Case-based Study of Production Assembly Communication

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This paper proposes that construction documentation accompanying common building products provides instruction oriented to the definition of integrated parts rather than communicating the procedural assembly required of labor. To better understand this distinction and its influence upon constructability, the character of production information is examined by case study. Installation documentation from three common building products is critiqued for its ability to convey assembly task information and effect labor's procedural response. This examination continues a current academic interest in the instruction of work protocols and the development of construction communications.

Key Words Construction Communications, Assembly Procedure, Task Instruction, Industrialized Production.

Introduction

In the 1970's Japan began to apply production efficiencies derived from factory methodologies to the construction of housing (Gann, 1996). By the end of the twentieth century, the US construction industry has also begun its pursuit of systematic control over residential production. Both efforts strove to introduce pre-engineered products and practices into the always dynamic construction environment. The impact of 'industrialization' onto residential building brought fresh inquiry to the field of construction science and management - particularly in the areas of project delivery information and production modeling.

Developing alongside construction's shift in residential production was the field of construction computer modeling. Maturing over the same period as Japan's foray into industrialized home production - new theories and approaches in construction computer modeling progressed concurrently (Halpin, 1977; Paulson, 1978; Ioannou, 1989; Skolnick et al 90; Martinez and Ioannou, 1994; Sawhney and AbouRizk 1995; Wakefield and Sears, 1996; Shi, 1999; Zhang et al., 2002).

While this paper does not focus on specific industrializing efforts or modeling strategies, it does recognize a purpose shared by both. Their commonality is an effort to systematically format construction's parts, processes and resources for increased control over onsite productivity. Pertinent to this study are the programming challenges onsite operations present to systems-based implementation. (Halpin and Martinez, 1999; Gibb, 2001; Hook and Stehn, 2008). The translation of pre-engineered / analyzed efficiency is influenced by a comprehension of labor's onsite performance. (Halpin and Rigs, 1992; Shi and AbouRizk, 1997; Mehrotra, 2003; Wakefield et al., 2003; Senghore et al., 2004). Construction communications are seen as a key interface between industrialized construction and onsite human performance (O'Brien et al. 2000, 2002; Wakefield et al. 2001). Thus the industrialized efforts of construction make its production communications a focus of study.

Three instructional case studies are presented which review the character of procedure's representation. Their instruction sets graphically sequence part relationships and may also include text-based definitions of the work process. Instructional focus on parts addition verses labor's procedural contribution for assembly is of interest to this work. It is suggested that present gaps in site-relevant production information can be attributed to the still-frame format of most construction's communications and the prototyped nature of building materials designed and pre-manufactured offsite. The included cases highlight how production-grade assembly information currently reveals itself and critiques its dependence upon and facilitation of onsite procedural knowledge.

Case One - Shower Wall Insert



Figure 1: Wall panel insert with diagram

The following case reviews the production information provided with an industry standard residential shower insert. Its informational component includes text-based instructions referencing graphic production diagrams. An example of the text-graphic relationship is observed in the instruction of a panel's connector insertion into receiving slots (see figure 1). The textual instructions read:

• "Position each end panel so that the hooks of the end panel go into the slots on the back wall and then push down until panel tops are even"

The use of graphic callouts such as arrows to depict material management is both typical and helpful; however the efficacy of such indicators may be challenged when not uniformly applied. For example, Figure One defines both an assembly process (thick arrow) and material part (thin arrow). The figure's slight variation in iconography adds graphical noise without significantly raising a viewer's capacity to discern their operational difference.



Figure 2: Panel wall attachment diagram

Another example of production information within the instruction set details the shower panel's attachment to the structural wall (see figure 2). The written instructions for the task state:

• "Locate and drill a 3/16" hole in the center of the nailing flange at the top of the panel and centered on each stud...Hammer 3/4" galvanized roofing nails through each hole and into the studs, securing the wall panel...Add a bead of caulk down the front vertical surface of the back panel"

Figure two's graphics attempt to indicate distinctly different assembly processes. The drill and nail procedures are combined into one representation of new arrow type - and/or by the graphic inclusion of black 'dots' presumably indicating drilled hole or nail head? One might excluded the latter analysis (i.e., nail head) in the absence of a thin arrow callout previously established in Figure One. Here the part callout (thin arrow) is mismatched to the text's instruction calling for 'addition' process (i.e., caulking). This instance of graphical ambiguity is questioned when iconography specific to the same process is clearly employed in later figures (see Figure 3).

