CPM network plan for building a brick patio.



NETWORK PLAN FOR BUILDING A BRICK PATIO diagram#5.4

where an arrow represents an activity, and the circles at each end of the arrow represent the beginning and end of an activity.

Here, "a network plan depicts the scheme of action to be followed in completing the project as planned by management and is used to establish time and resource limits for each tack within the project." (Radcliffe, 1967)

PAct differs graphically from CPM network graphics. In PAct, an O represents an operation, equivalent to the activity arrow of CPM. In PAct, parts are shown with the ☐ symbol. CPM does not show parts. The line in PAct signifies a lineage of parts in a part/whole hierarchy. Since parts are not shown in a CPM diagram, there is no similar representational requirement to show relations between parts. In addition, PAct uses a graphic symbol to represent agents, the bubble shape. CPM does not show agents.

The glossary of terms for CPM does not include reference to parts or agents. These are the essential elements of a PAct diagram.

4.3.2. The Precedence Diagram: A Tool for Analysis in Assembly Line Balancing

This technique builds on the CPM. Like CPM, this technique

analyzes work processes in terms of the commutability of the individual work elements (operations). Commutability means that parts of a product have been combined in such a manner that the result is independant of the order in which the elements are taken. Assembly is commutative when it can occur in a variety of orders; A+B+C=D or A+C+B=D, both producing D.

A precedence diagram looks like the following example of work elements on a television assembly line.

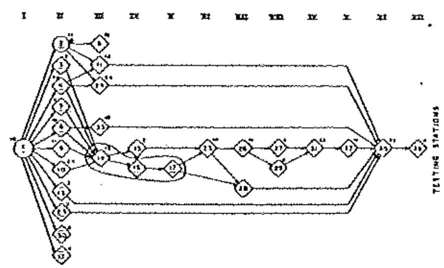


Figure 3. Precedence Diagram for Work Elements on Television Line.

diagram #5.5

Each diamond shape contains a number identifying the actual work element; the numbers ontside the diamond refer to the corresponding time durations. The connecting lines or arrows indicate precedence relations. The bubble surrounding work elements 14,16, and 17 indicate that for safety reasons the placement of the TV picture tube (work element #14) must immediately be followed by certain fastening operations #16 and #17. It would not be correct to combine these work elements (operations in PAct terms) into one, since it is possible to have them performed by successive operators (PAct agents). Yet they must be denoted to insure that they are performed in succession.

The key reason that these diagrams are used is to balance assembly lines for existing products, using existing assembly systems and facilities. Therefore, the above diagram was prepared

"within a framework of such given conditions. For the assembly line diagrammed above, only those changes in method or facilities were considered that management would be willing to make in the course of normal line balancing. As in industrial practice, major changes in product design, general assembly method and layout of assembly lines were not considered as possibilities to facilitate line balancing. However, rearrangement of small tools and equipment, work benches, and fixtures is normally feasible and davantage was taken of this in diagramming. The decision as to which conditions are fixed, and which are not, must be made in each case. The goal is to attain the greatest possible commutability of work elements by minimizing the restrictions caused by fixed facilities." (Prenting and Battaglin, 1964)

The use of precedence diagrams has to do with making improvements in assembly line technology. Like CPM, this technique enables the analysis of delays in production streams, maximum exploitation of commutability of the individual work

processes, and is also useful in training new personnel. Instead of the knowledge of the production line being entirely committed to memory, the data are displayed logically on paper.

This diagramming technique relates to the operations in PAct diagrams. In PAct, parts and operations are of equal interest. In precedence diagramming, the operations are of more interest than the parts. PAct is not aimed at efficiency, while this diagramming technique is specifically used to save time.

5.3.3. Modeling and Control of Assembly Tasks and Systems

"As assembly automation systems become more complex, the analysis and design of these systems requires more sophisticated tools to achieve desired performance, including speed, reliability, and flexibility. Current research efforts in the Flexible Assembly Laboratory at CMU (Carnegie Mellon University) are focused on developing representation and modeling tools to be used as a basis for automated planning, design and programming of assembly systems and their supervisory controls."

That research has produced a diagram protocol, an example of which follows:

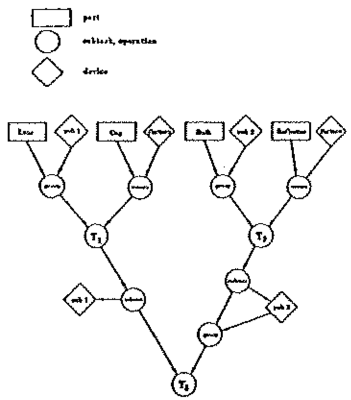


diagram #5.6

where parts, operations and assembly devices are represented as nodes between lines which indicate precedence relations.

Like the precedence diagramming technique reported on above, this effort also seeks to describe work processes with the objective of modeling uncertainty, to enable better tradeoffs between speed, reliability and flexibility in automated assembly line operation.

