Development of the Use of Performance Information

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This paper documents the history of the development of performance information [1982-2020], for the delivery of services. It identifies traditional industries as client controlled. In the past, clients utilized a structure of technical professionals who had education, certifications, and experience. Professionals set both policy and structure for their professionalism. The traditional industry does not differentiate between the values of vendors, professionals and stakeholders. This paper identifies that professionals are resistant to using performance information which differentiates. The initial proposal to successfully implement information management was to use automation. However, the industry resisted the automation and the research identified that simplicity and transparency was the only solution. This paper identifies that the Performance Based Studies Research Group’s (PBSRG) success in performance information development was due to a unique design and methodology to research performance information as a disruptive technology. A new methodology called the Information Measurement Theory (IMT) was designed to redefine risk, expertise and information. The major source of validation of the new concepts was joint academic and industry research tests. Three major research tests confirmed that the client creates over 90% of all risk. PBSRG worked with a manufacturing company to design a high-performance roofing program which ended after 16 years due to it being based on client centric concepts. An expert contractor took the lessons learned and maximized the use of performance information with a vendor centric approach.

Keywords: Expert, Expertise, Project Management, Project Performance, Best Value Approach, Procurement, Risk Management, Information Management, Performance Information, Automation.

Introduction Traditional Construction Industry is “Client Centric”

The construction industry has had performance issues for the past 30 years; construction projects were not finishing on time and on budget causing customer dissatisfaction [Berstein 2009; British Property Federation 1997; Cahill & Puybaraud 1994; CFMA 2006; Chan & Chan 2004; CII, 2015; Davis & Sebastian 2009a, 2009b; Doree 2004; Egan, 1998; Egbu, 2008; Georgy Luh-Maan, Lei & Zhang, 2005; Glancy 2008; Horman & Kenley 2005; Ibrahim, Roy, Ahmed & Imitiaz, 2010; IHS Markit, 2013; Imitiaz & Ibrahim 2005; Kashiwagi, & D. Kashiwagi, 2016; Langlinais 2011; Latham, 1994; Diekmann, Songer & Brown, 1999; Lepatner, 2007; Murphy 2012; PBSRG, 2020; Post, 2000; Rijt 2009; Rivera, 2014; Rivera, Le, Kashiwagi & Kashiwagi, 2016; Rivera 2017; Rwelaimila, Talukhaba & Ngowi 2000; Simonson 2006; Tucker 2003; Wang 2009; Wearden 2008]. The traditional construction industry is an “owner centric” industry [Alzara, 2016; Kashiwagi, 2020; PBSRG, 2020; Rivera, 2017]. The core of the client centric industry is a structure of technical professionals who manage, direct and control the supply chain. They utilize design drawings and specifications [directions to the contractors] to identify
Development of the Use of Performance Information

the clients’ requirements. The construction industry is a specification driven industry (Alofi, 2017; Almutairi, 2017; Kashiwagi, 1995; Kashiwagi, Halmrast & Tisthammer, 1996; Gransberg, 2008; Hale, Shrestha, Gibson & Migliaccio, 2009; Konchar & Sanvido, 1998; Lam, A. Chan & D. Chan, 2004; Ling, Chan, Chong, & Ee, 2004; Murphy, 2012; Williams, Young, Tzeyu & Murat, 2003).

Manufacturers of construction products assist the professionals in the construction industry by identifying performance criteria for all products being utilized in construction. The professionals identify the methodology to measure all material criteria [American Society of Testing Materials (ASTM) and other technical organizations]. Once the criteria and (ASTM) tests are agreed upon, each manufacturer tests their own material according to the ASTM test procedures (Blau & Budinski, 1999). The industry then reconvenes with professionals representing industry stakeholders to set the values of the material’s performance criteria [example shown in Table 1] (Kashiwagi, 2014a, p. 14.7). This method of setting material requirements in a project has the following flaws:

1. Requires professionals to make decisions to create the test methodology and the acceptable performance level. Decision making is used because the requirement cannot be easily observed or proven.
2. The final ASTM material specification requirement is a combination of the lowest material criteria values of material provided by participating manufacturers, which cannot ensure “in-field” performance. The relationship between performance criteria set in this manner and “in-field” performance is unknown.
3. The material specification that the client’s designers utilize is a result of a combination of the lowest criteria metrics from all the competing manufacturers’ material. The specification requirement does not usually represent an actual material [Material B and C in Figure 1 have the lowest criteria metrics].
4. There is no proof that a material that meets the ASTM minimum requirement will perform. This is based on professional’s acceptance of the ASTM structure.
5. Professionals do not usually use “in-field” testing to verify material criteria performance.
6. Each manufacturer after seeing the minimum material criteria performance will now attempt to lower their material’s performance capability to lower the cost of their material.
7. The professionals using the specification assume that all products have the same performance and meet the industry set minimum requirements.
8. If an industry disaster occurs, the professionals may reconvene and change the ASTM standards and requirements for the materials being investigated.

The fallacy of this approach was demonstrated in the 1980s when an unreinforced polyvinyl chloride (PVC) single ply roofing system prematurely and catastrophically failed by shattering in cold winter conditions (Koontz, 1997; Paroli, Smith & Whelan, 1996). The shattering of the unreinforced PVC system was caused by the migration of plasticizer, resulting in shrinking and brittleness and eventual shattering in cold temperatures. This resulted in the National Roofing Contractors Association (NRCA), the governing industry group in the roofing industry to issue a bulletin, warning clients of the danger to their facilities caused by the shattering of the PVC roof system [NRCA & SPRI, 1990]. The failures also led to the modifying of ASTM standards. The bulletin warned facility owners of the potential catastrophic failure of their roofing system and
recommended that owners replace the roofing system as soon as possible. This event shows the shortcomings of the specification system which utilizes ASTM requirements for material specifications. The minimum specification has no relation to actual “in-field” performance. Some ASTM tests attempt to simulate aging and exposure to the sun and professionals extrapolate results to an in-field performance period. However, there is no proven relationship between these simulated tests and in-field performance [Kashiwagi, 1996]. The failed unreinforced PVC roofing system met all the technical ASTM performance requirements for the material product. The same issues were discovered in the testing of the hail resistance of Sprayed Polyurethane Foam roof systems done by Performance Based Research Group (PBSRG) [Kashiwagi, 1996].

