Under what conditions are "Industrialization" and "Integration" useful concepts in the building sector?

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Abstract

When are "Industrialization" and "Integration" operative concepts in the building sector? This paper examines this question. It discusses the multiple – and confusing - ways these terms have been used in the building industry literature. The paper proposes that reliance on confusing definitions of these terms has for too long obscured careful observation of how the building sector actually works and has thus made innovation and advancement of the sector more difficult. The paper points out that the principles of Open Building and its related literature have clarified these issues and thus serve as a useful diagnosis and innovation platform.

Keywords: Industrialization, Integration, Open Building, Levels of Intervention and Control, Design Distribution

Introduction

"We teach students to integrate design and technology" (from a design course syllabus)

"A great epoch has begun. There exists a new spirit. Industry, overwhelming us like a flood which rolls on towards its destined end, has furnished us with new tools adapted to this new epoch, animated by a new spirit. Industry on the grand scale must occupy itself with building and establish the elements of the house on a mass-production basis. We must create the mass-production spirit. The spirit of constructing mass-production houses; the spirit of living in mass-production houses; the spirit of conceiving mass-production houses." [1]

Introduction

Words have their pleasant ambiguity, making them useful in everyday conversation because they convey shades and nuances of meaning that, in the context of gestures, tone of voice and social context, make communication possible. But when we need more formal descriptions,

these nuances and gestures are not helpful. It is then that we must be more precise and unambiguous, and are faced with the choice of coining new words – always difficult - or narrowing the meaning of already known words, a task no less fraught with problems. [2]

This paper examines two important and well-known words found in the building industry literature – "industrialization" and "integration". It points out some of their associations, meanings and their capacity to obfuscate.

The ambiguity of these words is well known. I will argue that this very ambiguity – and the resultant confusion - has been a major barrier to better methods and better research in the building sector. The words are used indiscriminately, as I will show. We have an epistemological problem, in that the complexity of the processes by which parts are aggregated in various stages into elements, components, parts, products, buildings and so on remains ill-described. The paucity of unambiguous terms to amplify and clarify these manifestations should tell us that the world of our concern – the ecology of people making things - has escaped adequate inquiry at least in the English language.

I will then argue that several of the principles of open building theory have relevance to the use of these two words, and conclude with examples in the real world in which industrialization and integration may have use in describing what we do in designing, constructing and adapting buildings.

How to describe building industry structure and dynamics?

Despite the fact that the building industry contributes very substantially to each country's and the world's economy, it is understudied. [3] By its nature, it is very complex and hard to account for. It is inextricably caught up in local cultural preferences, politics and regulations, real estate and labor markets, local geo-technical and climatic conditions, while also being part of local and regional product and service supply chains and the global finance industry. This "ecology" of production is difficult to map and explain. [4] In part this is because data about the behavior of this industry at other than a gross aggregate level is difficult and expensive to obtain, and the data that is available is fraught with conflicting jurisdictions, collection and analysis methods, and problems of industrial secrecy.

Most literature on the building industry, at least since the 1960's, has used the word "fragmented" to describe it's structure, referring to what is widely thought to be its disorganization. [5] [6] Fragmented may make sense as a descriptor when the reference is to industries such as the automotive or aerospace industries, in which very few players now dominate (it was not this way at the dawn of the automobile age) and in which supply constellations are organized in alignment with their relatively consolidated and top-down industry structure.

But unlike these industries, the building industry is characterized by the very large number of parties who initiate building activities and regulate them, the equally large number of parties who supply parts and services to these initiatives and the variety of outputs matching the variety of those in control. And, unlike the automotive and aerospace industries, a very large number of the players in building processes are laypeople operating in the "informal" sector,

as witnessed by the magnitude of sales at home project centers such as Home Depot and Lowes, and their equivalents in other countries, not to mention the ubiquitous informal sector in less developed countries.

“Disaggregated” is probably a better term to describe the “shape” of this economic sector. Disaggregated literally means "separated into constituent parts". [7] The sense in which I mean this is that the building industry – its many agents and products, rules and processes – operates in ways fundamentally different from other more highly “aggregated” sectors in the economy, and behaves without an obvious "steering" mechanism other than the building market and culture as such.