While this technique has some diagrammac similarities with PAct, and also focuses on assembly, it is otherwise not directly linked to PAct. On the other hand, it may be possible that this way of modeling assembly tasks could be used to specify the O (operations) of a PAct diagram. (Krough and Sanderson, 1986)

5.4.4. And/Or Graph Representations of Assembly Plans

This diagram technique forms the basis for efficient planning algorithms which enable an increase in assembly system flexibility by allowing an intelligent robot to pick a course of action according to instantaneous conditions. Choices are made upon weighing complexity of manipulation and stability of components in alternative diagrams.

"The AND/OR graph consistently reduces the average number of operations." (de Mello and Sanderson, CMU, 1986).

Such a diagram looks like this:

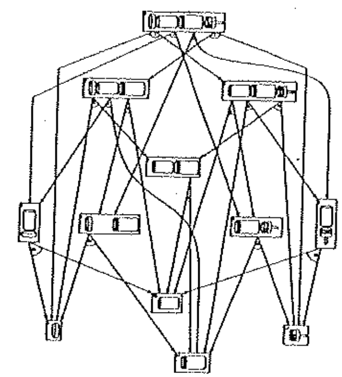


diagram #5.7

where each node is labeled by a database corresponding to an exploded view drawing of the artifact. The whole graph is also called a hypergraph. The graph shown represents a disassembly problem. The four hyperarcs (see the top-most box with the four line pairs under it numbered 1,2,3 and 4) each correspond to one way the whole assembly can be disassembled and each one of them points to two nodes that are labeled describing the resulting subassemblies.

AND/OR Graph representation for the assembly problem is useful because it encompasses all possible partial orderings of assembly. Like the other graphic diagramming techniques illustrated, this is also a way of seeing relations between parts and operations with the view to improving speed, reliability or choice in work processes. These seem to be in the family of tools linked to Taylorism.

5.4.5. Simplified Generation of All Mechanical Assembly Sequences

"Sequence of assembly of a set of parts plays a key role in determining important characteristics of the tasks of assembly and of the finished assembly. Matters such as the difficulty of assembly steps, the needs for fixturing, the potential for parts damage during assembly, the ability to do in-process testing, the occurance of need for rework, and the unit cost of assembly, are all affected by assembly sequence choice. The rational exploration and choice of assembly sequence is consequently an important task for a production engineer.

"Exploring the choices of assembly sequence is very difficult for two

reasons. Firstly, the number of valid sequences can be large even at a small parts count and can rise staggeringly with increasing parts-count and, secondly, semingly minor design changes can drastically modify the available choices of assembly sequences." (DeFazio and Whitney, 1986)

DeFazio and Whitney work out a logic (based on earlier work by Bourjault in France) which consists of two kinds of diagrams: the liason diagram, and a chart of all valid liason sequences for any given assembly problem.

They show these for the assembly of a ball-point pen, as follows:

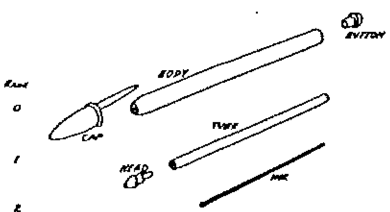


Figure 3: Component parts of the example ballpoint pen. The load of ink is shown in the approximate shape it assumes once injected into the tube.

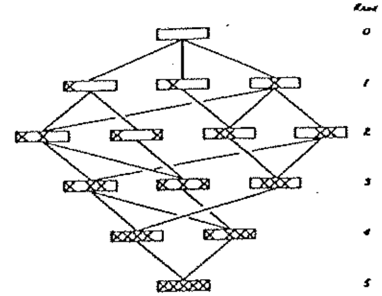


Figure 6: Graphical representation of all valid liason sequences for the example ballpoint pen. The empty box in the zeroth rank represents the begining (disassembled) state, and the fully marked box in the fifth rank represents the final assembled state. Assembly proceeds from state to state, along lines representing available state transitions.

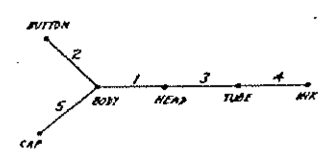


Figure 5: Liason diagram

diagram #5.8

of the ball point pen, its liason diagram, and one possible diagram of all valid liason sequences under conditions of no constraint on subassemblies. In the diagrams, only parts and their relations to other parts are shown.

An important comparison is offered between the parts-tree representation of assembly and the liason diagram concept.

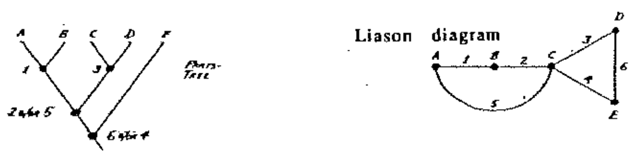


Figure I-1: Liason diagram and parts tree for an example assembly. Note that the issues of which parts of the pair A,B are in a relationship with which parts of the pair C,D; and which parts of the set A,B,C,D is in a relationship with E, are explicit in the liason diagram and ambiguous in the parts tree. Note too, that while the parts-tree implies some information about order of parts association, it can be represented by at least two liason sequences, 1, 3, 2, & 5, 6 & 4, or 1, 2, & 5, 3, 6 & 4. Note lastly that the first of these sequences can evoke four parts trees, consequent to left-to-right interchange of either or both the two parts pairs, A, B, and C, D.