Table 1: Example of a Matrix of Manufacturer Performance (Kashiwagi 2014a)

| PHYSICAL PROPERTY | TEST METHOD | MANUFACTURER'S DATA | PROPOSED REQUIREMENT |
|-------------------|-------------|---------------------|----------------------|
|                   |             | A       | B     | C     | D     | E     | F     |
| Initial Elongation % (break) | D412 | 150%  | 100-200% | 200%  | 100-150% | 140-250% | 140-160% | 100% Min. |
| Initial Tensile Strength (max stress) | D412 | 400  | 150-600 | 450  | 300-400 | 400-625 | 500-600 | 150 psi Min. |
| Final Elongation % Weathering | D412 | n/a  | 100% min | 200% | 125% | N/a | 140-160% | 100% Min. |
| Permeance | E96, B | 3.7  | n/a  | 3.5  | 2.9  | N/a | 2.6-3.0 | 2.5 U.S. perms Min |
| Weathering (5000 hours) | G53 | No cracking | No cracking | No cracking | No cracking | N/a | No cracking | No cracking |
| Adhesion | C794 | 2 pli | 6-10 pli | 3 pli | n/a | N/a | n/a | 2 pli min. |
| Tear Resistance | D624 | 20-30 lb/in | n/a | 30 lb/in | n/a | 33-53 lb/in | N/a | 20 lb/in |
| Low Temperature Flexibility | D522 | n/a | n/a | Passes | Passes | N/a | Passes | Passes |
| Viscosity | D2196 | 30,000-50,000 | 8,000-25,000 | 115-130 KU | < 60,000 | Varies | 35,000-40,000 | 35,000-50,000cps |
| Volume Solids | D2697 | 62%  | 80%  | 57-66% | 62% | 66% | 62% | 57-80% |
| Weight Solids | D1644 | 0.77 | 0.66 | 70-77% | 0.75 | 0.74 | 0.71 | As listed by Mfg. |

Owner Controlled Industry Requires Technical Professionals

The traditional owner centric approach requires professionals [architects, engineers, quantity surveyors, purchasing agents and project managers]. All professionals require a combination of minimum college education, certification through testing and in-field industry experience. Similar to other complex industries, the construction industry depends on the education, experience and decision making of their professionals to mitigate risk.
Professionals identify requirements then design, manage and inspect the contractors’ work to mitigate project risk. Contractor failure is covered by vendor insurance and bonding. Manufacturers who manufacturer material that does not meet the proper ASTM standards are financially liable for the nonperformance of their products. Professionals are not liable for nonperformance if they utilized and met industry processes which have been setup by other experienced professionals. The minimum specification approach, which motivates contractors to lower cost, moves the responsibility of performance from the contractor and manufacturer to the client’s professional representative, who then attempts to mitigate risk through their decision making, directions and control. Many professionals utilize their decision making as their act of risk mitigation. However, Information Measurement Theory (IMT) [Kashiwagi, 2020] identifies that decision making is only required when individuals do not understand what is going to transpire. If a professional knows what is going to transpire, there is no decision making required and there is no risk. Therefore, the professional’s decision making, and risk are inseparable characteristics.

**Industry Structure (IS), Professionals and Performance Information**

The Industry Structure (IS) was created to explain the source of poor performance [schedule, budget and customer satisfaction] of the construction industry, see Figure 1 (Kashiwagi, 2020). Quadrant I is the traditional owner centric environment. It requires professionals to identify the construction requirement using their technical expertise, then to create a project design document that contractors can follow. Contractors compete on price to be selected by the client. The competition is used to ensure that the owner gets the lowest possible price [price-based sector in Figure 1]. This environment assumes the following:

1. All vendors have the same ability to understand and then to deliver the construction requirement. If the owner’s professionals identify that a contractor is not capable, the traditional structure allows the professionals to prequalify contractors who could meet the minimum project requirements. Then it is assumed that the prequalified contractors are “all the same”.
2. In the United States, the contractors hire professionals who use cost estimating tools to predict construction requirements. It is critical that both the designers and contractor’s professionals do not miss the costing of any required construction requirement. Automated tools such as the Building Information Model (BIM) [3D drawings] minimize errors in the supply chain.
3. In every country besides the United States, a quantity surveyor professional [who is certified by the Royal Institute of Quantity Surveyors, (RICS)] is utilized to identify every material quantity in the project in the form of the Bill of Quantities (BOQ). The project is then awarded to the lowest priced contractor.
4. The professionals have accurately identified the optimal construction solution.
5. The owner’s professionals can identify and mitigate risk through inspection and testing.
Quadrant I requires the owner to utilize professionals to identify and mitigate risk. The owner’s professionals are required to:

1. Identify the construction requirement.
2. Identify the lowest priced contractor. This assumes that all contractors have the same capability to deliver the construction. By observation of the industry nonperformance, [not on time, not on budget, and customer dissatisfaction] this assumption is not accurate. Deductively, when actions are based on concepts that are not accurate, the risk and cost is increased.
3. Manage, direct, and control the contractor to mitigate the risk of not finishing on time, on budget and meeting quality expectations and customer satisfaction. The vendors are attempting to maximize their profit, which motivates them to lower the cost.

As identified by the industry structure (IS) figure, competition is high and performance is low [Kashiwagi, 2020]. The structure of the price-based sector is inefficient and results in lower performance. The impact of the high competition in Quadrant I is that competitors drive the price down. Quality and competition can only both be high, when the level of expertise is high. Quadrant II is an environment where the client identifies the expert contractor based on price and high performance, then utilizes the expertise of the contractor to lower the price. The problem with this concept for the traditional professionals, is that the construction industry and clients do not utilize performance information [on time, on budget and customer satisfaction and previous performance] to select contractors and do not utilize the contractor’s expertise [instead they manage, direct and control (MDC) the contractor]. The industry is utilizing professionals’ experience, decision making, management and control to minimize risk [nonperformance]. Using performance information to identify and utilize expertise is an extremely different paradigm. The industry does not have experience with using performance information [what it is, how to collect the information, agreement between the clients and the contractors].

The paradigm shift would require the client to accomplish the following:
1. Change the industry supply chain from a client centric approach to a vendor or contractor centric environment.
2. Question the assumption that all contractors “are the same”.
3. Question the assumption that the client’s professional representative could deliver construction better than an expert contractor.
4. Question if the professionals have the capability to identify the difference among contractors, concepts and options.
5. Transfer the accountability and responsibility for project performance from the owner’s technical representative to the expert contractor.
6. Change the role of the owner’s professionals to identify, collect and utilize performance information.
7. Change the role of the owner’s professionals to quality assurance [non-technical] instead of quality control [technical].
8. Professionals roles would become technical in their specific technical area. With automation and information systems being utilized, professionals will have an ever-shrinking role.

Based on the poor performance of the traditional construction approach [owner centric environment], the Industry Structure (IS) proposes that the contractor and not the owner’s professional representatives may be the construction expert. Moving the responsibility would align the responsibility for performance from the client who is buying the construction to the expert contractor who is providing the construction, thus making the contractor more accountable. This would make identifying and utilizing expertise much more important. This concept may be disruptive to the current industry of professionals because they do not currently have this capability.