When the conventional wisdom is that the building industry should behave in a way similar to the automotive or aerospace industries, it is little wonder that words such as “industrialized construction” and “integrated” will be in currency. But those industries are not suitable references, and therefore concepts such as “industrialized” and “integrated” need to be used carefully when brought to bear on building industry dynamics and used to explain or characterize the building industry or practices in it.

Industrialization and Prefabrication

Let us first examine *industrialization*. [8] Industrialization has to do with production in very large numbers of products of a general nature, parts that can be used by many players, acting autonomously with their own purposes quite distinct from the purpose of the producers. Examples abound, being an inevitable result of specialization, and pressures to reduce cost and improve quality. In the inventory of parts from which buildings are assembled today, most result from this process. There is good reason to think that this is not new, and precedes the industrial age. There has always been someone who, recognizing a general need, decided to make something that he expected others to want. From before mechanization, this source of entrepreneurial initiative has been known. [9] Now we harness machines and computers to help devise large catalogues of parts for the marketplace.

This business – rather than “technical” - view of industrialization sees the maker taking the initiative and assuming risk. After research and development, competitive positioning, experimental prototypes, investment in capital equipment and infrastructure, finding a place in a supply constellation, the producer decides if the risk will eventually earn a return on investment. The result is the production of relatively small and neutral parts suited to a range of users. These parts are “project independent”. Users, attracted to these products because of their utility to their individual purposes, decide to use what is already available, instead of making them (the buy vs. make decision).

Industrially produced, project independent parts are generally neutral enough that they can be tested and certified by nationally and internationally recognized testing bodies such as the UL (Underwriters Laboratory) [10], making local testing and public approval unnecessary. Today, building parts are produced in sophisticated factories, using well-organized production processes. In this process molds, jigs, automated equipment, labor, and supply chains are in place using product templates, catalogues or libraries of parts (now stored as

parametric elements), and so on. That is, the parts are designed even if parametrically, and production is undertaken at the risk of the producer.

It should be noted here that large, bulky, and complex assemblies for buildings (incorporating many subsystems of different kinds) require more costly research, more costly production processes, and thus require much larger and stable demand to produce a return on investment. The industrialized (project independent) production of these assemblies is thus rare, and when they are produced, they are always architecturally neutral; that is, they are hidden assemblies such as packaged heating and air conditioning units.

Construction, on the other hand, is the production of an artifact never seen before and never to be exactly repeated.[11] In construction, the user takes initiative, assumes the risk and reaps whatever profits result.

The image of a great basket of parts helps. The basket is filled with parts produced at the risk of the producer without knowing their downstream project application (industrialized production). The construction process involves reaching into the basket of available parts to select those needed for the artifact to be made, of whatever scale or complexity. The locus of initiative is, again, the distinction.

Prefabrication ("bespoke" production in the UK) is a variation on construction, in that the user takes initiative (places an order) and assumes risk (having provided the design). [12] Unlike construction, prefabrication takes place at a distance from the site where the part will be used. It can, but need not, employ sophisticated means, labor saving methods, and information management. The result is project-dependent and is therefore constrained by the same factors as construction. Prefabrication is also not new, having been a mode of production well before the advent of machines and computers.

No Conflict between Industrialization, Prefabrication and Construction

There is, of course, no conflict between the most advanced industrialization processes and its products, and construction; or between industrialization and vernacular ways of building. [13] The famous "2x4 system" - used to build houses in the US since the 1830's - is a case in point. This vernacular is fed by a vast industry making the parts – all produced in highly automated plants – and all "industrialized" (project independent). But few would say that this way of building constitutes "industrialized construction". [14]

While there is no conflict between these two processes, conflating industrialized methods of production and construction (or prefabrication) causes confusion. As noted above, the difference does not have to do with the use of sophisticated equipment. Robots can be found on the construction site and in factories. Hand labor is found in both. Prefabrication of roof trusses can be done by hand, or in highly automated plants, driven by sophisticated CAM (computer aided manufacturing) software, using products of industrialization but producing parts (trusses) ordered by their user. In such cases, the trusses are not examples of "industrialized construction" but of "prefabrication", no matter how large the batch.