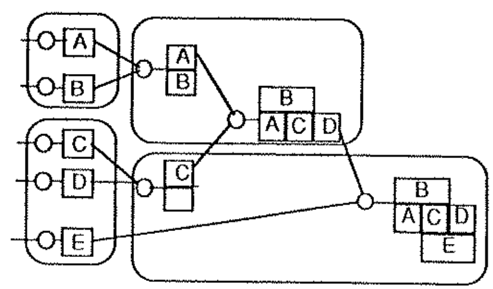
diagram #5.9

DeFazio and Whitney suggest that parts-tree diagrams carry only some of the information of the liason diagram. Specifically, a liason diagram makes explicit which parts connect to other parts, for example in diagram #5.9, in which the liason diagram shows exactly that □A connects to □C (indicated by line 5). This is not shown in the parts-tree diagram. Thus, normal parts-tree

diagrams are not sufficiently detailed to show liason(s) between the parts pairs A,B and C, D, nor is the connectivity of part E to the parts A,B, C, D explicit. Liason diagrams make all of these issues explicit.

This seems to be a very significant advance in methods of making absolutely unambiguous which parts have connectivity to which other parts. However, the liason diagram technique does not lent itself to a display of agents controlling (changing) parts, while a part/whole diagram can.

A parts-tree diagram can accomplish some of the liason diagram specification in the following way, giving us the diagram structure we need to put agents into the diagram. The following diagram is then equivalent to the liason-diagram, in the diagram #5.9 above, with the important addition of the agents:



diagram#5.10

Of course the issue of parts liason is fundamental to any study of parts making in which parts interaction is of interest. A part must show up when its interaction with another part is to be scrutinized. This is obvious not only in the direction of assembly but also in the direction of disassembly, as we can see in the following diagram in the PAct technique:

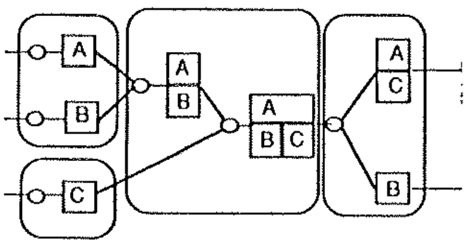
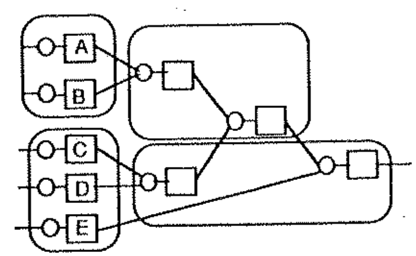
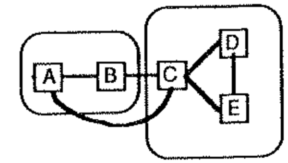


diagram #5.11

As there are many alternative assembly sequences, so there are many in the disassembly direction. The ordering of assembly need not be repeated in the disassembly direction. Such differences often can be accounted for by the presence of agents in the disassembly operations different from those in the assembly, but not always. This of course cannot show up in the diagrams of DeFazio and Whitney, which do not easily include the question of agents. Diagram #5.12 shows the problem:





liason diagram

diagram #5.12

where, in the right-hand diagram, ©3 and ©4 cannot appear given the diagram form.

<u>5.3.6. Evolution of the Industrialized Unit</u>

In Bender's book <u>A Crack in the Rear View Mirror</u>, a number of diagrams in a parts-tree form are presented. A few are presented here. They are part of the effort in the book to describe how hardware has evolved historically, the author suggests, by the introduction of industrial techniques and systems thinking.

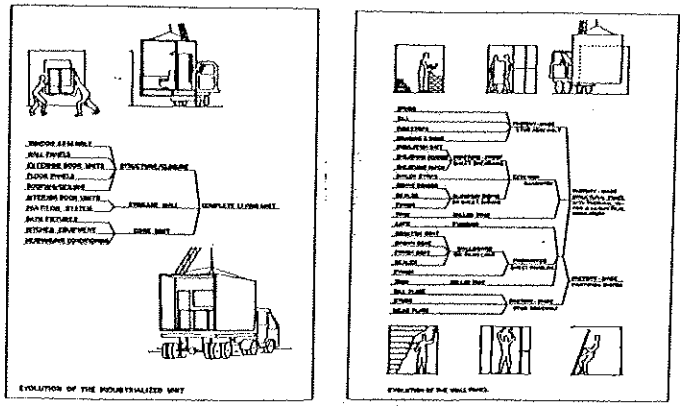


diagram #5.13

The diagrams appear to show that over time, basic building parts shown at the left of each diagram, at least in these cases, have found themselves being replaced by artifacts with identities of their own. For example, the door frame and panels now appear as one thing called the hollow door. The impression is given that the parts at the right of each diagram are somehow better, or more advanced or "industrialized". "Improvements" apparently have to do with parts reduction.