A USAF engineer discovered by personal experience the resistance of professionals to the concept of using performance information. The current client centric industry and professionals have not had success in delivering high performing construction. For the past twenty years, the industry has attempted to utilize more expert vendor centric approaches such as design-build (DB), construction management at risk (CMAR), Private Public Partnerships and Job Order Contracting (JOC)] [(Egan, 1998; Grimsey, 2002; Grout, 1997; Hopper & Goldman, 2004; Hutton & Solis, 2009; Konchar & Sanvido, 1998; Kashiwagi, 2014a, p. 15.18; Kumaraswamy & Morris, 2002; Matthews & Howell, 2005; Nellore, 2001; Pietroforte, 2002; Williams, Young, Tseyu & Murat, 2003; Wong, 2006). But the key to this paradigm shift is the identification and utilization of expertise and performance information. Without performance information, the result will continue to be litigation and higher construction costs.

**USAF Performance Information Project**

In 1980, a USAF civil engineer was attempting to identify the performance of a sprayed polyurethane (SPF) roof system (Kashiwagi, 1983) for installation at Holloman Air Force Base (AFB), New Mexico. The SPF roof system had the following advantages:

1. Lightweight [2.5 LB/CF].
Development of the Use of Performance Information

2. Monolithic and manufactured by the contractor on the roof deck by mixing two liquids in an exothermic reaction.
3. Has a high insulating value [R value of 7 per inch] which stopped the movement of metal decks caused by heat in the southwest.
4. Could be installed directly on existing metal decks or existing roof systems.
5. Renewable with a protective coating.
6. Inexpensive when compared to the traditional built up roof system which was the USAF standard roofing system.

The USAF structural engineer/roofing program engineer identified that the SPF roof system did not perform and was not recommended on USAF facilities. Applications of the SPF roof system at any USAF base would require his professional approval. This was very discouraging and convinced the civil engineer at Holloman AFB not to proceed with the effort.

The USAF Civil Engineer office [office responsible for all civil engineering officer assignments] sent the civil engineer to Arizona State University (ASU) to get a civilian institute (CI) master’s degree in construction management [he actually received an industrial engineering masters with a minor in construction management which is significant in the civil engineer’s future career]. One of the requirements of the degree was to write a thesis that would improve the USAF construction program. The civil engineer decided to do his master’s thesis on “identification of the performance of the SPF roof system based on performance information (Kashiwagi, 1983). The USAF engineer recalled that the expert of the SPF roofing industry was located in Tempe, AZ, where ASU was located. The project was to investigate why there was such a differing perception of the SPF roof system performance between the USAF roofing professionals and the SPF expert vendors. The engineer’s thesis objective was to use the concept of performance information to identify the actual performance of the SPF roof system. A secondary objective would be to identify why there was such disparate concepts of performance of the SPF roof system. The third objective would be to identify if the USAF could use the SPF roof system to successfully protect USAF facilities. The civil engineer became a researcher. He started the investigation and quickly confirmed the following (Kashiwagi, 1983, p. 1 - 22):

1. No one in the roofing industry used extensive performance information.
2. No one had SPF roof performance information.
3. There were conflicting performance opinions from the USAF roofing program, USAF roofing consultant and from the SPF industry stakeholders [major SPF roofing contractors] depending on professionals and stakeholder experience.
4. The project was to create performance information that would end the disagreement.
5. The performance information could not have a preconceived bias. The collection of the performance information would have to be non-biased.

To ensure the accuracy of the information and to minimize bias of the performance information, the researcher personally collected the performance information. He would personally go through the files of SPF roofing contractors to randomly select the oldest roofs [without any idea of the performance of the roofs], inspect the roofs and collect and compile performance information which included customer satisfaction, roof performance duration and leak information.
The research identified that there was no motivation among USAF professionals to utilize performance information of construction services in the USAF. The creation of performance information would require a tremendous effort. It would require multiple sources of information, creating a new information structure of the performance and the identification and verification of high-performance SPF roof systems and contractors and the documentation of their installed roofing systems.

The researcher realized that the current professionals used their own experience to decide what the performance of different roofing systems were. The technical position of the professional in charge of identification of performance was not usually changeable or challengeable. The USAF roofing expert, ASU and the Air Force Institute of Technology (AFIT) education administrators offered no financial and information assistance on the project. The advantage of the researcher’s CI AFIT [Civilian Institute AFIT] assignment was that his time was already paid for by the USAF as a part of the master’s degree. Instead of the traditional one-year AFIT Civilian Institute assignment, the researcher was given two years [1981 – 1983] to finish his Master of Science (MS) degree in industrial engineering with a minor in Construction Management. The researcher was highly aligned and motivated to understand why professionals, who build their expertise on science, logic, and fact, had such diverse professional positions on building system performance. His objective was to identify why a professional or an expert vendor would be allowed by the industry to maintain an inaccurate position in a science-based profession [engineering and construction management].

The research’s strategic plan was to (Kashiwagi, 1983, p. 16):

1. Identify if the SPF roof system had sufficient performance through documentation.
2. Identify if the SPF roofing contractors were sufficiently motivated to document and publish the SPF performance information.
3. Collect sufficient performance information to identify the performance or nonperformance of the SPF roofing system, to impact the perceptions of the USAF roofing professionals.
4. Write a SPF roof specification that could be used by the USAF civil engineers at the base level.

The USAF researcher received no encouragement or assistance from the USAF roofing engineer [and his professional roofing consultant] at the Engineering Services Center located at Tyndall AFB. The researcher was instructed by his thesis advisor that the thesis objective of using performance information to potentially impact the decisions by the USAF roof engineer and the USAF, was too optimistic and time consuming. The project professor at ASU felt it was interesting that the USAF technical experts were not in support of the research project [that would seem to benefit the USAF].

The research study objectives included (Kashiwagi, 1983, p. 16-22):

1. Identifying the performance of the SPF roof system from a large database of SPF roofs.
2. Identifying the impact of the environmental conditions in the installation of the SPF roofing system and the duration of its performance.
3. Identifying the differences between the performance of different types of SPF roof systems.
4. Identify if the results of the inspection of SPF roof system could lead to the improvement of the SPF system performance.
5. Identify if the resulting performance information of the inspected SPF roof systems could be used to change the USAF approach to utilizing the SPF roof system.

**SPF Roof Inspections and Resulting Performance Information**

The project used the following methodology in the research project (Kashiwagi, 1983, p. 45 - 62):

1. Roofs were randomly picked from contractors’ or owners’ files. Preference was given for older roofs and roofs in the geographical area that allowed the maximum number of roofs to be inspected.
2. Project participants were responsible to open their files and give the researcher access to all roofs, including putting the researcher on the roof and making the client available for performance questions.
3. Any industry participant could volunteer for the inspection of SPF roof systems.
4. The performance information would belong to both the contractor and the researcher.
5. The researcher would identify items of nonperformance and using his engineering background give potential solutions.

