INDUSTRY STRUCTURE: MISUNDERSTOOD BY INDUSTRY AND RESEARCHERS

Dean Kashiwagi[1], Jacob Kashiwagi[2], John Savicky[3]

ABSTRACT

Misunderstanding of how the construction industry structure works can lead to unseen costs, inefficiencies, higher construction costs, poor results from training programs, and lower value. A deductive based Construction Industry Structure (CIS) analysis was first introduced in 1992. Continual testing of the model in the best value environment and past industry performance in the low bid environment has given deductive validation of the CIS model. Misunderstanding of the CIS may have led to the failure of construction management (CM) research to correct industry issues. CM education/research has become isolated from the construction industry. CM proposes solutions that are management based (control, direction, and inspection). The deductive logic of the CIS identifies the traditional management approach as reactive, inefficient and ineffective in the more developed manufacturing sectors. Traditional CM claims the construction industry is different from all other industries in complexity and uniqueness of construction projects. The assumption is based on observation and inductive logic, and is almost impossible to validate through inductive testing. The traditional inductive logic/testing procedure of validating a theory from observations through testing has not been accomplished. The authors propose that the inductive testing and data requirement is unsupportable by the industry. The authors propose that researchers go back to basic deductive logic, common sense, dominant simplistic models, and deductive testing to increase the efficiency of the construction industry. CIS identifies the construction industry problem as a structural misalignment and a systems issue, and not a unique technical issue. The authors use logic, deductive test results, and results from other industries to validate the proposal.

Keywords: construction industry structure; efficient construction management; alignment of resources

1. INTRODUCTION

Construction industry performance has had poor performance and a lack of capability for the past ten years [1-8]. There are two factors which contribute to the continuation of the status quo and poor construction performance: first, academic research does not have a structure which can introduce change, and secondly, no one has identified what is the solution to the construction industry problems. Academic research has had minimal impact in assisting the construction industry improve its performance [1, 4, 9-12]. Some of the reasons include:

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1. Academic research is funded by government grant agencies that are not accountable for producing dominant results.

2. Non-traditional approaches are not as acceptable to research grant selection boards that are made up of traditional researchers [11, 13].

3. The cycle of traditional research development is too short for new concepts to be thoroughly tested, modified, and tested again.

4. Industry does not support hypothesis testing for academic researchers due to the inflexibility and detailed requirements of inductive testing and a lack of dominant deductive reasoning/logic for the industry to participate in the tests.

5. Research is done by graduate students who continually change. There is no corporate knowledge that stops the reproduction of the same proposals over time. Many of the refereed publication studies propose solutions that are never tested on real industry tests. Many of the same ideas are regenerated five to ten years later by other graduate student [14].

The method of research in traditional construction management is using inductive logic [15]. It depends heavily on literature searches and survey of the perceptions of industry participants to identify factors of performance and problems of the construction industry. Hypothesis testing to determine the validity of their perceptions in real life tests is rarely done. Valid inductive testing of concepts would require hypothesis testing using repeated industry tests to discover the causes of industry performance or non-performance. This type of logic/testing requires isolation and testing of the theoretical concepts. Due to the tremendous number of variables, the requirement of random sampling and validated hypothesis testing results, using real industry tests are almost impossible [16]. To get the required amount of industry support for such tests is very difficult. This has led to most construction management research emphasizing literature searches and discussing the perceptions of other researchers, and the utilization of surveys which attempt to measure the perceptions of industry experts. The researchers try to validate their analysis of industry perceptions by using statistical analysis of the survey results to identify what the most are commonly held beliefs. This mode of research forces the continuation of the existing status quo, because it does not have dominant results that can cause change [17]. Without dominant performance information (results of increased customer satisfaction/expectation, on time, minimized change order rates, and higher profit margins) perceptions and decision making by industry experts will maintain the status quo [18]. Deming [19] stated that two important ingredients of progressive thought were "theory" and deductive logic concepts. One such concept is if problems continue, the system may be stable, and the only way to increase production is to overhaul the entire system. Deming [19] states, "We rely on our experience." The answer is self-incriminating: it is a guarantee that this company will continue to pile up about the same amount of trouble as in the past. Why should it change? Experience without theory teaches nothing. In fact, experience cannot even be recorded unless there is some theory, however crude, that leads to a hypothesis and a system by which to catalogue observations. Sometimes, only a hunch, right or wrong, is sufficient theory to lead to useful observation.

The industry has tried to improve the construction performance by using different delivery systems (Design-build (DB), Construction Management @ Risk (CM@Risk), Indefinite Delivery Indefinite Quantity (IDIQ), and Public Private Partnerships (PPP)), but there is not enough dominant results to identify if the change has solved the real issues or convince the industry to change their paradigm [20-22].

Deductive logic or common sense proposes that since the construction industry non-performance problem has existed for such a long time, it may be a systems problem instead of individual participant's non-performance or lack of technical expertise or a problem that can be overcome simply by re-ordering or changing the grouping of participants [19, 23, 24]. Directed solutions toward an industry sector have not solved the performance issue and will not solve a systems issue. For example, if the contractor's cannot manage themselves, putting a construction manager over the contractor is not a logical solution that will lead to efficiency and increased quality. If the contractor is forced to submit the lowest possible bid using the lowest priced subcontractors and materials, tighter inspection will not raise the level of performance. Management, direction, control, and inspection will not increase a vendor's performance [19, 25]. Deming [19] proposes that when changes cannot change the level of performance, the system is stable, regardless of the perception and expectations of management. He also proposes that a stable system's production cannot be increased by more management and control. More management and control will not increase the importance of craftsperson training and the increased use of skilled personnel. The entire system must be changed to increase efficiency (lower costs), quality, and production. It is the responsibility of the client and the client's representatives to change the system because they are the determiners of the current system. However, most construction management research solutions have focused on the contractors' efficiency and attempt to use more technical personnel to increase management and control [19]. Current construction management research attempts to [14].

