Critique of Construction’s Paradigm from Existing State of the Art Research

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Abstract:

Lorch 2003, as quoted by International Symposium (2007), suggests that the focus of the construction industry has been on the ‘know-how’ rather than the ‘know-why’. This bias towards the ‘know-how’ may be the cause for construction’s deficiency in theories (Koskela and Howard 2002a, b).

It is argued that in construction “there is a generalized failure to explore the behavioural, environmental and managerial theories that help us link our infrastructures into the wider social and economic issues vital to the long term future of our communities and our environment” (Call for papers, International Symposium 2007). The increasing focus on the impact of the built environment on the global ecosystem (Stern 2006) has provided further impetus for the need to understand the ‘know-why’ rather than just provide a catalogue of ‘know-how’ or the ‘know-how-better’.

A debate on the ‘know-why’ of process improvement requires a survey of the existing state of the art research to discern the ‘theories’ that underlies the research on processes. Research is understood to be at the boundary between science and technology, between theory and practice, between ‘know-why’ and ‘know-how’. A critique of existing state-of-the-art research serves as the background to discern construction’s ruling paradigm.

Keywords:
Change Taxonomy, Environment, Paradigm, State-of-the-Art Research, Theory

1. Introduction

In a pre-paradigmatic environment, according to Kuhn (1962), the indirect method of aligning theory with research activity, the debate of issues, the existence of ambiguities and paradox positioning is acceptable, if not common, in order to gain knowledge and clarity.

The discovery of gaps in knowledge and questions regarding observed anomalies between theory and practice, worldview and research aim to affirm or negate the internal coherence of a paradigm with practice. Through this unifying method,
fragmented research constructs are unified into a theory that is then tested for conformity to its reigning paradigm.

This paper will serve as a catalyst for debate on the implications derived from state-of-the-art (SoA) research through the application of Popper’s (1972) Analytical Process and Slaughter’s (2000) Change Taxonomy.

2. Methodology

The methodology used is Popper’s (1972) Method of Conjecture and Refutations (see Fig. 1) and Slaughter’s (2000) modified taxonomy for change (see Fig. 2). This methodology is used to discern the types and levels of change in current SoA research in construction. The levels of change are captured in a change taxonomy matrix. This work indicates a preponderance of incremental advances in research with minimal systemic and sparse radical breakthroughs in science or technology.

![Fig. 1. Popper’s (1972) Analytical Process of Conjectures and Refutations](image)

<table>
<thead>
<tr>
<th>Incremental</th>
<th>Systemic</th>
<th>Radical</th>
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<td>– small (gradual)</td>
<td>– multiple, linked, rapid (step)</td>
<td>– (new) breakthrough in science or technology</td>
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Fig. 2 Change Taxonomy, adapted from Slaughter (2000)

Popper’s (1972) philosophical method of analysis (Conjecture and Refutations) applies to individual (segmented) rather than systemic cases using the following linear process of logic:

- $P_1 = \text{Original Problem}$
- $TT_1 = \text{Tentative Theory}$
- $EE_1 = \text{Error Elimination}$
- $P_2 = \text{Emerging Problem}$
A methodical application of these analysis techniques to state of the art research in the industry yields inferences and theoretical implications that are otherwise obscured in the drive towards solving problems, such as maximizing efficiency. The objective of this paper is to highlight the anomalies between industrial/manufacturing paradigm expectations (i.e. efficiencies) and construction realities at the research and theoretical levels.

3. **Review and Analysis of State of the Art (SoA) Research in Construction**

This two step analysis (analytical process of conjecture and refutations and the filter through change taxonomy) results in a matrix. This matrix can be expanded to include all other current initiatives in construction science to generate a partial worldview of SoA research in the industry.

The selected peer reviewed articles, from a literature search, constitutes a set of most of the work, up to 2007, published by construction industry researchers on the topic of theory or lack thereof. A broad survey of the literature and research initiatives in the construction industry follows:

- **Organization related:**
  - Project Management (Drucker 1963, 1970; Miozzo and Ivory, 2000; Morris 1994; PMI 2000; Tushman and Anderson 1996)
  - Partnering (Baden, 1995; Bennett and Jayes, 1998; Godfrey, 1996; Larson, 1995; Rackman et al. 1996; Slaughter, 1998)
  - Project Definition Rating Index, (PDRITM) (Cho, et. al. 1999; Durmont, et al., 1997)
  - Learning Organizations (Edmondson and Moingeon, 1998)
  - Knowledge Management (COM, 2000; Egbu, 2004)
  - Open Building (Kendall and Teicher, 2000; Van der Werf, 1990)
  - Virtual Organization (Winch, 1989)

- **Performance related:**
  - Lean Construction (Alarcon, 1997; Ballard et al. 2002; Ballard and Howell, 1994, 1998a, b; Howell, and Ballard, 1994 a, b, 1997; Koskela et al. 2002; Santos, 1999; Vrijhoef et al. 2002)
  - Concurrent Engineering and Fast Tracking (Ballard, G., 1999)
  - Just in Time Production (JIT) (Gilbreths and Gilbreth, 1922; Hopp and Spearman, 1996)
  - Total Quality Management (Shewhart 1931; Shewhart and Deming 1939)
Continuous Improvement Theories (Wortmann, 1992; Wortmann et al. 1997)
Theories of Integration (Wortmann, 1992)
Robotics (Sangrey and Warszawski 1985; Warszawski 1990)
Fabrication and Mechanization (Slaughter, 1991, 2000)
Industrialization (Sebestyén, 1998)
Re-Engineering (Winch, 2003)
Last Planner (Ballard, 1994, 2000);
Constructability and buildability (Ferguson 1989; O’Connor 1986)
Value Engineering and Management (Cook 1997)
Life Cycle Costing (Kohler et al. 2005)
Critical Path Scheduling (Weist and Levy 1969)

IT related:
"3D CAD - parametric oriented, web based real time multi-user platforms (Fenves, 1996; FIATECH, 2004; Johnson, 1995; Koskela and Kazi, 2003)
Digital Building Process and As-built Documents (Tabatabai-Gargari and Elzarka 1998)
BIM – Building Information Model (FIATECH 2007)

Codes and Standards related:
Performance Base Building Codes, Standards and Specifications (Foliente 2000)

Contract and Structure related:
Integrated Project Delivery Systems (such as: Design-Build and similar variations (Bowley, 1966)
Construction Management @ Risk and multiple variations (Lathan 1994)

Environmentally related:
LEED® (US Green Building Council)
BREAM™
GBTool™ (UK)
BASIX (Australian)
HQE® (CSTB - France)

Koskela’s (2000) dissertation focused on a search for a theory of production. His work posits that a theory of production in building construction embodies the concepts of transformation, flow and value. The underlying premise, which he builds in subsequent papers along with other authors, is that construction productivity lags behind that of manufacturing. According to Koskela (2000), a crisis or a pre-crisis state exists in the construction ‘industry.’

This lag of productivity is somehow related, according to Koskela (2000), to the lack of a theoretical foundation in construction, which is deemed to be a barrier to progress. However, the concept of “progress” is not further defined. Most of the concepts initiated and presented in Koskela’s dissertation are further developed in the subsequent articles and therefore are not treated in detail at this time.

Why were these statements made?