A higher-order discrepancy in procedural communication is found within instructions presented for the plumbing interface. Textual instruction reads:

• "Decide which side panel will need cutouts for plumbing fixtures. Carefully locate, mark and cut holes using the proper size hole saw"



Figure 3: Iconographic depiction of caulking process

No graphic information is provided depicting the tools or processes necessary to affect hole location, marking or cutting (see figure 4). This omission requires that labor provide all suitable work processes for existing conditions. And while it may be common for instruction sets to revert to text-only descriptions when graphical counterparts are unavailable, the inclusion of process-qualifying definitions, such as "Carefully" seem superfluous in the light of the missing representational detail.



Figure 4: Installation procedure for existing conditions

These initial observations while seemingly pedantic offer challenge not only to the fidelity of graphical standards, but to communicative modality – or the clear conveyance of an intended message. If labor is expected to accurately translate vague representation into specific acts of construction, it seems logical that procedural communication could better match onsite production.

Case Two - Roof Shingle Application

This case identifies potential information gaps in the relationship between operational procedure and assembly instruction provided for the standard shingle roofing product (see figure 5). Its instructional format employs a text/graphics combination to convey work's instruction; however a dependency on terminology to define physical tasking becomes immediately apparent.



Figure 5: Shingle starter course with instruction

The instruction set's reliance on text is observed for a Starter Course where labor is expected to;

• "<u>Trim</u> 5 5/8" from the starter course shingle. Trim 6 ½ off the <u>rake</u> of the starter course shingle and <u>flush</u> with the <u>drip edge</u> along the rake and <u>eaves</u> edge, and continue across the roof" (underlines added)

The highlighted terminology is assumed common to the work domain, yet a participant lacking its conventions is required to inspect the provided graphical figures for clarification. Unfortunately, the diagram corresponding to these terms only indicates two of the five directly - rake and trim (see figure 5). It is noted that two of the other terms are identified in separate figures provided later in the instruction set. Absolute verification of the 'flush'

process is missing so its definition must be known or deduced. Both graphic and textual 'trim' indications do little to explain that the process of cutting is a once per course event - an omission that could conceivable promote anomalous repetition of procedure.

Setting aside the above-mentioned issues, the information set contains further potential for work's confusion. Procedural ambiguity is identified in the Starter Course text describing the nailing task:

• "Use 5 fasteners for each shingle, placed 2" to 3" up from the eaves edge"

The Starter Course diagram never graphically indicates nail parts nor the text's proscribed procedure (see figure 5). The instruction set does provide a separate general conditions diagram indicating a nail configuration which contradicts (e.g. by number and relative position) the Starter Course's instruction (see figure 6). This is a clear example where disparate text and graphical formulations of similar processes may adversely affect worker's comprehension of correct (intended) procedure.



Figure 6: General nailing diagram

A second case of unclear and potentially ambiguous production representation is found with the instructions specifying material distribution. The manufacturer states that roof shingles should be blended through a diagonal roof application to minimize material-bundle color variation. The text indicates this distribution textually by specifying the intended direction of work.

• "starting at the bottom of the roof and working across and up"

The only graphics capable of supporting the directive to work diagonally are those indicating the start positions for each new course row. However, all relevant diagrams potentially infer a linear completion of coursework prior to the start of a new rows (see figure 7). The apparent contradiction in text and graphical communication was not speculative in this case — as the operations of inexperienced labor was clearly influenced by the graphical instruction. (see figure 7). Participant review of their anomalous single-axis performance also identified a Starter Course's text directive to, "…*continue across the roof*" (see above citation).



Figure 7: New course diagram and resulting activity

Case Three - Residential Window Installation

The following case reviews the production documentation provided for residential window installation (see figure 8). It was initially theorized that product features such as unit price, warrantee, and market standardization would promote a more developed instructional format in comparison to other cases.