1. Use inductive hypothesis testing without getting adequate industry support for testing the concepts on real projects.

2. Depend on management solutions which deductively do not increase profit, performance, and efficiency.

3. Replace hypothesis testing of concepts on real industry tests with statistical analysis of survey data of the concepts from industry experts.

4. Have a reliance on literature search (what other researchers observe) and industry participant surveys to propose solutions.

2. PROBLEM

The construction industry and construction management academic research groups have not been able to significantly improve construction industry performance, nor assisted the industry to increase their technical expertise/craftsperson skill level, nor explain why the construction industry performance is continually decreasing and problematic. The Egan Report [1], the Latham Report [9] and Kashiwagi [26] along with others identify on-going problems with construction industry performance. The construction industry is one of the few industries that have had the repeated problems over twenty years, and the only major industry with falling productivity in the last few years [3, 7, 8].

3. DEDUCTIVE LOGIC CONCEPTS

The authors propose that the construction industry non-performance is a system problem due to illogical structure and processes. The authors also propose that the current construction industry structure is stable as defined by Deming [19]. Therefore, the authors are proposing that the existing system to deliver construction is both stable and nonperforming. The authors will attempt to use deductive logic based on dominant concepts (obvious, well accepted concepts, logic based) instead of the traditional inductive research approach. Deductive logic will be used instead of the perceptions of current industry experts that govern the current and traditional industry practices and perceptions [27]. Therefore, instead of using an extensive literature search to identify what experts in the industry are currently thinking, a new systems solution will be proposed based on deductive logic, and validated using deductive logic and actual test results of the proposed system solution.

The value added work will show that the academic research community has maintained the status quo and actually increased the severity of the problem by using researchers' and industry participants' observations and conclusions such as management based solutions, more decision making, attempting to improve the technical skills of supply chain participants in a price based environment, utilizing technology that increases the in formation flow between participants which encourages the lack of accountability and reactive behaviour and using delivery systems that are not measureable, unenforceable and which are not consistent with the goals of efficiency, minimization of risk, dominant measurements and the transfer of risk and accountability to experts.

Instead of the traditional inductive logic (which tends to continue and proliferate current thinking) [16, 18, 27], the authors will use deductive logic to establish an entirely new model and paradigm of the delivery of construction services. The model will be theoretically established using the following models:

1. Construction Industry Structure (CIS) model and related models.
2. Best Value Performance Information Procurement System (PIPS.)
3. Event model.
4. New Risk Management Model

The authors will then validate the optimal best value environment by identifying the results of actual testing (780 tests, 15 years of testing, $700M construction services.) The authors will then propose that the dominant results of the testing should result in further analysis of the new model and paradigm.

4. CONSTRUCTION INDUSTRY STRUCTURE

The Construction Industry Structure (CIS) (**Figure 1**) [26] defines the construction or any industry based on the factors of performance and competition.

Due to the worldwide competitive environment, buyers of design and construction services have moved to increase competition (Quadrant I – Price Based Award and Quadrant II – Value Based or Best Value). The price based system has the following characteristics [28]

1. The client's representative directs through specifications and controls and inspects the contractor's work for compliance using minimum standards.

2. There is no transfer of control and accountability to contractors.

3. The client's specification's minimum standards are turned to maximums by vendors due to price based pressure and driven downward instead of upwards by vendors (**Figure 2**).

4. Contractors who are short on experience, reactive, and only do what they are directed, become more competitive because their low initial price, but are later in the project forced to increase the prices when deviations from the specifications are identified. Low performing contractors are far more likely to submit change orders when deviations are discovered from the initial specifications due to their lack of perception, incomplete directions from the owner, "unforeseen" events which are usually identified ahead of time, and solved without cost or time deviation by the high performance contractors [13].

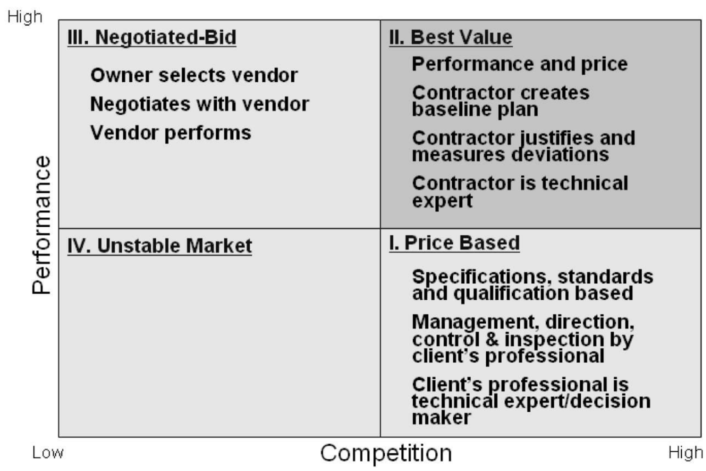

Figure 1. Construction Industry Structure [26].

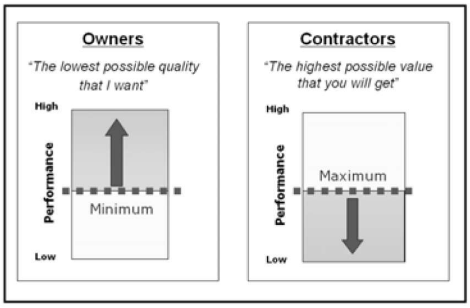

Figure 2. Minimum/Maximum Dilemma [28].

