

THESIS

KNOWLEDGE MANAGEMENT
IN THE BUILDING INDUSTRY

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ABSTRACT

KNOWLEDGE MANAGEMENT

IN THE BUILDING INDUSTRY

Research studies of the American building industry from as far back as the 1920's, and through to the 21st century have been consistently critical of the inefficiencies and mismanagement in industry practices (AEC, 1921; NRC, 1952; Lefkoe, M. R.; 1970; NRC, 2009). The American industry grew and learned from European and British practices, which have not fared much better and have been equally criticized for decades (Latham, 1994; Egan, 1998). It is these same practices that are now a major influence on how the global construction industry conducts itself today. The same influences, impacting today's global industry's professionalism and managerial methodologies, have also greatly influenced the creation and practice of international construction law – based on western settled law.

This research identifies that institutional practices of the building industry's governance and contractual practices have led to widely applied self-imposed industry constraints; which manage discrete, limited and specific information, but constrains knowledge. These restrictions on critically valuable knowledge have caused great inefficiencies, and formed a *traditional* business methodological phenomenon that propagates adversity.

Traditional western industry practices, and numerous variants of it, have established a legal base of *stare decisis*, or “to stand by things decided;” these legal decisions have emboldened an invariant legal construct which restricts innovation in the assessment of existing and proposed industry practices. Studies of the building industry have too often sought to use

legal precedent to the detriment of the industry, in lieu of harnessing it and advancing industry innovation through discrete engagement.

Project¹ contractual constructs increasingly magnify project complexity and restricted knowledge exchange under the guise of a premature assumption of unknown risks in projects that have yet to be designed. While simultaneously hindering processes that seek to be inclusive, collaborative and successful in producing a documented, clear contractual intent agreement, that eliminates phantom risk, prior to commitments to specific project events.

The advancement of dynamic social and transactional business management processes, enables the creation of knowledge that is focused, timely, economical, and shared; identifying data, ideas, insights, opportunities, questions, issues, and problems, in a defined context, or event². Such processes promote the questions of “Why,” “How,” “What,” “Where,” and “When,” within the problem context (or event) structure (Von Krogh, G., Nonaka, I., & Ichijo, K.; 1997). The *Processes* for Knowledge Management, and their contexts (*events*) for knowledge vision and innovation, create expectations and roles for resources (asset specificity) who through process governance and discrete contextual transactions, limit risk, manage time, cost, and quality of the components to make a project whole³.

¹ *Project(s)*, for this thesis, is defined **not** as a *one-off*, but as a context where many interdependent activities and events reside, in differing states of existence or maturity

² The terms *Context(s)* and *Event(s)*, when used in this thesis represent where knowledge related to tasks or activities, in design and construction (the building industry), are created and improved upon. They serve as a reference to locate knowledge within a process management structure; thus organizing discrete networks of explicit and tacit knowledge (resources and assets), eliminating bureaucratic barriers to knowledge access. Tasks and activities are granulated to increase quality management.

³ *Transactions*, within this thesis, form a governance structure, that manages both the physical and non-physical resources and assets, including knowledge, that are required in the specific contexts (or events) of specific building industry tasks or activities.

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LIST OF KEYWORDS

Architecture

Building Industry

Business Process Management

Construction

Construction Management

Design Management

Integrated Project Delivery

Knowledge Management

Process Management

Process Manager

Chapter 1

Introduction

1.1. Incomplete Contracts, Delays, and Litigation

Today's building projects are perceived as a singular whole endeavor accomplished through linear subsequently phased sequences of service and production executions. Any variations to such planned executions, after phase completion, are most often deemed as causations for claim delays and disruptions in subsequent operations.

In the last ten years or more, several hundred commercialized project management websites have propagated the internet and are based on the same phased execution governance-structure that has existed for, and proved legally problematic, for the last fifty years. These tools serve to document and transmit explicit data and information at a faster pace. These tools serve only to attempt to manage the industry's inherent legal processes in an ever-increasing networked interdependence. According to William Davidow, our *over-connected* society has become ever more subjected to "unpredictability, accident-prone (ness), and subject to contagions." A greater demand for *information* provides more *information*, but does it provide the right *information* at the right time to the right people, in the correct context, that is a critical challenge in the building industry. The industry touts a new mantra of satisfying customer needs; but, when the customer's needs require change, the customer is vilified with the legal consequences of such a change (Davidow, 2011).

1.2. Problem Statement

International and domestic efforts for industry improvements are most often based on the discrete transfer of data and information within the building industry, in accordance with *traditional* contracts and other sequential *waterfall* project delivery methodologies. Such

delivery methods require the traditional explicit definition of a scope-of-work, either in its entirety, or more often in a phased manner that can result in a more subjective and incomplete interpretation. A related issue within the building industry today, that no known research has addressed, that building projects are contracted, and perhaps construction started, before anyone- including the owner- knows what the end product will be. There is an increasing existence of a fluctuating gray period of time, during which potential building designs (research and development) and potential construction (production) activities proceed simultaneously. As the research and development activities provide new or updated information to the construction activities, contract disputes ensue over changes in contract cost and time.

The scope of construction contract disputes globally are increasing. The global industry's' contract mega-disputes in the first half of 2014 have totaled \$160 million, and have lasted a year on average to resolve (Harris, 2014). Ten years ago the U. S. Department of Commerce reported a conservative estimate that the U. S. Commercial, Institutional and Industrial capital facilities' experience \$15.8 billion in inadequate business practices, standardization and technology adoption (GCR, N. (2004); and a yearly average from \$4 to \$12 billion in construction litigation costs in the U. S. alone (NCR, 2009; pg. 15).

1.3. Purpose Statement

This research seeks to acknowledge that beyond data and information, there exists knowledge, both in explicit and tacit states, which is critical to building industry success. Knowledge, in the building industry, is not typically recognized unless it is within the contractual context in a solely explicit state. This research seeks to understand and conceptualize a conceptual network framework for an institutional and project, process-based knowledge management system for the improved synthesis of knowledge and the increased efficiency of the building industry.

1.4. Research Questions

How has knowledge management in the building industry evolved into its' current state?

What lessons can be learned from this evolution in regards to the processing of information and knowledge?

Can new business process management methodologies be developed to increase efficiencies, decrease uncertainties, and deliver better projects through a knowledge-based process system?

1.5. Boundaries and Limitations

Historical research is presented in a concise fashion, which seeks to identify key evolutionary changes. Particular events (knowledge contexts) or changes may have been deemed less impactful within the industry; others may see these events (knowledge contexts) otherwise. The historical research is more limited to western development of the building industry, whose methods appear to be dominant globally.

A conceptual networked knowledge-based process model shall serve to represent an *advocacy* from the perspective of the project and the knowledge generated within it. A process model seeks institutional improvement, to serve the customer. “Traditional” practices, which are most representative of the industry since the 1950s, are critically analyzed for academic study.

1.6. Conceptual Framework

The research is to include an exploratory study of the historical foundations of knowledge management within the building industry, which shall inform a new conceptual knowledge process model.

A new conceptual networked building industry knowledge-based process model is hypothesized to exist in a graduated network of a project(s)'s definition, to provide *definable* environments, which are managed by a knowledge-management system structured to manage an

event (knowledge context) processing framework focusing upon the dynamic granulated design and development of a project and its subsequent physical production.

The scope of frame-worked events (knowledge contexts) shall accommodate a dynamic dialectical process of actions and interactions that synthesizes knowledge, and nurtures the process of knowledge transcendence and conversion from the abstract tacit to the explicit and discrete (Nonaka et al., 1995; Nonaka, et al., 2003). A cooperative consultancy framework shall serve to engage, inform and confirm project specific explicit and discrete information that can serve to address a project's needs and define a project either in its entirety or in discrete managed scopes-of-work, facilitating innovative, dynamic and evolutionary project definition.

1.7. Research Methodology

An exploratory analysis of the development of the building industry is first presented, keeping in mind Senge's first point in describing principles of the Fifth Discipline, "*Today's problems come from yesterday's "solutions"* [italics and quotes in original]" (Senge, et al., 1994; pg. 57).

This is followed by a pursuit to define the institution, governance and the execution of events (knowledge contexts) that are needed to lead to a successful project outcome. A conceptual *proof-of-concept* model is then developed and presented that is intended to provide a launch point for future research in the development of a more holistic model.

Chapter 2

Review of Literature

The following review provides a foundational understanding of the building industry and its problems that have resulted in a modern day adversarial business environment. The objective of the review is to understand the governance and contractual contexts that have made one of the worlds' oldest and largest industries into one of the most inefficient. The building industry is fraught with risk. Risks resulting from perceived and actual uncertainties have resulted in a governance structure that seeks to exhaustively document not solely the scope of the intended work, but more importantly any and all potential causation of *interference* between project participants. As is the case with construction legal claims, it has been deemed critical in standard practice to identify causation, so as to assign blame. These efforts are believed to have added to the bureaucracy, the inefficiencies, and costs in the building industry.

The literature review seeks to understand the development of current practices through a brief historical exploration; followed by a review of governance, contractual and managerial efforts in complementary industries. Based on these reviews, a new process framework shall be presented as a *proof-of-concept* model that shall address the challenges to the building industry.

2.1. History of the Building Industry

The building profession may be the oldest profession known to man; for shelter is the most basic of necessities for survival (Shute, 1573). The editor of International Construction magazine, places the value of global construction at seven-and-a-half trillion dollars, roughly 10-percent of the global economy (Sleight, C., 2014).

The documented role of building in human society has a history of more than 4,500 years; and construction laws, or building regulations, are known to date back to 1750 B. C.; when

Hammurabi's Code, with its "eye for an eye" system of justice ruled in the Middle East; Hammurabi code provision number 229 states: "If a builder build a house for someone, and does not construct it properly, and the house which he built fall in and kill its owner, then the builder shall be put to death" (Allensworth et al., 2009).

During Julius Caesar's Roman times (63 B.C. to 14A.D.) Vitruvius, chief engineer to Caesar, prepared a ten-volume treatise on Roman building practices, which recognized the need for suitable soils, managerial competence and cost control, and also favored definition of scope of work and allocation of risk. From the time of Imperial Rome through to the 19th century, law as it applies to building practices had been generally regulated by local, crown-law, and parochial perceptions (Allensworth, et al., 2009; Ettlinger, 1977). By the 19th century, common law, derived by previous judicial decisions, had come into use (Allensworth, et al. 2009). Common law, which originated in England in the 13th century, together with constitutional and statutory law, has served as the foundation for design and construction contracts to this day (Allensworth, et al., 2009).

2.1.1. The Architect

As far back as Plato (Politicus 259E), Architects were described as "rulers of workmen", who "contributed knowledge, not craftsmanship;" who were engendered two endowments, *knowledge* and *innovation*. Societal cultures sought special structures to establish hierarchical displays of governance and stability. The emerging profession of the Architect required a source for their knowledge and for this Vitruvius had written in his treatise: Architects shall be proficient in "all the arts and sciences" (Kostof, 1977).

During the Dark-Ages, also called the Middle-Ages, from the fifth to the fifteenth centuries, western societies experienced a *cultural and economic deterioration*; by the ninth

century the decline had stabilized somewhat with the rules established by the era of Charlemagne, together with the church and its' related monasteries; providing structure to society, and an intensified demand for Architecture for the nobility and religious orders (Ettlinger, 1977). By the end of the Middle-Ages, a *renaissance* or *cultural awakening* renewed interest in arts and architecture, beyond those of exclusive social class. Marking this awakening, Leon Batista Alberti, following the example set by Vitruvius centuries before, wrote a more modern treatise on building, *The Ten Books on Architecture*. Alberti's publication established a societal distinction of the Architect as a gentleman and a *professional* (Wilkinson, 1977). Alberti's Ten Books addressed not only rules, but consideration for Value, Climate (Air), Views, Serviceability, Durability, Partitioning, and Regional climate. He presented the Architect as capable of designing all things, from humble farmhouses to palaces and cities (Alberti, trans. 1755).

By the reign of Elizabeth I in the sixteenth century, the *Science of Architecture* had arrived in England. John Shute, in the first known English language writings of classical Architecture, described for the crown the Practice-of-Architecture and the duties of the Architect. Shute wrote "*Architectur [sic] (by the common consent of many notable men) as celarius joyth [sic], ys of all artes [sic], the most and excellent, containing in it sundrie [sic] sciences and knowledge wherwyth [sic] it is furnished and adourned [sic], as full well Vitruvius doth affyrme [sic] and declare by his writings*" (Shute, 1573).

Shute, having been sent by his noble employer to study in Italy, sought to represent the "Renaissance ideal of the designer as universal man," accomplished in the tools of architecture, as well as "literature, history, and philosophy as well as medicine and astronomy." In the era of Post-Reformation, as nation states arose, an increasing number of *men-of-property* sought out Architectural services to establish their estates. The Architect, in serving his clients, was

characterized as a gentleman known to work in collaboration with the builders, as was common in much earlier times (Wilton-Ely, 1977).

These men-of-property sought to ensure claim to their lands and they sought those knowledgeable of structures and their art of influence. As with John Shute, either men of means or those in their employ, traveled to enrich their knowledge. In the decades and centuries to come, a number of these travelers, thanks to the invention of the printing press, began to share their observations to those who could afford to buy such publications. By the sixteenth century such publications included what were termed *pattern* books; the gentleman property, a man of means, might attain such books so-as-to dabble and direct workmen in their own building endeavors; and even call himself an Architect (Wilton-Ely, 1977).

2.1.2. The Surveyor

Another gentlemanly profession that arose to serve the men-of-property was the Surveyor. The Surveyor was educated in Arithmetic, Geometry, Trigonometry, and Measurements. With this education, the Surveyor initially served to quantify trade goods subject to taxes or tariffs, transported both by land and by sea. For men-of-property, he served first to survey, measure and map gentlemen's estates so as to establish boundaries, and secondly to ensure that taxes paid were appropriate to actual size and use. Measurements, as provided by the Surveyor, would expand to include the quantification of building materials. Originally such measurements may have been as simple as measuring and grading trees or logs, stones, and other raw materials; to then be milled, shaped and placed. This surveyor services would grow to include the quantification and qualification of milled boards, glass, brickwork, and all other materials required for building; providing a scrutinized detailed accounting of materials to prevent errors in accounting thereof. It was not uncommon during this time that those who became aligned with

the profession of architecture were often Surveyors as well (Davis, 2006, pp. 102-106; Leybourn, 1722; Wilton-Ely, 1977).

Today a globally recognized organization, the Royal Institute of Chartered Surveyors (RICS), founded in London in 1792 as the Surveyor's Club, is seen as having established global standards for the profession of Surveying. In 1791, the previous year, the Architect's Club of Great Britain was formed, to be followed in 1834 with the Royal Institute of British Architects, a true professional organization, as recognized by Queen Victoria, hence its' *Royal* prefix. In 1788, Sir John Stoen, noted father of the profession and the first Professor of Architecture at the Royal Academy, provided an updated definition of the Architect's professional responsibility: *"The business of the Architect, is to make designs and estimates, to measure and value the different parts; he is the intermediate agent between the employer, whose honour [sic] and interest he is to study, and the mechanic, whose rights he is to defend. His situation implies great trust; he is responsible for his mistakes, negligences [sic], and ignorances [sic] of those he employs; and above all, he is to take care that the workman's bills do not exceed his own estimates."* (Wilton-Ely, 1977).

As we will see in the United States, the English Royal household had been termed the Office-of-Works, which oversaw all construction for the head-of-state. This office, by the eighteenth century, would be headed by a Surveyor, but by 1761 was headed by an Architect.

2.1.3. *The Clerk-of-Works*

The Clerk of Works, in England, is a term originating from the year 1241. In that time it was a royal appointment that was tasked to oversee the scope and financing in the construction and modifications to royal castles. By the 19th century, the position of clerk-of-works was one paid directly by the building client, but was "*employed by the architect*, [italicized in original] to

whom he is responsible for the perfect performance and execution of the various works under his care and supervision, in accordance with drawings and specification, and such written or verbal instructions as he may from time to time receive from the architect during the progress of work” (Hoskins, G. G.; 1876, pp. 11-12).

The clerk-of-works was knowledgeable of building trades and methods, raw materials, measuring and valuing of both work and materials. He serves as the custodian of all drawings, specifications and sketches, and he serves to convey their intent and guidance, in regards to what is to be done-and not how it is to be done. A project contractor is responsible for ordering all required materials, staging the work, and laying out all the components of the work. The clerk-of-works shall serve to check the work of the contractor; in quantities, measurements, and quality, but does not assist the contractor in his performance of his duties. The clerk-of-works reports progress and his findings to the architect with daily reports. Such reports include weather, drawings received, drawings required, number of workers per trade on-site, and values of work put in place. Included in his report, he would also include any additions, deductions or deviations from the contract to date. The contractor in this arrangement is plural, in that the clerk-of-works contracts on behalf of the client for each separate trade; though often a major trade contractor may be permitted to subcontract others trades, creating a “sole-contractor” arrangement ((Hoskins, G. G.; 1876, pp. 12-16, pg. 20).