The researcher reached out to the SPF contractor industry and identified the following SPF contractor locations, SPF roof systems and weather conditions:

1. Phoenix, Arizona, silicone coating, dry arid environment.
2. Longmont, Colorado, silicone coating, snow/winter area.
3. Eau Clair, Wisconsin, silicone coating, four seasons including snow/winter.
4. Louisville, Kentucky and southern Indiana, silicone coating, temperate and four seasons.
5. Elizabeth, New Jersey, asphalt, and aggregate covering, four seasons including snow/winter. This roof system was inspected despite objections by industry participants.
6. College Station, Texas, urethane coating, four seasons.

The research study results included (Kashiwagi, 1983, p. 16; Kashiwagi, 1999):

1. Database of 1125 polyurethane foam (PUF) roof applications including roof area, number of penetrations, roof slope, roof traffic, ponded areas, areas of blistering/delamination and exposed SPF.
2. Inspection and documentation of 247 PUF roofs.
3. Performance information collected on the SPF roofs included: Customer satisfaction, maintenance performed, percentage deterioration of the system and required replacement, and the coating system performance under different environmental conditions.
4. Of the 247 roofs, 94% of the roofs inspected had less than 5% deterioration and 97% of the owners were satisfied with the roofs.
5. The highest performing SPF roof was the silicone coated SPF roofs. The urethane aliphatic roofs were performing; however, the urethane coating was reverting [going from one
Development of the Use of Performance Information

component cured coating to the two original raw materials components]. It was later identified by the researcher that the aromatic urethane, made by a different manufacturer, was the highest performing SPF roof system, despite what the industry experts were stating [Kashiwagi, 1999].

6. A specification for installing the silicone coated sprayed polyurethane foam (SPF) which included the latest lessons learned from the silicone coated SPF roof system. [The specification was proposed to be used on two USAF bases].

7. An economic analysis model which considered the potential duration of the SPF roof system based on performance information and the insulating quality of the R-7 SPF roof system.

8. A vapor flow model to analyze the potential of saturation in the closed cell system. Even though the SPF was monolithic closed cell and waterproof and the silicone coating was a breathable coating [resist UV degradation of the SPF], standing water in areas due to a lack of slope and drainage acted as an impermeable waterproofing membrane. The standing water would then cause the SPF to get saturated in the ponded areas when there was an appreciable vapor drive moving from the inside to the outside of the building [Kashiwagi, 1995; Kashiwagi, 1991].

9. The SPF roofs were being installed in ¼ inch passes and was the source of blistering in traffic areas. The inspection identified that if the roof was installed in ½ inch passes the blistering problems in traffic areas would be severely minimized. This was one of the greatest contributions of the research to the industry [Kashiwagi, 1999].

10. The asphalt coated and aggregate SPF roof system was not recognized by the roofing contractor association as a legitimate SPF roofing system. However, the vendor and his roof installations met the requirements of the inspections. A quick engineering analysis identified that the roof system without the asphalt may be a high performance roof system. After getting the USAF researcher to sign off on a patent, a major SPF manufacturer applied and received a patent for the Aggregate Covered SPF roofing system [North Carolina Foam]. Later inspections identified that the potential flaw in the system was that because the SPF was not observable beneath the layered aggregate, the installation quality of the SPF was poor and led to potential blistering problems.

11. Taking the lessons learned from the research, the researcher produced a performance-based SPF specification and supplied it to a couple of USAF bases that could be used to procure SPF roof systems. The specifications were a performance-based specification [Air Force Office of Special Investigations District 7 (AFOSI), 1983].

Reaction of the Research by Arizona State University and the SPF Roofing Industry

The researcher was awarded a Master of Science Engineering (MSE) degree in December 1983 [2.5 years of research work]. The MSE research led to the most publications from an MSE thesis at the ASU Department of Industrial Engineering and from CI AFIT graduates. The University published the thesis and it was immediately edited by the researcher, recopyrighted and republished by SPF industry stakeholders [Kashiwagi, 1984]. One of the contractors also requested their own publication with their own performance information [Kashiwagi, 1985b]. The National Roofing Contractors Association (NRCA) published the research results, it was the first-time performance information of the SPF roofing system was published in two refereed international symposiums [Kashiwagi, Pandey, & Tisthammer, 1997; Kashiwagi, 1985a]. The
Journal of Thermal Insulation published the results of the thermal analysis and performance of the SPF [Kashiwagi & Moor, 1993; Kashiwagi & Moor, 1986].

The researcher’s observations became industry standards and led to further inspections and research analysis [min ½ inch SPF passes, the minimization of ponded areas, the use of the aggregate SPF roof system] [Kashiwagi, 1996]. Two USAF bases [Nellis AFB and Williams AFB] utilized the thesis performance specification to procure SPF roof systems [AFOSI, 1983]. The thesis work impressed Arizona State University to bring the researcher back to complete his PhD work. The roofing industry was thrilled with the performance information and it led to a $1.3M performance study of the hail resistance of the Urethane SPF roof system [Kashiwagi & Pandey, 1998; Kashiwagi & Pandey, 1997].

The Response of the USAF Roofing Professionals

The response by the USAF roofing engineer was extremely different from the industry reception of the performance information. The USAF roofing engineer did not take kindly to the researcher’s thesis results. He did the following [AFOSI, 1983]:

1. Recommended that the researcher’s next assignment as the roofing instructor at the Air Force Institute of Technology (AFIT) school be rescinded.
2. Alerted the USAF Office of Special Investigation (OSI) [police and investigation arm of the USAF] and started an investigation on the researcher for “Conflict of Interest” and fraudulent information not in the best interest of the USAF. He was proposing that the research results were inaccurate and the researcher had not acted in the best interest of the USAF, may have been inappropriately compensated for his efforts and leaked classified USAF information to contractors on two USAF procurements [all his claims were found to be inaccurate by the USAF OSI].
3. Made derogatory and inaccurate personal statements about the researcher to the OSI investigators fueling the charges of “conflict of interest” and fraud.
4. Used his relationships and influence in the USAF, using commands and AFIT education group, to ensure the researcher’s USAF career would end. He stated in his written statement to the OSI [and to the researcher in person] that the researcher would never be put in a position of teaching other USAF engineers.
5. In his entire statement to the OSI, the USAF roofing engineer did not address the research results of the SPF performance information. He stated that the performance information was biased. He did acknowledge that a couple bases were using the researcher’s SPF performance specification to procure SPF roofs. The OSI investigator noted that the USAF roofing engineer’s claims were confusing in that for a USAF base to use a SPF specification to procure a roof, he would have to approve the specification as stated by his own USAF roofing policy.