5. Contractors who manage and minimize risk that they do not control, and who are the better value when considering total project cost, become non-competitive because they are less comfortable with and do not fully utilize the reactive, change order or deviation system (**Figure 3**). They are directed by the clients in the price based environment to assume that the specifications are perfect and all inclusive. They are directed to ignore their previous experience and bid the lowest possible price that assumes a perfect specification and drawings. They are actually being told not to be proactive and not to use their experience, but become reactive like the less experienced Contractor # 4 (**Figure 3**).

The characteristics of the price based, specification driven, management, direction, and controlled environment include [29, 30]

1. No accountability for deviations.
2. No transfer of risk and control to vendor.
3. Increased transactions.
4. Increased management positions.
5. Increased inspections.
6. More detailed specifications.
7. Increased flow of information to all parties.
8. Contract and procurement officer become more important.
9. More reactive as contractors submit bids at the last minute, without the ability to check the accuracy of their bids.
10. Subcontractors' prices are shopped.
11. Manufacturers continually lower quality to lower the price of their product.
12. Minimum standards are subjective and do not have correlation with actual performance.
13. No performance measurements based on product performance in the field.
14. Social relationships are more important.
15. Prices are meaningless due to a lack of connection to performance.
16. Inefficient.
17. The use of incentives.

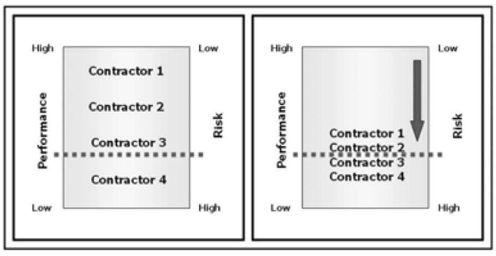

Figure 3. Price-Based Award [28].

In the price based environment, price is the only recognizable and dominant factor. Every other factor is an interpretation and must be decided upon. It is a confusing environment that depends on a relationship between the client expecting the highest performance and the contractor offering the lowest possible performance because of the price based award and pressure on profit (**Figure 2**). Besides the option of going to court in which the cost of litigation creates a “lose-lose” result, the difference in expectation must be resolved in a partnering or negotiated session with the low price contractor. This partnering or negotiation with the lowest bidder, invalidates the competitive bidding because it results in a change of scope from what all the other bidders bid. This leads to a deductive result that vendors must spend more effort and resources to get work, than to do it well, and where the relationship with the clients becomes of the upmost importance. Getting work becomes more important than doing work. This structure is not efficient, economical, and it does not result in better quality. Because of the confusion and lack of transparency, services become more expense, more risky, and result in poorer quality. Vendors and contractors also make less profit in an inefficient environment. The introduction of other delivery systems will not change this environment unless the paradigm is changed.

5. BEST VALUE ENVIRONMENT

The best value environment is where risk is minimized through the use of expertise that is properly aligned. It is the best value because it provides the highest quality for the lowest price due to the absence of risk (use of experts) or inefficiency (minimized transactions between parties) [31, 32]. In the best value environment, risk is transferred to the high performance vendor, who has minimal technical risk because they are a technical expert. The only vendor personnel who can reasonably accept technical risk are the experienced, high performing individual(s) who have expertise and can minimize the technical risk. Low performing vendors and individuals bring both the vendor and the buyer risk and need to be managed, directed, and controlled by the client [33].

In the best value or value based environment, designers and contractors must do the following to be awarded work (see **Figure 4** for an example of a best value closed loop system).

1. Compete based on documented proven capability of the company and key contractor components including the project manager, site superintendent and critical subcontractors in construction, or lead architect, project manager, and critical sub-consultants/engineers in design.

2. Quantify the scope of work and the risk that they do not control and that is not in the scope of the project and have a risk management plan to manage/minimize the risk through preplanning and clear assignment of tasks.

3. Propose key personnel who can preplan and create a baseline of the project from beginning to end, who can manage and minimize the risk that they do not control by managing and minimizing deviation, and who can clearly exhibit the expertise to manage the project by identifying the unique characteristics and risks of the project. The vendor’s key personnel are interviewed and must prove that they are expert, visionary, and accountable of managing and minimizing project deviation.

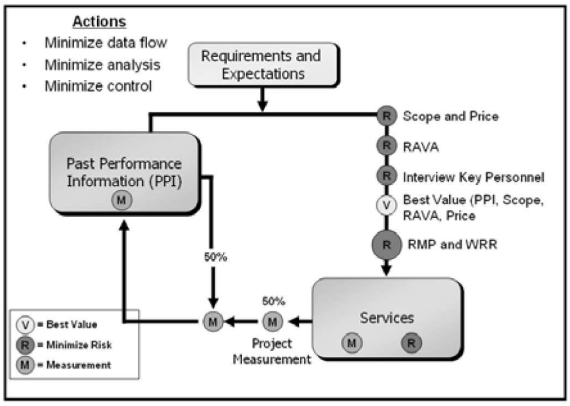

Figure 4. PIPS/PIRMS Self Regulating Closed Loop [26].

4. Give an accurate and competitive price. If the value of the different proposers cannot be identified by dominant information, the low price best value proposer (not the low bidder in the traditional price based system) will be awarded the project. Client representatives do not double check the proposer's plan neither do they assist the proposer, on determining their price and baseline plan. Professionals/Vendors must accept accountability and liability for submitting an accurate price, and give dominant information that show that they can accomplish the work they are proposing.