The empirical discrepancy between productivity in construction with that in other industries, such as manufacturing, prompted the statement that construction productivity lags behind that of manufacturing because, according to Koskela (2000), there is a lack of a theoretical foundation in construction. Construction peculiarities—on site, one-of-a-kind (“prototype nature”; Drucker (1963); “unique-product production”) and temporary organization—are also ‘determining factors’ for this lag in productivity. Carassus 2004 further elaborates the characteristic of construction:

- The only production process in which products are static on site (immobile)
- Structures are prototypes adapted to each site and environment
- Structures have a very long life (relative to other manufactured products)
- Structures are adapted to evolving demands
- Institutional rules play an essential role

Furthermore, according to Lundin and Söderholm, 1995; Lundin, and Steinkórsson, 2003, ‘action’ is identified as ‘the essence of temporary organizations.’ Others further define construction temporality as: ‘temporary multiple organizations’ (Cherns & Bryant 1984) or a ‘quasi-firm’ (Eccles 1981).

The underlying concept of Koskela (2000) is that construction, even with its differentiating peculiarities, is an ‘industry’ (Groák, 1994; Bennet et al. 1998a; Bowley, 1966; Dubois and Gadde 2002), and as such could be directly compared with other ‘industries’. This basic premise will be challenged in the following studies and observations.
What are the author’s arguments and proposed solutions?

Koskela’s (2000) arguments point to the fact that manufacturing techniques and framework are not directly translatable to construction due to its peculiarities. However, if the imported manufacturing concepts of transformation, flow and value are incorporated as an integrated theory of production, a novel theory of production can be achieved that is sensitive to construction’s peculiarities, thus ameliorating the anomalies of discontinuities, constraints and variabilities.

What did he develop?

Koskela (2000) developed a methodology for highlighting construction peculiarities as well as the theoretical foundations for a theory of production, based on current practices (mostly transformation), some applications of the flow concept and the even rarer application of the value concept.

Gut reaction to particular issues.

Construction, as practiced, is broader than just a theory of production, and involves many other disciplines, as acknowledged by Koskela (2000). A basic interpretation of construction as an “industry” is Koskela’s (2000) basis for comparison with other industries, such as manufacturing. Several studies have highlighted the similarities and differences between construction and ship building, electronics, aerospace (Green et al. 2004; Voodijk and Vrijhoef 2003) and automobile (Barber et al. 1998; Gann 1996) industries.

However, the differentiation (an understanding of construction as an industry of industries, rather than an industry – a meta-industry) goes to the core of the problem. This differentiation, along with an unidentified construction worldview may be the root cause that prevents a direct transference of other industries’ techniques and theories to the construction sector in general as well as in particular projects.

If this is the case, importing technologies, techniques and frames from other industries may prove to be more difficult than anticipated, a continual source of ill-fit, as well as not being able to yield the desired benefits after adding complexity to the production process. The peculiarities, the lack of a theory of production, and the anomalies found in this comparative work point to a higher level of crisis: the need to identify a building construction worldview and second identifying theories that better reflect building construction’s background, field and peculiarities.

What Koskela (2000) points out in this paper, and in subsequent studies, is the presence of an anomaly. Construction embodies technologies (theory and action) with embedded scientific principles with anomalies and violations of expectations. Kuhn (1962) states that: “The manner in which anomalies, or violations of
expectations, attract the increasing attention of a scientific (research) community needs detailed study, as does the emergence of the crises that may be induced by repeated failure to make an anomaly conform.”

The issue of anomalies in building construction is further discussed in Ballard and Howell (2004): Howell et al.’s (1993a, 1993b) central concept regarding project end and means is the combined impact of work flow variability and dependence, and their implications for the design of operations. Later, Ballard (1994), Ballard and Howell (1994), and Howell and Ballard (1994a and 1994b) began publishing measurement data on work flow variability. The first data showed a 36% plan failure rate (i.e. 36% of assignments on weekly work plans were not completed as planned).

Later publications (Ballard and Howell 1998 a, b) expanded the data set, revealing a 54% grand average plan failure rate over a wide range of projects and project types. The data, according to Ballard and Howell (2004) represented what they term as a paradigm-breaking anomaly for traditional project management: variability was in fact not spasmodic but persistent and routine. Neither was it small. What’s more, according to the authors, analysis revealed that the large majority of plan failures were well within contractor control, contradicting the traditional assumption that variability was from external causes. This failure to actively manage variability became visible, as did the corresponding need for active management of variability, starting with the structuring of the project (temporary production system) and continuing through its operation and improvement, a target of the Lean Construction trend and initiative. Koskela responds to the issue of this anomaly with a question, the subject of our next inquiry.

Applying Popper’s (1972) method of conjecture and refutations:

\[ P_1 = \text{Construction productivity lags behind that of manufacturing; a crisis or a pre-crisis state exists in the construction ‘industry.’} \]

\[ TT_1 = \text{A search for a theory of production that is based on T, F & V concepts} \]

\[ EE_1 = \text{Eliminate variabilities and the propagation of variabilities} \]

\[ P_2 = \text{Manufacturing techniques and frame stubbornly remain not directly translatable to construction due to its peculiarities} \]

Applying Slaughter’s (modified) Change Taxonomy

Although the discovery of a new worldview and theories could yield systemic (multiple, linked, and rapid) increases, construction continues to be recalcitrant when applying theories based on new worldview constructs, indicating the continual presence of anomalies between theory and practice. In this case the advances in product and processes remain incremental--gradual, although impressive. For
example, step increases would represent concrete or steel strength doubling in a continually decreasing time-line.


Koskela and Vrijhoef (2001) state that the prevalent theory of construction is: implicit, deficient, and a hindrance to innovation. Without explicit theories, it has not been possible to access core ideas of concepts and methods of other templates, such as manufacturing, and re-create them in a construction environment. The driver of “least cost,” as in the transformation model that decomposes projects into parts and later into tasks, abstracts away the issues of uncertainty and time, creating a scenario of ‘myopic control’ and inflated variability. The atmosphere at project execution becomes one of handling crisis and a divorce between plan and execution impedes top-down and bottom-up systematic learning and capturing problem solving lessons learned for posterity, thus impeding implementation of innovations.

Lillran (1995) argues that organizational innovations do not transfer well in their original setting over industrial borders. But the core ideas or concepts of the organizational innovation must be abstracted and re-created in an application that fits local conditions. Koskela and Vrijhoef (2001) state that, as a consequence of the absence of ‘radical’ managerial innovations, present construction management practice is characterized partly by methods originating from the ‘craft period’ with some centralized control brought from ‘manufacturing left-over’. Trade (the craft mentality), the authors state, has no incentive to share learning experiences for the sake of re-applying them in future projects by a differing crew for the sole benefit of the general contractor. Problem solving becomes innovation when solutions found are retained and re-applied to future projects in a systematic mode. Along the same lines, Pries and Janszen (1995) state that innovations come from the supply base.

A high level of inherent variability minimizes the cost of each task in the transformation view, and each task input exponentially increases the number of required interactions, resulting in a corresponding increase in complexity, discontinuities and variabilities.

In conclusion, the authors state that a new production template (of radical innovation), based on an explicit theory of production and with full recognition of construction peculiarities, is needed.

Why were these statements made?

In previous papers, Koskela advanced the proposition that change in building construction should come from the bottom-up. However, there is a problem of
harnessing the knowledge of actual practice due to the inherent variability of the industry. Koskela and Vrijhoef (2001) identified the need to harmonize theory with practice but with practice leading the way. A method, then, is sought to accomplish this task with the building construction industry.