What is not clear is whether or not the same basic parts stacked at the left of each diagram still do or can exist in the

diagrams, and are used to make the "new components" at the right, or whether they disappear from the technical repertoire. Still another question is whether the parts stacked on the left can serve both the higher value added elements shown on the right, as well as other higher value added parts flows not shown in these diagrams.

The reason these questions are unclear is twofold. First, it is never clarified whether or not a design of a part has changed. A design change may or may not result in a change in parts count. Second, agents are not accounted for. If we reduce parts, it is a direct consequence that fewer people can get their hands on parts. This is an important omission. Agents are suggested by reference to centralized work, labor, but never pinned down in the text.

"The development of the construction of windows, from a number of operations on different materials by various crafts, to a single product selected from standard catalogues and ready for installation provides a clear example of the industrialization of a component." [author's note: yet this "single" product exists as the result of a number of operations by various agents.]

"This approach to the manufacture of building components presents both problems and possibilities. Work is centralized. The material bypasses many local suppliers. It must be standardized to be useful nationally, and designed for effective packing and shipping. This results in a limited number of shapes, sizes, and finishes. Standardization restricts the expression of regional or community customs and practices and shipping may add large costs to the distribution of the product." [author's note: standardization by itself does not have these consequences. Reduction of parts in the technical repertoire does, as does the production of commodity products which do not correspond to the situations of control of territorial powers.]

"On the other hand, these developments increase value and reduce cost by moving labor off the site and into a shop. They provide more efficient working conditions, wider use of power equipment, tools and jigs, better material handling equipment, and freedom from uncertainties of weather."

"They also create better opportunities for the design of the product and improve the assembly process. Product research and design can be concentrated, and quality control improved when cost is spread over a large number of units." (Bender, 1973)

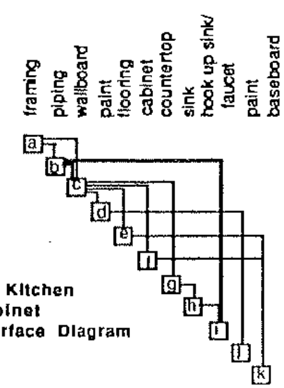
The difficulty with these diagrams and assumptions is that they bring many issues into one diagram form and one narative, without helping us to distinguish or clarify them.

By contrast, each PAct diagram shows only two things: a specific parts flow leading to a specific part, and the pattern of agents controlling the parts. Many diagrams need to be made to enable their comparison. Bender's diagrams don't allow comparison because all the alternatives are in one diagram, making distinctions between alternatives inaccessible. Finally, without agents appearing, at least one-half of the story Bender seeks to tell is lost.

5.3.7. Analysis of Component Interface and Effect on Construction Coordination.

This study (Reedy, Irwig and Logcher, 1977) analyzed the impact of component interfaces on building processes and the effect of these processes on the way in which construction can best and most efficiently be planned and coordinated. The analysis of each assembly presented (kitchen and bathroom cabinets and equipment) is based on an interface network, a graphic diagramming representation of component interfaces; that is, which parts touch which other parts in what ways. The analysis of parts positions and position "dependencies" are displayed. The diagram patterns should provide an indication of the amount of coordination that will be needed between trades.

Examples of the diagrams in the report are as follows:

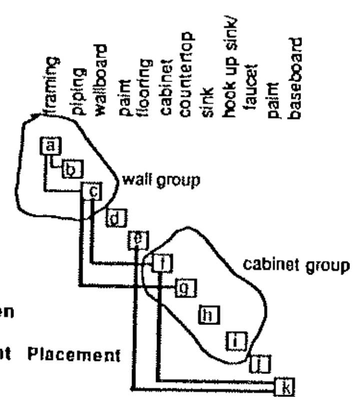


US Kitchen Cabinet Interface Diagram

diagram#5.14

where the boxes with letters represent components. One follows the other in the order of assembly. The light lines linking boxes indicate physical interfaces (presumably fixed) while heavy line indicates adjacencies which are not fixed. Some parts do not have interfaces with immediately prior part. Some parts have interfaces with many other parts.

Another diagram indicates both placement groups (parts which exhibit strong positional ties, such as parts of a wall), as well as notation to show parts that have dependencies on other parts for their position.



US Kitchen Cabinet: Component Placement Groups

diagram#5.15

where the light lines below the sequence of parts shows a strong positional relationship (e.g. studs to wallboard); the heavy line

below the sequence indicates a loose positional relationship. The circles indicate the different placement or element groups.