Through the fulfillment of his official (clerical) duties, the clerk-of-works serves to monitor the work. In preparations for foundation, the clerk serves to inspect the soils, to ensure that an adequate foundation accounts for actual soil conditions. This phase of the work also includes the placement of buried pipe drains, for which the clerk inspects for pipe for damage and proper slope. Where piping and foundations intersect, the clerk ensures that the different trades are in

accommodation of one another. As building materials arrive the clerk inspects them for quality and quantity. As work proceeds, the clerk shall ensure that portions of the specifications related to the protection of work-in-place is complied with by each of the trades (Hoskins, G. G.; 1876, pp. 20-35).

The clerk shall also ensure that accommodations for subsequent work, by the same or different trades, are put in place to protect against the need to dismantle completed work in the future.

Such required accommodations and the efforts for their execution “were termed the “scourge of the architect and the dread of the proprietor”” (Hoskins, G. G.; 1876, pp. 32-34).

2.1.4. *The Builder*

By the beginning of the nineteenth century the city of London was experiencing a population explosion, which would nearly double the population in thirty years. A need for organization in the construction of large amounts of housing was seized upon by Thomas Cubitt. Cubitt, a carpenter by training, became the first to be termed a General Contractor; he would more famously be known as a developer. Cubitt became the first builder to bid out subcontracts for a fixed price, versus the traditional *costing by piece-work* of the time. This went against the grain of the tripartite client-designer-craftsman relationship. With Mr. Cubitt's exception, the term *architect*, from the time of the seventeenth century, was understood to represent the person who prepared the designs and worked on the building site. The architect supervised the building site, hiring and coordinating trades. To represent the architect, particularly on larger projects, he would engage a superintendent. The superintendent was required to be familiar with the design, building materials, tools and methodologies. He served the architect in the inspection of materials and the quality of work completed by the craftsmen, and he coordinated the hiring of individual craftsmen as needed for the work. As building knowledge and the sophistication of

building processes increased, both the craftsmen and the architect were required to know more and more, and each increasingly referenced published works to increase their knowledge. The industrial revolution, from about 1760 to 1830, with increased building demand would further define the roles of builders (Davis, 2006; Wilton-Ely, 1977).

2.1.5. Professional Education

The nineteenth century saw three locations where architectural education was taught: Florence, Italy; Paris, France; and Munich, Germany. Italy and France placed great emphasis on the artistic nature of the profession which grew out of the Renaissance, whereas Germany, in addition to artistic studies, was known for studies of materials and engineering. Most of these programs included both classroom/studio training but would also include practical apprenticeships in the offices of architects and engineers as well. The Paris educated architects would have a great influence in America in the latter half of the nineteenth century, whereas German educated architects would have a great influence in America after the second world war (Ettlinger, 1977; Wilton-Ely, 1977).

2.2. The Building Industry in America.

The early European settlements in America, particularly religious and trading companies, employed carpenters to design and construct buildings in societal settings. These trades were composed of master carpenters and journeymen. By the early eighteenth century, other building artisans, such as masons, bricklayers, joiners, glaziers, painters, and plasters came into existence. Master carpenters were known for their possession of both technical and supervisory skills, originally called “undertakers”, and were sometimes called the master builder. Just prior to and after the U. S. Revolution, building trade organizations, or guilds, began to form, as had occurred in Europe and Britain (Woods, 1999).

2.2.1. *The Architect in America*

With the founding of a new nation, and the need to establish its' legitimacy, those who were Architects of British or European training were sought for the erection of public buildings. By this time the use of the term architect, was of critical discussion among those of foreign training. Most often at the time, an architect was either a gentleman, educated through travels, books and cyclopedias, as original gentlemen had done in Europe, though they had little formal training; or they were master artisans. It was Benjamin Henry Latrobe; a British trained architect and engineer, who President Jefferson (a gentleman architect himself) had selected to design and supervise the construction of the U. S. Capital in Washington, D C. Latrobe had been hired by Jefferson to expand the President's House (now the White House), after his moving in. Subsequently Latrobe would often times be called the father of the Architectural profession in the United States. During the Capital's original construction, and later reconstruction after its burning during the War of 1812, Latrobe's design(s) were not received well. The capital's design would be criticized by not just members of the public, but by members of the U. S. Congress, whom he described as "clowns and buffoons". For his classically endowed architectural efforts, Latrobe asserted that their perceived worth may yet be deemed "to be practicable" only in the centuries to come" (Woods, 1999).

After the battles of war had ended, a great effort arose for the construction of customs houses, state capitals, hotels, banks, exchanges, universities, schools, hospitals, asylums, and penitentiaries. With these large scale works, there still existed a large bond between the upcoming professional architect and the master builders. But, at least one master builder, and author of numerous publications including the 1830 publication *The Practical House Carpenter*, indicated that the Architect needed to be distinguished from the builder. He noted that the

architect was a great source of information and invention, and criticized people and groups who sought economy or their own individualistic fancies (Woods, 1999).

2.2.2. Builders in America

Entrepreneur craftsmen, particularly master carpenters, were known to be engaged to design and construct the simplest of buildings, with great reference to published pattern books. Private businesses, most often, engaged a gentleman architect, who would supervise the construction. As late as 1908, published manuals instructed architects in the operations of building superintendence (Nichols, 1908). As the architects became responsible for larger projects, architects would have superintendents in their employ.

The building industry was changing from the master and apprenticeship relationship. Though demand for buildings had increased, the master was becoming the employer, the apprentice was becoming the employee. The employer, the master builder (master carpenter), was now often responsible for very large-scale projects and spent more of his time concerned with managing finances, materials and employees. The superintendent, employed by the architect on behalf of the owner would become increasingly important to manage the job site. As was common in Britain, the superintendent would contract with individual suppliers and craftsmen, coordinate and manage their activities, and ensure the quality of materials and craftsmanship. This would further distinguish the position of the architect in a supervising role, in which he visited the job site on occasion, relying more on the superintendent.

As gentlemen architects garnered distinction, an elite group of architects met to form the American Institute of Architects in 1836, but experienced organizational difficulties and did not meet again until 1857 (Rutledge, 2008; Woods, 2009). During the last half of the nineteenth century, building codes, first published by insurance underwriters, were becoming common in

large cities. Together with zoning regulations, building development and design was becoming more and more complex. In 1897, the state of Illinois became the first jurisdiction requiring that architects become licensed by the state. Other states would soon follow suit.

The transition from late 19th and early 20th century saw the greatest increase in complexity to the building industry (Allensworth, et al., 2009). This included the implementation of the first state mechanics lien laws (protecting trades people), and then federal surety bonds (protecting the federal government from performance defaults on federal projects). In addition, an increase in building codes by insurance underwriters and municipalities followed such devastating events such as the Great Chicago Fire of 1871 and the San Francisco Earthquake of 1906. Similar regulations were compounded in 1916 by New York City's new Zoning Resolution law (Allensworth, et al., 2009; Davis, H., 2006).

The General Contractors Association was founded in 1918, in Chicago; renamed the Association of General Contractors (AGC) in 1920. The AGC, representing primarily private contractors, was performing its professional association responsibilities, providing a definition to general contractor. Establishing association ethics, they addressed the title, role, and functions of a general contractor, as well as their relations to other project partners. To perhaps provide a militaristic leadership to the many efforts of the AGC, the former chief of the U. S. Army's construction division in World War I, General R. C. Marshall, was appointed General Manager of the AGC, who in turn hired his former second in command as Assistant General Manager.

The 1920's experienced significant changes in the U. S. building industry, including federal government efforts for a "Reconstructing Construction" effort. The U. S. Department of Commerce expanded their development of standards beyond materials and measurements, engaging with newly formed building specialty organizations in the standardization of building

materials and methods. A report issued in 1921, titled “Waste in Industry,” provided a scathing review of all U. S. industries, but particularly dedicated almost 50 pages to a thorough analysis of the Building Industry. The United States was in the middle of its first post war depression and industries were adjusting to non-war activities.

In general industries were criticized for their waste. Waste was identified in four areas: *faulty management* of materials, facilities, equipment and labor; *interruptions* causing idle labor, materials, plants and equipment; *restrictions* that were intentionally caused by owners, management or labor; and *lost productivity* due to ill-health, defects and accidents. Specifically in the building industry the main cause of waste was from irregular work use of labor, inefficient management, and labor regulations. This was followed by unsafe working conditions and poorly designed equipment. Management was deemed the most important. And what followed was the concept of scientific management (AEC, 1921; pg. 2; pp. 53-54).

US construction projects, postponed due to war efforts (by government order), were in need of attention. Post war Europe was also going through reconstruction, providing additional increases in demand for building standards for quality and efficiency. There were repeated calls for increased productivity, and the AGC’s General Marshall put forth efforts with both major political parties, all the way to the White House. The AGC endorsed the AIA standard contracts, but a national organization provided representation, or a seat at the table, in proposing revisions to the standard contract. The AGC proposed sixteen modifications, five of which were not received well by the architect, engineer and owner representatives. These included

- adjustment in the market for the price of materials;
- a provision for bond reduction as the project progresses;

- a policy stating that where a penalty for contractor delays exist, a bonus for early finish shall also be provided;
- effects of weather on schedule and productivity;
- the addition of arbitration in lieu of either the architect or engineer being the final judge in regards to contract interpretation (AGC, 1920).

2.3. Facilities for the Federal Government

The land for the nation's capital, Washington and the District of Columbia, was established by Congress with the Residence Act of 1790. At the time there was no federal organization to manage a federal building program. The Treasury Department and the Postal Service had experience with Customs Houses and Post Offices; but many of these facilities were either in rented space built for some other purpose or hastily built with questionable durability – which would require regular replacement. So the time had arrived for the United States of America to establish buildings that represented the strength of the nation (Lee, 2000).

The first several decades of the nineteenth century the federal government was cautious and hesitant in its building activates. The government had increased responsibilities across the country, and was in need of facilities to accommodate federal government functions across an expanding country. Beginning in 1789, the construction of new government facilities was the responsibility of the U. S. Department of Treasury (USDT).

As with the Renaissance, there was a stated need for “symbols of strength and stability...” (Lee, 2000; pg. 12) in buildings “...which inspired confidence in the federal government on the part of the local citizenry” (Lee, 2000; pg. 12). The structures would serve to educate and inspire more cultured communities. The program was seen as two parts, the nation's Capital, and the facilities outside Washington, D. C (Lee, 2000).

Between 1789 and 1830, several architects were hired to design some of the fifty-nine customs houses spread across eleven states. And by 1818, some reputable architects were supervising their construction, in addition to their design. By 1830, the architect's role in the building process, together with the superintendent, was much better understood. By the early 1830's several significant customs houses were in dire need of expansion and better accommodating facilities. New York City was one of these. A new customs building was designed and then supervised, by Architect Alexander Davis; who worked closely with the Secretary of the Treasury. The project started in 1832, to be completed in 1842, with construction costs having quadrupled from the original estimate-the most expensive federal building to date. The project was plagued by superintendents modifying the plans, and having disagreements with customs and building officials. (Lee, 2000).

Another expensive customs house would start to shape the future of federal building delivery methods. At the Boston customs house, begun in 1835 with a design competition, the winning architect also created a close relationship with the Secretary of the Treasury. The architect, Ammi Young would serve in both a supervisory capacity and as the construction superintendent. The building would be finished twelve years later at more than triple the original building estimate (Lee, 2000).

In these early years, the country possessed few architects of the caliber that Great Britain had relied upon for their great buildings. And beyond educated gentlemen, few understood the profession of architecture. Army engineers were known to supervise the construction of distant civil and military installations, which were constructed under a superintendency model to manage construction responsibilities. Private architects were designing houses for land-owners and commercial buildings for businesses, such as banks. Early customs house designs were then

sought from these private architects, and once approved by the Secretary of the Treasury and the customs collector; it would be superintended by the local customs official, reporting directly to the Secretary (Lee, 2000).

A fellow architect of Mr. Young's generation was a gentleman by the name of Robert Mills. Mills had moved to Washington, D. C. in 1830 to work as a draftsman in the Treasury Department's Land Office. He was known by the Secretary of the Treasury, and was often consulted on architectural matters. He would ultimately receive the title "Architect of Public Buildings," in 1836. Since beginning work in the Treasury Department, he had developed plans for custom houses as well as eight Marine Corps hospitals. During the construction of the Boston customs house, the Secretary had consulted with Mills in regards to several issues. The architect had proposed using European marble, and requested that the federal government pay for a trip to Europe to obtain information on heating, ventilation and practices in stone dome construction. Mills advised that the trip set a bad precedent, and that U. S. federal buildings should be constructed of American stone, crafted by Americans. (Lee; 2000).

As the demand for architects increased, and their scarcity persisted, yet another issue arose by the 1840's. At least one noted architect had received commissions for projects that were far-flung from each other, causing logistics problems for supervision as well as superintendence (Lee, 2000).

2.3.1. The Office of the Supervising Architect

By 1850, the quantity of federal building projects had created a very large level of responsibility. Within the capital city, Robert Mills was one of few federally employed architects, though working in the land office, who were responsible for several buildings in Washington. The Secretary of the Treasury would then manage the projects outside of Washington. Mills had

previously sought methods of standardization of buildings of similar or the same function to begin to incorporate more efficiency into the buildings in Washington. But, “[t]he full implementation of standardized design required a centralized administrative entity” (Lee, 2000; pg. 37).

In 1851, the Bureau of Buildings was formed within the Department of the Treasury, and Ammi Young, who had worked on numerous federal projects, since the Boston customs house, was appointed as the chief designer for all federal buildings. This Bureau would be responsible for the building of the capital city, and serve to ensure consistency with the master plan of the city. With a new presidential administration, a new Secretary of the Treasury James Guthrie took office in early 1853 (Lee, 2000).

Over the next several years, Secretary Guthrie made significant changes to government building efforts outside of Washington. He contacted the Secretary of War and requested that an officer with the Corp of Engineers be assigned to his office to head the Bureau of Construction as General Superintendent of Buildings. The man selected was Captain Alexander Bowman, a West Point graduate. He and his staff would oversee all federal government field superintendents. The qualifications for superintendents were also clarified, as expressed by the Assistant Secretary of the Treasury: “...that a *Superintendent* be a practical architect or builder, it is proper he will be acquainted with principles of construction, that he knows the quality of materials and be conversant in their prices, the he be a good judge of work, and have had experience in the management of laborers and in the construction of public works,” (Lee; 2000,pg. 42). An example of Guthrie’s militaristic claim over the management of construction was immediately evident when he had a superintendent, on a troublesome and costly customs house in Alabama, removed and replaced by an officer from the Corps of Engineers. (Lee; 2000).

Guthrie and Bowman developed systems that "... included a calendar of reports, disbursement procedures, and accounting oversight" (Lee, 2000; pg. 56). Design responsibilities were consolidated under the immediate direction of the Treasury Department, to include "...the preparation of plans, specifications, estimates, and contracts" (Lee, 2000; pg. 44), which shall be developed with due consideration for the number of occupants and the business to be transacted. Occupants of existing government facilities shall be consulted in regards to existing efficiencies and inefficiencies, as opposed to those less acquainted with the functions required (Lee, 2000). During this same period, when Guthrie was ensuring that that monies were spent wisely and met the government's needs, some members of Congress began legislating the locations and sizes of buildings, as well as over-sized (or under-sized) appropriations, to suit their "pork-barrel" needs. Guthrie pushed back. More money was being spent on customs houses and post offices than merchant marine hospitals, a forerunner to today's Veterans Administration Hospital. Guthrie's successor, the Treasury Secretary at the time, was equally as skeptical in regards to the way in which federal buildings were being authorized (Lee, 2000).

During the time that Young served as chief designer, for the Capital, he had also complete drawings and specifications for customs houses that were completed and sent to local customs officials to receive bids through a superintendent for construction. The superintendent was hired directly by the Treasury Department. Beginning during Guthrie's tenure, some of these drawings and specifications would be retitled and reissued for multiple customs houses, thus starting to economize on design production. Secretary Guthrie would leave in early 1857, to be replaced by Howell Cobb. Bowman remains until 1860, when federal funding and national stability was waning (Lee, 2000).

With the election of Abraham Lincoln in 1861, and the appointment of a new Secretary of the Treasury, change was again happening in regards to federal building management. Secretary Salmon Chase appointed Isaiah Rogers, an architect, to head the Bureau of Construction. Chase's first action was to fire Young, and consolidate both Bowman's and Young's positions into the Engineer-in-Charge in 1862; Rogers title would be renamed Supervising Architect in 1863 signifying him as in charge of all Treasury's architectural operations. Alfred Mullet, who had worked in the office since 1861, would become Rogers' deputy and eventually succeed him in 1866 (Lee, 2000).