**What are the author’s arguments and proposed solutions?**

The authors re-affirm that the prevalent theory of construction is implicit, deficient, and a hindrance to innovation. Because the prevalent theory is implicit, the methods of other templates, such as manufacturing, cannot be re-created in a construction environment. Hence, there is a perception of a drought of both external and internal innovations, due to the peculiarities of construction, mostly its temporary organization characteristic. Innovation, as a proposed solution, encounters a solid wall of resistance from the craft mentality because tradesmen have no incentive to share learning experiences for the sake of re-applying them in future projects with a different crew, for the sole benefit of the general contractor.

**What did he develop?**

The authors developed the rationale for the need for a new production or project template. The authors have highlighted the need to identify the construction industry’s current paradigm as a stepping stone towards working on a new and better-fitting paradigm.

**Gut reaction to particular issues.**

The most significant statement in this paper is the acknowledgement that there exists a trade (the craft mentality) that has no incentive to share learning experiences for the sake of re-applying them in future projects with a different crew for the sole benefit of the general contractor. This statement may be foundational to identifying the existing paradigm or the underlying culture of that paradigm. Pries and Janssen’s assertion (1995) that innovations come from the supply base is in contrast with the theories of project and the theories of management, as well as the theories of design, that are all based on planning, controlling and execution directed from the top-down. This finding is another case of the inherent anomalies found in building construction that are aggravated by the peculiarity of temporary organization which makes it different from other industries.

**Applying Popper’s (1972) method of conjecture and refutations:**

\[
P_1 = \text{High level of variability due to the craft mentality perceived as an anomaly}
\]

\[
TT_1 = \text{Need to identify existing cultural paradigm at the supply base}
\]
\( EE_1 = \) Eliminate variabilities and the propagation of variabilities through capturing and transmitting lessons learned

\( P_2 = \) No clear and obvious relation between theory and practice but levels of complexity are added to the process; possible crisis and realization that current paradigm (building = supply base) cannot resolve the anomalies and crisis

### Applying Slaughter’s (modified) Change Taxonomy

Construction reality continues to betray the efforts to systematize, control and make the process and final product predictable, a la manufacturing. Progress in this area of knowledge remains gradual and incremental.


Koskela (2002) elaborates that “during the next decade, the formation of a theory of construction will be the single most important force influencing the construction industry.” This theory, he proposes, will consist of two parts: First, a theory of production in general (T, F & V); Second, the application of this theory to the characteristics and peculiarities of construction (on site, one-of-a-kind and temporary organization). On the most general level, Koskela (2002) identifies three possible prescriptive actions to a theory of production: design the production system, control the production system (Gilbreths and Gilbreth 1922) and improve the production system.

Likewise, the author identifies three broad based ‘deficiencies’ in reaching a theory of construction. First, chronic performance problems can more or less be associated with problems of theory. Second, with the lack of explicit theory, it has been difficult to implement methods of flow and value management in construction. Third, our efforts to develop construction, say through industrialization or information technology, have been hindered by the lack of theory.

These three themes are discussed in detail by Koskela (2002) within his framework for analysis. The idealized transformation view has a high realization error in complex practice since ‘certainty’ does not prevail in construction. The inherent variability in production degenerates into mutual adjustments by the team on site. Inherent variabilities, again, are due to the peculiarities in construction. Koskela (2002) answers the question of why with: “The various initiatives, such as ‘industrialization’ and ‘information technology’ in construction have often failed to produce the results intended because the fundamental problem is theoretical.” Halpin (1993) echoes that: “we have not gone far enough in seeking a basic framework for the construction of facilities.” This study abruptly concludes that using the Last
Planner method (Ballard and Howell 1998a) can lead to manifest performance improvement by using transformation, flow and value theory as foundation.

**Why were these statements made?**

Halpin’s (1993) and Koskela’s (2002) progressive discovery of the cause of the problems and anomalies in construction leads to the statement that chronic performance problems can more or less directly be associated with problems of theory. A search for the points of a proper theory of construction continues, but appears to be limited by the frame of a theory of peculiarities.

**What are the author’s arguments and proposed solutions?**

Last Planner appears to better integrate the T, F & V concepts and therefore is a better candidate, in the eyes of Koskela (2002), to find an integrated theory of production.

**What did he develop?**

Koskela (2002) continues relating performance problems to theoretical problems, which is a higher level of analysis than comparative performance of any one industry against building construction performance. Koskela (2002) also developed a method for establishing that current trends and initiatives for change are not radical and are not sufficient to engender significant structural changes.

**Gut reaction to particular issues.**

By highlighting the idea that during the next decade, the formation of a theory of construction will be the single most important force influencing the construction industry; Koskela (2002) insinuates that there can be a total theory of construction and not just of production.

What we have here is described by Kuhn (1976) as a functioning but un-identified paradigm with rules and theories that are implicit but not explicit to the paradigm: “Rules derive from paradigms, but paradigms can guide research even in the absence of rules.” (Theories are derived from rules and vice versa.) Lack of a standard interpretation or of an agreed upon reduction to rules will not prevent a paradigm from guiding research; indeed the existence of a paradigm need not even imply that any full set of rules exists (Polanyi, 1974 as quoted by Kuhn 1976). Paradigms may be prior to, more binding, and more complete than any set of rules for research that could be unequivocally abstracted from them. Normal science is a puzzle-solving activity that is a highly cumulative enterprise, eminently successful in its aim and the steady extension of its scope and precision.
The distinction between discoveries (novelties of fact) and invention (novelties of theory) is exceedingly artificial. Discovery commences with the awareness of anomaly, i.e., with the recognition that nature (in our case, standards of practice) has somehow violated the paradigm-induced expectations (even though a paradigm has not been currently identified) that govern normal science. It then continues with a more or less extended exploration of the area of anomaly and it closes when the paradigm theory has been adjusted so that the anomalous has become the expected.

In construction, then, the standards of practice, anomalies with espoused implicit theories, indicate that work needs to be done at all levels (practice, theory, rules) up to and including the identification of the existing paradigm in construction.

**Applying Popper’s (1972) method of conjecture and refutations:**

\[
P_1 = \text{Need a theory of construction}
\]

\[
TT_1 = \text{Need a theory and an applied theory: 1. Production in general, 2. Applied to building construction peculiarities}
\]

\[
EE_1 = \text{Design, control and improve production systems through Last Planner incorporating T, F, & V}
\]

\[
P_2 = \text{Certainty does not prevail in construction; on site team adjustments prevail; owner introduced chaos remains possible; current trends and initiatives are not sufficiently radical to render significant structural changes (i.e. may need more manufacturing-like controls)}
\]

**Applying Slaughter’s (modified) Change Taxonomy**

The lack of theory in construction continues to be the center preoccupation of the authors. The expectation is that once a worldview and a theory are uncovered in the relationships of products and process, the hoped for efficiencies will be achieved. We continue on a gradual ascent in a change taxonomy, albeit dealing with knowledge that will influence technologies and physical creations.

### 3.4. Koskela, L., and Howell, G., 2002a, “The Underlying Theory of Project Management is Obsolete”

This study advances the position that there is a theory of project and a theory of management as espoused in the PMBOK (Project Management Body of Knowledge) guide by the Project Management Institute (PMI) (Duncan 1996; Kerzner 2001). Koskela (2002) analyzes the anomalies (deviations from assumptions or outcomes) between theory and practice to conclude that a wider and more powerful theoretical foundation is needed. Why? Mastery of theory, according to Fugate and Knapp (1998) is the single most important factor distinguishing a profession from a craft. Mastery of theory along with mastery of practical skills of the field is the hallmark
of a professional. Theory is the differentiator of craft from science, of the common view of construction as a field of ‘know-how’ from a field of ‘know-why’.