The best value professional/vendor is then required to have a baseline plan with contractual milestones based on time and cost, a risk management plan (RMP) to manage and minimize all concerns and risks that they do not control before the project begins and a weekly risk report (WRR) that tracks, manages, and minimizes deviation of time and cost during the execution of the contract, justifying and validating every deviation [34]. The vendor and all their key components will then be rated/measured on their performance, and that rating will become 50% of their future performance rating that will be a large factor on their ability to get future work with the client.

Figure 5 shows a vendor's business perspective of why best value environments motivate vendors to use highly trained personnel who can manage and minimize risk. Vendors respond to three types of owners: owners who transfer risk and control of projects to expert vendors by using best value procurement, owners who partner with the vendors and share the risk, and the price based owner who direct, manage, and hire only the vendor who is the lowest price (assuming that all vendors can be prequalified and are of the same quality) [35]. Vendors usually have high performers (who they must pay the highest salaries), medium performers and inexperienced personnel (who earn the lowest salaries, need constant management and direction and are the most inefficient).

The most efficient relationship is between the best value outsourcing client and the vendor's high performing personnel. The vendor can maximize their profit even though the high performance personnel have a higher salary cost. The efficiency and the ability of the high performing personnel to manage and minimize risk to finish on time, minimizing change orders, and doing quality work creates a win-win between the client and vendor (high value, lowest possible cost and maximized profit for the vendor). If the vendor uses the highest train personnel in the price based environment, their performance will decrease due to the client's expert continual management and control, the impossibility to preplan, and the reactive environment of someone being managed and controlled.

However, many clients do not understand this principle as they do not transfer risk and accountability. Instead, they maximize their decision making, and they buy based on low price and attempt to direct, control, and inspect. The Vendor Business Model (**Figure 5**) identifies the client and their selection of the price based, management approach as the source of the risk of non-performance. By selecting the price based award with its management, direction, control, and inspection approach, the client has forced the vendor (whose objective is the maximization of profit) to send the most inexperienced personnel to the client. Another drawback of the price based system approach is that there is no motivation of the vendor's personnel to become highly trained, proactive, and quality oriented. This describes the dilemma of the design and construction industry as they attempt to maintain the professionalism of their practices. Their three largest problems are the shrinking marketplace of outsourcing clients where they can utilize expertise to minimize inefficiency, the inability to increase the number of highly trained craftspeople in the inefficient and highly managed industry, and the turnover of contractors without regard to experience [2, 7, 36, 37].

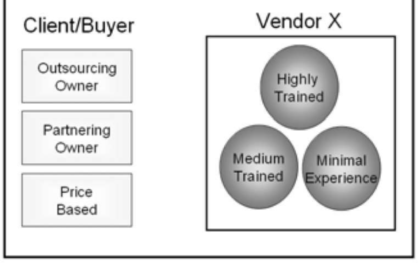

Figure 5. Vendor Business Model [26].

6. PRICE BASED ENVIRONMENT IS A SYSTEM ISSUE

The description of the price based environment matches the current poor performing design and construction industries. The Construction Industry Structure (CIS) (**Figure 1**), the Minimum Requirement/Maximum Value (**Figure 2**), the Price Based Contractor Reaction **(Figure 3)** and the Vendor Business (**Figure 6**), all identify the price based delivery system as the major source of low performance, the lack of accountability, and diminishing industry skill levels. The price based environment was setup and controlled by the client/buyer. The deductive logic shows that the potential solution lies in changing the system from a price based system to a best value system. Deductive logic identifies a best value environment when risk and control is transferred to an expert vendor, where the environment is measured, where all parties are accountable and measured, and where the vendor who is minimizing the risk is managing and minimizing deviation instead of meeting minimum subjective standards [19]. The best value environment also requires a mechanism for the owner to practice quality assurance, and the contractor to practice quality control.

7. PIPS/PIRMS

The Performance Information Procurement System/Performance Information Risk Management System (PIPS/PIRMS) creates a best value environment and is a system solution to the design and construction performance issues. It is the only best value system solution with documented performance and a deductive logic that meets the requirements of the previously discussed best value environment, and which minimizes the need to manage, control, direct, and inspect. PIPS/PIRMS has the following major phases (**Figure 6**):

1. Phase I: Selection of the best value vendor.

2. Phase II: Pre-award/pre-planning and creation of the risk management plan (RMP) and the weekly risk report (WRR.)

3. Phase III: Project delivery by the risk management of deviation of time and cost. The process has six major filters to ensure performance (**Figure 4** and **7**). These are given as under:

    1. Requires the vendors to prove the capability of the company through documented past performance including the performance of critical personnel (project manager/lead designer), and critical sub-vendors (engineering and professional consultants).

    2. Requires the vendors to understand the general scope of the project in terms of requirements and technical risk in a concise, short, overview (a two page submittal).

    3. Risk Assessment/Value Added (RAVA) submittal that forces the vendor to identify the risk that the vendor does not control, and how they will manage and minimize that risk. It also asks the vendors to document dominant added value being offered by the vendor (that is not in the client's specified scope, and will create a dominant difference in project value) that makes them different from their competitors.

    4. The interview of the critical personnel of the vendor to identify the person's relative vision, ability to predict things before they occur, and their capability to be accountable.

    5. Prioritization of the best value based on the capability to perform (the past performance information, scope rating, RAVA rating, and interview rating and price).