Due to the USAF Air Force Civil Engineering Center [AFESC] structural/roofing engineer’s efforts, the reaction to the USAF civil engineering researcher’s results was one of non-acceptance and an attack of the integrity of the research project manager and the researcher’s integrity by the USAF roofing community. The researcher’s next assignment to teach at the Civil
engineering school was terminated due to the roofing engineer’s recommendation. The USAF roofing engineer informed the researcher that he would not teach any USAF captain in the future. An Office of Special Investigation (OSI) investigation was opened on the USAF researcher claiming the appearance of the conflict of interest [receiving payment, giving unfair advantage to contractors competing on USAF roofing projects and providing fraudulent research study results]. Interestingly, the validity of the actual performance information results was not discussed by the USAF roofing community. The objective of the OSI investigation was to identify if the researcher had broken USAF regulations [acceptance of inappropriate funding] in doing his research work [AFOSI, 1983].

After a year’s investigation, no evidence of wrongdoing could be identified by the OSI (AFOSI, 1983). The case was closed. A letter of reprimand was written to the researcher by his reporting officer, the Director at the Air Force Civil Engineering Center [AFESC], for being under the appearance of a “conflict of interest”. The researcher was directed to discontinue all further research work with the SPF roofing system for three years. During the USAF OSI proceedings, the USAF researcher had no legal representation, was given no information and was pressured to take a polygraph test. Every industry person who assisted in getting access to the database of 1125 roofs, and 247 inspected SPF roofs was questioned for potential illegal payment and inappropriate actions with the USAF researcher.

The researcher was confused on why such a valuable research work resulted in an OSI investigation. The researcher could not understand why the USAF structural/roofing engineer used derogatory, biased and inaccurate statements to the OSI investigators [captured as a part of the OSI written record in the investigation]. Not once was the value of the SPF performance information noted by the USAF roofing engineer in his written statement. The researcher spent the next three years writing papers on his research investigations of the performance of SPF roof systems.

Despite an unblemished record [researcher was a Reserve Officers' Training Corps (ROTC) distinguished graduate (DG) and awarded a fully funded two-year master’s degree at a civilian institution, assignments were normally only one year], the researcher lost his opportunity to become the roofing instructor at the USAF civil engineering school, and was forced to find another assignment. He was assigned to a civil engineering officer slot that required a master’s degree with no job description. If the slot was not filled, the USAF Engineering Services Center (AFESC) would lose the position. In other words, the researcher was sent to a slot that had no job or what was known by other USAF officers as a “dead-end job”.

The USAF research study results were controversial for the following reasons:

1. The results of the study conflicted with the current USAF 91-35 roofing policy for USAF facilities [set by the USAF roofing engineer].
2. The results went against the USAF roofing policy of restricting any SPF roof installations except in rare circumstances and would still require a USAF headquarters approval [AFESC structural/roofing engineer that originated the OSI investigation].
3. The decision by the USAF Roofing Engineer and the Industry roofing consultant utilized by the USAF roofing program [interview with Ed Schreiber, 1982 located in Detroit, MI] was to
utilize the traditional four ply built up roofing (BUR) system and not roofing systems such as
the SPF roof system [which were identified as experimental and had no performance history].
This was based on their professional expertise and not performance information. They did
not have the performance information on either the BUR system nor the SPF system to make
a logical analysis of value [price and performance duration].
4. The information used to educate USAF civil engineers on the SPF roof system was
inaccurate. It was based on professional technical expertise of the USAF roofing engineer
and roofing program professional consultants.
5. The SPF roof system performance information collected in the research was the first
performance information in the roofing industry and in the USAF roofing education and was
not given to USAF engineers. Through the personal efforts of the researcher, two USAF
bases agreed to use the SPF specification generated by the research project.
6. The number of roof inspections [247], the number of different environmental conditions of
the inspected roofs [6] and the dominant performance results [97% customer satisfaction,
94% less than 5% deterioration], troubled the USAF roofing manager and AFIT roofing
education program.

USAF Researcher Changes Technical Professional to Continue Research

The researcher was attempting to change the USAF civil engineering environment from an
owner centric industry which utilized technical professional experts to manage, direct and
control the quality of construction systems, to an environment where performance information
could be used by owners to identify and utilize expert contractors.

In fairness to the USAF roofing community, they did not know how to discuss the value of the
performance information. They resisted the researcher because he was attempting to change their
paradigm. He was using performance information to challenge the expertise of professionals.
Because of his actions, he was targeted. In normal situations, an USAF officer investigated by
the OSI would not be promotable. He would never get a recommendation from his superiors to
compete for lucrative career enhancing assignments.

An inherent problem with traditional environments that utilize professional technical expertise, is
that different areas of technical expertise create silos. The civil engineering technical expertise
was one silo in the Air Force Institute of Technology (AFIT) and taught all USAF base civil
engineers. The roofing technical area was its own silo within the civil engineering silo. The
AFIT roofing instructor was an MSE level professional who educated the lower-ranking officers
who maintained facilities.

There was another silo which was the Industrial Engineering/Systems Engineering silo. This
group educated USAF industrial and systems engineers to optimize USAF aircraft,
communication and electronic systems. This silo utilized PhD level officers who understood the
optimization of technology systems in the USAF and educated the higher-ranking officers and
managers of the operational USAF systems. Normally each silo could control the progression of
the USAF officers in their own silos. However, in this case, the USAF researcher who was using
performance information in the civil engineering roofing area, was listed as an industrial
engineer [MSE in industrial engineering] whose notable achievements in his performance information area of expertise caught the attention of the AFIT Industrial Engineering staff. His achievements met their requirements even though they were not appreciated by the civil engineering area (Kashiwagi, 2019, Chapter 7):

1. ROTC Distinguished Graduate (DG).
2. Successful completion of a Master of Science Engineering (MSE) Degree in Industrial engineering at Arizona State University with a minor in Construction Management [only officer in Industrial/Systems Engineering and Civil Engineering].
3. The highest publication record of any USAF MSE graduate at civilian institutes [five major publications in three years].
4. High recommendation of the ASU Industrial Engineering department due to his previous MSE performance. They promised the AFIT industrial engineering office that the researcher could finish his PhD on time in three years [huge risk of USAF PhD candidates in the civilian university programs].
5. A 99 percentile Graduate Research Exam (GRE) rating on quantitative section.
6. Assignment at the Air Force Engineering Services Center [high level command assignment] where due to his ingenuity and logic and IE degree, he identified the optimal solution of a $98M Runway Rapid Repair Program using a time-based simulation program (United States Air Force Officer Effectiveness Report, 1985). He also served a prestigious assignment to the Royal Saudi Air Force Peace Hawk/Shield Program in Riyadh Saudi Arabia as an USAF technical engineering consultant where he ended up saving the Royal Saudi Air Force (RSAF) $12.5M to stay within budget on their Peace Shield Command and Control project.