Kloppenburg and Opfer (2000) analyzed forty years of project management and found an omission, a silence, of the theoretical. Koskela and Howell (2002b) contend, however, that there is an implicit and narrow theory which may explain the following points: frequent failures (Kharbanda and Pinto 1996); a lack of commitment towards project management methods (Forsberg et al. 1996); and the slow rate of methodological renewal (Morris 1994).

A theory consists primarily of concepts and causal relationships that relate those concepts (Whetten 1989) and, in the case of construction, ‘prescriptive’ and revealing how action contributes to the goals set for it. On the most general level there are three possible actions: design the systems employed in designing and making; control those systems in order to realize the production intended, and improve those systems.

Koskela and Howell (2002a) argue that the underlying theory of project management is essentially based on economic transformation theories where, in addition to the ten PMBOK core planning processes (scope planning, scope definition, activity definition, resource planning, activity sequencing, activity duration estimating, cost estimating, schedule development, cost budgeting and project plan development), there is one executing process, and two controlling processes, thus Managing as Planning.

By assuming that translating plan into action is the simple process of “issuing orders,” it makes plan production essentially synonymous with action. This is done through instatements such as: work authorization (like job dispatching in Manufacturing – Emerson 1917); selecting a task (per plans); communicating the authorization; and a feedback mechanism of performance reporting (Hofstede 1978; Ogunnaike and Ray 1995). Management at the operations level consists of the centralized creation, revision (updating) and implementation of plans.

Transformation theory, according to Koskela and Howell (2002a), presents anomalies when theory encounters the real (empirical) world. In order to evaluate a theory, a comparison is made between alternative theories such as flow and value theories (Koskela 2000). In summary, the major difference between transformation view and the flow view (i.e. Just In Time (JIT), Gilbreths and Gilbreth 1922; Hopp and Spearman 1996; and Lean Production, Alarcon 1997; Ballard and Howell 1998a; Santos 1999) is that the latter includes ‘time’ as one attribute of production. Because ‘time’ is affected by uncertainty (Howell et al. 1993a) in the production process as well as interdependencies between tasks, the focus of the anomalies is directed towards uncertainties and linkages which are not acknowledged in the transformation view.
Applying Popper’s (1972) method of conjecture and refutations:

The flow view’s basic thrust is to eliminate waste from the flow process, that is, through reducing uncertainty, whereas the transformation view accepts existing uncertainty. For example JIT and Lean Production can be analyzed as follows:

\[ P_1 = \text{Management as planning with execution (dispatching: selecting tasks and authorization) and controlling via feedback (thermostat model) closes a loop that leaves out the element of time and uncertainties and is wasteful in practice} \]

\[ TT_{1a} = \text{Time compression leads to waste reduction} \]
\[ TT_{1b} = \text{Variability reduction leads to waste reduction} \]

\[ EE_1 = \text{Planning when implemented consists of tasks in time: eliminate time associated uncertainties (TT_{1a}) as well as uncertainties associated with the interdependence between tasks (TT_{1b}).} \]

\[ P_2 = \text{Externalities and peculiarities continue to introduce uncertainties, variability. Accommodation of JIT and Lean Production depends to some extent on production excess capacity and availability on demand. The issue remains of production and material flow control with no attention to the issue of value generation.} \]

The value generation view is based on reaching the best possible value from the point of view of the customer (client) (Shewhart 1931; Cook 1997; Suh 2001). The major difference between the transformation view and the value generation view is that the customer is included in the latter. Whereas the transformation view assumes that customer requirements exist at the onset (scope of work definition) and can be decomposed along with the work, the value generation view admits that at the onset, customer requirements are not necessarily available or well understood and that the allocation of ‘value’ requirements to different parts of the project is a difficult problem (especially given a fixed budget).

Koskela (2000) argues that these three views (T, F & V) are not alternative, competing theories, but rather partial and complementary. What is needed is a production theory and related project management theory that fully integrate the transformation, value and flow concepts.

In this study, the authors also contrast the theory of control named the thermostat model with that of a continuous learning and improvement model. The second theory is based on the idea of a project plan being a hypothesis that is tested through the project itself, which becomes an experiment characterized by the peculiarities of one-of-a-kind by a varying team on a particular site and therefore with multiple variables. The final product is a comparative analysis of the project (experiment results) with the hypothesis. (Shewhart and Deming 1939).
\( P_1 = \) Plans are hypotheses to be tested in a project experiment
\( TT_1 = \) Building Design and Construction is a dynamic process of acquiring knowledge
\( EE_1 = \) An attitude of controlled experimentation with the plans as a guide and with defined purposes.
\( P_2 = \) Variable team infers that lessons learned are not irreversible or transferable to the next project team which may not possess interest and receptivity to issues that have not become critical.

The authors argue, along with Wiest and Levy (1969) that it is questionable whether the precedent relationships of project activities can be completely represented by a ‘non-cyclical’ network graph in which each activity connects directly to its immediate successors. The overall effect of revisions, repairs and rework on large projects is significant (Cooper 1993; Friedrich et al. 1987).

In conclusion, Koskela and Howell (2002a) state that without an underlying theory, it is almost impossible to access the deficient assumptions or argue about methodology. “Project management as a discipline is in crisis” states Koskela (2002a), and a paradigm change, long overdue, has to be realized. Koskela and Howell (2002a) propose two routes for a new theoretical foundation: (1) based on new theories of operations management, new project management methods may be developed and tried out and (2) advance practice may be consolidated and explained theoretically.

**Why were these statements made?**

Koskela and Howell (2002a) analyze the theory of project and the theory of management and continue to issue a call that a wider and more powerful theoretical foundation is needed since without an underlying theory, it is almost impossible to have access to the deficient assumptions or argue about methodology.

In this paper, the theory of “project” assumes the same elements of the previously mentioned theory of “production.” Koskela and Howell (2002a) may be purposefully equating “project” with “production,” although this direct relation is not made explicit, other than describing a theory of “project” by the T, F & V components also used in a theory of production.

**What did he develop?**

Under the umbrella of an underlying theory of project management, Koskela and Howell (2002a) group the following current topics as taught in academia: (1) a theory of project, (2) a theory of management, (3) a theory of planning, (4) a theory of execution and (5) a theory of controlling. All five theories are then contrasted with the empirical evidence gathered from practice in order to define anomalies. In
their Exhibit 2, the authors state that deficient definitions of planning, execution and control, as well as an implicit theoretical basis, are the root causes of the three types of problems previously mentioned. The final call is for a more intimate relationship between theory and practice must be created, in order to placate the serious anomalies found.

**Gut reaction to particular issues.**

The statement that “Mastery of theory,” according to Fugate and Knapp (1998), “is the single most important factor distinguishing a profession from a craft,” is applied to the theory of project management. This study does not acknowledge that the divisions within the fragmented construction field have fully developed theories according to their professions. For example, there is a well developed theory of structures and theory of mechanics (including climate comfort as well as physical comforts, such as plumbing).