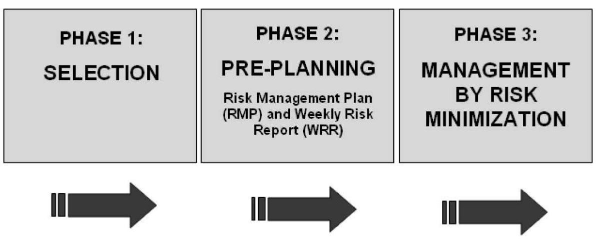

Figure 6. PIPS/PIRMS Phases [26].

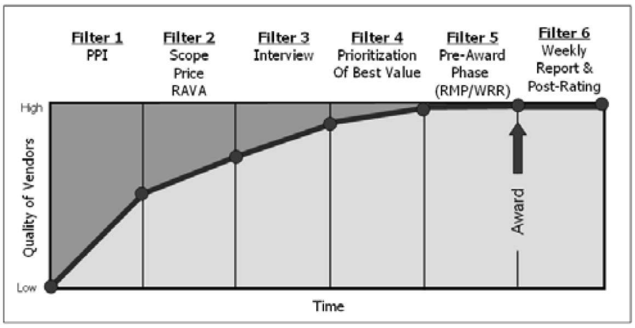

Figure 7. PIPS/PIRMS Filters [26].

6. Pre-award Phase where just the best value vendor creates a risk management plan (RMP) and a weekly risk report (WRR) that they will use to manage and minimize the deviation of the project.
7. Project Award.
8. Self-regulation of the construction project, utilizing the baseline plan, and minimizing the cost and time deviation from the baseline plan.
9. Final project rating of the entire team based on managing and minimizing the deviations in the project and final customer satisfaction of the client.

Modifying the contractor's team's performance by 50% based on the results of the recently completed project.

8. HIGH PERFORMERS HAVE MINIMAL TECHNICAL RISKS

A major departure from the traditional project management practices is the understanding and handling of risk. Information Measurement Theory (IMT) identifies that by definition, high performance/expert personnel have minimal or no technical risk [26]. If there is technical risk, it is only because the client hired a vendor who does not have the expertise and therefore is not capable of minimizing risk. The authors propose that unforeseen conditions can be minimized if experts are used to manage and minimize the risk. The only risk high performers have is risk that they do not control (risk that is brought by other participants, mainly the client in the form of over-expectations, items outside of the scope, decision making at the wrong time during the process, and the changing of expectations) (**Figure 8**). High performers/experts see the project from beginning to end, before they compete for a project, and know the risk that they do not control before they accept the project. By deductive logic, a system that increases management, direction, and control moves the activity to the more inexperienced vendors and personnel (**Figure 8**). This results in lower performance, reactive behaviour, minimum standards or expectations, and minimum accountability.

Price based contracts emphasize the technical risk that the vendors must control. Price based contracts attract the less experienced, and makes the very experienced less competitive (**Figure 5** and **8**). Best value contracts must identify and communicate the expectations of the client but emphasize the requirement of the vendors managing and minimizing the risk that they do not control. Price based contracts must cater to the inexperienced and increase the flow of information, contract documents, and client management, direction, and control. Best value contracts cater to the high performing contractors who need minimal information, who act in the best interest of the client by giving high technical service (no technical risk) and manage and minimize the risk that the vendor does not control through the use of quality control and risk management plans.

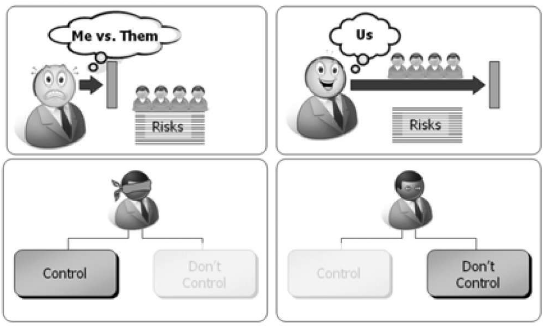

Figure 8. Inexperienced vs. Experienced Vendor Risk Model [26].

High performers and experts by definition are rarely surprised, are rarely affected by "unforeseen conditions," and if there are "unforeseen conditions," high performers have a preplanned solution that they can easily identify, manage, and minimize the cost and time deviation. Due to the low performing mentality of the construction industry, and resulting low performance of the industry participants, the risk of "unforeseen conditions" has increased, and instead of requiring high performance, the industry has created a transaction based solution of management, direction and control, which increases the number of participants who do not have the capability to minimize the risk. These participants create silos where they verify and manage the vendors schedule and cost, negotiate prices, and approve all deviations in schedule or materials. In this inefficient system, the inexperienced contractor becomes more competitive than the high performance contractor with very experienced personnel, who cannot efficiently do their project in an environment of redundant and un-needed transactions.

9. NEW RISK MODEL

A new risk model was developed for project management in the best value environment [38]. The risk model uses the event model (**Figure 9**) as a foundation. The event model has the following features:

1. It has initial conditions, changing conditions during the event, and final conditions.
2. Once the initial conditions are fixed, the final outcome can be predicted with an accurate and a complete perception of the initial conditions.
3. The more accurate and complete the perception of the initial conditions, the more accurate the prediction of the event and the outcome. Many are confused with the concept, and perceive that if they do not know the initial conditions, that there is potentially many outcomes, and there is a method to manage and control the event to result to reach the expectation. This concept has been identified as a non-substantiated concept, is not logical or consistent with history, has no documentation, and constantly being attempted with very poor results [39].

The price based environment results in the following event (**Figure 10**):

1. The client/owner due to a lack of information makes a decision and has an expectation based on time, cost, and provided construction. Due to a lack of information, they do not know if their expectation is valid.