These are essentially business views, and usefully distinguish the matter of initiative, risk and control. While distinct operations and behaviors, they need each other today more than ever. Both complement the other. But they are different by definition and in practice.

Why the term "industrialized construction" has emerged at all is interesting. It is the same thinking that has fostered the emergence of the term "mass customization", an idea in currency that also conflates terms and processes unnecessarily. [15]

A reading in the literature suggests that this confusion is largely an academic problem and that in practices that survive, the two loci of initiative sort themselves out. The efforts of even the most brilliant architects confusing these issues have fallen pray to ideologies that separate them from this reality. [16] Therefore the issue at hand is that the academic and research communities are out of step with the real world and are thus not able to be as helpful as they could be if theory and beliefs matched what is really happening.

The idea of integration has strong roots

Ortega writes, "The need to create sound syntheses and systemization of knowledge…will call out a kind of scientific genius which hitherto has existed only as an aberration: the genius for integration. Of necessity this means specialization, as all creative effort does, but this time the [person] will be specializing in the construction of the whole." [17]

This call from one of the 20th centuries major philosophers may capture best the drive for that illusive wholeness that so many also in our field – the field of the built environment – continue to express. It is the wellspring and the root of the idea of integration. This search for "integration" has been widespread, especially in but not limited to the University. [18]

One of the more recent of such searches is found in Christopher Alexander's magnum opus, titled The Nature of Order. [19] "This four-volume work is the culmination of theoretical studies begun three decades ago and published in a series of books -- including The Timeless Way of Building and A Pattern Language -- in which Alexander has advanced a new theory of architecture and matter. He has tried to grasp the fundamental truths of traditional ways of building and to understand especially what gives life and beauty and true functionality to buildings and towns, in a context which sheds light on the character of order in all phenomena."

The span of time of Alexander's work (C.A.1968-2008) corresponds closely to the heightened interest, found in the academic and government sponsored building industry literature, in the concept of "integration". While Alexander would now almost certainly reject many of the fundamental assumptions of those advocating integration, there is arguably something shared nonetheless – a sense of having lost the organic unity thought to have once obtained in the pre-industrial era. This is certainly a powerful idea. But it is also romantic wishful thinking today. I'd like to try to explain why.

Integration and Design Integration

"Integration" has several meanings, but the most common one is the idea that many things become "intermixed", have "equal participation" or are "combined to form a whole". [7] Its use suggests the possible loss of identity of the parts to the whole.

Children in Waldorf schools around the world learn to experience the merging of two primary colors into a third one at an early age. They use the wet paper method. Each child is given a sheet of wet watercolor paper, a brush and two primary colors. The children are invited to apply one color directly to the wet paper, then the other color. Right in front of the child's eyes, the two colors merge and form a third color. On the paper emerges the reality of three colors: the two original primary colors and the result of their merging. This may be one of the child's first ways to grasp the idea of two things loosing their identity to a third reality. This seems to be one example of integration. [20]

The word integration is found in the building sector in technology integration, product integration, and industrial integration. One additional phrase in currency in the architectural and engineering literature is design integration. What can this mean? What are its origins? In what context is this term found?

If by designing we generally mean what we do when we make a proposal for what should be built, by someone else, for someone else to use, we probably also have in mind some ideas regarding who is involved in these tasks – who takes initiative, who controls what, and so on.

Fundamentally, we distinguish or partition the act of designing from the act of making what is proposed. Of course, once the distinction is made, designing and making can be undertaken by one party, or by several parties. This is not new. Specialization brought us this distinction very early, always ruled by convention and tacit knowledge as well as specialized skills, tools and public oversight. I have participated in both, having practiced as an architect making drawings to instruct a builder what to do, and I have also built by my own hands what I have designed.