These diagrams address sequence of assembly and parts positioning issues that may impact labor practices. Alternative sequences, and therefore alternative positional relations could be studied with this technique.

However, the technique does not make explicit in the diagrams themselves the agents who do the work. The diagrams are strictly technical. There is no place in the diagrams to specify the operations which are involved in the sequence, and also, the only operations discussed are assembly. It is really about design of the assembly.

5.3.8. Value Chain Analysis

Sustaining Competitive Advantage (Porter, 1985) addresses the business operations context in which making occurs, is explicit about agents, but doesn't account for the objects which agents make. The value chain concept was introduced by Porter as a tool for analyzing the sources of competitive advantage of a firm. These include all the activities a firm performs and how they interact. In his model, parts and their manipulation are not specified, because his model is interested in business operations.

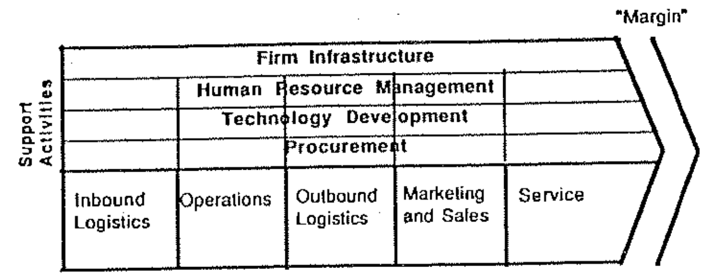
Nevertheless, the diagrams he uses are useful because they emphasize issues that have to do with the context of production.

He terms the larger stream of activities in which a firm's value chain is embedded the <u>value system</u>. Each agent in a value system has its own value chain, upstream or downstream of the firm in question. These other agents include suppliers, "channelers" or various middle agents, and users or "buyers". He says that gaining and sustaining competitive advantage depends on understanding not only a firm's value chain but how the firm fits in the overall value system. I quote from Porter:

"Every firm is a collection of activities that are performed to design, produce, market, deliver and support its product. All these activities can be represented using a value chain, shown in the figure (diagram 5.13 below). A firm's value chain and the way it performs individual activities are a reflection of its history, its strategy, its approach to implementing its strategy, and the underlying economics of the activities themselves. (this derives from the business system concept developed by McKinsey and Company, which shows that analyzing how each business function is performed relative to competitors can provide useful insights)

The relevant level for constructing a value chain is a firm's activities in a particular industry (the business unit). An industry or sector wide value chain is too broad, because it may obscure important sources of competitive advantage. Though firms in the same industry may have similar chains the value chains of competitors often differ. People Express and United Airlines both compete in the airline industry, for example, but they have very different value chains embodying significant

differences in [operations]. Differences among competitor value chains are a key source of competitive advantage. A firm's value chain in an industry may vary somewhat for different items in its product line, or different buyers, geographic areas or distribution channels. The value chains for such subsets of a firm are closely related, however, and can only be understood in the context of the business unit chain." (Porter, p 36)



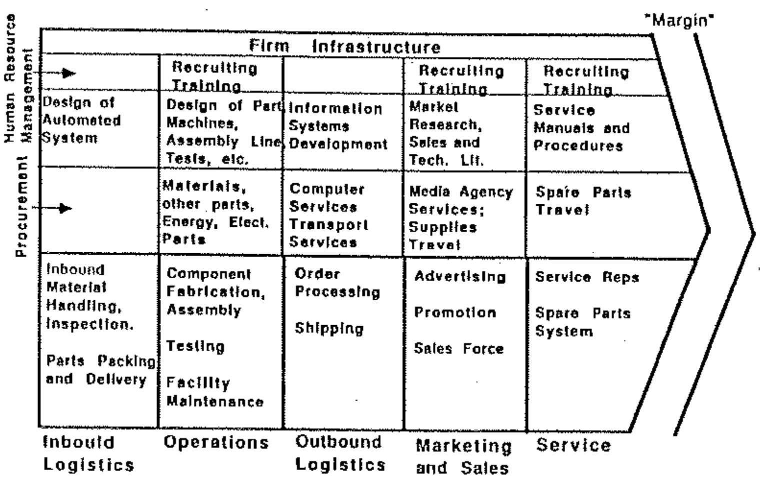
diagram#5.16

In the diagram above, the box called "Operations" is the place where PAct diagrams would find themselves.

Inbound logistics would be the supply side of a PAct diagram, and outbound logistics to the downstream or use side.

All other elements in Porter's model are inputs or influences to the actual making described in a PAct diagram.

In a value chain for a Copier Manufacturer, Porter "opens" the boxes in the generic chain as shown in the following diagram:



diagram#5.17

where operations are specified to include component fabrication and assemhly.

Porter's work comes close to the goals of PAct, particularly in delineating the context of agent behavior in which any manufacturing or "making" activity will occur. What is missing is the attention to the manipulation of parts that is so important to relate directly to agents.