Based on his ability to produce significant results, the AFIT group identified the researcher in 1989 as the best officer candidate for a 1992 professor slot requiring him to get his PhD at Arizona State University in the Industrial Engineering department. His mentor and PhD committee were from the same academic staff who worked with him five years earlier on his MSE. The USAF researcher had sidestepped the USAF roofing engineering technical staff professionals and their resistance to using performance information and was now given another opportunity in the development of the use of performance information. The same AFIT organization that had terminated an assignment in the Civil Engineering office was now inviting the “persona non gratis” researcher back into the higher-level PhD position in Industrial Engineering as a system engineering researcher. The researcher became the only USAF engineering officer educated through the Air Force Institute of Technology (AFIT) civilian institute (CI) with 5.5 full years of education.

**USAF Research Project Utilizing Performance Information**

The aforementioned researcher did his PhD research project at ASU to investigate the utilization of performance information. A method for professionals to utilize performance information would have to be created. This would assist in overcoming the resistance in changing from a client centric to an expert vendor centric environment. The lessons learned to replace professional decision making to identifying and utilizing expertise included (Kashiwagi, 1991, p. 4 – 5):
1. The client’s professional’s decision making needs to be minimized to increase accuracy and efficiency in identifying and utilizing expertise.

2. Vendors should be required to provide performance information that identifies their value to meet the requirements of a unique project.

3. A process is required where the clients can get vendors to compete using the vendors’ performance information. The easiest method to eliminate the biased decision making of professionals is to automate [minimizing all thinking and decision making where the professional’s bias is utilized].

The USAF PhD thesis project was divided into the following tasks (Kashiwagi, 1991, p. 9-12):

1. Create a simple explanation to differentiate the professional controlled and owner centric environment from the utilization of expertise to create a contractor or vendor centric environment.

2. Change the traditional owner centric procurement process to a vendor centric procurement process by replacing the decision making and direction and control of the professionals to the identification and utilization of the expertise of the best value vendor.

3. Minimize the amount of information needed for communicating the project requirement from the owner to the vendors.

4. Automate the normal selection of the best value vendor with a computer model that identifies the best value vendor.

5. Once the best value vendor is selected, the vendor is requested to provide a detailed schedule, a simple risk mitigation schedule, go through a technical review of their process and track the project time and cost deviation.

The scope of the research project was to create and run the new procurement approach to the selection of the best value vendor minimizing the decision making of the professional. It did not include Task 5 listed above. The project avoided any resistance of traditional professionals in the USAF. The entire research project was designed by the researcher and reviewed for technical competency by the Industrial Engineering and Construction Management committee at Arizona State University and the private sector client in Traverse City, Michigan. The researcher needed to prove that the approach could be technically run, before facing the expected resistance of industry professionals who previously had resisted the use of the performance information. The research project had the following deliverables (Kashiwagi, 1991, p. 297-323):

1. A best value procurement process.
   a. That could compare different products by different non-technical performance characteristics that could meet the client’s requirement.
   b. That identified client’s requirement in terms of value [price, performance, customer satisfaction].
   c. Used vendor’s performance information from past projects.
   d. That identified the best value vendor for the unique project requirement.

2. Roofing performance criteria which included physical characteristics of the project roof, the energy savings of the competing roofs, the performance characteristics including roof service duration, warranty length, life-cycle cost, customer satisfaction, and roof leak prevention.
3. An automated selection process utilizing the Displaced Ideal Model (DIM) [Zeleny, 1982] which took the input of the performance criteria, the owners relative weights which represented the owner’s requirement, and the information factor which was the relative amount of information of each performance factor [based on the relative spread of values, more information created by a larger spread of relative values].

4. An Industry Structure (IS) figure that explains the transformation from the low bid approach to the best value approach.

The strategic plan of the USAF researcher at the time of the PhD project was to:

1. Create the automated procurement system for the PhD dissertation requirement.
2. Run a case study to test the concept also to meet the PhD requirement.
3. As an instructor at the AFIT industrial engineering department, identify USAF systems requirements where the new automated procurement system could be tested to continually improve the new approach.

The client that ran the case study to test the concept was impressed by the capability of the approach to accomplish the following [Kashiwagi, 1991]:

1. Reduce the procurement time and cost.
2. Have different approaches and systems to compete against each other to create a value engineering event.
3. Minimize the need to have professional expertise on his staff.
4. Identify the best value considering all criteria without having to make decisions by having an automated system.

The test was successful. The ASU industrial engineering and construction management professors were impressed by the expertise of the researcher. The only question they had for the researcher in the defense of the thesis was “Who owned the information technology (IT) developed by the researcher?” The USAF industrial engineering department was interested only in the researcher passing his dissertation requirements in three years to become a professor. They were not accustomed to a PhD student developing a new usable technology. The ASU professors were amazed with the researchers capability to integrate the in-depth knowledge of the industry, a change of paradigm that had never been tested, and the ability to select and utilize an automated multi-criteria decision making model that automated the decision making of professional project managers. The researcher had become the expert.

In an attempt to get a patent on the developed technology, the researcher realized that the USA patent office could not understand the technology or the underlying logic. The realization was made that the technology [Information Measurement Theory (IMT) and Best Value Approach (BVA)] could not be easily understood or transferred. The researcher decided to utilize the licensing of the technology at ASU, instead of having endless discussions with the patent office. It has become the most licensed intellectual property (IP) technology developed at Arizona State University (ASU) [64 licenses over 28 years].
Development of the Use of Performance Information

After graduating from ASU in 1991, the USAF researcher gave a presentation to his new industrial engineering (IE) department staff. He was impatient to start testing the automated procurement system on USAF system developments. He quickly found out that his USAF IE superiors were not oriented toward research tests to optimize and develop the USAF systems. They were oriented toward teaching USAF IE professionals the technical structure they could use to replace the current professionals. They were not interested in changing the paradigm of replacing the professional decision making with the identification and utilizing expertise with performance information.

At the same time, the USAF was downsizing due to the bringing down of the Berlin wall and the end of the cold war with the Soviet Union. The overall USAF created a very attractive option that allowed the researcher to leave the USAF. In six months, the researcher became a research director at Arizona State University and within two years created the Performance Based Studies Research Group (PBSRG) and started running tests utilizing the new information-based procurement system.

The “Economic Feasibility of the SPF Roof System” [USAF Performance Information research project] and the “Performance Design/Procurement System for Nonstructural Facility Systems” became the beginning of an effort to reshape the supply chain, change the project management model [from manage, direct and control to identify and utilize expertise], change the risk management model [minimize decision making, transfer risk to mitigating risk] and move toward the automation of the delivering of services. Over the next 28 years, the name of the approach changed from the Best Value Procurement to the Performance Information Procurement System (PIPS), and then to the Best Value Approach (BVA).