The authors are looking at the narrow scope of putting a project together and by bringing in the issue of planning, have done a great service to elucidating a fundamental principle: **plan production is essentially synonymous with action.** In the past when architecture or design became differentiated from construction, the same critique was made about design plans, assumed to be essentially synonymous with action. Now we have another layer of planning, construction management planning, which is also essentially synonymous with action. It is even argued that sub-contractors have become another layer (sub-contractor planning) that is also synonymous with action, further relegating actual production and assembly to a sub-sub echelon. “The delegation appears to be a winding road to China…” The principle that planning is essentially synonymous with action may play a significant role in the actual paradigm (see Fig. 1).
There is no doubt that there is a crisis (when we compare building construction productivity with that of other industries) and a blurring of where solutions may be found (such as a body of theories that can be tested and refined). Koskela and others are voices documenting the anomalies and the magnitude of the crisis. However, the proposed solutions remain within the existing and unidentified paradigm and apparently something is not working and is at odds.

The unidentified paradigm in building construction may be an implicit and deeply embedded paradigm difficult to grasp, although once identified becomes obvious. This assumption is made because building construction practice is so ancient (building a shelter from the forces of the natural environment), and predates any figment of a conscious understanding of science, technology, techniques, craft, frame of reference, field, background and the concept of paradigm.

Kuhn (1962, 1976, 2000; et al. 2003) observed that: “All crises begin with the blurring of a paradigm and the consequent loosening of the rules for normal research.” In our case, it could be the blurring of the embedded building construction paradigm with the assumption that it is the same or synonymous with the industrialization paradigm (Ballard and Howell 2003a). In this respect research during crisis very much resembles research during the pre-paradigm period, except that in the former the locus of difference is both smaller and more clearly defined. All crises close with the emergence of a new paradigm candidate and with the subsequent battle over its acceptance. This battle is a reconstruction of the field from new fundamentals, a reconstruction that changes some of the field’s most elementary theoretical generalizations as well as many of its paradigm methods and applications.

Kuhn (1976) observed that it is particularly in periods of acknowledged crisis that scientists have turned to philosophical analysis as a device for unlocking the riddles of their field; this is the thrust of this paper. Scientists have not generally needed or
wanted to be philosophers. Indeed, normal science usually holds creative philosophy at arm’s length, and probably for good reasons. It is no accident that the emergence of Newtonian physics in the seventeenth century and of relativity and quantum mechanics in the twentieth should have been both preceded and accompanied by fundamental philosophical analyses of the contemporary research tradition (Dugas 1950; 1954).

The identification of anomalies in the theory and practice of building construction is a major contribution to the field of knowledge. There are only three types of phenomena about which a new theory might be developed, according to Kuhn (1962):

1. Phenomena already well explained by existing paradigms, however in most cases nature does not provide ground for discrimination.
2. Those whose nature is indicated by existing paradigms but whose details can be understood only through further theory articulation but not invention.
3. The recognized anomalies whose characteristic feature is their stubborn refusal to be assimilated to existing paradigms and thus give rise to new theories.

It is the third type of phenomena (see above) that Koskela and Howell (2002a) identified as typical of the state of the construction industry.

**Applying Slaughter’s (modified) Change Taxonomy**

The search for a ‘master theory’ that encompasses the five theories currently employed in construction may be equivalent to the search for a General Unifying Theory, as theory and praxis continue to display variability and other anomalies. The progress thus far in the change taxonomy regarding knowledge has been gradual – incremental.


Koskela et al. (2003) is another study that further analyzes selected initiatives in construction regarding a perceived need for change. This paper considers the scope of change needed, the big foundational ideas of change, as well as the initiation of change and keeping its momentum. The paper addresses four questions: First, which kind of change? Second, how are those changes, in principle, achieved? Third, presuming that construction is a fragmented and fluid industry that cannot be changed overnight, where should change start? Fourth, how can the change momentum be maintained after it begins?
Regarding the first query, which kind of change? According to Papert 2000, as quoted by Koskela et al. (2003), there are two approaches to the renovating school of thought: the problem-solving approach (individual problem solution) and the systemic approach (how the whole thing works). The majority of industry initiatives, according to Koskela et al. (2003), address the individual problems in question: cost, productivity (time and cost), quality, safety, and sustainability. First, solutions offered are not expected to lead to reform. Second, the suggested solutions address an underlying and 'obvious' cause of the problems through a pre-understanding of the nature of the problem or opportunity. “The pre-understanding is determined by a person’s perspective within the guiding [professional] paradigm” (“professional” added to Koskela’s statement).

Koskela et al. (2003) analyzes four commonly understood solutions: structural, behavioral, communications (information management) and physical (machinery). Solutions to problems found in building construction are exemplified by design-build as a structural response to the anomalies found in design-bid-build (known as traditional project delivery system). Structural change alone, according to Koskela (2003a), does not provide a solution, such as the structural change to project delivery system (PDS) by adding design-build to a model that originally was dominated by design-bid-build.

Why is change in the construction industry so difficult to realize? Dubois and Grade, 2002; Groák, 1994 have a possible explanation: “Construction cannot be considered a coherent industry with definable boundaries and characteristic problems.” Therefore we have a lack of fit between the present paradigm trying to mold construction to other industries and its inherent reality.

**Applying Popper’s (1972) method of conjecture and refutations (to PDS)**

\[ P_1 = \text{Systemic structural change required for project delivery system, overriding concern with cost and resulting conflicts} \]

\[ TT_1 = \text{One contract incentive for cooperation between design and builders} \]

\[ EE_1 = \text{Unify design and builder into one contract to eliminate design-builder conflict reflecting on the owner (sidetrack the Spearing Doctrine where the owner through the designer provides documents that are adequate and sufficient for construction)} \]

\[ P_2 = \text{Performance is equal to the traditional Design-Bid-Build in terms of cost, time, quality and sustainability results since the intrinsic mode of operation between the designer and the builder (their respective behavior, practice and cultures) does not change with a project whose peculiarities are one-of-a-kind and by different teams, therefore lacking efficient teamwork. Lack of integration of design and building cultures (behavioral approach) fail to achieve higher expectations of efficiency and effectiveness.} \]
Behavioral approach is based on the mentality (attitude, behavior, practice, culture) and motivation of people as the root of the problem. Teamwork and partnering are then suggested solutions to increase cooperation by identifying shared goals and establishing communication rules. For example, we now add the process called partnering to a Design-Build project team:

\[ P_2 = \text{(The new starting point) Design-Build Performance is relatively equal to the traditional Design-Bid-Build in terms of cost, time, quality and sustainability results since the intrinsic mode of operation between the designer and the builder (their respective practice, behavior, and cultures) does not change, therefore lacking efficient teamwork)} \]

\[ TT_2 = \text{Agreement on Project Success Criteria increases teamwork efficiency (behavioral and inter-firm cooperation)} \]

\[ EE_2 = \text{Problem resolution scale (resolve problems at the lowest level of competency within a prescribed and strict time period)} \]

\[ P_3 = \text{Non-Binding Charter; Higgin and Jessop (1965) “any lack of cohesion and coordination is less the result of ill-will or malignancy on the part of any groups or [individuals] but more the result of forces beyond the control of any individual group and which are affecting all”} \]

In order to identify early the forces that are beyond the control of any individual, the stakeholders are then asked to participate in the process called Project Definition Rating Index (PDRI) (see item 3.8 below). They are also asked for an increased commitment, an investment to improve communications via technologies (see item 3.9 below) and make the owner aware of the chaos that changes can create during the process. Communications (Information and Communication Technology - ICT) is based on the premise, or the belief, that access to information and clarity of communications is the issue.