2.3.2. The Government's Superintendent and Fast-Track Construction

As the architectural profession struggled to establish itself, the federal government was in need of buildings. With responsibility for renting of temporary facilities, and the arrangements for construction of somewhat more permanent buildings, placed within the Treasury Department, there was need for organization. By 1853, the government owned 23 buildings, and Congress had made appropriations for 15 new buildings. In 1853, Treasury Secretary Guthrie, who was responsible to ensure that appropriations were properly spent, saw the need for a more efficient management system to oversee design and construction of all new federal buildings. New federal regulations placed further responsibilities upon the department, requiring: 1) that the federal government be relieved of rent requirements; 2) that federal offices be permanently located; 3) that federal buildings be built to suit the government's needs, and be titled separate from private properties; 4) that federal buildings have proper fire protection, including isolation from private properties, if necessary; 5) that scattered federal facilities be "evidences of the dignity" (Bell, 1886; pg. 4) of the Government "appealing to the loyalty and pride of every citizen;" (Bell, 1886; pg. 4) and 6) that the "Government may have an opportunity to encourage the best architectural

work and to educate the national tastes in the design and workmanship of private building” (Bell, 1886; pg. 4).

This would be the time that Guthrie brought in Captain Bowman from the Corp of Engineers. Together with the Secretary and the Supervising Architect a system was developed to deliver the much needed federal building facilities. Building sites were selected, purchased and property title transferred to the federal government. This placed the building project under federal jurisdiction. Mr. Bowman, who oversaw all building superintendence, was equal to the Supervising Architect (SA), in his responsibilities to the Secretary. Together with his clerks, the Chief Superintendent (CS) would seek to employ superintendents for each project. Each particular project superintendent would be furnished plans and specifications from the Treasury, as prepared by the Office of the Supervising Architect.

At the commencement of work for a project, the superintendent would provide to the CS a listing of “all persons he may think indispensable to employ for the most efficient and economical prosecution of the work, together with a statement of the proposed compensation” (Bell, 1886; pg. 4). He may increase such staffing in the future to include “clerks, overseers, master mechanics,” etc. Funding for each project is advanced to the superintendent at the beginning of each month, based on monthly estimates submitted by him to a disbursing agent in the office of the CS. Payments for labor and materials will be made by check, through a bank located near the project’s location. The disbursing agent then provides quarterly audited accounts to the Secretary of the Treasury (Bell, 1886).

Each superintendent was instructed to proceed through sequenced phases of construction. First, establishing “the accuracy of the metes and bounds of the site,” (Bell, 1886; pg. 7) and establishing “indestructible landmarks” (Bell, 1886; pg. 7) of the same. “Should there be reason

to suspect the stability of the foundation of any building under his charge, the superintendent will remove all doubts by digging and boring. He will [in conjunction with the office of the Supervising Architect] ascertain the quality and cost of required building materials, and the facilities of procuring them in the vicinity of the work,” (Bell, 1886; pg. 7). He thereby ensures that any foundational changes required are determined prior to actual construction. With any design changes completed, plans and specifications for excavation and foundation work, or a portion thereof, are provided to the superintendent for bidding and subsequent execution. This may be followed with basement plans and specifications, first floor, etc., “in like manner each class of work follows the other in the natural sequence of construction” (Bell, 1886, pg. 31). The superintendent, “when not otherwise directed,” (Bell, 1886, pg. 9) makes direct contract arrangements with material suppliers and separate portions of the work. Such contracts are secured through a local 60 day publicly noticed bidding period. All bids that are received are documented with specific plans and specification requirements and forwarded to the Treasury Department for review and approval prior to signing of the contract. The superintendent shall also forward any information that he can responsibly “obtain as to the character and responsibility of the bidders” (Bell, 1886, pg. 9). The final contract forms are filed with a certificate from the superintendent, “stating that the contract was given to the lowest responsible bidder,” (Bell, 1886, pg. 10) and that no member of Congress “is directly or indirectly” (Bell, 1886, pg. 10) associated with the contract. No contracts, once approved, can either be assigned or subcontracted to any other parties. If there are substantiated claims for extra work, such work shall be in the form of a new contract, to be submitted to the Secretary of the Treasury for approval. The new contract, for material or labor, may or may not be with someone already contracted with on the project already (Bell, 1886).

The superintendent is responsible for the physical and financial management of the building project. He would provide a monthly accounting for all expenditures and construction progress.

If by chance a superintendent is to be replaced, all accounts are settled up and material is inventoried. The superintendent provided a certified statement to his successor that all outstanding debts have been paid, with a copy to the Treasury (Bell, 1886).

The superintendent, through to the end of the 19th century served much as the clerk-of-works did in Britain at the time (Hoskins, G. G., 1876).

2.3.3. Professionalism in America

Private architects began organizing professionally, first with the American Institute of Architects (AIA) on the east coast in 1857, and the Western Association of Architects (WAA) from Chicago westward, in 1884. The two organizations would merge in 1889, but only after the AIA agreed to be more inclusive to include any practicing architect. In 1875 there began an artistic criticism and wanting for their inclusionary influence in public building endeavors. This would establish a public debate between the AIA and the Treasury Department that would last from the 1870's, until after World War II. Initially, it was criticism from the New York based exclusive AIA members, many of whom were Paris educated in the art of architecture. They had many private business clients, and weren't necessarily in need of more work, except for instances of market downturns.

The AIA argued for public design competitions, with their rules, to be judged primarily by AIA members. The competitors would be paid for their participation. The winning architect was to receive a commission to complete plans and specifications; and to supervise the construction. This began the presentation of the "one contract for the entire building" (Bell, 1886; pg. 31) scenario (Bell, 1886; Woods, 1999).

The Treasury Department responded that a competition process and the necessity to competitively bid the entire project would require “the preparation of drawings and specification for all detail of work for the entire building before construction could commence” (Bell, 1886, pg. 31). This would cause long delays from the time that the necessity for facilities is identified, to when the facilities are actually available for use. It would result in a disservice to the public “necessitating a hasty consideration of demands of various public officers who are to be accommodated therein” (Bell, 1886, pp. 31-32). It had been accepted that “after construction has commenced, that change of plans and interior arrangement are found to be advisable on account of conditions not known or anticipated when the general plans were first made” (Bell, 1886, pg. 31-32). Such changes were manageable by the Supervising Architect and the Superintendent, by implementing the changes just prior to bid letting of individual phases of the project, or through a new contract for the changed area versus a contract change. As private contracting organizations grew in their sophistication, the Treasury expressed additional concerns in regards to the “speculative contractor whose facilities and capital might enable him to underbid smaller local contractors,” (Bell, 1886, pg. 32) and then in-turn they would hire the same local contractors. The phased system that the Treasury was engaged in produced smaller manageable packages of work. The department had identified that workmen were specializing in their trades; and the phased system provided the architect and superintendent to work directly with the specialized workmen, ensuring explicit understanding of plans and specifications, as well as an endured responsibility for the quality of work. It was feared that a single contractor “would expect to make a profit on each sub-contract,” (Bell, 1886, pg. 32) and would marginalize overall quality as well. The phased system, in its provision of smaller chunks of work, ensured better quality plans and specifications, and more precise costing of work to be executed in short time

periods, soon after the scope of work was defined. This was deemed in sharp contrast to a single contract where work priced today would not even start for months or years in the future, adding to the Treasury's concerns in regards to an increase in uncertainty (Bell, 1886).

The concept of one-contract for the entire building in private practice started with the WAA's publication of a fixed-price Standard Uniform Contract in 1888, which would later become known as the first edition of the AIA Contract Documents. The document was drafted with the involvement of the WAA, the AIA, and the National Association of Builders (NAB), partially in response to the U.S. Supreme Court's ruling in the case of *Dermott v. Jones*⁴. It was also believed that most construction contracts were commonly drafted from the owner's position. Contracts were drafted by either an owner's attorney or architects, who have a professional duty to the owner. With the growth of new professional builders' organizations, such as the NAB, new guidance to builders cautioned their membership in regards to insisting upon complete plans and specifications. The new Standard Uniform Contract was deemed to rigidly express contractual risk allocation, as imposed by the Legal Sanctity of Contract (Bell, 1886; CABN, 1887; CABN, 1888; Allensworth, et al., 2009; Woods, 1999).

Another U. S. Supreme Court ruling of 1918, now called the Spearin Doctrine, ruled that if a contractor is to perform work in accordance with drawings and specifications provided by the

⁴The *Dermott v. Jones*, 69 US 1 (1864) was a construction contract case heard by the Supreme Court of the United States. Mr. Jones, the builder, contended that his scope-of-work was as stated in the "specifications". The court found that the contract consisted of the "specifications and the instrument to which they are attached . . . They make a common context, and must be construed together. In that instrument the defendant in error made a covenant." The *Dermott v. Jones* case decision was deemed to ". . . rest(s) upon a solid foundation of reason and justice. It regards the sanctity of contracts. It requires parties to do what they have agreed to. If unexpected impediments lie in the way, and a loss must ensue, it leaves the loss where the contract places it. If the parties have no provision for a dispensation, the rule of law gives none. It does not allow a contract fairly made to be annulled, and it does not permit to be interpolated what the parties themselves have not stipulated." The builder had not completed the entire scope-of-work in the "contract", as defined by the court, due to the finding of unspecified conditions which were deemed to be a risk the builder had accepted. Having not completed the work per the contract, the builder was not entitled to payment (Allensworth, 2009; pg. 5, Footnote 9; and *Dermot v. Jones*, 69 U.S. 1, 17 L. Ed. 762 (1864) 5n., 44).

owner, and those documents are found to be in error, the contractor is not liable for any costs or delays which result from delays caused by the correction of such error. The Spearin Doctrine, together with standard contracts, led to the rise of claims for errors and omissions in addition to ambiguous contract interpretations that lead to delay claims in building projects. The courts would from then forward rule against the drafter or preparer of the contract documents, particularly in regards to drawings and specifications, typically the owner, and his agent (Allensworth, 2009).

Lobbying efforts by the AIA, for the hiring of private architects for federal projects through competitions, resulted in the Secretary of the Treasury stating that he would decide on a project-by-project basis whether the project warranted a public competition and the hiring of private architects (Bell; 1886). For many private architects, government projects would not come until after World War II.

Professionalism has numerous definitions. Per the subtitle of Andrew Abbot's book *The System of Professions*, it is the division of expert labor, where each profession, in service to society, through the application of expert knowledge through objective and subjective diagnosis of a problem and professional inference, provide a treatment. This is true of doctors, lawyers, engineers and architects (Abbott, A.; 1988). Professions are also known for their organizations, where members of the same profession share their knowledge and continue learning. Such organizations originally sought to regulate their professions, but today they are merely advisors to governments who license professionals. Medicine was the first to be licensed in the State of Virginia, in 1798. But, by the middle of the 19th century, while some other states had adopted licensure; claims of the restriction of people's freedom led to the repealing of licensing laws in

ten states. In similar fashion, all laws dealing with the licensing (admission to the Bar) of lawyers were abolished in two-thirds of the states by 1840 (Hogan, D. B.; 1983).

The trend did not last long, as today, doctors, lawyers, engineers (including surveyors) and architects are licensed in every state within the United States. These professions require the taking of a national standardized exam, through a national licensing organization to which every state is a member. Individual states may require additional testing, but the national examination provides a universal threshold for professional competence.

Until 1947, no state in the United States required the licensure of a general contractor. The first state was North Carolina, and the response was scornful of coercive discriminatory practices of government restrictions on those wanting to perform building activities in the state (Edwards, C.; 1947). At the time only specialty trade sub-contractors might be licensed by the states, or more often cities. The same is true today in parts of the United States. The policy of laissez faire and caveat emptor, still live on from 150 years ago (Hogan, D. B.; 1983).

From the 1930s through World War II, most construction would be implemented with either government involvement or direction. After WW II, almost a decade of government sponsored infrastructure work was required to make up for war delayed projects. The 1950s would see a great demand for construction beyond the government. With the increase in demand, there was an increased concern for proper design and construction procedures to ensure efficiency. New building design and construction standards were deemed necessary to ensure efficient construction that provided a quality-of-life environment. Several declarations were made. First that a long-term commitment to design and construction research was required. Design included space-planning with area efficiency ratios, definition of building-types, and standardized technical terminology pursuit of modular construction, programming (functional research) of

building plan layouts, and use of building life-cycle analysis to ensure duration-of-life meets duration-of-needs. Other practices were to include the studies of the building envelope for energy conservation, structural engineering standards, heating, ventilation, and air conditioning standards, electrical system standards, and plumbing standards. Building construction practices were to include pre-bid conferences, coordination and completeness in drawings and specifications, standardized specifications, standardized bidding practices, standardized supervision and inspection practices, establishment of completion dates, and research during the design phase for alternative materials, products, and construction means-and-methods (BRAB, 1952).

For the design and engineering professions⁵, an increased emphasis on the design sciences of programming, functional analysis, and systems integration required fully coordinated and complete drawings and specifications prior to bidding and construction. For the construction parties, their practices, methods and management in construction activities and the management of man-power and equipment, were deemed of need for greater efficiency (BRAB, 1952).

⁵ Carl M. Sapers, *Ruminations on Architectural Practice*, 25 CONSTRUCTION CONT. L. REP. 3 (2001):

“[T]he increasing complexity of construction projects . . . challenged the architect’s historic role as the most knowledgeable player at the job site. As Professor Salvatore of Columbia University observed, architects came in the 1970s to know less and less about more and more until the architect is ‘sometimes said to know nothing about everything’ (citation omitted). Even if we stop short of Salvatore’s caricature, it is clear that the architect was no longer venerated for his or her comprehensive grasp of all aspects of building. During this same period, whenever the economy tightened, opposing forces claimed greater pieces of the architect’s historic domain. Civil engineers claimed the right to design hospitals, office buildings, and court houses. Interior designers claimed the right to design 60,000 square foot office build-outs. Mechanical engineers made arguments that, in the end, suggested that the shapely Hancock Tower in Boston was merely a chase for the mechanical system. Professionals became increasingly targets of the plaintiff’s bar; in the 60s and 70s architects were conventionally sued if anything went wrong at the project. The fall of the house of privacy made the architect a direct target of unhappy subcontractors and contractors. The rising tide of civil litigation elevated the role of the insurance industry. The insurance industry not only affected practice by describing conduct that would result in the loss of coverage, it insisted on a place at the table when the AIA construction industry documents were being drafted. The effect of listening too closely to the cautions of a prudential insurance industry was that the architect further -retreated from the dominant role he had once played” (Allensworth, 2009; pp. 4-5, Footnote 8).

There would also be an increased emphasis on building operations, and that both the design and construction professions needed to keep maintenance and operations management in mind while performing their functions (BRAB, 1952).

2.4. Summary

The evolution of the building industry has been long and arduous, with the most significant advances having occurred in the last hundred years in increasing complexity. Technologies use in the industry has increased almost as fast as the technology becomes available, but how wide spread is its actual use? A National Institute for Science and Technology's report titled *Cost Analysis of Inadequate Interoperability in the U. S. Capital Facilities Industry* (GCR, N. (2004), reports great efforts since 2001 to harness technology to improve productivity and efficiency. In 2012, the Commerce Department provided yet another scorecard for the industry, as shown in Table 2.5.1. Since the aforementioned report, productivity in the building industry has decreased further. The value-added measure, a key variable in modern business evaluation, shows in Table 2.5.2, how the manufacturing industry, has improved in their productivity. Many modern researchers have looked to manufacturing for potential methodologies for improving the construction industry, such improvements have not yet appeared to have transferred from manufacturing to the building industry in accordance with this data (Teicholz, P.; 2013).