2. They then hire a design firm to translate their expectation into a constructed project. The design firm realizes that if they disagree with the client's perception of the initial conditions (cost, time, and expected construction quality,) they will not get hired. So they make a decision to not tell the client of any misalignment or over expectation, and design the project maximizing decision making. During the design they are forced to make further decision.

After the design is completed, the designer will then encourage the client to prequalify the contractors, and hire the low price contractor, who follows the plan of the designer. Because the designer is hired to make the client's expectation the final outcome, the designer attempts to manage, control, and direct the contractor.

Based on documented construction industry performance, this risk management model is very unsuccessful [1-9, 11, 12]. The performance of being on time, minimized change orders, and meeting the client's expectations does not relate to the years of construction industry activity. The best value environment risk model minimizes decision making and expectations (**Figure 11**). Instead of selecting the designer based on relationships and decision making, the client selects the designer who has the most dominant past performance information, most accurately identifies the initial conditions, and provides a milestone baseline plan which will be used to minimize the risk and deviation that the designer does not control.

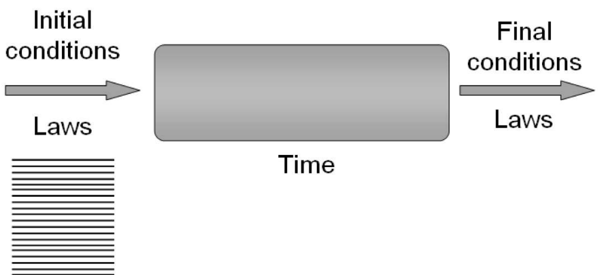

Figure 9. The Event [26].

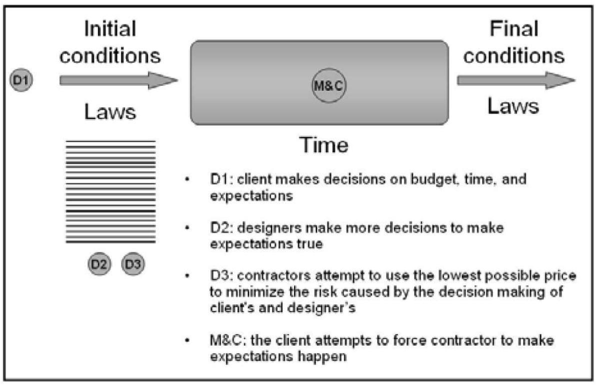

Figure 10. Traditional Risk Model Source [26].

A difference between the traditional best value and the optimal best value environment is that the optimal best value environment has the following characteristics:

1. Less subjectivity. Minimized client decision making in the selection and delivery of services and products.

2. In the selection phase, the client's representatives should minimize the information to the prospective vendors. If the vendor is not dominantly different, they should receive the same score as everyone else. The best value will then be the lowest price. This is not understood by the industry and makes the PIPS/PIRMS process a unique best value process.

3. The client should not trust the vendor. The vendor should dominantly show the future event in a simplistic manner that the non-technical client can understand. Many clients use highly trained professionals for their representatives, and thus do not require simple explanations that everyone can understand. This is one of the biggest drawbacks in the traditional client's approach, and does not transfer risk and control to the vendors.

The best value designer's proposed baseline plan and final event outcome replaces the client's expectations due to their expertise to more accurately identify the initial conditions and potential outcome. The design firm than finishes the design, then uses the same process to identify the best value contractor. The best value contractor's perception of the initial conditions and the baseline plan to produce the final conditions supersedes the designer's expectations due to the construction expertise of the contractor. The contractor is the most expert at identifying the initial conditions which includes the designer's requirements, the existing conditions, and the construction baseline plan.

High performance contractors deliver construction on time, with no cost generated change orders, and meeting the accurate expectations of the clients and their professional representatives. They include:

1. Minimize risk before they start a project by putting the right expertise on the project that can accurately identify the initial conditions, and know how to get to the final conditions.

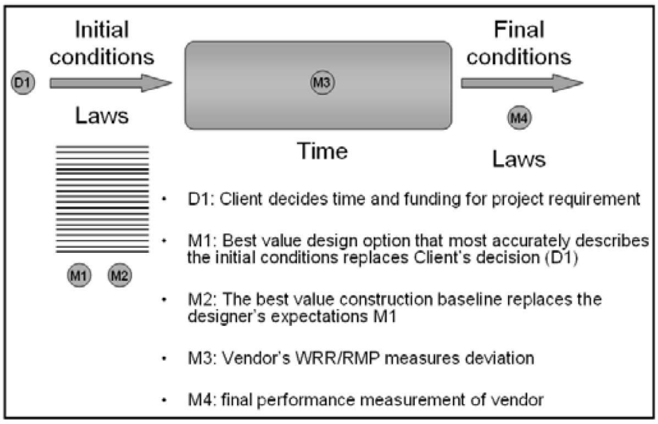

Figure 11. New Risk Model Source [26].

2. Translate the scope of the project (even with detailed specification and drawings,) clarifying the scope of the project, creating a baseline milestone schedule, determining construction cost and risk, and the potential solutions to manage and minimize the risk before starting the project.

3. Identify, manage, and minimize the concerns and the risks that they do not control, that may affect the project due to client over-expectations, client nonperformance, problems caused by other participants (permitting, review bodies, client related individuals) and potential unforeseen conditions (defined by the scope and baseline schedule.)

4. Maximize their profit (motivated by profit) by finishing ahead of schedule and minimizing transactions and potential risks that they do not control.