However, according to Koskela et al. (2003), new technology does not change the more fundamental way work is done (Strassman 1997; Koskela and Kazi 2003). An Ekstedt and Wirdenius (1994) study finds that construction behavioral-culture programs in comparison to manufacturing are easier to implement but with limited real results. Higgin and Jessop (1965) report that lack of cohesion and coordination is the result of forces beyond the control of any individual or group, yet it affects all. That is, the system in practice (or context) has externalities that determine behavior. Trying to change behavior (one-of-a-kind, temporary organization) is more or less futile. The following is an example, an analysis of ICT using the same format:

\[ P_{icti} = \text{Access to clear, correct, complete and timely information in an ambience of deteriorating design documentation and quality due to reduced fees (Tilley and McFallan, 2000)} \]
One platform, web based, with shared real time information and accessible to all stakeholders on demand increases efficiency by reducing discontinuities, constraints and variability in the planning phase. Planning and execution efficiencies are deemed synonymous.

Eliminate duplication of outdated information and avoid discontinuities and variabilities in document generation and use

Difficult to implement due to the cost and the learning curve of one platform when stakeholders are accustomed to their own platforms. For ICT benefits to be unleashed there must be: upstream support of organizational changes to owner, financial institutions, and code officials; downstream to each sub-contractor, supplier and vendor. Implementing a translator of existing platforms with one web-based platform, so that each stakeholder can use both, is prohibitive due to the peculiarities of one-of-a-kind and temporary organization (Lundin and Söderholm 1995; Lundin and Steinthórsson 2003).

Physical (machinery) problems are associated with the low level of mechanization and either industrialization (off-site pre-fabrication) or on-site construction robotics and automation. The belief behind this issue is that industrial production is more efficient as shown in the following example:

Low level of mechanization

Industrial production is more efficient through the use of robotics and automation that eliminates human induced variability and waste, thus bringing the efficiencies in planning to bear directly with execution, making real the previous theory that planning and execution are synonymous. The underlying theory is that ‘perfect – correct, complete, coordinated and timely’ planning by both design and construction management translates into ‘perfect’ execution.

Eliminate down time, by robotics that can work 24/7/365, control of variables and elimination of internal and external discrepancies, conflicts and the resultant waste.

Coordination issues with other trades remain unless the whole project can be done with robotics and automation. ICT flow through one-of-a-kind project, on site and by differing teams requires a universal platform where activities and parts brought by suppliers and vendors are integrated, that is, the whole production template is changed. Apparently this radical change is cost prohibitive due to project peculiarities, especially one-of-a-kind, where increased complexity and cost does not yield sufficient project benefits and efficiencies for the required investment in time and learning.
Before proceeding with answering questions two, three and four, the authors discuss the issues of production paradigm (Ranta 1993; McLoughlin 1999), theories of production and production templates. The authors conclude that “industrial history indicates that improvements in the range required in construction happen only when the whole production template is changed.” This production template change is based on new big ideas, new theories (and we add “new paradigm”).

Answering the first query, Koskela et al. (2003) state that current trends and initiatives are mainly of the “individual (segmented) problem solving approach” and are based on a divide and conquer mentality (also called the scientific, transformation method, or decomposition). Regarding problem solving approach in quality assurance, for example, they held to the principle of constraint removal, the current mental model of production.

The next query posed is: How can the changes, in principle, be achieved? Koskela et al. (2003) accept the principle that a systemic change is needed in construction; how, then, can it be achieved? Construction places its hopes on external ideas as drivers for change, such as industrialization or ICT. Regarding industrialization, the target is to transform construction into manufacturing. Regarding ICT, the premise is that increased use of data sharing via computers/Local Area Networks (LAN)/Wide Area Networks (WAN - internet) will lead to organizational renewal and eventually increased efficiencies and waste reduction. However, both of these initiatives are deemed to increase complexity without benefits at this time. The observation that “something is wrong,” that there are “anomalies” in the current construction paradigm is echoed by Butler (2002) who states that: “Construction has become more and more complex. Disciplines have divided and sub-divided and whole new trades have sprung up. Contractors seldom self-perform a substantial portion of the work. To make matters worse, subcontractors are beginning to do the same by hiring their own subs to do the work” (Allen 1996).

The result of this downstream activity is, according to Bennet and Ferry (1990), a “total lack of production control.” Tilley and McFallan (2000) have documented that design and documentation quality has decreased at the same time that project cost, time and inter alia disputations, lower quality and lack of attention to sustainability have increased (Koskela 1992; Howell and Ballard 1997; Koskela 2000). This is attributed, by Koskela et al. (2003), to a progressively more forceful application of the transformation model of production: decomposition of the total transformation (the project) into smaller transformations and eventually tasks, then minimizing the cost of each task independently on the basis of the lowest price. This leads to two major problems: First, in the case of planning (design plans and management plans for construction), the completeness, correctness, coordination and timeliness of the documents tend to decrease with decreasing fees. Second, as planning is pushed downstream, the amount of coordination of production control
and corresponding variability tends to increase beyond what the project budget can bear.

The construction model (Ballard and Howell 1998a) is a model of project control, not production control, according to the "contractual agreement;" thus construction can be said to have no theory of production control proper. Tavistock Institute (1966) had pointed out that the disparity of the formal system (contracts, documents, Project Management, Schedule, Cost Estimating) and the informal system (on site, varying team, management of uncertainties, variabilities, discontinuities, tasks independence, sub-sub-contractors) in relation to the total task is the root cause of all the problems. The informal system manages a climate of endemic crisis which is self inflicted and self perpetuating. Two solutions are proposed, ICT and behavioral approaches, as previously seen. However, in most cases the participants become resigned to the notion that no meaningful, real change is possible.

Koskela (2003) argues that a change from transformation to a flow template can be achieved through deliberate design and imitation. In a practical way, theories should be used for explaining why problems exist and how they can be avoided (Koskela and Ballard 2003). Experimentation should then be used for translating theories into practical methods and tools.

The next query approached is: Where should change start? Two approaches to this query are presented: First, basing the owner’s procurement strategy on performance, rather than cost. Performance is considered at the beginning of a project, where the scope of the project is created (chaos theory states that minor, almost insignificant, deviations at the start end up in crisis). Second, working with those that actually manage production, the end where the product is created (design, pre-fabrication, erection, on site construction and site personnel). Koskela et al. (2003) argue for starting at the end because this is where cost, time, and quality are concretely formed and because what we learn can be taken upstream.

The final query is: How can change momentum be maintained? The authors address two interrelated levels of change momentum maintenance: the firm and the industry. At the firm level (organizational change, Beer and Nohria 2000), one approach focuses on top-down changes on formal structures and systems to mainly create economic value (thus termed Theory E). The other approach focuses on the development of a culture of high involvement and learning in a participative manner (hence Theory O). Koskela et al. (2003) proposes using both E and O simultaneously creating ‘small wins’ (Weick, 1994) with each step-by-step change. Through controllable opportunities of modest size that produce visible results and serve as background to identify the next possible problem to solve, a pattern is thus built that attracts allies and deters opponents. The iterative process of problems-solving changes needs to be scrutinized prior to experimentation by the following questions:
• Is there a Plausible Explanation (PE) – at a sufficiently detailed level – as to why the candidate solution would work?
• Is there Empirical Evidence (EE) showing that the candidate solution brings the benefits sought for?
• Is the candidate solution self-standing or does it requires surrounding (ancillary - AN) changes for working efficiently and providing manifest benefits?
• If the solution is imported from another domain: Has it been conceptually and Empirically Confirmed (EC) that the solution works in the context of construction?