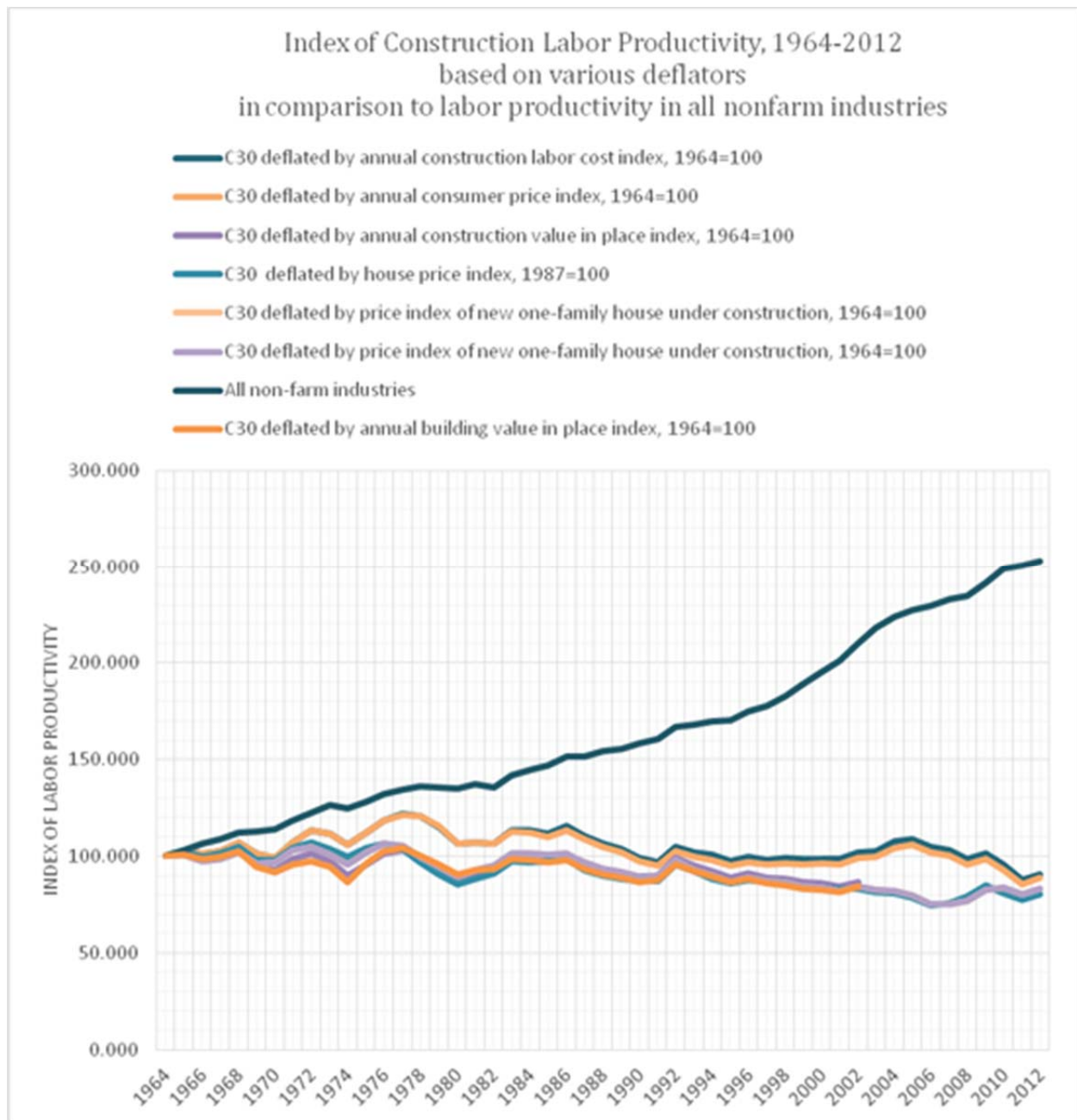


Figure 2.5.1
Index of Construction Labor Productivity, 1964 - 2012

Value Added per Employee 2005 dollars

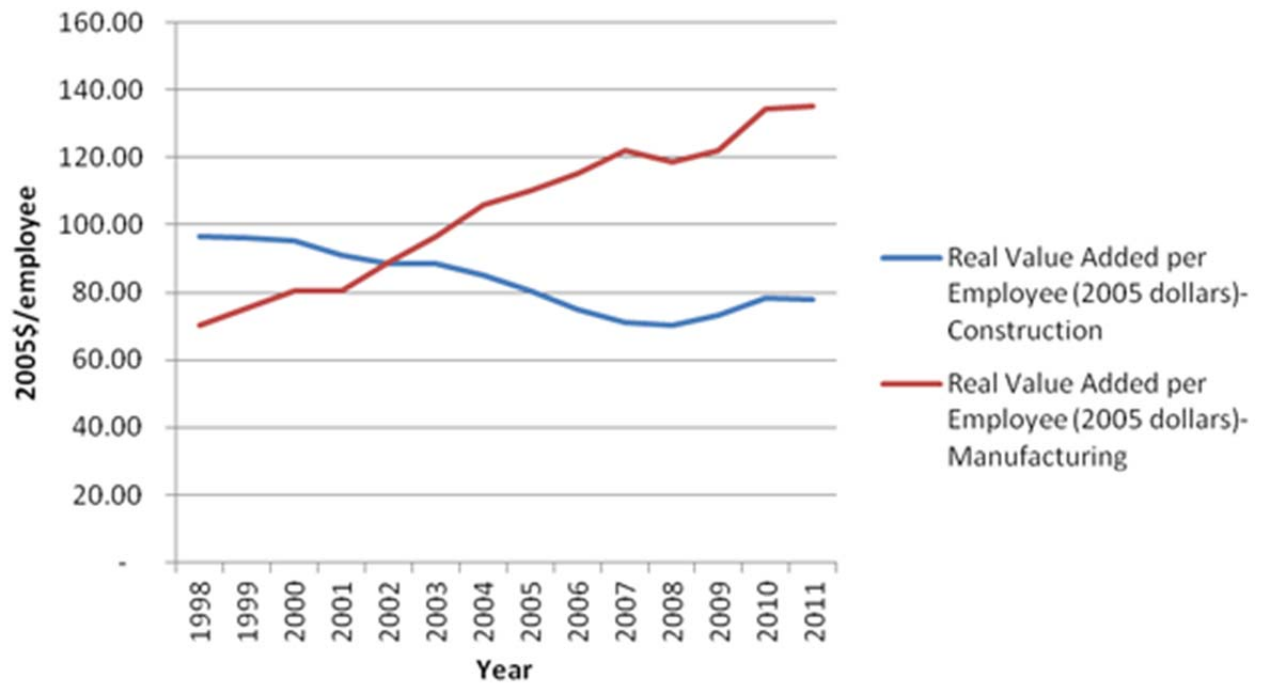


Figure 2.5.2
Value-Added per Employee: Construction vs. Manufacturing

Chapter 3

Knowledge Management Processes

3.1. Knowledge Evolution

The historical exploration of the building industry (summarized in Figure 3.1.1) described how building knowledge has evolved from the individual builder's knowledge to the initial founding of building as a science in the times of Vitruvius, studied by architects. By the time of the Renaissance building sciences brought forth the foundations of the science of architecture.

The architect's together with engineers, surveyors, and clerks-of-works were not just sources of information, but managers of processes whereby building projects evolved in an atmosphere of cooperation, trust and respect for the professions, the tradesmen, and their guilds.

By the beginning of the 20th century, guilds became unions, buildings became managed projects, and building regulations, including professional licensure for architects and engineers became more prominent. With increasing building complexity with building systems, including heating, plumbing, ventilation and electricity, professional organizations sought to research, develop, and to an extent provide guidance to others within their professions. The increasing complexity in construction itself saw the beginnings of construction and trade organizations, all seeking to better inform themselves of their trades. By the 1920s, this included general contractors.

The beginning of the 21st century has seen the growth of mega-corporations in the architecture, engineering, and construction professions. Most often this is done to diversify and expand into new markets and also serves to gather market and professional knowledge into their organization. Business strategy says such organizational knowledge growth is beneficial for the

corporations in a competitive market, but it may not necessarily be beneficial to the building industry, Industry consolidation may lead to increasing size and differentiation of knowledge silos in an industry whose products require very high levels of integration. If each mega-corporation develops its own individualized version of the building industry, those project partners outside the corporations will have difficulty working on integrated project teams.

For the benefit of the large and the small builders, a better industry structure is required to better exchange knowledge through a market system. What is proposed in this thesis is a networked process structure that can provide greater diversity of knowledge, and more pertinent knowledge, when, where, and in the form it is needed. For the knowledge management process, this role needs to manage the interests of the owner, while managing the research and development (design) phase, and facilitating the issuance of contract packages to concurrent production and fabrication (construction). In the context of integrated project management this new role will be called the Process Manager.

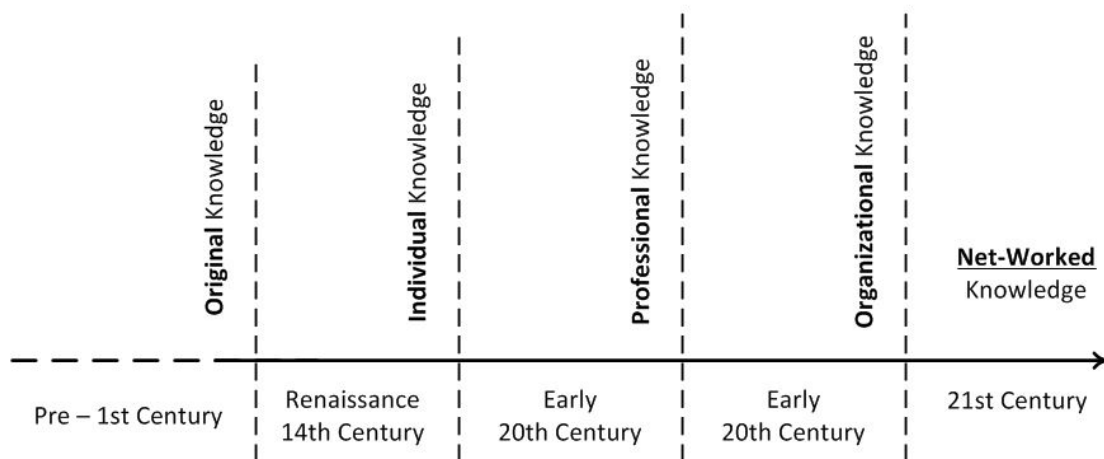


Figure 3.1.1
Knowledge Evolution in the Building Industry

3.2. Processes

The goal of process management is to master complexity and the unpredictable. Process or agent-based management is deemed the fourth phase of the evolution of industry. This was preceded by the first industrial revolution of 1780, the second industrial revolution around 1900, and a third revolution in the 1970s with the introduction of information technology and globalization of markets. The fourth revolution includes “smart factories, intelligent machines, and networked processes that facilitate and result from the 4th industrial revolution that is now beginning” (Sinur, J., et al.; 2013).

New business models based on processes seek to be proactive and interceptive of customer needs, as the next generation of pull-vs-push market demands in the provisions of products and services. Processes seek to expand “beyond traditional and organizational boundaries to large-scale business networks” (Sinur, J., et al.; 2013; pg. 20). The business needs to become more dynamic and efficient, creating a need that expands beyond simple business-process-models (BPM), to shift from serving in a reactive capacity to becoming more proactive. When fully realized, such process models create an adaptive enterprise that can manage change in real-time. The development of intelligent-agent, or strategic BPM models, are anticipated to have “the ability to manage innovative and intelligent processes that span wider scopes and deeper levels of complexity,” incorporating “big data, predictive analytics, social platforms, mobile smart devices, and cloud computing” (Sinur, J., et al.; 2013; pg. 23).

For proponents of industrial production construction methodologies, new process management technologies have the potential to change business as much as Fredrick Taylor did 100 years ago, but on a potentially much grander scale. Such a change is dependent on diligence and creativity, that needs to be understood as a process that requires the creation of prototypes that must be

tested, and allowed to evolve in a methodology that is iterative in nature and emblematic of continuous improvement (Davenport, T. H.; et al.;1990; Taylor, 1912)).

A Process-Oriented-Architecture (as opposed to a Service-Oriented Architecture), expands beyond information management, into the processes of knowledge management” that uses Role Activity Theory and Role Activity Diagramming (RAD), to supersede any “mechanistic information-oriented” processes (Sinur, J., et al.; 2013; pp. 23-26).

3.3. Application of Processes

A key to enhancing innovation and efficiency in the building industry is the elimination or reduction of risk. To do either, the risk must first be identified, and then managed. Traditional project delivery, through contracts, seeks to manage or transfer risk, as opposed to preventing risk.

Contracts serve to define performance expectations and assign rights and responsibilities to contracting parties. Through *stare decisis*, the legal system acknowledges and respects that licensed professionals’ provide unique services in which they exercise their judgment in a reasonable and prudent manner. The law also recognizes that parties to a contract can choose to contractually expand or limit their responsibilities and is therefore a concern in all contractual negotiations. Building contracts are complicated in the traditional building delivery systems by the separation of design and construction responsibilities, (Lee; 2000) with building owners contracting separately with design and construction professionals. Neither the design party nor the construction party wants their responsibilities expanded to include the actions of the other party. Through contracts the assignment of specific responsibilities to the singular party who is best positioned to carry out both the specific responsibilities, and the associated risks; and is authorized with the authority to do so.

Such a separation of the research and design from the production and fabrication is a violation of the basic premises of lean methodologies and business goals, which require providing value to the customer. This requires an emphasis in “maximizing flexibility in responding nimbly to (trends) [owner’s] demand[s]” (Shimokawa, K.; 2009, pg. iii). Such comparisons to manufacturing industries have most often focused solely on production and fabrication and have sought to impose production processes on research and design. In the case of Toyota, the noted Toyota Production System (TPS) was based on research related to factory production. Jeffrey Liker the author of *The Toyota Way* (2004) was a co-author of an *MIT Sloan* article in 1995, titled “*The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster.*” Published a decade before his book, the article focused on Toyota’s “unstructured development process, its multidisciplinary teams [which are] neither collocated nor dedicated” (Ward, A., et al.; 1995, pg. 43) to a particular product (automobile) development. Their development teams would be “simultaneously designing a product [automobile] and its manufacturing system” (Ward, A., et al.; 1995, pg. 43). Mr. Liker would later co-author *The Toyota Product Development System: Integrating People, Process, and Technology* (2006) which particularly addressed the design and development process. The process used what Liker and his co-authors described as set-based concurrent engineering; which applied iterative design to sets of possible solutions and gradually narrowed the set of possibilities to converge on a final solution. This conflicts with some interpretations of a design process in the construction industry that believes a design process converges on a single solution that is then revised many times to arrive at a point of accepted completion. Such an iterative process was noted to be comparable to software development processes which are iterative, agile and based on scrum methodology.

These processes are most noted for their ability to establish an environment for learning (Ward, A., et al.; 1995; Sobek, D. K., et al.; 1999).

The same well regarded Japanese industrial processes have been studied for how they manage knowledge, particularly by Ikujiro Nonaka and his colleagues (Takeuchi, H., & Nonaka, I.; 1986. Their studies do not concentrate solely on Japanese processes, which is why their studies provide strong evidence for the effective design of knowledge management processes (Von Krogh, G., Ichijo, K., & Nonaka, I., 2000; Nonaka, I.; 1994; Nonaka, I., et al.; 2000; Nonaka, I., et al.; 2008; Takeuchi, H., & Nonaka, I.; 1986).

3.4. Knowledge Management Context

The growth of industries through the late 19th into the 21st century has seen an evolution from craft production into mass production up to and through World War II. Through the 80's, 90's and 00's, industries have struggled to understand how the most successful amongst them has prospered and dominated world economies. Not the least of these evolving industries is the construction industry. Peter Drucker coined the term “knowledge worker” around 1960 (Drucker, 1993), and, according to Drucker, the 80's and 90's opened the world to transnational business ventures. The knowledge society in the late 20th century was beginning to grow, but the construction industry was still experiencing growing pains (Forbes et al, 2011). Whereas industries such as automotive, aerospace, software and other industrial based research and development industries have flourished, the construction industry has not (Forbes et al, 2011). Some researchers have tried to learn from these industries (Ballard et al, 1998; Ballard, 2000a; Ballard, 2000b; Koskela, 1992, 2000, 2003), but only very recent research is beginning to study the design and building industry and the role of knowledge management in successful design and construction projects (Khalfan et al, 2010).

When Jeffrey Liker and his colleagues identified what they termed the Second Toyota Paradox, they had identified a difference in how western and eastern approaches to knowledge management have differed. Companies often trying to adapt to what has become known as “Lean” management approaches fail to understand the epistemological aspects of research and development and concentrate solely on the ontological, striving for certainty. This restricts innovation, resulting in actions of imitation producing little value. Ontologically, a factory has a mode of operations which may be mapped for a value-stream analysis to objectively remap the factory for efficiency. Epistemologically, the broader question is “What is the factory trying to achieve?” Thinking beyond the physical and explicit opens a process that seeks answers to why instead of what. It is in this way that the Japanese have viewed knowledge as being much more tacit in nature (Nonaka, I.; Takeuchi, H.; 1995).

A framework for a knowledge management process model for the design and construction industry begins with Ikijuro Nonaka’s *Theory of the Knowledge Creating Organization (Nonaka’s Theory)*, (Nonaka, I., & Toyama, R.; 2005, pg. 421) where the building organization is the project entity, irrespective of contractual definition. The model engages with a dynamic and iterative relational supply-chain of knowledge creation that represents the project’s entire life-cycle. Along this life-cycle axis knowledge, and its form as defined by Nonaka’s Theory, is cyclically created, captured, and dispersed, while monitoring for the variables of certainty and relevancy to a particular project component(s) and the project in its entirety. Knowledge is context (*Ba*) specific, but context exists in numerous states: virtual, physical, existential (emotion, recognition, value, action), an individual context, and a shared context as represented in Figure 3.4.1 (Takeuchi, H., Nonaka, I.; 2004). The contexts, in this

thesis, are termed *events*⁶, which serves as a context for the knowledge creation process. These contexts, or events; do not begin as typical physical constructs such as tasks or activities, but they can and do evolve into them.