If that is at least a point of departure for "designing", what is integration when the word is attached? In academic, governmental and some professional architectural and engineering discourse, we see the use of the phrase "design integration" or "integration of design and production".

It is worth recounting a case that demonstrates how the phrase design integration has reached a state of uselessness. At a recent international conference on Design Management (CIB W96) in Copenhagen, a session was organized called Design Integration. [21] I was asked to be chair of that session, which allowed me to read all of the papers. This reading revealed the following words or phrases associated with design integration:

- Concurrent engineering
- Multidisciplinary teams
- Introducing knowledge early
- Thinking in levels of abstraction
- Optimizing
- Collaborative participation
- Inclusion
- Sharing of knowledge and learning,

- Sharing of visions
- Group processes
- Interoperability
- Lean construction
- Supply chain integration
- Value engineering
- The idea that problems can be subdivided into overlapping, interconnected segments that correspond to existing or emerging disciplines but are connected in a coherent and comprehensive manner

These were the actual terms associated with "design integration", found in the dozen or more papers I read. What are we to understand from this? Does design integration mean joining designers together somehow? If so, exactly how is this to be done? Is the joining done at the hip, or by brain links? Do we find partnerships, contracts, virtual networks, or the law as the operational devices of design integration? Does design integration mean a hierarchical relationship between parties, or a relationship of equals, or neither?

Experts in the building industry around the world have worked diligently for more than 50 years to put the concept of "design integration" into practice. It seems that the latest effort to accomplish "integration" will be found in building information modeling (BIM) and the recent IDS (Integrated Design Solutions) movement. [22]

I would suggest that a resolution is possible by introducing the concept of control, one of the central concepts in Open Building. That is, we need to know what party (an individual or group) makes executive decisions. Thus, to make the phrase "design integration" useful, we must ask "Who controls what?" This is a decidedly political and business-related question that takes us outside our professional or "technical" expertise into a field of social, economic and cultural discourse and values.

Effective Terms of Reference

As mentioned above, the term "disaggregated" is a more apt term than "fragmented" when describing the organization and dynamics of the building sector. This means that a number of independent and geographically distributed parties are at play. The relations between these parties, their patterns of control, are key to understanding the dynamics of their interactions and their output.

There are many kinds of relations; we have teams, partnerships, collaborative structures, virtual corporations, vertically or horizontally organized networks and supply constellations. We would find it very strange and probably bad if one party (an individual or a company) claimed to be able to control everything! For a long time we have had specialization and it won't go away. Rather, we experience more specialization as the world becomes more complex and fast paced.

It would be a bad idea if the building industry would model "integration" as we find it in the automobile or aerospace industries, for example. Do we really want a few giant companies controlling all the building activities, with tight, top-down supply chains, in the US, or in other markets? I think few would argue in favor of that, or in favor of abandoning the range of small, medium and large organizations that give the building industry tremendous agility, dynamism, resilience and innovative capacity.

Control and Dependencies

When we design a complex artifact like a building, we compose it from many parts. During the process of composing, we need to change parts, delete some, adjust them, or add new ones, as we learn more or as conditions outside our control change. It is normal that when we change one part, others are implicated. Soon the perturbations in the whole can become too complex to be controlled successfully when every part is subject to alteration upon the change of another part, and when manipulation of parts is distributed among a number of parties. To manage this complexity, we decide to fix some configurations - leaving them stable. These stable configurations become constraints on the manipulation of other configurations or parts. We follow this process until we are think we are "done" with the designing or until the party requesting it gives approval.

It may be that "integrationists" want to eliminate such complex dependencies by unifying parts, so that the parts no longer have autonomous identities among which dependencies can occur. Along with this naturally goes a unification of control. Clearly, if we have a whole composed of two parts, the individual parts can be controlled by one party, or by two. The more parts we have, the more potential parties can take part in making and changing the artifact. When all parts are made into one (integrated - unified) clearly only one party can exercise control because the whole cannot be sensibly partitioned. The "one party" may be a group "acting as a whole" (by consensus or by vote) or it can be one individual who seeks out the advice of others but who has exclusive authority to act (control). We know the difference, however, which only goes to raise the question of how groups actually "work together" in making form.