This iterative process appears similar to Popper’s (1972) philosophical method of analysis (Conjecture and Refutations) and applicable mostly to individual (segmented) rather than systemic cases. Because it is applicable to individual cases, the following iterative process may now apply:

\[ P_1 = \text{Original Problem} \]
\[ TT_1 = \text{Tentative Theory} \]
\[ EE_1 = \text{Error Elimination} \]
\[ PE = \text{Plausible Explanation (why it should work)} \]
\[ EE = \text{Empirical Evidence (will achieve expectations)} \]
\[ AN = \text{Self-standing/Ancillary effects} \]
\[ EC = \text{Empirical Confirmation of transferability} \]
\[ P_2 = \text{Emerging Problem} \]

In conclusion, Koskela et al. (2003) argue that (1) a systemic change (not problem specific oriented change) has to be achieved for eliminating root causes of the problems, (2) external ideas or impacts (industrialization and ICT) are not the solution, but a ‘new big idea’ for managing construction has to be found--a new paradigm, (3) instead of upstream structural changes (contractor and organizational top-down), we should look at operational changes downstream that create the end product and work backwards, (4) changes do not occur automatically even in a favorable environment, but through small wins in a fragmented milieu that gather strength and eventually achieve system-wide changes in an entrepreneurial environment.

Why were these statements made?

Current trends and initiatives are neither radical nor sufficient to engender a structural change in the industry, but it remains to be established what kind of change is needed and how these types of changes can be implemented and maintained (Koskela et al. 2003). This paper centers around the research needed to answer four well posed queries with the \textit{a priori} presumption that construction is a fluid industry that cannot be changed overnight, that incorporates a cursory
definition of “fragmented.” A better definition of how construction is understood to be fragmented or fluid is needed beyond what is presently available through a literature search, for recommended future work or even a possible dissertation topic.

This proliferation of trends and initiatives is not uncommon in a pre-paradigm identification scenario, according to Kuhn (1962): During both the pre-paradigm period and the crises that lead to large-scale changes of paradigm, scientists usually develop many speculative and unarticulated theories that can themselves point the way to discovery. Often, however, that discovery is not quite the one anticipated by the speculative and tentative hypotheses. Only as experiment and tentative theory are articulated together to match does the discovery emerge and the theory become grounded.

What are the author’s arguments and proposed solutions?

Koskela et al. acknowledge that a “big foundational idea change” needs to take place if the construction industry is to be changed significantly. Koskela et al. (2003) analyzed the two change approaches according to Papert (2000): problem-solving approach (individual problem solution) and the systemic approach (how the whole thing works). Afterwards, Koskela et al. (2003) concluded that a problem-solving approach, from the bottom-up, that acknowledges how things are done may be indicative of a practice, technique or craft that could be analyzed for pertinent theories that can then be incorporated with an overall frame. However, the validity of this approach must be confirmed by an equally well adjusted flow between paradigm-rules-theories-practice in both the downstream and upstream modes.

The argument is then made that industrial history indicates that improvements in the range required in construction happen only when the whole production template is changed.” This production template change is based on “new big” ideas--new theories. These statements point to a need to identify the reigning paradigm and establish once and for all what kind of industry building construction represents, if the term fits and applies, and if not, what building construction is, based on the existing paradigm. When confronted with anomaly or with crisis, scientists take a different attitude toward existing paradigms, and the nature of the research changes accordingly (Kuhn 1962). The proliferation of competing articulations, the willingness to try anything, the expression of explicit discontent, the recourse to philosophy and to debate over fundamentals--all are symptoms of a transition from normal to extraordinary research. This transition could assume any of the following manifestations:

1. In principle, a new phenomenon might emerge without reflecting destructively upon any part of past scientific practice; or
2. A new theory might be simply a higher level theory than those known before, one that links together a whole group of lower level theories without substantially changing any of them; or.

3. In an evolutionary sense, new knowledge would replace ignorance rather than replace knowledge of another and incompatible sort.

From Koskela et al.’s (2003) statements, it appears that his position aligns with Kuhn’s statement number 2 mentioned above. We argue, on the other hand, that statement number 3 is more applicable: Considering ignorance about what is the prevailing and active construction paradigm, a new basic and probably very simplistic knowledge (such as the earth is round, or that the sun is the center of the universe) may end up as a better accounting of the found anomalies and current crisis.

**What did he develop?**

Koskela et al. (2003) developed a method for analyzing four commonly understood solutions in the areas of structural, behavioral, communications (information management) and physical (machinery) that we adapted into Popper’s Analytical Process (iterative method of conjecture and refutations).

Koskela et al. (2003) developed, or elucidated, the issues surrounding increasing complexity of the proposed trends and initiatives without significant results. This brings to mind Kuhn’s (1976) statement: “When complexity increases far more rapidly than its accuracy or benefit and that a discrepancy corrected in one place is likely to show up in another may lead to a similar proclamation as that of Alfonso X that if God had consulted him when creating the universe, he would have received good advice, or Copernicus comment in *De Revolutionibus* that the astronomical tradition he inherited had finally created only a monster.” “Proliferation of versions of theories is a very usual symptom (or concomitant) of crisis” Kuhn (1976).

The acknowledgement that construction is a fragmented industry is one of the more significant insights or statements made, along with the differentiation of formal planning as per Project Management and informal planning as per the job trailer executors, operators. The discrepancies, variabilities and constraints between these two modes of planning (actually he calls Project Management planning and on-site executing or implementing), along with the concept of fragmentation in the construction ‘field’ is significant to an understanding of actual operations and may lead to insights about the existing paradigm. Carassus (2004) observes: “Fragmentation is determined in particular by three factors: fragmentation of the order, the degree of technical complexity and the capital intensity of the activity.” Each segment of the ‘sector system’ contains a large number of companies. He calls this “differentiated fragmentation.”
Gut reaction to particular issues.

The current reading has added to the issues of discontinuities, variability, constraints, peculiarities, and lack of theory, the issues of fragmentation and the anomalies innate in current concepts of planning.

Applying Slaughter’s (modified) Change Taxonomy

The hopes for significant improvements in construction continue to be manifested in the search for a new (radical?) template, theory and paradigm of the industry that allows the different types of pegs to be inserted with a ‘good fit.’ Otherwise we can expect incremental innovations to come from supply based viewpoint.


Koskela (2003a) analyzes the causes for the well known problems of construction. A number of renewal initiatives such as industrialization, open building, design-build, partnering, re-engineering, Just in Time, Lean Construction and others are mentioned or analyzed. These initiatives imply or claim to be structural changes to the organizational pattern and or the flow of information and materials. Koskela (2003a) proposes a theoretical framework in order to discuss the issue of structural adequacy of these initiatives composed of three main theories (1) production, (2) management and (3) peculiarities in the building construction industry (Nam and Tatum 1988; Riis et al. 1992; Wortmann 1992a and b; Wortmann et al. 1997), as follows:

This framework is composed of a theory of production (incorporating the aforementioned concept of transformation, flow and value –T, F & V) and a theory of management and conceptualization (design, operations and production system improvements) and a theory of the peculiarities of construction (on site, one-of-a-kind and temporary organization). Based on this framework, a number of conclusions are drawn:

Due to its peculiarities, construction is characterized by a high level of variability (a role of management is therefore to stem the penalties due to variability and the further propagation of variabilities).

All renewal initiatives have given modest if not disappointing results.