The authors propose that the client's misunderstanding of risk and risk minimization is the biggest source of risk, and their management, direction, inspection, and decision making approach allows risk to be maximized because it allows non-expert vendors who do not have the expertise "seem competitive" and "qualified." As decisions and expectations are made by the client, they are actually creating and maximizing risk that will occur as the project unfolds (**Figure 10**). Traditionally the clients believe that the difference between their expectations and the actual state of the project is risk that the vendor is creating through ignorance and non-performance. They therefore hire project managers to manage and control the vendors to attempt to minimize this perceived risk. In actuality, the risk is being caused by the client's decision making and expectations, and made worse by designers and contractors who are reactive, constantly making decisions to attempt to meet the expectations of the client. Best value delivery minimizes all decision making, false expectations, and risk by finding the parties who can best identify the initial conditions of the project in terms of funding, client's expectations, and time.

9.1 Transfer Risk and Accountability to High Performance Vendors

The price based environment does not transfer the risk and accountability to the vendor (**Figure 1**). The best value environment transfers the risk to the vendor, forces them to have a baseline plan and manage and minimize the risk by managing the deviation [19]. Inexperienced vendors cannot see from beginning to end, are reactive to the client's behaviour and needs, and are concerned with technically being qualified to do the project. They do not consider the non-technical risk that they do not control. Procurement processes that use contracts that concentrate on the technical requirements of a project attract vendors and personnel who are inexperienced and reactive (**Figures 8**). Best value environments force vendors to identify their relative level of expertise by having [40]

1. Every critical component of the vendor's team to personally understand the project from beginning to end, and have a past performance rating that verifies their capability.

2. Vendors communicate in writing a concise scope of the project in terms of cost, time, and expectation.

3. Vendors identify what may be expected that is not in the scope, or what may stop them from completing their project that is not identified in the scope (the risk that they do not control) and propose how they will manage and minimize the uncontrolled risk.

4. Identifying what makes them dominantly better than their competition.

5. Their key individuals interviewed individually to identify their level of perception, vision, and capability to preplan, accept accountability and create a conservative baseline plan.

The selected best value vendor must then accomplish what they have proposed by:

1. Using the milestone schedule, managing and minimizing the risk that will cause deviation from the milestone schedule, and make all parties accountable for their actions by documenting all deviations with the reason and source of deviation.

2. Performing quality control and risk management (review and correct their own work).

3. Allow the client to do quality assurance through a weekly risk report (WRR). The client's representatives can still audit and inspect the vendor's records at their will.

9.2 Validation of Deductive Logic Models Through Testing and Dominant Test Results

The authors are proposing that the deductive logic presented above, will be validated by implementation through tests. In the majority of these cases, the Performance Based Studies Research Group (PBSRG) presents the deductive logic models to the research clients (owners delivering construction). The research clients perceive the dominant nature of the deductive logic and based on the possibility of improving the construction delivery, agree to the tests. Although the research clients are constrained by legal and political constraints, PBSRG is able to document the deviations, and run the tests. PBSRG then has repeatedly run tests, modified and improved the process, and retested. As the testing has proceeded over 15 years, the tests have encompassed many if not all of the issues being addressed by construction management research efforts at other universities. The added value of the PBSRG research of the testing of the best value Performance Information Procurement System (PIPS) and follow-on Performance Information Risk Management System (PIRMS) has been that the concepts can actually be tested in real tests. BSRG testing has overcome the following problems that other construction management research groups have faced in doing their research.

1. Industry has volunteered to partner with PBSRG. The industry participation is the strength of the PIPS/PIRMS testing.

2. PIPS/PIRMS testing has involved industry partners in the entire delivery chain (clients, professionals, contractors, subcontractors, designers, engineering consultants, craft person training organizations, and industry groups).

3. Test opportunities in industry are the foundation of the research effort. Instead of asking the opinions of industry participants, PBSRG actually runs tests to identify the importance and relationship of concepts.

4. PBSRG is able to integrate the graduate education with the research effort, creating efficiency and sustainability.

5. Sustained research effort over 15 years showing validity of concepts and the research methodology.

This is the longest documented construction management research effort at a major university. The research results for the past 15 years are documented at pbsrg.com. The results include the following dominant factors [13, 26, 35, 41, 42].

1. $8.5M research funding over 15 years, research office of 26 personnel, and a Construction Management Masters Degree program emphasizing the IMT, industry structure analysis and PIPS/PIRMS technology.

2. 175 refereed conference and journal papers on the development of IMT, PIPS/PIRMS, and research tests.

3. 483 Presentations, 8,600 Attendees in the U.S., Asia/Australia, Europe, and Africa.

4. 683 Procurements, $808M construction services over the past 15 years.

5. $1.7 billion non-construction services at Arizona State University (ASU) and other clients. Due to the resistance to the change of paradigm and potential loss of revenue of some participants proposed by the PIPS/PIRMS results and IMT deductive logic, PBSRG moved the technology/processes to other industries, convincing the host university ASU, to deliver food services, information technologies, professional services, and commodities using PIPS/PIRMS. The results identify that the efficiency of the system will generate $100M over the next ten years for the university.

6. 50 different clients (public & private) have participated in the testing over 50 years.

7. 98% Customer satisfaction, on time, no contractor generated cost change orders. This far exceeds any other documented performance.

8. Minimization of up to 90% of the client's professional representative's risk management efforts and transactions due to reduced risk levels and the transfer of risk and accountability to the vendors. This is the only documented reduction in need of management in the construction management industry.

9. Increase of vendor profits up to 100% in test cases.

10. PBSRG was able to convince the Dutch infrastructure group, the largest construction buying agency in the Netherlands, to deliver 1B Euro infrastructure projects using PIPS/PIRMS to minimize the sources of inefficiency, relationships, and poor performance caused by the price based market. Despite PIPS/PIRMS being an "American idea," the dominant performance results and deductive logic has resulted in the largest delivery test utilizing PIPS/PIRMS.