Levels of Intervention

One way to avoid the trap of “integration” is to understand the idea of levels of intervention. [23] This is not a new idea - large infrastructures are always organized on levels - but is easily forgotten, and in any case constitutes an inevitable trend in the building sector.

For example, in large buildings, we see a tendency to separate a ‘base building’ from ‘fit-out’. This separation is also called “core and shell” and “tenant work”, or “support and infill”. Whatever the words used, the distinction is increasingly conventional – internationally - and is mirrored in the real property and building industries’ practices, methods and incentive systems.

For example, commercial office buildings have used this distinction for at least forty years. Tenants lease space in buildings in which the layout for each is custom designed and individually adaptable over time. Private and governmental institutions owning large administrative buildings likewise make that separation to accommodate ongoing relocation and reconfiguration of functional units. Large building companies have distinct, dedicated divisions to service both the construction of base buildings and the installation of tenant improvements or fit-out. Tenants may own their fit-out partitioning and equipment (usually called FF&E or Fixtures, Furnishings and Equipment) and can sell it to the next users, or may clear out the space when they leave (increasingly using parts prepared for disassembly or

recycling), to be fitted out anew by the next occupant. This way of using built space already constitutes a substantial market, which, in turn, has given rise to a well organized industry serving the demands for tenant "fit-out", including finance companies, product manufacturers, design firms, construction companies and a host of others among which are well known companies such as Steelcase, Haworth, Herman Miller, and Knoll, among others.

Another example is shopping malls. Developers build large structures giving much attention to public space but leaving retail space empty. Overall architectural, technical and space standards are established and documented in detailed tenant handbooks, enabling national or international retail chains (or local businesses) to lease space and bring in their own designers and fit-out services.

Why has this trend emerged? The answer lies in a convergence of three dominant characteristics of the contemporary urban environment. First is the increasing size of buildings, sometimes serving thousands of people. Second is the dynamics of the workplace and the marketplace where use is increasingly varied and changing. Third is the availability of, and demand for, an increasing array of equipment and facilities serving the inhabitant user. In that convergence, large-scale real estate interventions make simultaneous design of the base building and the user level impractical. Social trends towards individualization of use make functional specification increasingly personalized. Greater complexity and variety of the workplace demand adaptation by way of architectural components with shorter use-life, such as partitioning, ceilings, bathroom and kitchen facilities, etc.

The observed separation of base building from fit-out includes utility systems as well. Adaptable piping and wiring systems on the fit-out level, for example, connect to their counterpart and more fixed main lines in the base building, which themselves connect to the higher level infrastructure operating in the city.

Thus we see a significant contrast between what is to be done on the user level on the one hand and what is understood to be part of the traditional long-term investment and functionality of the building on the other. This is the reason for the emergence of the base building as a new kind of infrastructure.

The distinction here - between "levels of intervention" - is always useful when we compare infrastructure with what it is serving. In the case of buildings, the comparison has multiple dimensions, including the following, framed in terms familiar in the US office building sector if not more broadly:

BASE BUILDING	**INFILL or FIT-OUT**
Longer-term use	Shorter-term use
Public or common service related design	User related design
Heavy construction	Lightweight components
Long-term investment	Short-term investment
Equivalent to real estate	Equivalent to durable consumer goods
Long term mortgage financing	Short term financing

When this distinction is made in practice, it is usually the case that each level is under the control of a different "party" or agent. It is even then possible to say that each such "party" must "integrate" the work within their area of responsibility to maintain quality, schedule and cost. But the use of "integration" here is directly aligned with a pattern of control, rather than being a strictly technical definition. That is the key point: integration cannot be divorced from the exercise of control. [24]