Creation of a Research Platform PBSRG for Disruptive Technology

PBSRG research is in the following areas (Kashiwagi, 2019; Kashiwagi, 2020):

1. Changing environments from owner centric to vendor centric.
2. Changing the project management (PM) model from decision making, management, direction, and control to identifying and utilizing expertise.
3. Redefining risk and identifying the source of risk as stakeholders who make decisions. A major part of redefining risk is to identify that the expert vendor does not have risk and mitigates risk caused by the nonexpert stakeholders.
4. Optimizing the supply chain by the identification and utilization of expertise and the use of performance information.
5. Transforming the stakeholder communication from professional expertise using detailed technical information to the language of non-technical metrics that minimize decision making.
6. Optimize the Best Value Approach (BVA) to reduce the cost and time of services.

PBSRG is a unique research center. It is led by a Director who created the Information Measurement Theory (IMT) and the BVA and the IP technology that is the most licensed IP developed at ASU. PBSRG research, using IMT concepts, have shown the ability to simplify
complexity and has continually created methods that cut costs and increase value. PBSRG is structured to do the following (D. Kashiwagi & J. Kashiwagi, 2019):

1. Use the CIB [international council of research and innovation in building and construction] W117 working commission to integrate worldwide research of the BVA in countries around the world.
2. Host the CIB W117 journal to ensure the most recent BVA results are immediately published and that BVA experts are utilized to peer review papers.
3. Continually run industry tests on BVA research concepts throughout the world.
4. Work only with visionaries who want to test the concepts of BVA. By working only with visionaries, PBSRG minimized the resistance from stakeholders who are attempting to protect the traditional practices of using professionals and who lack the capability of changing the paradigm.
5. Have flexibility and control over PBSRG research direction. When the BVA research identified that the biggest opportunity to change was in project management and not the professional engineering area, PBSRG research moved from Arizona State University Civil Engineering department to the SKEMA Business School Project Management dBA program. PBSRG is unique because the founder and inventor is a part-owner of the PBSRG research technology and is the only academic research group that licenses the intellectual property (IP) [through Arizona State University].

**PBSRG Projects that Developed the Use of Performance Information**

The development of performance information took place in the following research projects:

1. USAF master’s thesis SPF roof system performance (Kashiwagi, 1983).
2. USAF PhD procurement test (Kashiwagi, 1991).
3. State of Hawaii (Kashiwagi & Savicky, 2003; Kashiwagi & Mayo, 2001a; Kashiwagi & Mayo, 2001b; Kashiwagi, Savicky & Parmar, 2003).
4. State of Utah (Kashiwagi & Byfield, 2002a; Kashiwagi & Byfield, 2002b; Kashiwagi & Byfield, 2002c; Kashiwagi & Byfield, 2002d).
5. Dutch Fast Track Projects and Implementation of the BVA (D. Kashiwagi, J. Kashiwagi, 2011; Van de Rijt, Witteveen, Vis & Santema, 2011).
6. US Army Medical Command (Kashiwagi, D., Kashiwagi, J., Smithwick, J., Kashiwagi, I., Kashiwagi, A., 2012; J. Kashiwagi, Sullivan & D. Kashiwagi, 2009).
7. State of Oklahoma tests.
8. State of Minnesota Construction Projects (Kashiwagi, D. et al., 2012).
9. Neogard Alpha Program (Gajjar, D. Kashiwagi, Sullivan, & J. Kashiwagi, 2016; Gajjar, Sullivan & Kashiwagi, 2013; Gajjar & Kashiwagi, 2020; D. Kashiwagi, Gajjar, Kashiwagi, Zulanas & Dhaval, 2017; Kashiwagi, Gajjar, Kashiwagi & Sullivan, 2015; D. Kashiwagi, Smithwick, J. Kashiwagi & Sullivan, 2010; Kashiwagi & Tisthammer, 2002; J. Kashiwagi, & Sullivan, 2016).
10. New Alpha Program (https://cibw117.org/the-alpha-certification-program/).
USA First Research Project Establishes Client Centric Environment That Cannot Utilize Performance Information

The first research test identified by the construction industry was a client centric environment. Clients utilized professionals to deliver services. These professionals used the traditional structure or silos to make their decisions that resulted in the delivered service. Although the professionals were educated in the sciences, the lack of information caused them to build a structure of experience, subjectivity and decision making. The environment is inductive and probabilistic. It required decision making by professionals using their experience. The professionals used their expertise, tenure and decision making to resist change. The client centric environment was described with the following observable characteristics:

1. Professionals are educated, and certified to utilize their experience to govern the client centric environment.
2. Professionals identify and create the service requirements and then control the delivery of the service.
3. Professionals use specifications to direct contractors.
4. Performance information collected by observation is not utilized by professionals.
5. Client centric environment is cost based using minimum specifications.
6. Client centric environment assumes that contractors who meet the minimum standards are all the same.
7. Client centric environment requires licensing, bonding and insurance to minimize risk.
8. All projects have risk.
9. All contractors have performance risk.
10. Performance information of construction systems is not utilized in a client centric environment.

The SPF roof system performance was resisted by the USAF environment because the USAF was a client centric governed environment utilizing professional expertise. Despite the resistance of the USAF management level professional, it was quite unusual to have two USAF bases civil engineering deputies use the researcher’s specification on SPF roof installations and attempt to install the SPF roofing system against the USAF roof policy. The researcher’s expertise was not utilized further due to the control placed on the researcher by the USAF roofing professionals.

Users of Performance Information Are Resisted by Structure of Professionals

The researcher overcame the resistance by being focused and working on publications and application of performance information in industrial engineering applications. The researcher had an uncanny capability to use performance information that resulted in large savings in project cost. He optimized the value of the USAF $100M Rapid Runway Repair program by running time simulation. He followed it up by making a $12.5M saving through a design change in the Peace Shield Royal Saudi Arabia command and control system [United States Airforce, 1988]. Ironically, the researcher’s skills used a new approach. His expertise did not need experience, relationships or time to have an impact on the USAF structure. He used performance
Development of the Use of Performance Information

information to easily solve problems caused by USAF professional decision making [United States Airforce, 1988].

He returned to the research arena to create the automated procurement system that utilized performance information. He continued to use major lesson learned from the first research test:

1. Find and work only with visionaries who could see into the future.
2. Create and run an automated procurement system that utilized expert vendor performance information to minimize decision making by professionals.

The automated delivery system test was successful. To do further testing, the research had to be taken outside of the USAF bureaucracy run by professionals which did not have interest in testing disruptive technology to optimize the performance of USAF systems.