Figure 8: Window installation and instruction

This case's assembly representation presents a well-integrated yet standard text and graphic combination. Diagrams are sequentially numbered with individual frames attempting to represent a single assembly task (see figure 8). Diagrams indicate a user's point of view in the activity plain and effectively apply 'picture-in-picture' (circled) detailed views of product assembly. Diagrams employ traditional graphic callouts which remain uniform and distinct throughout the entire instruction set. Contrasting previous cases, directional arrows are consistent in their indication of process (i.e. material manipulation), with extension lines limited to the definition of parts referenced by the text.

Concerning the representation of required processes, the instruction set provides limited characterization. Regarding Figure Eight's textual direction to,

• "center the window in opening"



Figure 9: Window installation and instruction

-its corresponding diagram lacks any graphical companion. The instruction set does populate diagrams with representations of tooling to suggest work processes (see figure 9). Figure Nine is a good example of tool imagery implying procedure. While the proper tool icons are shown in poses relative to their actual utilization, the figure's compositional approach highlighting multiple activities could cause confusion for inexperience / unskilled labor. Similarly, Figure Nine's accompanying text-based definition calls for procedural checks of;

• "plumb, level, and square. Diagonals must be within 1/8th inch"

- without clear indication or positive correlation to the tools providing each activity. Furthermore, it is questioned whether the level's symbolic representation illustrated in Figure Nine has mislabeled the plumb process or is simply identifying the tool itself. The graphical standard established by the instruction set suggests the latter function, and thereby diminishes any attempt to visually supporting the textual call for plumb processes.



Figure 10: Fasten-all-sides vs. one-nail-only

Overall, correlation between text and graphical task descriptors found within this instruction set is deemed to be higher than for the previous two cases, yet the potential for procedural confusion remains. Consider for example Figure Ten's text-only request to:

• "fasten on all sides (of the exterior window nail flange)"

Its accompanying figure offers little more information than an earlier diagram instructing that one fastener be added to assist initial installation and shimming procedures (see figure 10). While labor might infer a complete nailing process from the secondary tool-icon presented in Figure Ten, its graphic inclusion more likely references the option for alternative mechanical attachments (i.e. screw or nail). In either case, clear graphical distinction between a full or partial fastening procedure is lacking.

Results

Considering the examined cases, it is apparent the production documentation contains communicative elements that can be detrimental to effective procedural instruction. When closely inspected both the literal and figurative elements of instruction sets show weakness in the areas of graphic representation, text-graphic correlation, and descriptive semantics. And while individual anomalies may remain insignificant to overall production, their combinatory effect can challenge the point of instructions may simply be ignored until intuition or training fail into error or uncertainty. What is clear from this cursory review of production information sets is that constructors provide a large amount of practical skill and expert knowledge when translating assembly instruction. And in those instances where instructional modality and labor's task familiarity do not correspond or possibly conflict – the potential for anomalous production exists and may be encouraged.

The examples provided within this study, begin to identify some basic considerations in the design of a more effective procedure-formatted construction communications. A few of these points are summarized as follows:

- When combinatory work processes, resource, or material movements are required, it may be advantageous to define their individual representation in separate instructional frames.
- Graphic representation of tooling can/should reflect intended use.
- Text-based definitions of processes, parts and resources should be supported by graphics that are easily identifiable to the broadest audience.
- The graphic standards chosen to highlight procedural communication should be uniform and discriminating

Conclusions

The instruction sets of three construction products show a common focus in their representation of tooling, materials and aggregate parts. Their approach to procedural instruction identifies common weaknesses in the text and graphic relationship defining tasking. In those cases where text and graphics are not complimentary, labor is forced to reconcile ambiguity. Where communication modality is diminished, the potential for production error exists and may be increased. A common bias is found in part detailing used as a surrogate for clearly defined work processes. The cases also present instructive techniques that imply procedure yet fail to actually define the physical acts and logical contributions provided by onsite labor.

As construction continues to push the boundaries of industrialized production the recognition and integration of labor's onsite processes becomes an increasingly important management issue. The issues highlighted within this paper suggest potential areas for modification of the product-centered and top-down production information traditionally provided by construction's designers to the field. The study agues that construction information accompanying systems-based building products could be better represented by incorporating the character of procedural contributions made by onsite labor. It is theorized that instructions reflecting the operational nature of field-processes will best support industry goals of productivity, safety, and quality.

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