The Emergence Of A Fit-Out Industry

"Integration" or "integrated design" as a model for single-source or unified delivery of building technology or building processes thus may make sense, in particular situations. In open building theory, the most successful examples are evident at the "fit-out" level. It is well understood that industrial manufacturing is most effective and dynamic where individual users are directly served. Witness the automotive, electronics and telecommunications sectors. One example in the commercial sector is the emergence, over the past decades, of service providers that provide unified control of complete "slab-to-slab" fit-out. Steelcase pioneered this technology/service bundling, in their commercial office fit-out Pathways product, in the 1990's. [25]

The potential market for residential fit-out is at least as large. Designing base buildings understood as 'infrastructures for living' will stimulate the evolution of a fit-out industry that will itself accelerate innovation and distribution of new domestic fit-out services and systems.

Residential application of the distinction between base building and fit-out, although based on the same principles as observed in office buildings, shopping malls and hospitals, is particularly important because it affects a very large market whose potential is not yet understood or exploited.

In Japan, a fit-out system, targeting the activation of post war residential apartments as well as newly built base buildings, has been launched in the market. Technical sub-systems and products that can be combined in full fit-out systems are increasingly available in the international building supply market, and in the Netherlands and Japan, for instance, there is evidence of continued commercialization efforts to develop marketable fit-out systems.

In general, the creation of a genuine fit-out industry is not a technical or industrial design problem. As noted above, necessary material subsystems and components like partitioning, bathroom and kitchen equipment, piping and wiring are available. What is needed is the introduction of installation teams modeled on the "work cell" familiar in automotive manufacturing, where, in the case of building processes, a trained team brings in all the ready-to-assemble parts – organized off-site in boxes and bundles – installs everything inside the empty space, and hands over a finished dwelling with a users manual, avoiding the disruptive sequencing of subcontractors. Backed up by sophisticated data and logistics management, this will combine efficiency with customization at a range of price points. It is important that the legal and economical frameworks needed for the emergence of such an industry are put in place by local and national government bodies, and by the financial companies that understand the market potential. [26]

Roughly speaking, the cost of an integrated fit-out system for a modest apartment dwelling unit is in the order of the cost of the cars its occupants use. This shows the magnitude of the shift we are identifying - an entirely new industry of impressive scope, based on "industrialized" production of parts and delivering what is best called an integrated durable consumer good. In this perspective the trend towards base building infrastructure also allows the building industry to effectively come to terms with industrial production in its most creative mode.

Meeting The Sustainability Agenda

Base buildings that are well insulated and built for long-term and efficient performance are easier to build when freed from intricate and complex fit-out demands. Double-envelopes can be designed to meet the highest building performance standards, reducing heating and cooling loads while providing ample natural illumination. Fit-out components and parts, on the other hand, are those that consume energy and are particularly related to eco effects in buildings. This is even more so when facade elements become parts of fit-out packages. Because individual fit-out users are responsive to new products and services from the manufacturing sector, accelerated turn around cycles will boost the large-scale re-orientation of environmental construction to the demands of a carbon free ecology. In fact, the United States Green Building Council's LEED rating system already recognizes the distinction we discuss here. [27]

Conclusion

The implications of the perspective put forward in this paper can be surmised. Many aspects of our work as architects and engineers and builders – in practice, research units and teaching - are involved. Adopting a perspective that includes the concept of control has been and will continue to be disruptive. However, if we don't adopt this perspective, we should anticipate a continued lack of effectiveness in dealing with relentless and ubiquitous forces at work in the built field. That is not to say that students will not continue to flock into the schools, or that creative and skillful architects and engineers will not continue to practice and practice successfully. But in a larger sense, our future depends on emerging from behind the shroud of such terms as *integrated design solutions* and *industrialized construction* and all that is embodied in these terms.

The problems in pursuing this shift of attitudes and perspective are not trivial. Necessary professional re-orientation may well determine the pace, direction and quality of change. Note that the practical examples of working with levels of intervention and in recognition of patterns of control cited above have emerged from sound economic reasoning and a willingness to respond to market forces, not from ideology. The time may have come to establish a more explicit platform for study and development of what seems to have come not as a new design idea, but as a new reality to be taken seriously.

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