Although Koskela (2003a) admits that the causal relationship of such disappointments cannot be definitively established, he suggests that the neglect of changes at the level of operation and improvement contribute to the lack of results.
Therefore, he argues, we “need to develop further the theoretical foundations or first principles, of production in general and especially in construction.”

**Why were these statements made?**

Based on his dissertation, in this study, Koskela (2003a) analyzes a selected number of the trends and initiatives in construction that address the well known problems of construction. Problems or identified anomalies are the starting point of the argument that well intended structural changes to the organizational pattern and/or the flow of information and materials fail to achieve the desired results, viewed from the framework of his production theory (T, F & V) and the peculiarity theory (on site, one-of-a-kind and temporary organization).

**What are the author’s arguments and proposed solutions?**

Koskela (2003a) proposed solution is to highlight the need to develop further the theoretical foundations, or first principles, of production in general and especially in construction. The theoretical foundation, however, still looks to manufacturing for guidance, frame of reference and theories (Heim and Campton 1992; Hop and Spearman 1996).

**What did he develop?**

Koskela’s (2003a) thrust, in order to correct the neglect of changes at the level of operation and improvement, is to highlight the need for a more integrated theory of production based on the T, F & V concepts. The difficulty of establishing causality is acknowledged by Koskela (2003a), but the issues, even if they are muddied, are real and merit confrontation. Kuhn (1976) acknowledges the immense difficulties often encountered in developing points of contact between theory and practice, especially when the underlying worldview does not allow for a clear and obvious connection of theory to practice, which may be the current case. What appears to be taking place throughout these studies is a preliminary identification of the puzzle or parts of the puzzle that could lead to worldview (paradigm) identification, a subject that will be treated at length in Part II.

**Gut reaction to particular issues.**

Per Kuhn (1976) we see building construction search for an identification of deficiencies and anomalies and a concerted attempt to incorporate the technologies, frame and theories of production that continue to rub against the grain of a theory of construction peculiarities. Adding complexity to a system without significant results is a sign that the working paradigm is not properly attuned to the circumstances; however as mentioned, there have been few attempts by this and other writings
identified through the literature search (Ballard and Howell 2003a; Groåk 1994; Ranta 1993) at identifying an existing building construction paradigm.

Applying Popper’s (1972) method of conjecture and refutations:

\[ P_1 = \text{High level of variability perceived as an anomaly} \]
\[ TT_1 = \text{Need for a theoretical foundation or first principle of production in general and specifically of building construction based on theories of: 1. production, 2. management, and 3. peculiarities} \]
\[ EE_1 = \text{Eliminate variabilities and the propagation of variabilities} \]
\[ P_2 = \text{No clear and obvious relationship exists between theory and practice, but levels of complexity are added to the process; possible crisis and realization that current paradigm (building = manufacturing) cannot resolve the anomalies and crisis} \]

Applying the Slaughter’s (modified) Change Taxonomy

Construction interpreted as a ‘system’ continues to elude efforts at control in the production and process variability aspects. The changes that these efforts generate can be considered incremental (gradual). The peculiarities of construction interfere in capturing ‘once and for all’ lessons learned in the total construction process, although they are captured in the specific product manufacturing industries.


This article discusses Koskela’s (2000) treatment of the T, F & V construction peculiarities based on the findings of seven practical examples, as to whether construction must and can always be improved by resolving the peculiarities and at what cost. It is concluded that the peculiarities should be resolved when they are not needed. However, before a decision is made, the additional costs or even the potential value loss that may be caused by peculiarities must always be related to whole life costs and value of the object built, along with the extra cost and effort expended for resolving the peculiarities.

Why were these statements made?

After several years of wrestling with issues of building construction peculiarities, the lack of fitness with manufacturing and industrial paradigms has brought a resignation that perhaps the cost and effort for eliminating the peculiarity (or peculiarities) is not proportional to the benefits when considering the whole life cost of the object built. Most of the studied cases are residential, where components,
although variable, can be made to fit a particular module and thus facilitate the amelioration of a peculiarity or two.

**What are the author’s arguments and proposed solutions?**

The solution is to live with the peculiarity of construction, and put aside the quest for the “BIG IDEA” that would make construction be like manufacturing.

**What did he develop?**

A comparative analysis of differing examples was developed.

**Gut reaction to particular issues.**

The issue of finding construction’s unique existing paradigm remains.

**Applying Popper’s (1972) method of conjecture and refutations:**

- \( P_1 \) = High level of variability perceived as an anomaly
- \( TT_1 \) = Theories of: 1. production, 2. management, and 3. peculiarities, do not resolve variability. A new theory of construction is needed.
- \( EE_1 \) = Eliminate variabilities between theory and practice but one that conforms to practice.
- \( P_2 \) = A new worldview is needed that approaches the problem from a different direction.

**Applying Slaughter’s (modified) Change Taxonomy:**

A new paradigm may entail a radical change in levels of variability, while continuing the gradual and systemic efforts at reducing that variability. However, the elimination of the variability is not possible under the current framework and furthermore, it may not even be in the best interest of construction, since variability may be the locus of innovation (like the possibility of constant mutation in RNA/DNA is the source of variability in nature).

**4. Change Taxonomy Matrix**

The research work on construction and the two techniques from industry are improvements on historical methods and techniques, based on what works and how it works in the field (see Table 1). These improvements are gradual in nature and it is not anticipated that the process or the product will change drastically in the near future. If the efficiencies that are observed in manufacturing and other industries are not realized, we may have to change the paradigm of the industry to one that
accommodates the observed nature of construction, at least until a radical change is invented ("first time technology," Garcia Bacca 1989) and then a paradigm change can be articulated.

Table 1. Application of Slaughters modified Change Taxonomy to SoA Research and Techniques

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5. Conclusions

Bury (1932), as quoted by Mitcham (1994), observed, “The spectacular results of the advance of science and mechanical technique brought home to the mind of the average man the conception of an indefinite increase of man’s powers over nature as his brain penetrated its secrets. The evident material progress which has continued incessantly ever since has been a mainstay of the general belief in progress that is prevalent today.” Progress in the construction industry can be discerned by looking at the state of the art research, initiated primarily by academicians.

This state of the art research in construction can be characterized as mostly dealing with the “know how.” Recent publications have portrayed the lack of theory, or “know why” as a blind spot in our knowledge and perhaps a source for the lack of progress towards efficiency in the construction industry. When a segment of state of the art research, dealing in particular with the topic of theory in construction, is analyzed, a mosaic of the industry can be perceived, albeit subjectively.
This paper on the topic of theory showcases a mosaic of the construction industry through which an image emerges: the systemic nature of the industry and its capacity for change (see Fernández-Solís 2006, 2007a). The emergent systemic nature of the industry opens up the possibility of a better paradigm for construction, one that is based on integrating the observed anomalies between industrial expectations for construction (the current paradigm) and its actual performance.

Construction is a complex industry with inherent inefficiency, which is also the breeding ground and source of creativity. The changes in construction are mostly incremental or systemic in nature, as shown by the analysis of the state of the art research in construction, using Popper’s analytical technique of conjecture and refutation. The systemic nature of the construction industry has the inherent characteristic of complexity and appears to be unique among all other industries. The rate of change and adaptation in the construction industry is also relatively slow when compared to other industries, a statement relegated to further study.

A paradigm that accommodates the intrinsic nature of the industry needs to be sought, rather than continuing to force the industry into a manufacturing (industrial) paradigm (see Fernández-Solís 2007b).

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