11. The results of PIPS/PIRMS testing has won the Construction Owners of America Association (COAA) Gold Award, the 2005 CoreNet H. Bruce Russell Global Innovators of the Year Award, the 2001 Tech Pono Award for Innovation in the State of Hawaii, along with numerous other awards.

12. The formation of the W117 Performance Measurement in Construction working commission of the International Council for Research and Innovations in Building and Construction (CIB) working commission.

13. The formation of the CIB Journal for the Advancement of Performance Information and Value to proliferate the use of deductive logic and the use of performance information.

14. The assignment of Professor Dean Kashiwagi to the University of Botswana as a Fulbright Scholar in 2008 to transfer the technology to the African continent. Professor Kashiwagi was the only engineer of 220 award recipients to go to the Sub-Sahara region as a Fulbright Scholar.

15. The successful initial testing of PIPS in Botswana, Africa and the subsequent assignment of Professor Kashiwagi as a visiting professor to ensure the sustainability of the research program.

The successful testing of the PIPS/PIRMS system is validation of the deductive logic of the Construction Industry Structure (CIS) model, the Information Measurement Theory, the new Risk Management Model, and the PIPS/PIRMS systems. The former procurement director and now Associated Vice-President of Arizona State University Business Services Ray Jensen [43] stated, "I have been successful in the business of procurement and services delivery for the past 30 years. I saw in PIPS/PIRMS, improved solutions of performance/contract administration issues that are so dominant, that I am willing to change my approach to the business after 30 years." The best value PIPS/PIRMS test results agree with and validate the concepts of [19, 23, 25, 27, 44, 45]. They are deductive logic concepts of consistency, common sense, and accurate perceptions of physical and humanistic laws that have existed for centuries to eliminate waste.

10. CONCLUSIONS AND RECOMMENDATIONS

The construction industry and the academic research community have not had a significant impact on improving construction performance because they may not have perceived the construction industry to be a stable system with systems/environmental problems. One of the reasons that the systems solution was not perceived or considered is the traditional inductive research methodology which requires testing of observations to identify governing theory. There is very little direct testing of hypothesis based on observations in the construction industry, due to the variability, multitude of technical factors which are difficult to measure, and the lack of confidence by the industry in the research work of construction management university programs. Construction management research has been limited to literature searches, survey of experts, and documenting construction results, which maintains the status quo approach of using management techniques to solve the industry problems. To optimize industry performance, stability, and sustainability, the authors substituted the deductive logic and dominant concepts of Information Measurement Theory (IMT), and Deming [19] and Goldratt's [25] analysis of stable systems and theory of constraints instead of the traditional inductive approach of using a literature search to identify concepts, then using a survey of industry personnel to identify the critical factors that would improve the construction performance. This bypassed the traditional hypothesis testing and validation of expert opinion using statistical tools.

The deductive logic and Performance Information Procurement System/Performance Information Risk Management System (PIPS/PIRMS) test results identify the traditional and current price based structure with the accompanying characteristics of client management, direction, and control approach as an inefficient and ineffective system for increasing construction performance. The deductive IMT concepts identified the solution to increasing construction performance is the creation of a best value environment which contained the following:

1. The best value is the best quality for the lowest price.

2. Alignment of participants based on their expertise.

3. Awarding projects using best value (performance capability and price) to the best qualified vendor.

4. Requiring vendors to manage and minimize risk that they did not control.

5. Transfer of risk, accountability, and control to the best value vendor.

6. Measurement of performance.

7. Increasing performance by having the vendor minimize deviation instead of using minimum standards.

8. Quality assurance by the client's representative and quality control by the vendor.

9. Minimized transactions (management, control, direction, inspection, meetings, negotiations and information flow).

10. Minimized participation by the client and client's representatives.

The best value environment was created by the PIPS/PIRMS implementations in the industry supported tests. The results of the testing of the deductive logic based theory resulted in the following dominant conclusions.

1. A 15 year research with 600+ tests using the best value environment and PIPS/PIRMS resulting in 98% performance, up to 90% less management and control function and increased the vendors profit by as much as 5% (100% increase.)

2. The best value environment process was taken outside of the construction industry and successfully run on $1.5B of services at Arizona State University, resulting in over $100M of efficiency.

3. The deductive logic approach of the PIPS/PIRMS research that was endorsed in the past by visionaries [19, 23, 25, 27, 44] was recognized by industry research participants and led to successful and dominant results which validated the logic.

These research results could have a tremendous impact on future construction management research because it proposes that the management, direction, and control approach (as proposed by the traditional construction management research) is actually the source of the construction performance risk, and should be changed. It proposes that the systems problem requires the use of leadership/alignment techniques, quality control and quality assurance (dominantly understood in the manufacturing industries), and will affect the future roles of all the participants in the construction industry. It also proposes that solutions that do not follow the tenants of efficiency and best value (i.e. increasing decision making, the flow and transfer of information, the amount of management, direction and control, and the verification of cost and schedule by one other than the vendor) causes complexity, confusion, and will further degrade the construction industry performance and isolate academic research from the reality of the construction industry.

The research results also identify the traditional inductive research methodology of observation, hypothesis, testing, and analysis may be inefficient, require testing/data which are difficult to get, and therefore the reason for not receiving the support of the industry to run tests. The authors recommend deductive research which uses dominant, common sense theory, and applied in tests for confirmation of the deductive theory. The dominant information motivates industry to participate, and the hypothesis can easily be confirmed due to the dominant test results.

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