Process management seeks to recognize that knowledge is most often related to multiple building tasks and events, and seeks to recognize the knowledge and to associate it with tasks and activities to increase their value to a particular project.

Contracts represent knowledge in its physical (explicit) contexts, as illustrated in Figure 3.1.1, only. Both Research and Development (Design) and Production and Fabrication (Construction), currently exist in their own separate dimensions of a single knowledge context, with their own interpretative versions of each other's context state.

⁶ The references to dimensions such as *time* and *context* are defined as follows: as a design or construction task proceeds, it achieves a different level of completion. Most often projects are managed using start and finish dates. Process managements use of *time and maturity* allow for more granular management, identifying at-what-time does a task, need to be 30 percent complete (or *mature*), to permit another task to follow. The use of the term maturity, allows for a broader, but uniform Process Management application, allowing for a quantified measurement of either physical or nonphysical tasks, or a qualitative measurement of the required completion level for the next task to proceed. The term *context* refers to the intended application of knowledge, whose context may be shared with many other tasks and activities on a project. The Process Manager ensures that such commonly applicable knowledge is shared, and applied appropriately to all the projects tasks and activities.

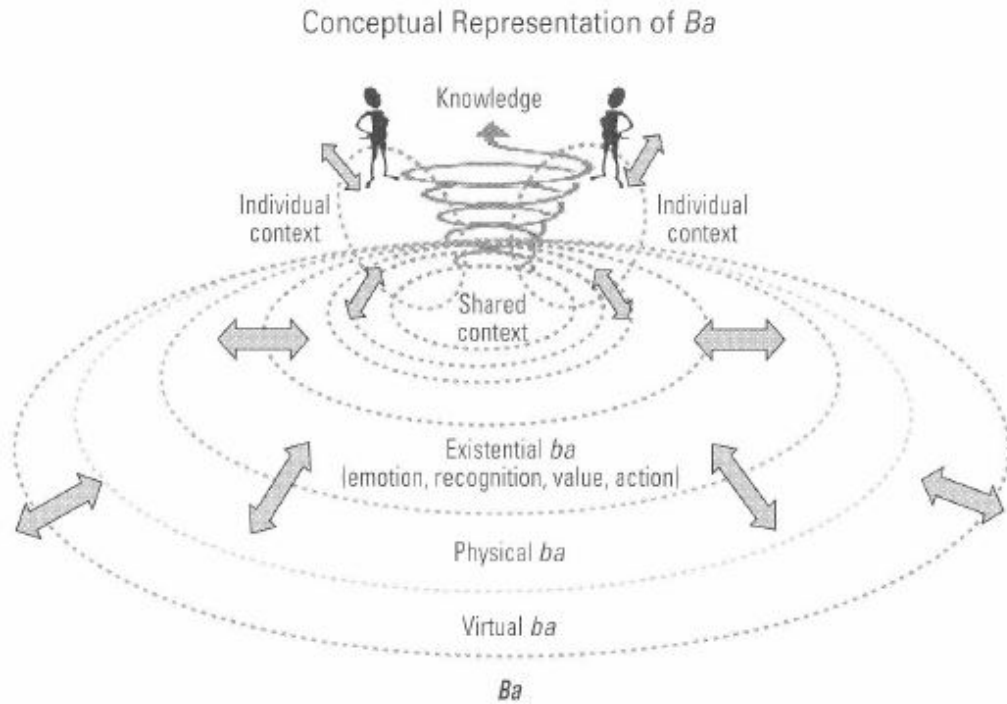


Figure 3.4.1
Knowledge Context(s)

An ontological system for the building industry called OmniClass, as developed by the OCCS Development Committee Secretariat (OCCS, 2014), is one such system that can serve this purpose. An organized effort has been underway for ten years to develop OmniClass,TM which includes Table 11 – Entities-by-*Function*, Table 13 – Spaces-by-*Function*, Table 12 – Entities-by-*Form*, and Table 14 – Spaces-by-*Form* (OmniClass Construction Classification System; 2014), which start to associate with some programming components. Such classification systems can tag tasks by types, providing a method for managerial and database associations. Similar to the buildingSMART[®] alliance efforts, the OmniClassTM efforts have concentrated on data and information related to construction activities, as well as operational and facility management. This thesis seeks to recognize and engage these efforts, but believes that such efforts narrow the prospects of innovation in the future. They are ontological in nature, and do not address the

epistemological dimensions of knowledge associated with the research and development of projects.

A project's design program⁷ does not represent a boundary of project knowledge, but is a guide that steers subsequent knowledge creation. Once a Function and/or Form is established, the knowledge related to such constructs, and the tasks that they propagate, must be accessed and engaged from *assets* to inform its development. As shown in Figure 3.4.2, and simplified in Figure 3.4.3, an *event* serves as a context for the knowledge creation process. It proceeds through four stages: Socialization, which provides a context for the sharing of tacit knowledge; Externalization, a process of conversion of knowledge from a tacit state to an explicit state; Combination, or the sharing of explicit knowledge; and Internalization, where explicit knowledge is internalized to become an individual's personal tacit knowledge.

⁷ See Appendix B for more information on project programming.

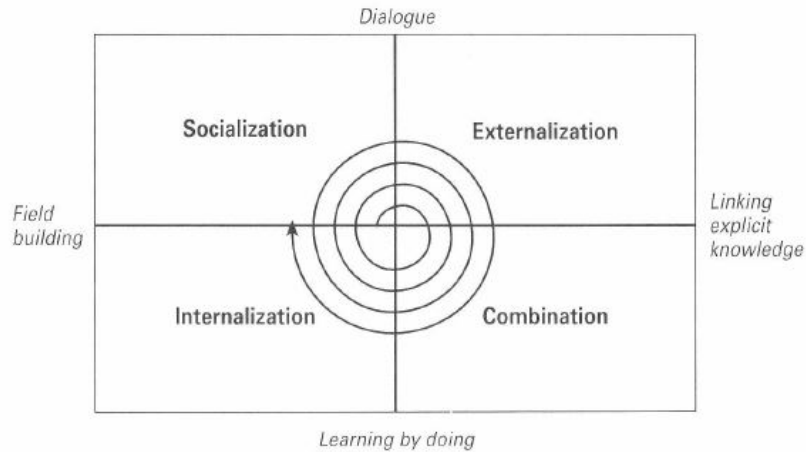


Figure 3.4.2
Knowledge Conversion Process

As with the Shewhart Cycle (Plan, Do Check, Act), knowledge conversion cycles seek, as part of the tacit-to-explicit knowledge conversion, a conversion of knowledge from an Epistemological state to that of an Ontological state-which is more representative of the goals of the buildingSMART® alliance and OmniClass™. The event structure, within the Process Management framework, purposefully provides an ability to define and monitor the *events* scope or context; providing the capability to manage and maintain focus.

Knowledge that is created is harvested through all phases of conversion. This requires both an ontological database and an epistemological database structure (see Figure 3.4.3).

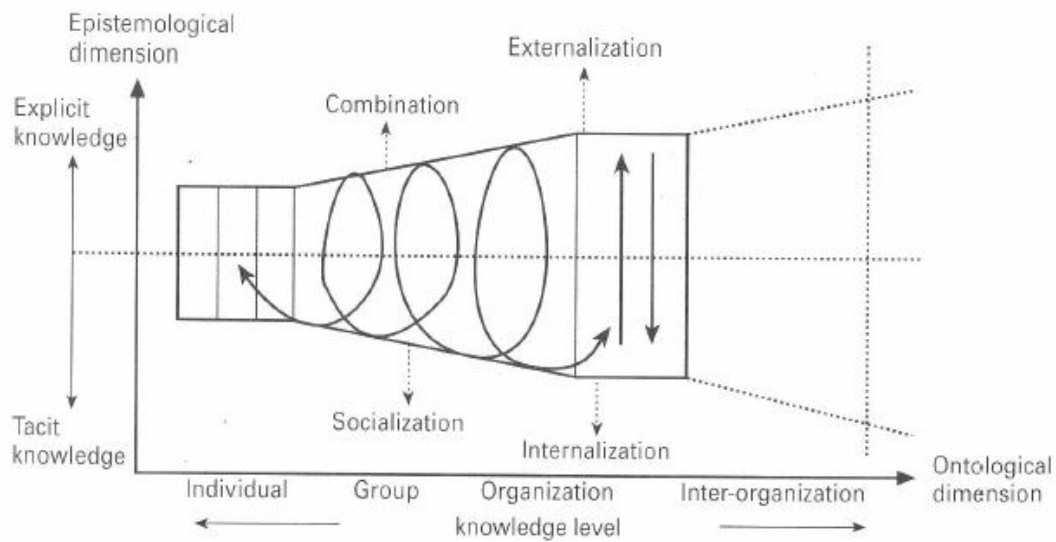


Figure 3.4.3.
Epistemological and Ontological Dimensions

3.5. Model-World (The “Model”)

The process management model, which manages the knowledge, draws from the concepts of Business Process Management (BPM) in establishing its constructs. BPM serves as a strategy for managing knowledge contexts (events) as they evolve and relate to one another. The model forms a horizontal connection between events and sub-processes of differing levels of maturity. No model is perceived as being fully mature, but serves as a reference for continuous improvement in the development of its processes and sub-processes. The model itself is composed of *sub-models* and *sub-sub-models*, each of which serves to define the knowledge of a project in increasing granularity. Models (sub-models and sub-sub-models, etc.) mature through five typical levels of maturity: Level 1 – Initial Model, Level 2 – Committed Process, Level 3 – Established Focused Process, Level 4 – Improved/Managed Process, and Level 5 – Optimized Process (Luftman, J., 2015).

A construction project is to be viewed as a collection of process models, and not a single process. Each process and sub-process evolves and improves at differing levels of maturity; and may exist in different dimensions of time and context. This is in contrast to standard practices of “General Contracting” and “Construction Management” which seeks to both identify a project as a single one-off occurrence, and a delegation of discretely defined sub-contracts. The one-off treatment assumes a single, complete contract; and discrete-sub-contracts assume that the single-complete-contract can be segregated into smaller complete-contracts, ignoring any interdependencies. In other words, an owner could be led to believe that the sum of the parts equals the whole. The conceptual roles of either the general contractor (GC) or the construction manager (CM), as has been put forth in the past are to coordinate the subcontract trades. In similar fashion, the traditional role of the architect is to coordinate the work of engineers and other consultants. As professionals, the GC or CM is advised legally to not involve themselves in design coordination. Likewise the architect is advised legally to not involve themselves in the coordination of construction activities (Allensworth, W., et al.; pp. 259-262; pp. 359-360 (2009)).

The lack of coordination between the architect (research and development) and contractor/construction manager (production and fabrication) is perhaps the biggest source of controllable legal claims. The biggest areas of risks are scope change, resource allocations design defect or lack of functionality, schedule delays, schedule estimates, outsourcing, schedule dependencies, and monetary adjustment (Kendrick, T.; 2003; pg. 36). All are believed preventable through process management⁸.

⁸ See Appendix C, for an analysis of Critical –Path-Method (CPM) scheduling methodology, for a comparison to Process Management.

3.6. Process Management

Neither research and development nor production and fabrication are a single process. Each is composed of many processes. Lean advocates in construction have sought for efficiencies within current construction project constructs, based on traditional methods. The lean advocates have also sought to apply their understandings of industrial lean practices to design, e.g. research and development (Ballard, G.; 2000b; Ballard, G.; 2008; Ko, C. H., et al.; 2014). These efforts seek to solve the problems of construction phase risk using industrial lean management techniques, and related philosophies, to correct the industry's tendency to execute construction contracts based on incomplete designs, wishful schedules, and budgets developed more on owner budgets than actual anticipated costs. With much of these philosophies based upon Toyota Production System, there is little acknowledgement of the Toyota Product Development System. Figure 3.6.1 illustrates an analysis of the concept of waste within Toyota's design (research and development) processes. Whereas lean principles state that waste must be eliminate, in favor of value-added; it appears that Toyota *wastes* 75 percent of their time designing some of the bestselling and profitable automobiles in the world.

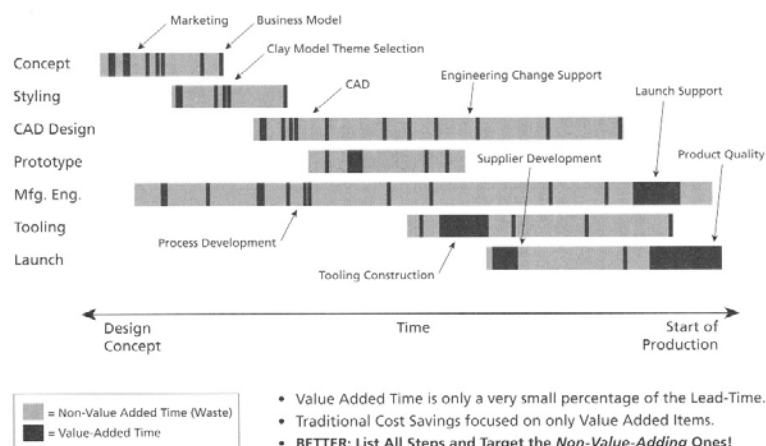


Figure 5-1. Product Development Lead Time

Figure 3.6.1
Toyota's Product Development Lead Time

To apply principles of the TPDS to a Knowledge Management Process (KMP), the TPDS development process is informative, as described in Figure 3.6.1, which illustrates that Manufacture Engineering (the planning for production) and Tooling (preparation for fabrication) occur while the design development occurs; and prior to actual production. The entire TPDS development process is overseen by a chief engineer (Morgan, & James M.; Liker, 2006).

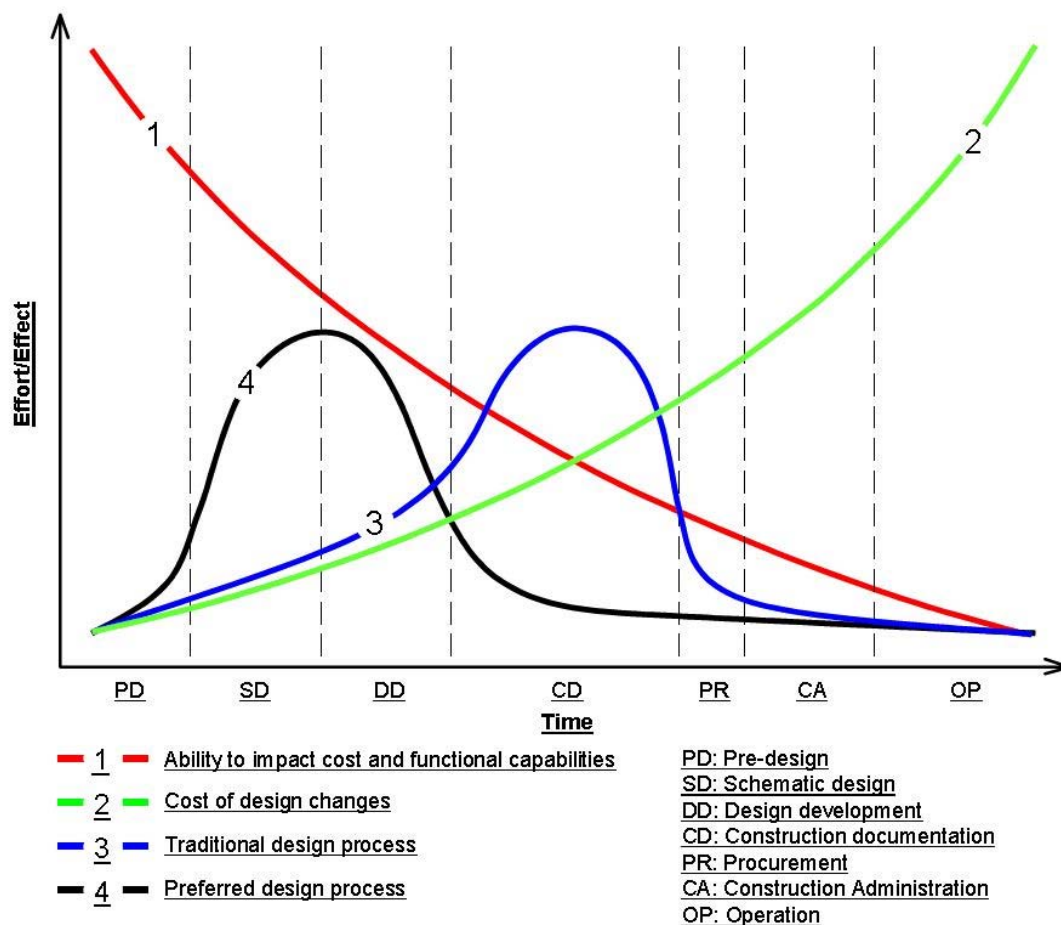


Figure 3.6.2
MacLeamy Curve

In-line with the TPDS example, experts (resources and assets) are required to be integrated into process events to add to each event's knowledge creation. Recent building industry project delivery methods have sought to maximize knowledge input into the early

phases of the design processes, to minimize impacts to project cost, functional capabilities, and the cost of design changes, as illustrated in Figure 3.6.2. To maximize value and minimize waste, the Process Manager controls the interactions within and between events through transactions⁹. All such transactions have costs associated with them. Other resources to specific events are overseen by the Process Manager as described in Figure 3.6.4. Events should not be allowed to grow beyond where uncertainties are unmanageable. When events establish excessive numbers of uncertainties they should be split into sub-events, as illustrated in Figure 3.6.5. The process management process seeks to reduce or eliminate the risks associated with modern fast-track and guaranteed-maximum-price contracts, based in incomplete contracts. Through process management contract packages, following the concepts of the MacLeamy curve, a modified version, see Figure 3.6.3, seeks to enable an incremental delivery methodology that reduces risks.