5.3.9. Summary of Comparisons

In summary, many diagamming techniques exist to account for particular attributes of making artifacts and the agents involved. They are organized around concepts such as activity scheduling (CPM, line balancing, Porter's value chain diagrams), or assembly sequences (CMU, Draper Labs, MIT Kitchen study).

Control of parts is a concept which has not been diagrammed before now. I try to account for this lapse by suggesting in §5.4 that artifacts have been seen as static, and agents usually seen as singular or one-at-a-time, leading to largely subjective views of static objects in relation to singular agents, a sufficient standpoint for partial snapshots of making processes, but one which does not capture their inherent dynamics or the continuum of parts making.

5.4 Why Control has been Neglected in Technology Studies

In backround reading for the research, two distinct streams of studies began to appear. One was found in the great wealth of material of a technical nature. This includes academic, professional, and government agency research reports on what could be called the issues of hardware and technical production: materials processing, manufacturing assembly, assembly line balancing, work study, construction productivity and the like.

Among such technical studies, research into materials processing discusses in detail how an automobile part is produced: the dies, lathes, tempering, the sequencing of operations, and its assembly into a larger configuration. Such studies give agonizingly detailed pictures of what goes on. The excellence, number and diversity of such studies has, of course, been essential to the development of the history of technology, if not the technology itself.

In these studies, attention is paid to optimization, efficiency, and rationalization. This is the imperative which accompanies the technological progress myth, which suggests that 'everyone' knows that optimization calls for reduction in operations, reduction in parts count, reduction of decision points, standardization, reduction in number of times a part must change, and similar concepts from the lexicon of 20th century progress talk. Does this progress myth correspond to reality?

The other stream was found in the equally generous contributions on subjects surrounding, but somehow never quite engaging, the above stream. This one could be called the studies of the social/political/ economic context of technology. These

include studies of the regulatory environment, the organizational structures of firms, the psychology of work, the economy of materials flows, business centered value added flow analysis, and so on. (eg: Schön, 1967; Perrow, 1984; Noble, 1986; Porter, 1985; Ventre, 1990)

At some point in the research, I discovered that recognition of these two streams as having to do with each other is essentially what has been unfolding in the writings found in the Technology and Culture journal over the past two decades. The struggle there has been to find a way to distinguish but still bring into view together both the "hardware" and "people" traditions in technological discourse.

In that tradition, Mumford wrote persuasively that

> "History as the interpretation of the changes and transformations of a whole culture must necessarily take account of technology as one of the essential components of a culture, which in the very nature of the process affects, and is affected by, the pressures and the drags, the movements and resistances, the creativities and torpidities of every other aspect of society. By the same token, the historian of technology will find his account of technical processes seemingly isolated from the general flux of events, far more significant when he restores technology itself to its dynamic social context." (Technology and Culture vol.2 no.3, 1961)

Other authors, in a wide range of articles in Technology and

Culture, work hard and lay important foundations for the discourse that is emerging more clearly in work on the history of technology in the contextualist tradition.

In the reading, however, I remained unable to find a framework that accounted for an essential characteristic of all parts, namely that each part is an inbetween state in a more or less constant state of transformation. An artifact exists in a continuum of human action, and a continuum of artifact states, and I could find little attention paid to that reality in what I read, with the exception of Habraken's Transformations of the Site. (1983) That book presents an examination of the built environment from the view that what we study - parts of all levels of complexity - is where human action and physical parts come together. He shows that it is by studying the transformations of artifacts by people that we learn most about artifacts, and, by the way, we can also learn about the people acting by observing the forms they change. The concept of control is introduced, and through that concept PAct has its relation to what is presented in Habraken's book. PAct's contribution has been to put the concept to use in a tool which operationalizes control in the description of parts making

Stepping back briefly from reading such works of a technical or contextualist tradition, however, a reader is left with

an essentially "parts-centric", materialist, and static view of the artifact and what it has to do with its surroundings. The question is, what do all these studies share?

I think that what is shared is an impulse - and a clear drive - to reject change in the formulation of parts production and construction logic. Adaptation (as opposed to standardization) inflicted by others, this view claims, is inefficient, wasteful, and leads to damage. The view prevails that if something must be altered, "I" should do it because "I" am the expert. In PAct terms, change is permissable in "my" domain, but why should a downstream agent change the part I make? And more exactly, the rejection of change other than assembly is evident. Deforming, cutting, and taking parts away are evidently seen as the kind of messy and wasteful business that reveals bad planning and bad design. These "changes" to preferred standard parts have been called "adaptation losses" (Malet, 1974). To quote from that source:

> "Standardization, though yielding production economies where it permits longer production runs, also causes diseconomies, since a limited number of standardized types are generally less well adapted to the specific demand, resulting in "adaptation-losses". Where the probability distribution of demand is known, an adaptation loss function can be calculated, and an optimum pattern of standardization selected to minimize the loss function." (Malet, 1974, p57)

A PAct diagram in which adaptability loss is eliminated would appear as in:

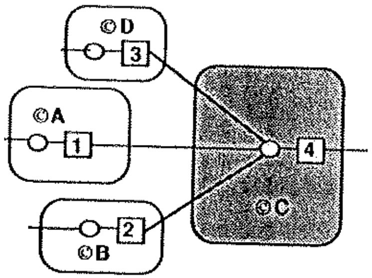


diagram #5.18

in which ©C has no adaptability loss since its only operation is assembly. If ©C were to contribute "losses" by way of adapting or changing parts, the diagram would appear as:

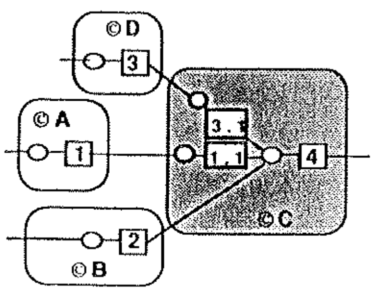


diagram #5.19

in which ©C must do intermediate operations making □1.1 and □2.1 in order to make □4.

Of course, if we do not look closely into a making process, such occurances may escape notice, particularly if we have in mind that assembly is the operation that is the "appropriate" one for the agent in question. If we work out of the premise that adaptability losses are to be avoided, we will work in a way to inhibit that kind of change by technical means and my means of design. We will ignore and even subvert the realities of revitalization and rehabilitation by thinking only in terms of "snap-in" and "clip-on" products in the name of "user-friendly" product design.

But parts are "adapted" outside of any given party's domain, by assembly but also by the other kinds of operations. Studies of materials processing show parts changing form by deformation and removal, moving from one worker or corporate division to the next. Studies of assembly show parts being brought together with other parts, and thus changing.

But as Henry Ford said, "No fitting (shaping) in the assembly department". (Hounshell, 1984) That may be a useful admonition in a process whose diagrams are largely nested, but not in one of highly dispersed control patterns such as housing production is in reality.

In a very important sense, this declaration by Henry Ford captures in simple terms a paradigm PAct helps us to examine. Developing PAct has made me think that we can not mature as a housing industry or as professionals supporting housing processes when we declare that each agent is to see only its operation, its own change, and is not to pay attention to the change that will occur in the next agent's domain, nor that which came before.

In the outmoded view which is now in currency, coherence in complex value added chains is possible only by control patterns which have nested diagram forms. Some single agent has to have a "total systems view," or so we are led to believe. This does not correspond with reality, however.

The impulse of those holding to the myth of rational technological progress will inevitably, it seems, have to adopt forms of included control and explicit integration. In systems talk, this translates to "control of change". In systems talk, control means to regulate or limit, giving us <u>regulation of change</u>. In a diagram like this,

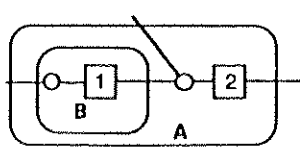


diagram #5.20

systems thinking would have us "read" ©A is "regulating" the change that ©B is engaged in while making □1. But in terms of PAct notation, ©B controls □1, ©A indirectly controls □1 and controls □2. According to the "total systems" view, there always has to be an ©A. In systems talk as we have inherited it, diagrams of dispersed control are indications of a serious deficiency, leading to "loss" of control and inevitable disorder.

When we do find discussion in the literature about change of parts which escapes the "part-centric" or "I do" perspective, it is largely found to focus on assembly or disassembly. These are the "good" (read optimal, efficient, "controlled") kinds of change. Thus, the dream of product manufacturers is to make parts which, once they leave that domain, are only subject to assembly, but never the messy acts of bending, cutting, sanding, boring, or adapting. Forms of change such as deformation and removal are of a lower, unpredictable status and are to be eliminated in the best of worlds, (Perrow, 1984) except far to the left in a value added chain which "I" control. One imagines a "total systems" advocate wishing that nature provided higher value added parts, ready for assembly. Repairing something should "ideally" involve only disassembly and reassembly: replacing a part.

The view of making put forward via PAct, however, must by definition take account of <u>other</u> people, both expert and laymen, taking things into their hands, making their own imprints. In the building industry, certainly assembly has its very important place, but so in the large do the other operations even more so. Parts find themselves changing, not only within a given control domain as a part makes it way along a companies' value added chain, but also later in the part's life as it enters other domains of control. Wooden, metal, synthetic, and other kinds of parts find themselves subject to many operations on their way to becoming parts in houses, and subsequently in other places along their value added chains.

For example, a sewing machine experiences many operations of the most varied sorts in its making, but later, the only "good" operations are those of replacing a part. Then there is the "closed system" aspect, in which a replacement part is only available from the agent who made the whole machine. To see a sewing machine that has to experience other than a disassembly and reassembly (replacing a broken belt or gear) is to see a sewing maching that has worn out or failed, from the point of view of its manufacturer, and almost certainly, its purchaser. Certainly a sewing machine manufacturer does not expect to see a machine transformed as we see production cars becoming customized vehicles illustrated in many popular culture automobile journals in the local magazine

shop, or houses being customized, or a mobile home having a wooden addition built alongside. From a certain perspective, these situations violate all the principles of "problem solving" and "optimization".