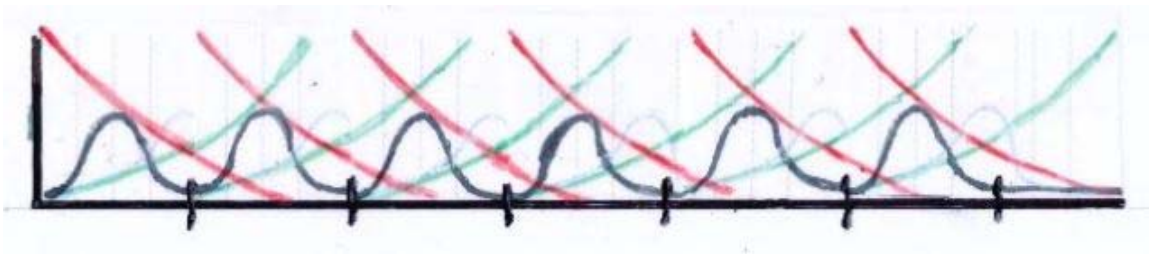


Figure 3.6.3
Modified MacLeamy Curve

⁹ See Appendix A for additional information on aspects of transaction governance in a process management context.

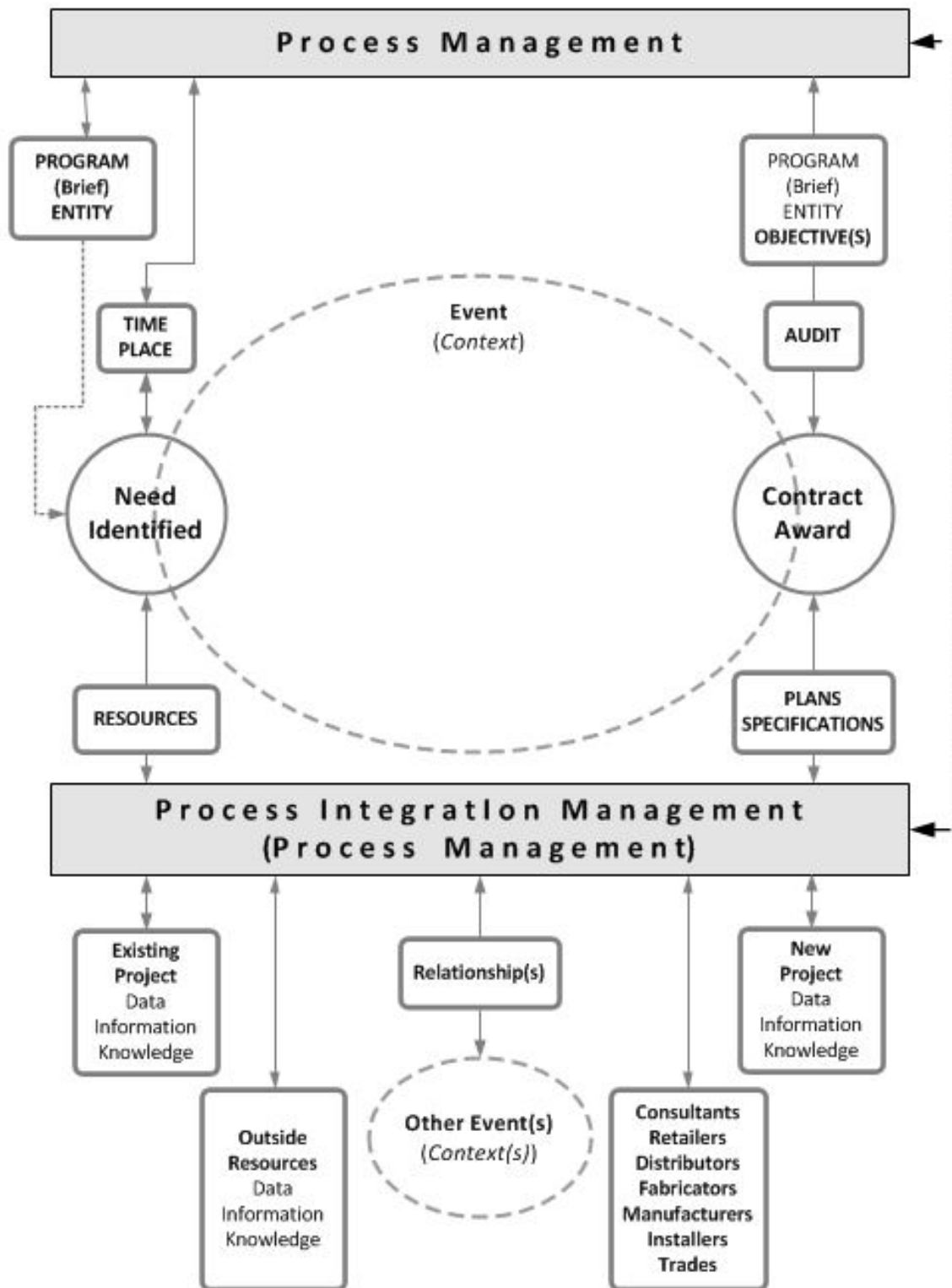


Figure 3.6.4
Process Management – Single Event

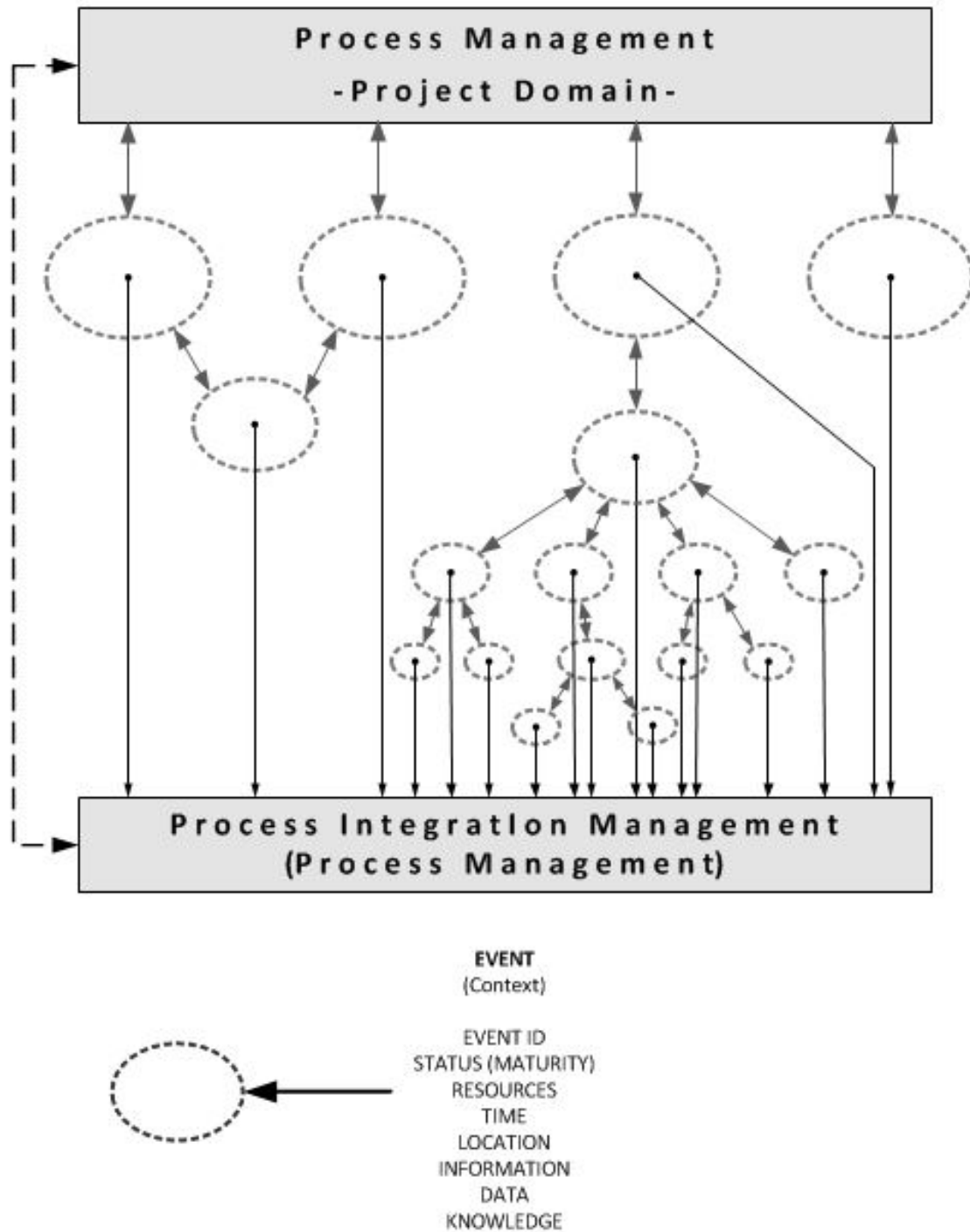


Figure 3.6.5
Process Management – Multi-Event

3.7. Process Events (*Context for Knowledge Creation*)

With a context for events, and the process manager controlling of transactions, the processes need to provide for the required expert knowledge resources that are restrictive due to traditional practices and their related case-law interpretations.. Whereas building projects in their entirety are complex, events are simple. If transactions are viewed as discrete contracts, they are then composed of simple exchanges. Liability is potentially limited to the cost of the simple transaction, or potentially waived completely. In research and development portions of projects, the events indicate their needs in regards to resources, including expert knowledge. Architects and engineers have historically relied on product and systems manufacturers, who are most knowledgeable of the products and systems, which they design, engineer and sell. Traditional relationships between designers and product manufacturers are that of a seller and a buyer's-agent, who will approve and specify the product. When such a relationship involves services related to custom products or systems, some sellers may limit their services until they are confident of a sale. In these situations a manufacturer, or several, may be brought in as a paid consultant, who works directly for the architect or engineer. Manufacturer's may still compete against one another in regards to meeting the project's needs; and then upon selection, provide final fabrication drawings (shop drawings) to become part of a contract for construction, providing invaluable knowledge to the project. Such a process has been used by the architect Frank Gehry (Tombesi, P.; 2002).

Early-Contractor-Involvement (ECI), Design-Assist Services, and Pre-Construction Services, have all been offered by GCs and CMs as additional services to owners in recent decades, but are unreliable based on current construction law practices based on traditional

delivery services. Once a GC or CM agrees to a contract with the owner, technically ECI, Design-Assist and Pre-Construction services stop, whether the design is done or not.

Through a *Process Manager* Project domain, GCs and CMs may also limit their liability through transactional events. Time and Cost data is critical throughout the research and development (design) portions of the project. GCs or CMs could serve two separate contractual roles, that of research and development (design) consultant to the *Process Manager*, and that of GC or CM of production and fabrication (construction). The GCs or CMs fee can be structured to reflect the services, overhead and profit for construction services contracted to date, separate from the consultant fees, which are event based transactions.

Through process transaction events¹⁰, each event or a group of events, that matures fully, is developed into a contract package. The contract package of events is limited to a precise trade, supplier or manufacturer. Where manufacturers have served, or are serving, as a consultants to the Process Manager; they too will serve separate contractual roles under separate transaction agreements, with specific contract conditions related to that package. Prior to the contract packages release, the manufacturers' provided consultant should provide all data sheets and fabrication drawings (submittals and shop drawings), paid for through his consultant transaction agreement, to be included in the contract package. The GC or CM, as a consultant to the Process Manager, should present an updated construction plan that proposes how new events will be coordinated and sequenced with currently contracted events, as they relate to the proposed contract package. The GC or CM should prepare a proposed plan of execution that identifies means, methods, techniques and procedures; demonstrating constructability, scheduling, and budget adherence. The plan should acknowledge all product data, shop-drawings and other event package documentation. The Process Manager should seek concerns from the design team and

¹⁰ See Footnotes, page ii.

consultants as to whether there are concerns in regards to the intended end results of the events in construction execution. Such event is then declared mature for contract execution.

This thesis assumes that phased or fast-track project delivery, or an improved process of delivering projects as quickly as possible, while delivering the customer value, will continue its prominence in the building industry. Knowledge losses between phases are made more erratic, complex and uncertain by application of current practices of fast-track project delivery (Atkins, J. B., & Simpson, G. A.; 2008).

In the building industry, waste is being interpreted as changes and delays, and efforts such as lean construction attempts to solve these issues. The Shewart Cycle, has been recognized by proponents of lean construction (Ballard, G., & Howell, G.; 1997); they state the logic of lean construction implementation requires a certain sequence of initiatives, which progressively reveal additional opportunities for improvement; they also recognize that the TPS philosophy that they seek to interpret is a *process*, but appear to fail to acknowledge an institutional arrangement or process philosophy, that addresses the design and development for the entirety of a project. One concept of lean advocates is that the person actually doing the work (in this case: events – or potential contract packages) has to plan and execute the work, similar to Shewarts Cycle, though they present it without Shewarts steps five and six – the iterative dimension.

A broader institutional¹¹ arrangement view recognizes that the person (s) who may actually be doing the work may also first serve as a potential transactional asset (resource) to a problem context (event). Resources by nature are a source of bounded rationality so no single resource may be appropriate. Specifically, if a resource hinders value-creation through a bureaucratic institutional arrangement that are intended to create value, such transactions may be

¹¹ See Appendix A, for additional information on transactional governance.

deemed wasteful to the event, the process and the project; and must be managed appropriately to reduce waste.

For each project event an estimated economic transaction budget is established for research and development of such events. Transaction costs associated with attaining required data, information, knowledge and other resources, such as consultants, potential suppliers, fabricators, and production personnel; are compensated subject to the budgeted appropriations and the relevancy of the contributions, and willingness for risk exposure; based on a structure of specific conditions of Incentive Intensity For suppliers, a potential contract to supply materials and/or products may be at stake. For fabricators, a fabrication contract may be at stake. And for production personnel, including contractors and subcontractors, a contract to execute the specific project event may be at stake. This specifically seeks to manage and control hostage-taking and opportunism through the design and development processes; and foster total quality management and continuous improvement¹².

Contract packages are inclusive of all product data (submittals), shop drawings, mock-ups, event execution (production) schedule, fixed cost, as accepted by the package team and approved by the owner, architect, engineers, consultants, and those who make a credible commitment to execute its production. The package includes construction execution means, methods, etc., that serve to exhibit the constructability, staffing, machinery and equipment, coordinated with all previous construction packages issued prior.

The process framework provides an institutional environment that provides for the engagement, compensation, and limitation-of-risk to ensure that the last planner is knowledgeable, capable, willing and committed to execute a specific project event – contract package. Such packages are

¹² See Appendix A, for additional information on transactional governance.

delivered Just-in-Time, compensating for any variants in project conditions known at the time of issuance.

Chapter 4

Summation and Discussion

4.1. Recent Developments

Recent alternative methods of project delivery have attempted to address project cost, schedule and quality. Many of these new methods have been developed to address concerns with large complex projects deemed to have higher risks and greater uncertainty than most other projects. Because such conditions can increase the industry's traditionally inherent antagonism between participants, several newer methods have sought to create a single collaborative team of owners, designers, and contractors that seeks to share in risk and reward in a relational contracting framework. These have included alliance contracting and integrated project delivery arrangements. Such contracts are known typically to include only the more traditional large participants in a primary team, excluding many suppliers, manufacturers, sub-contractors, and specialty consultants. A pain-share/gain-share (sharing in profits and losses) is limited to the primary participants. Relationships with those outside the primary contract are included through more traditional consultant or construction contract structures.

Alliance contracting is based on the concepts of relational contracting for on-going relationships. Such contracts are based on ill-defined project scope from the beginning. Draft standard alliance contracts are known to be 180 pages long, and require a dense structure to manage the administration costs throughout a project. Research has found that alliance contracts fail from 60 to 80 percent of the time (Stanek, M. B.; 2004).

Integrated project delivery (IPD) has developed mostly within the last decade, partly with the increased use of BIM software products, and efforts to facilitate virtual (three-dimensional) coordination not only between design team members, but also between design team members

and contractors and subcontractors. There is no single definition of an IPD contract arrangement, and at least three or more standard contracts address the concept. Often times it's a promise to attempt to work together, and other times it's similar to an alliance, as previously described. It is an agreement between traditional major construction project participants, and may not include other parties that may influence the project's success.

Another project delivery method is a Public-Private-Partnership (PPP). Though many variations may exist, two most common are a Public (government) entity engaging private financing to have a PPP entity build-own-operate-transfer (BOOT) a project that may typically be developed solely by the government. Private investors are compensated by revenue generated by the project for a period of time, often decades, after which the facility is turned over to the government.

Incentives are for the PPP entity to build a facility that can be operated at efficient cost, to maximize profits from revenue. Another form of PPP is design-build-finance-maintain (DBFM), where the government finances the project, and draws revenue from the project; while the PPP entity is responsible for designing within a budget of fixed financing, and to maintain the project under a maintenance contract. The PPP entity is incentivized to design and build a facility that is within budget, and requires reduced maintenance cost, to maximize their profit for the period of their maintenance contract. The DBFM is perhaps more common, but has risks of potential abandonment if the PPP business plan does not materialize. Other recent concerns have surfaced in regards to whether PPP's enjoy sovereign or governmental immunity in some aspects of their operations.

Each of these delivery methods could benefit from either integrated or auditory assurance through process management. Both the alliance delivery methods and the IPD method attempt to create an environment within which a process management system functions; but they appear to

do so through added bureaucracy and premature commitments to key participants. Some versions of alliance contracting seek to control opportunism through the use of transaction contracting. For a building project this may be represented by issuing phased packages of contracts, as designs are completed. If a particular contractor or sub-contractor performs poorly on one or more packages, future packages of contracts may be awarded to other parties (Stanek, M. B.; 2004).

Singular, large contract awards may also be subject to opportunism, especially when an owner, regulatory official or future building occupant requires changes. An owner today is held liable for any changes, no matter how small or whenever they may occur, and will often pay more for work that was not included in an original contract.

Even alliance and IPD contracts attempt to pre-establish as many aspects of a project as possible prior to thorough design analysis, detailed development or actual construction. If the owner's Process Manager maintains overall project scheduling, and budgeting and audits all transactions within and between all parties, instantaneous analysis of causation and potential schedule and budget impacts can be provided for quicker decisions based on timely and accurate data.

This thesis developed an argument that the internet and project management web sites have only taken traditional project delivery techniques and made traditional project problems more transparent quicker. Management of business process management systems, which harness not only data and information, but knowledge, can produce a more efficient and productive construction industry.

4.2. Networked Knowledge Management

Little if any research addresses incomplete contracts, delays, owner changes and the associated litigation, from a position of managerial acceptance. Decades of exhaustive research addresses causation and blame leading to the owner, the architect, the engineer, and other design consultants; with no studies addressing why the contractual governance structure has allowed for such problems to arise.

At least a hundred and fifty years ago the U. S. Federal Government began a century long stretch of construction projects, from the White House and the U. S. Capital building to many structures that still stand today nationwide, that are a testament to processes focused on achieving something that would endure beyond any short-sighted gains.

The building industry and its projects have grown complex due to the complexity of building systems and the number of experts, regulations, standards, and advanced computer simulation modeling that is becoming common in more and more buildings. Some members of the building industry choose to claim ignorance of the extensive processes of research and development that are increasingly becoming part of, and required of, standard professional building design and engineering practices. Cost engineering is required during research and development, but is often shielded from the design parties who are later blamed for cost overruns. Practical fabrication engineering, or constructability, during research and development; is shielded from fabricators, to later be blamed for designing something that cannot be built within the allotted scheduled time or for which the low bidder is incapable of producing.

How can such situations, that are common practice in today's building industry, be overcome? The aforementioned scenarios, based on real-life occurrences, can be overcome by

separating process from contract. Contract here means either construction or design in their legal frameworks as discussed previously.

From the beginning of the digital age business conducted through the written word and drafted illustrations have become the interchange of data. From data, information and knowledge is expected to be inferred based on who sent it and why. The person receiving the data has specific expectations, which the sender is expected to know and comply with. The type of data that is sent is expected to be of a specific computer file type, include specific classifications of data that is complete to a specific level of detail, which is organized and categorized into the correct one of a thousand categories.

With the introduction of Electronic Data Interchange (EDI) and the Internet, design and construction contracts have increasingly started to include discrete electronic data requirements for contract parties to adhere to. These were initially termed *Communication Specifications*. Around the same time the U. S. Department of Commerce's report in 2004 about the lack of interoperability and standards for the management and communication electronic project data in the building industry, that capital facilities construction and operations were losing tens of billions of dollars a year (GCR, NIST; 2004).

Several developments appeared in response. Autodesk, the software developer of Revit BIM software produced a BIM Communication Specification[®] (2008), at the same time NIST published the U. S. National BIM Standard (2007), and The Pennsylvania State developed the BIM Project Execution Planning Guide (2010), in association with the buildingSMART[®] alliance. In addition several standard form contracts have added addendum documents that address electronic communications and data files, particularly BIM.

What all these documents have in common is that they attempt to *predict* the required EDI exchanges required for the entire research, development, construction, and life-cycle of a building project. What this research recognizes is that such requirements are manageable, but most often unpredictable and dynamic in nature. A Process Management structure is required to manage and dynamically audit process flow to prevent problems presented above.

Such process management structure seeks to build processes from industry best practices, through continuous improvement, and use them to monitor and pose questions to current and potential actors within the overall processes, sub-processes and their event structures. When and where best practices are developed, they are harvested as a knowledge asset for potential reapplication elsewhere.

The process structure seeks to eliminate hierarchy and bureaucracy, through an interweaving of the knowledge contexts as illustrated in Figure 3.4.1. This requires exploration of new computer applications that manage data, information and knowledge beyond the *Construction Documents* (data and information associated specifically with the execution of the construction contract), as most if not all computer-based construction management software on the market do today.

A single project process has had and does have its own network of knowledge; though their process has no structured system of management. Likewise, the building industry is fragmented in the belief that knowledge is sacred, to be secured and guarded. Most often this means knowledge philosophically can sit on a shelf and collect dust, while its value dwindles.

New societal structures have recognized that not only collaboration, but knowledge sharing can enhance its value for both others and its original source. This is what western societal education is based upon. As presented through transaction cost economics, the sharing of

knowledge can be profitable as well. Software manufacturers do this through licensing agreements. Patent holders also license their ideas. Such licenses, whether for limited or ongoing use can produce *rents*, or fees that turn virtual perceived value into actual revenue and profits.

The contextual or event structures concepts presented in this paper assume that similar events are happening not only nationwide, but globally. The expansion of process management beyond a single project would seek to acknowledge the existence of such knowledge, and enable transactions beyond a singular projects boundaries, and beyond projects themselves. This is why the industry-wide belief that projects is “*one-offs*,” is detrimental to innovation in the building industry. Today, the building industry is fraught with corporate mergers and acquisitions, to either expand into to markets or capture new corporate knowledge sources. The majority of design and construction companies in the United States and globally are small in size. Does it benefit society to create new conglomerated silos of knowledge?

Many of the building industries small companies are good at what they do. They could also do better. The benefactor is the customer, the owner, their neighbors, and their towns and villages.

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APPENDICES

Appendix A: Transaction Governance

Terminology and definitions specifically related to Transaction Cost Economics:

Asset [Resource] Specificity – “A specialized investment [an application of knowledge] that cannot be redeployed to alternative uses or by alternative users at a loss of productive *value* [emphasis added]. Asset [resource] specificity can take several forms, of which *human, physical, site, and dedicated assets* [emphasis added] are the most common. Specific assets [resources] give rise to ***bilateral dependency*** [emphasis in original], which complicates *contractual relations* [emphasis added]. Accordingly, such investments [or applications of knowledge] would never be made except to contribute to prospective reductions in production costs [reduction of waste] or additions to revenue [added value]” (Williamson, 1996; pg. 377).

Asset specificity is therefore **the creation of value**. Whereas, the reductions in production costs; or the reduction the miss-application of assets or resources; are deemed equivalent to the concept of waste reduction, as is often presented by proponents of lean. The insurances that assets, or resources, that are necessary and specific to a problem event or process provide the required knowledge to that specific problem, and in doing so ***adds value***.

Bilateral Dependency – “An ongoing dependency relation obtains between a buyer [receptor of knowledge] and a supplier [the provider of knowledge] when one or both have made durable specialized investments in support of the other. Although sometimes this condition exists from the outset (the familiar bilateral monopoly condition), often it evolves during an ongoing contractual relation. Bilateral dependency, in which one or both parties specialize for the other, is a more widespread condition than preexisting bilateral monopoly. Such dependency poses *contractual hazards* [emphasis added] in the face of *incomplete contracting and opportunism* [emphasis added], in response to which contractual safeguards are commonly provided” (Williamson, 1996; pg. 377).

Discrete process events that are intended to resolved defined problems seek to ascertain specific assets required to address that specific event. Without managed events conditions may exist for either monopolistic behavior by one party, or bilateral monopolistic behavior among two or more parties. Either or both conditions could potentially *create a bilateral dependency* as well as *hostage situations* in the larger context of project events. Process management serves to provide oversight to prevent or terminate monopolistic behavior that does not provide appropriate ***value*** to the project.

Bounded Rationality – “behavior that is intendedly rational but only limitedly so; it is a condition of limited cognitive competence to receive, store, retrieve, and process information. All

complex contracts are unavoidably incomplete because of bounds on rationality [italics emphasis added]” (Williamson, 1996; pg.377).

Assets or resources whether singular or multiple, bring bounded or limited rationality to either a simple or complex project or its defined events. Bounded discrete contracts also create bounded rationality. Incomplete contracts are a misnomer in that parties have agreed to a discrete definition that can later be argued to be irrational to the extent that specifics had not been previously agreed to.

Bureaucracy – “The support staff that is responsible for developing plans, collecting and processing information, operationalizing and implementing executive decisions, auditing performance, and, more generally, providing direction to the operating parts of a hierarchical enterprise. Bureaucracy is attended by low-powered incentives (due to the impossibility of *selective intervention* [emphasis added]) and is given to subgoal pursuit (which is a manifestation of *opportunism* [emphasis added])’ (Williamson, 1996; pg. 377).

Unlike contracts that create principals or committees, and predefined multi-layered channels of communication, Process Management seeks a horizontal cross-disciplined integrated culture where processes serve to seek out the best and most appropriate assets and resources beyond the bounded rationality of the decisions of a small group of individuals.

Behavioral Assumptions – transaction cost economics seeks for understanding of the actions of human agents. The building industry is fraught with behavioral assumptions, engrained in contracts that assume the worst and to seek to punish versus prevent. Process Management seeks, through the use of transactions, to expose and disperse of assumptions; so those who are to execute (produce) events through contract packages know-why, know-how, and know-what is expected and agreed to.

Contract – “An agreement between a buyer and a supplier in which the terms of exchange are defined by a triple: price, asset specificity, and safeguards. (This assumes that quantity, quality, and duration all are specified)” (Williamson, 1996; pg. 377).

Credible Commitment – “A contract in which a promise is reliably compensated should the promisor prematurely terminate or otherwise alter the agreement. This should be contrasted with noncredible commitments, which are empty promises, and semi-credible commitments, in which there is a residual hazard. Credible commitments are pertinent to contracts in which one or both parties invest in specific assets” (Williamson, 1996; pg. 377).

Process Management seeks two types of credible commitments. These include commitments to design and development events, and commitments to execution and production contracts. The two are different. The failure to commit to the first process events means that an opportunity to commit to the latter is eliminated. The first commitment seeks to define the contract package that creates the latter.

Discriminating Alignment – the assignment and use “of the least-cost governance structures to manage transactions” (Williamson, 1996; pg. 378).

Alignment eliminates **waste**, and adds **value**.

Event – an event, is the *context* (Ba – “place”) in which knowledge exists in one of its many states; providing for a phenomenological time and place for the emergence of knowledge (Takeuchi, H., Nonaka, I.; 2004; pg. 102).

In the process management model, events vary in size based on the required assets or resources required. As events grow in complexity or size, they shall be broken down into smaller events.

Flow (Physical) – in of industrial production, the concept of flow is the physical arrangement of factory production equipment and activities that are intended to achieve the greatest efficiency (Mondan, Y., 2012; pg. 127-128).

Flow (Psychological) - Mr. Csikszentmihalyi states that Flow have several functions: to create “enjoyable experiences” (pg. 82); the ability of a person to “restructure consciousness...to make flow possible” (pg.83);and a social context that is not lacking of rules nor is it constraining, permitting states of clarity, centering, choice and trust (pp. 85-88), (Csikszentmihalyi, M.,1990).

Flow (“Managing Flow”) – Theory of a Knowledge-Based Firm, recognizes the need for processes to manage knowledge in today’s business environment. Nonaka states “In process philosophy, the world is an organic web of interrelated processes or series of events in which everything exists in relation.” (Nonaka, I.; Toyama, R.; 2008; pp. 13-14).

Governance – Nobel Laureate Williamson provides two definitions of governance, the first he accredits to Lon Fuller, as “the science, theory or study of good order and workable arrangements.” The emphases here are efforts “to identify, explicate, and mitigate contractual hazards.” Such hazards are attributed to “bounded rationality [see Definition, above] and opportunism.” This first definition is adopted by Williamson, and is equally adopted by this paper. (Williamson, 1996; pg. 11-12). A second definition describes it as “an exercise in assessing the efficacy of alternative modes (means) of organization. The object of which is to effect good order through mechanisms of governance. A governance structure is thus usefully thought of as an institutional framework in which the integrity of a transaction, or related set of transactions is decided.” This latter definition is representative of explicit contractual governance, which attempts to be discrete (Williamson, 1996; pg. 11).

Governance Structure – “The institutional matrix in which the integrity of a transaction is decided. In the commercial sector, three discrete structural governance alternatives are commonly recognized: classical market, *hybrid* [emphasis in original] contracting, and *hierarchy* [emphasis in original]” (Williamson, 1996; pg. 378).

Hierarchy – “Transactions that are placed under unified ownership (buyer and supplier are in the same enterprise) and subject to administrative controls (an authority relation, to include fiat) are managed by hierarchy. The contract law hierarchy is that of forbearance, according to which internal organization is its own court of ultimate appeal” (Williamson, 1996; pg. 378).

Hostage Model – The Hostage Model is concerned with “[C] redible commitments and credible threats,” which “appear in conjunction with irreversible, specialized investments.” Through the traditions of contract law, assumptions by non-lawyers have developed to believe that the legal system provides them specific protection for transaction exchanges (see also Private Ordering), “in a knowledgeable, sophisticated, and low-cost way,” this is far from reality. Contractual agreements have consequences, and are subject to bounded rationality and opportunism (Williamson, O. E.; 1996; pp. 120-144).

Hybrid – Long-term contractual relations that preserve autonomy but provide added transaction-specific *safeguards*, compared with the *market* (Williamson, 1996; pg. 378).

Incentive Intensity – “A measure or degree to which a party reliably appropriates the net receipts (which could be negative) associated with its efforts and decisions. High-powered incentives will obtain if a party has a clear entitlement to and can establish the magnitude of its net receipts easily. Lower-powered incentives will obtain if the net receipts are pooled and/or if the magnitude is difficult to ascertain” (Williamson, 1996; pg. 378).

Incomplete Contracting – “Contracts are effectively incomplete if (1) not all relevant future contingencies can be imagined, (2) the details of some of the future contingencies are obscure, (3) a common understanding of the nature of the future contingencies cannot be reached, (4) a common and complete understanding of the appropriate adaptations to future contingencies cannot be reached, (5) the parties are unable to agree on what contingent event has materialized, (6) the parties are unable to agree on whether actual adaptations to realized contingencies correspond to those specified in the contract, and (7) even though both the parties may be fully apprised of the realized contingency and the actual adaptations that have been made, third parties (e. g. courts) may be fully apprised of neither, in which event costly haggling between bilaterally dependent parties may ensue” (Williamson, 1996; pg. 378).

Institutional Arrangement – “The contractual relation or governance structure between economic entities that defines the way in which they cooperate and/or compete” (Williamson, 1996; pg. 378).

Institutional Environment – “The rules of the game that define the context in which economic activity takes place. The political, social, and legal ground rules establish the basis for production, exchange, and distribution” (Williamson, 1996; pg. 378).

Institutions – Douglass North is quoted as defining institutions as “the humanly devised constraints and structure political, economic, and social interactions. They consist of both

informal constraints (sanctions, taboos, customs, traditions, and codes of conduct), and formal rules (constitutions, laws, property rights)” (Williamson, 1996; pg. 4).

Just-in-Time (JIT) - is a concept of industrial production represented by practices in the Toyota Production System (TPS). It “is a method of *adapting to changes due to troubles and demand changes* [emphasis added] by having all *processes* [emphasis added] produce the necessary goods at the necessary time in the necessary quantities” (Mondan, Y., 2012; pg. 35).