Yet this highly constricted view is not the case in PAct diagrams of parts flowing into and out of control domains over the lives of those parts and buildings. Not only are substitute parts available from more than one supplier in healthy building value added flows, but the diagrams of such relations between parts and agents are dominantly of the dispersed control diagram sort, and operations in addition to assembly are common and part of the mark of craftsmanship and "expression" that still somehow has a place in and characterizes the building arts and other crafts for what they uniquely are.

From the dominant viewpoint of subjectivity ("<u>I</u> do") and rationality (<u>regulate</u> or limit change) now in currency, change, to the extent that it occurs outside one's own domain, has become, ironically, an enemy of progress. At the same time, change remains an everyday reality, so very "obvious" and "common sense" that it is not accounted for. Change, and therefore control in PAct language, is neglected.

When this is seen to be the situation, it is not surprising that attention to the "implicate order" (Bohm, 1983) of value added flows is at an immature stage of discourse and development. The language we use, because it is coupled to how we think and organize our observations, is a major feature in any explanation as to why change or control has been neglected. Bohm considers this dilemma in his reflection on the nature of movement in discourse in his field of physics:

"Whenever one thinks of anything, it seems to be apprehended either as static, or as a series of static images. Yet in actual experience of movement, one senses an unbroken, undivided process of flow, to which the series of static images in thought is related as a series of 'still' photographs might be related to the actuality of a speeding car. This question was, of course, already raised in essence philosophically more than 2000 years ago in Zeno's paradoxes: but as yet, it cannot be said to have a satisfactory resolution." (introduction to Wholeness and the Implicate Order, 1980)

He offers the idea of the rheomode, or

"the mode of language in which movement is to be taken as primary in our thinking and in which this notion will be incorporated into the language structure by allowing the verb rather than the noun to play a primary role." (David Bohm Wholeness and the Implicate Order, p. 30)

It seems to me that Bohm is addressing very much our present question. In our case, the phenomenon is change: his subject is movement. But they are of the same order. In both movement and change, division and fixity are only convenient

means of giving an articulated and detailed description of the whole.

"Making" (production, construction, etc) has been seen as ordered basically by way of technical sequences, and properly so. Now we have to go further. More complex orders are possible. Bohm points out that movements of growth, of a symphony, and evolution of living things evidently have to be described in different ways that cannot be generally reduced to description in terms of simple sequential orders. I think the same is apparent in the world of artifacts.

5.5 Summing Up

Control of parts making in the building industry has been the subject of the thesis. The idea of the research reported on here is that the production of parts, and buildings, while it is many other things, is also most vitally about control. This idea - which puts people and the physical parts they change together - has led to a new way of describing parts making: a diagramming tool which instantiates three variables of consequence to this view: people, parts and changes to parts.

The tool, limited by its bias toward elucidating control, is based on principles which give its users a capacity to describe any making process.

To demonstrate the tool, I have made a series of short comparative studies taken from the parts manufacturing and housing industries. This small series of demonstrations was selected because of a motivation with which the research began. That interest was to look into the health of ordinary housebuilding technology, and to understand the troubled relationship architects and other experts have had with the cultivation of conventional housing processes. I found that to see into housbuilding practices with clarity, it was first necessary to describe what was actually going on, and it was here that the concept of control came to be an essential lever.

When the concept of control was built into the diagramming tool, two distinct visual patterns became apparent in all the diagrams I made. I could see that these patterns - named dispersed in one case and nested or overlapped in the other case - represented real world situations of control, the delineation of which had been the subject of confusion. Two of these situations - and their diagram forms - are found to be useful ways to specify prefabrication and industrialization in unambignous terms, and in association, a lexicon of other terms we have met and found closely describable in PAct diagrams. Other aspects of parts production were also specified, including the relation of experts

and laymen, the place of designing in PAct diagrams, and the association of diagram patterns with both enduring and failed instances of parts production.

The present study stops far short of claiming a comprehensive or exhaustive picture of parts making. By its limited scope, the tool I have presented will be deemed successful if we can, by its continued development and use, improve our capacity to draw better maps of what actually happens when we take things in hand, one after the other, to shape them to our purposes with other people.

If this helps architects and other specialists to attune their belief systems in more harmony with reality, that will be an added indication that the effort has been worthwhile.

The efficacy of the tool now depends on the development of computer software to enable the rapid deployment and manipulation of many complex and information laden diagrams. This should now be possible. With such a program, PAct users can test the diagramming further, add new notation and new aspects, and move on to apply the tool to further studies aimed at understanding tbe control of parts.

7.0 References

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7.0 Technical Terms of Reference

(The following terms appear particularly in, but not limited to, the following pages