Lean Construction – There is no single definition of *Lean Construction*. Self-published and Academic papers tend to be self-published by the Lean Construction Institute (LCI) which tend to build upon each other’s writings, or revise and change their own less developed existing writings; this is potentially to the detriment of a philosophy unwilling to engage outsiders unless they first submit to the groups thinking. Though the term “Lean Construction” and other registered trademarked terms (owned LCI) appear in AGC’s ConsensusDocs (another copyrighted venture), no *Legal Definition* for “Lean Construction” or the practices referenced to it appear are provided in the ConsensusDocs.

Market – “The arena in which autonomous parties engage in exchange. Markets can either be thick or thin. Classical markets are thick, in which case there are a large numbers of buyers and sellers on each side of the transaction and identity is not important, because each can go its own way at negligible cost to the other. Thin markets are characterized by fewness, which is mainly due to asset specificity. *Hybrid* [emphasis in original] contracts and *hierarchy* [emphasis in original] emerge as asset specificity builds up and identity matters.” (Williamson, 1996; pg. 378).

Opportunism – “Self-interest seeking with guile, to include calculated efforts to mislead, [to] deceive, [to] obfuscate, and otherwise confuse. Opportunism should be distinguished from simple self-interest seeking, in accordance to which individuals play a game with fixed rules that they reliably obey” (Williamson, 1996; pg. 378).

Private-ordering – “Self-created mechanisms to accomplish adaptive, sequential decision making between autonomous parties to a contract, including information disclosure, dispute settlement, and distributional mechanisms to deal with gaps, errors, omissions, and inequities. (Court ordering, however, is normally available for purposes of ultimate appeal)” (Williamson, 1996; pp. 378-379).

Proof-of-Concept (PoC) - is the realization of a certain method or idea to ascertain its scientific or technological parameters. A proof-of-concept should be understood sufficiently so that potential application areas can be identified and a follow-on working prototype designed. (NSF, 2014).

Pull – the word “Pull” is often used in the description of industrial *production* systems which are engaged in the practices of “*Just-in-Time*” operations management. These are most typical in

small product lot operations where components will likely vary with the lots. Pull connotes the requesting, through a “*Kan-Ban System*”, only those components that are required for the production of a specific lot of product (Monden, Y., 2012; pp. 138-140).

Remediable – “A condition is held to be remediable if a superior alternative can be described and implemented with net gains” (Williamson, 1996; pg. 379).

Safeguard – “The added security features, if any that are introduced into a contract in order to reduce hazards (due mainly to asset specificity) and to create confidence. Safeguards can take the form of penalties, a reduction in *incentive intensity* [emphasis in original], and/or more fully developed *private-ordering* [emphasis in original] apparatus to deal with contingencies.

Selective Intervention – “This would [be] obtained if bureaucratic intervention between the semiautonomous parts of a hierarchical enterprise occurred only (but always) [sic] when there is a prospect of expected net gain. Because promises to intervene selectively lack credibility, selective intervention is impossible. If it were otherwise, everything would be organized in one large firm. Because, however, selective intervention is possible [;] hierarchies are unable to replicate market incentives” (Williamson, 1996; pg. 379).

Total Quality Control (TQC) – per Ohno, credited as the founder of the Toyota Production System: “The Toyota Production System is one and the same with TQC and with its principle of zero defects. They are simply different names...” (Ohno; 2009).

Nr. Nemoto, head of production control at Toyota starting in the 1960’s, gave a speech including the following passage in 1997: “That brings me to a book that came out of the United States a few years ago called *The Machine That Changed the World*. That book presents the findings of a research consortium based at the Massachusetts Institute of Technology (MIT). It’s a truly excellent book. It’s one really disappointing flaw is that it fails to mention the role of TQC in lean manufacturing. It’s a pretty thick book, but even where it mentions quality control, it leaves off the T [for total].” Mr. Nemoto in the same speech said later “I have a theory about why *The Machine That Changed the World* omits TQC in its description of Toyota’s approach. My theory is... TQC would be unconvincing and even insulting to American executives... After all, quality control was an American invention.” For Japanese readers he cautioned, “Japanese readers of *The Machine That Changed the World* need to keep in mind the book’s crucial omission. Otherwise, they could come away with a serious misunderstanding: that simply using the Toyota Production System is all they need to do to achieve higher quality.” (Nemoto, 2009).

Toyota Production System (TPS) – is an industrial production system whose basic philosophy is “continuous improvement” (Monden, Y.; 2012; pg. xxv). Its founder Taiichi Ohno emphasized that “Toyota production system has to ‘evolve’ [emphasis in original] constantly to cope with severe competition...” From its origin in 1983, the systems continued emphasis has been the rationale of “goals-means or causes-effects relationships” (Monden, Y.; 2012; pg. xxxvii).

Traditional Project Delivery – The term *Traditional Project Delivery* can often be interpreted as that way it has always been. This is not the case, see Chapter 2.

Transaction – “The microanalytic unit of analysis in transaction cost economics. A transaction occurs when a good or service is transferred across a technological separable interface. Transactions are mediated by governance structures (*markets, hybrids, hierarchies*) [emphasis in original]” (Williamson, O. E., 1996, pg. 379).

Transaction Cost - The ex-ante [before the event] costs of drafting, negotiating, and *safeguarding* [emphasis in original] an agreement and, more especially, the ex post [after the event] costs of maladaptation and adjustment that arise when the contract execution is misaligned as a result of gaps, errors, omissions, and unanticipated disturbances; the costs of running the economic system” (Williamson, O. E., 1996; pg. 379).

Specific Transaction Costs – have two attributes: costs incurred in advance of the anticipated exchange – which are sunk costs, and the value that such costs could have created in alternative applications, or by alternative users – opportunity cost (Williamson, O. E., 1996; pg. 124).

Value (Value-added) – as defined by Michael Porter, a leading business strategist, “Value,” is viewed in its relationship to cost. For a business event, or process, to deliver output that is deemed of value; valued resources shall be identified which are represented by cost, and defined as fixed-costs. The “Value” of the output, less fixed costs equals value-added (Porter, 1980, pg. 8).

Waste – see “Value” (Value-added), above. The total-costs of the output less value-added are defined as “Waste.” Porter notes that fragmented service industries become commoditized when identical, non-differentiated; products or services are delivered to customers. Such differentiation is not the end “Value” delivered, but the totality of total-cost, value, and “Waste.” Porter presents examples value-added being generated by production industries that provide forward integration; in either pre-assembly or expanded services, that are required overall, and reduce waste, thus adding value (Porter, 1980).

Weak Form Selection – “Selection from among the better of the feasible alternatives, as contrasted with the selection of the best from among all possible, to include hypothetical alternatives. In a relative sense, the fitter survive, but these may not be the fittest in any absolute sense” (Williamson, 1996; pg. 379).

Appendix B: Programming

Programming is an early project *process of discovery* which produces a Project Program or Brief. The processes of Programming and Designing have distinctions from one another, though they may be performed by the same individuals. The Programmer is often more objective, analytical, though is able to engage in abstract ideas. Designers are often more subjective, intuitive and disencumbered by physical concepts.

The Program begins with the drafting of a Schematic Program that then informs Schematic Design. Schematic Design then is a process of evaluation, refinement and archiving of Schematic Design information deemed less applicable to the current project, which may inform other projects. The Schematic Design process guides the preparation of the Programs' Development from the general to the more specific; which then *organizes and classifies information* for use in design development.

The Programming proceeds through five steps, which may be disordered and iterative:

Step 1 – Establish GOALS (Qualitative, What? Why?).

Step 2 – Collect and Analyze FACTS (what is known?).

Step 3 – Uncover and test CONCEPTS (Quantitative – programmatic versus design concepts). The most common programmatic concepts are inclusive of:

- Priority
- Hierarchy
- Character
- Density
- Service Grouping
- Activity Grouping
- People Grouping
- Home Base (Fixed, Free, Group, Satellite, Telecommute, Virtual)
- Relationships
- Communications
- Neighbors
- Accessibility
- Separated Flow
- Mixed Flow
- Sequential Flow
- Orientation
- Flexibility
- Tolerance
- Safety
- Security Controls
- Energy Conservation
- Environmental Controls

Phasing
Cost Control

Step 4 – Determine NEEDS (economic feasibility test – cost, space, quality).
GOALS, FACTS, CONCEPTS inform:

Space Requirements
Quality of Construction
Money Budget
Time
Cost Control:
Efficiency Ratio (Net-to-Gross Area)
Cost per Square Foot (Meter)
Percent-of-Building-Cost

Step 5 – State the PROBLEM (the Distillation of information and tested needs).

The **Problem Statement** is the premises for Design:

Function(s) – numbers and characteristics:

People
Activities
Relationships

Form (s) – physical and psychological:

Site
Environment
Quality

Economy:

Initial Budget
Operating Costs
Life-cycle Costs

Time:

Past
Present
Future

The iterative *process of programming* uses a matrix of programming steps and Problem Statement components to address a multitude of customer specific and potential *project defining guidance criteria*:

Function (s)/GOALS:

- Mission
- Maximum Number
- Individual Identity
- Interaction/Privacy
- Hierarchy of Values
- Prime Activities
- Security
- Progression
- Segregation
- Encounters
- Transportation/Parking
- Efficiency
- Priority of Relationships

Form(s)/GOALS:

- Bias of Site Elements
- Environmental Response
- Efficient Land Use
- Community Relations
- Community Improvements
- Physical Comfort
- Life Safety
- Social/Psychological Environment
- Individuality
- Wayfinding
- Projected Image
- Client Expectations

Economy/GOALS:

- Extant of Funds
- Cost Effectiveness
- Maximum Return
- Return on Investment
- Minimizing Operating Costs
- Maintenance and Operating Costs
- Reduction of Life-cycle Costs
- Sustainability

Time/GOALS:

- Historic Preservation
- Static/Dynamic Activities
- Change
- Growth
- Occupancy Date
- Availability of Funds

Function(s)/FACTS:

- Statistical Data
- Area Parameters
- Personnel Forecast
- User Characteristics
- Community Characteristics
- Organizational Structure
- Value of Potential Loss
- Time-Motion Study
- Traffic Analysis
- Behavioral Patterns
- Space Adequacy
- Type/Intensity
- Physically Challenged Guidelines

Form(s)/FACTS:

- Site Analysis
- Soils Analysis
- FAR and GAC
- Climate Analysis
- Code Survey
- Surroundings
- Psychological Implications
- Point-of-Reference/Entry
- Cost/SF
- Building or Layout Efficiency
- Equipment Costs
- Area-per-Unit

Economy/FACTS:

- Cost Parameters
- Maximum Budget
- Time-use Factors
- Market Analysis
- Energy Source Costs
- Activities and Climate Factors
- Economic Data
- LEED Rating Program

Time/FACTS:

- Significance
- Space Parameters
- Activates
- Projections
- Durations
- Escalation Factors

Function(s)/CONCEPTS:

- Service Grouping
- People Grouping
- Activity Grouping
- Priority
- Hierarchy
- Security Controls
- Sequential Flow
- Separated Flow
- Mixed Flow
- Functional Relationships
- Communications

Form(s)/CONCEPTS:

- Enhancements
- Special Foundations
- Density
- Environmental Controls
- Safety
- Neighbors
- Home Base/Officing Concepts
- On-Premises: Fixed, Free, Group
- Off-Premises: Satellite, Telecommuting, Virtual Office
- Orientation
- Accessibility
- Character
- Quality Control

Economy/CONCEPTS:

- Cost Control
- Efficient Allocation
- Multi-Function/Versatility
- Merchandising
- Energy Conservation
- Cost Reduction
- Recycling

Adaptability

Time/CONCEPTS:

- Convertibility
- Expandability
- Linear/Con-Current Scheduling
- Phasing

Function(s)/NEEDS:

- Area Requirements:
 - By Organization
 - By Space Type
 - By Time
 - By Location
- Parking Requirements
- Outdoor Space Requirements
- Functional Alternatives

Form(s)/NEEDS:

- Site Development Costs
- Environmental Influences on Cost
- Building Cost/SF(Mtr)
- Building Overall Efficiency Factor

Economy/NEEDS:

- Budget Estimate Analysis
- Balance Budget
- Cash Flow Analysis
- Energy Budget
- Operating Costs
- Green Building Rating
- Life-cycle Costs

Time/NEEDS:

- Escalation
- Time Schedule
- Time/Cost Schedule

Function(s)/PROBLEM:

Unique and Important performance requirements that will shape the building design.

Form(s)/PROBLEM:

Major form considerations that will affect the building design.

Economy/PROBLEM:

Attitude toward the initial budget and its influence on the fabric and geometry of the building

Time/PROBLEM:

The Implications of future changes, and potential growth, on the long-range performance of the project.

Source: adapted from Problem Seeking, Fourth Edition (Pena, W. M., & Parshall, S. A.; 2001).

Appendix C. Critical-Path-Method

Construction projects globally are planned and managed with Enterprise Resource Planning (ERP) software, such as Primavera, offered by Oracle®. Primavera project planning software is based on Critical Path Method (CPM), and per Oracle is not capable of reacting to changes in today's business environment in the way that "Agile development methods." Oracle and other CPM software document *delays*, digs for *legal claims* (Oracle, 2014).

CPM, developed over 60 years ago by E. I. DuPont Nemours Company; with the use of a computer, the Univac I. Less than a year after conception, a team created a CPM schedule for a \$10 million chemical plant; with a schedule including 800 activities, including "more than 800 activities, 400 of which represented construction activities and *150 design or material deliveries*." Which anticipated and scheduled up to 150 "design deliveries," in today's GMP contracts such scheduling may often be performed through Requests-for-Information, followed by delay-claims. Even the CPM method itself is noted to have taken 15 years to proceed from its conceptual form into and through development, to become a commercialized project control system. It would be adopted by NASA for the Apollo space program (O'Brien, James, J.; Plotnick, Fredric, L.; 2010). The original developers of CPM perceived that its use could provide the capability to more effectively plan and manage complex projects providing a method to integrate the independent efforts of separate stakeholders who plan and schedule their portions of the work in finer detail portions of project. The efforts sought to create a master schedule, provide an economical way to modify schedules for changing conditions, and to provide a means of informing management of schedule process and changes. This was to be accomplished first by *separating the function of planning from scheduling*. The developers' emphasized that any CPM schedule **must reflect actual available resources**, else the schedule is useless. Early studies included the DuPont

chemical plant, which actually varied 40 percent from the schedule. They determined this was from a lack of granularity in their planning. Another DuPont plant worth several million dollars was anticipated to have 8,000 events, versus the 800 on the larger plant. Another problem they experienced was that construction operations became extremely inefficient when the planned manpower overwhelmed the actual conditions, requiring the need to reduce actual resources (Kelley Jr, J. E., & Walker, M. R.; 1959, December).

The increased granularity that the founders of CPM recognized is largely lacking more today than in the 1950s and 1960s. Common schedules today include such vague activities as rough grade, excavate sewer, underground pipe, plumbing, HVAC and electrical; exhibiting large grouped sequential events. Such scheduling avoids integration of trades, and often increases potential claims by trades for delays due to failed coordination or the need for rework later, again due to lack of coordination (O'Brien, James, J.; Plotnick, Fredric, L.; 2010). Breaking up large tasks for greater integration, or the need for granularity, was noted by the DuPont pioneers as well as by several academics from MIT in 1967. They saw a need for a much greater interaction in decision making to *inform* the CPM schedule. Such interactions would provide opportunity to explore alternatives and provide optimization; and potentially provide the capability for dynamic schedule monitoring and control of projects (Crowston, W., & Thompson, G. L.; 1967). CPM today is seen by many long term CPM experts for its growing misuse. This is particularly the case in regards to legal claims. Those claims that are adjudicated in court have been reduced to less than two percent, with the majority settling out of court. Often settlements are due to artful presentations of scheduling delay *experts*. "Attorneys say scheduling software can be easily manipulated and too many expert 'imposters' lurk in legal claims." (Joyce, Erin; 2013).

Delay claims in general and government construction contracts specifically were subject to the “Rice Doctrine” from 1942, until 1968. This doctrine established that the effect of a delay of the effect of one delays impact on another delay must be proven to the courts beyond reasonable doubt. By 1968 the doctrines interpretation was applied less stringently, and the Contract Disputes Act of 1978; bringing forth more arguments that involved multiple delayed events, and their impact on overall productivity and schedule performance. Today Cumulative Impact Claims are widely used to counter claims that projects were not completed on time, and increased costs suffered by the contractor were due to the contractor’s management errors (Jones, R. M.; 2001).

Though NASAs use of CPM on the Apollo project is documented often, as is the Department of Defense’s (DoD) missile programs of the 1960s (O’Brien, James, J.; Plotnick, Fredric, L.; 2010); Today NASA’s research arm engages rolling wave schedules, a form of iterative and incremental project management (NASA; 2010). The DoDs’ X-15 project, as well as the Mercury space program, were managed as iterative and incremental projects as well (Larman, C., & Basili, V. R.; 2003).