Rules for Disruptive Technology Research

The use of performance information is a disruptive technology. Implementation of performance information is disruptive because it minimizes the work of professionals and redefines the definition of expertise, risk and mitigation of risk. A new research platform is needed with completely different rules. The new research structure was created from the Information Measurement Theory (IMT). This created a completely different set of rules for the research. IMT is a deductive logic that included the following concepts (Kashiwagi, 2014a):

1. Stakeholders are divided into observant [can see into the future] and nonobservant [cannot see into the future].
2. The majority of stakeholders are non-observant.
3. Observant stakeholders minimize thinking, decision making and passing information.
4. Influence and control are inaccurate concepts that is understood by the observant.
5. Individuals control their own destiny. They act and are not acted upon.
6. Decision making is inefficient and ineffective and based on what is not known.
7. Collaboration with non-observant stakeholders is nonproductive.
8. The BVA is an approach that minimizes the effort of professionals. The concepts are similar to automation. Automation is popular because it minimizes human activity, lowers cost and increases performance.
9. The future is one of efficiency and effectiveness. It aligns with automation.

A new platform based on the above concepts was required to successfully test the disruptive technology. PBSRG was created for the future and not for the present. It required the following capabilities:

1. A School where the School Director gave full support to the innovative research [School of Construction Management at ASU]. The researcher enjoyed the Director’s “no rules” approach to research. No permission was required for any research activity. The researcher became the only staff to be promoted to full professor in the School of Construction in 20 years.
2. Did not require assistance from the academic research community [whose objective was to sustain the role of professionals in government]. Required a different source of research funding. 
3. Partner with industry visionaries who needed to reduce cost, increase quality and minimize the need to manage and control the vendors. 
4. Be a worldwide research group to increase the probability of finding visionaries. Avoid resistance of the traditional professionals. 
5. Be the only research group to run industry research tests and publish the results in an international journal which PBSRG could publish quickly and continuously. 
6. License the BVA Intellectual Property (IP) through a major university. 
7. Control the IP by the constant improvement of the IP. 

The Performance Based Studies Research Group (PBSRG) was created in 1994. PBSRG has the following metrics in the areas of industry tests, publications, licensing and the first crossover research group in construction management which moved IP concepts from the construction industry to all industries. PBSRG utilized the performance information metrics to show its capability to optimize the supply chain in all industries (Duren & Doree, 2008; D. Kashiwagi & J. Kashiwagi, 2019; Kashiwagi, 2014b; Rivera, 2014; State of Hawaii PIPS Advisory Committee, 2002):

1. Duration of PBSRG: 1994 – 2020 [26 years]. 
2. Integrated PBSRG with the CIB [International Council of Research and Innovation in Building and Construction] working commission W117 “Use of Performance Information in the Construction Industry” in 2008. 
3. Research Funding: $17.6M [industry visionaries and not government research funding] 
4. Prototype Testing: 2,000+ tests with industry, ten different countries, $6.6B of services delivered [construction, IT, consulting services]. 
5. Industry research tests measure 98% client satisfaction, minimized cost [5 – 50%], and minimized contractor time and cost deviation to less than 1%. 
6. 350 refereed journal papers, conference publications and books. 
7. Director moved PBSRG, to the private sector in 2017, then moved the academic research to the SKEMA Business School Project Management dBA program [Doctor of Business Administration] in 2019. 
8. Licensed Intellectual Property (IP): 64 licenses [1997 – 2020] [most licensed IP technology at Arizona State University]. 
9. IP included: Performance Information Procurement System (PIPS), Performance Information Risk Management System (PIRMS), Best Value Approach (BVA). 
10. Research areas include information based and automated project management, information-based risk management, supply chain optimization, language of metrics, vendor performance metrics and the Best Value Approach (BVA).
Using the Automated Best Value Procurement (BVP) or Performance Information Procurement System (PIPS)

The first two major tests of the automated BVP and PIPS were the State of Hawaii (Kashiwagi & Mayo, 2001a; Kashiwagi & Mayo, 2001b; Kashiwagi, Savicky & Parmar, 2003; Kashiwagi & Savicky, 2003) and the State of Utah (Kashiwagi & Byfield, 2002a; Kashiwagi & Byfield, 2002b; Kashiwagi & Byfield, 2002c; Kashiwagi & Byfield, 2002d). The State of Hawaii utilized the approach on installing roofing systems. The State of Utah utilized the approach on procuring large general construction projects and the selection of architectural designers and engineering firms. Both were highly successful in delivering projects on time, on budget and meeting customer satisfaction. However, the client and expert contractors and designers made the following perceptions:

1. There was confusion on what was performance information.
2. The client was doing too much work keeping track of the performance information.
3. The client was responsible for collecting the performance information.
4. The client had to ensure that the performance information was accurate.
5. Client had to decide what information was not valid.
6. Client had to decide how to enforce the performance information in the project.
7. Client had to legally identify what was performance and what was not performance on a project. If the client was not happy with the project, the project performance of the vendor became a subjective rating.
8. Vendors were not sophisticated enough to understand why the automated Displaced Ideal Model (DIM) picked one contractor over another.

In both cases, the State of Hawaii and Utah industries resisted the best value procurement system even though the procurements were very successful [fast and efficient] and the best value vendors and clients were satisfied. Resistance was in the form of official protests of project awards, legislative hearings, questions in education hearings, charges that PBSRG at ASU was controlling the state’s procurement of services [Dooley, 2002a; Dooley, 2002b], charges of conflict of interest of the BVA delivery system, articles in the local paper and official legislative inquiries. Besides the visionaries, industry professionals rejected using performance information to differentiate performance. Of the first four visionaries who successfully utilized the BVA, four of them were let go from their positions [state of Hawaii, Utah, Oklahoma and University of Minnesota]. As in the first two performance information tests, the BVA delivered high quality and lower prices, customer satisfaction and on time and on budget construction. However, the client risk was very high due to the industry resistance. The industry did not understand the paradigm shift.

The professionals and their structure of governance resisted the change of paradigm. They were not open to replace their decision making with performance information and moving the governance to the expert contractor/vendor. When clients attempted to use the performance information in the professional’s service, the professionals used their relationships to politically remove the visionary. The personal experience of the USAF professionals removing the researcher and his performance information approach was only the first of many examples of the resistance of professionals.
Source of Risk [Project cost and time deviation]

Four major projects, the Dutch Fast Track Projects, Figure 2, (D. Kashiwagi, J. Kashiwagi, 2011; Van de Rijt, Witteveen, Vis & Santema, 2011) the US Army Medical Command Project (Kashiwagi, D., Kashiwagi, J., Smithwick, J., Kashiwagi, I., Kashiwagi, A., 2012 ; J. Kashiwagi, Sullivan & D. Kashiwagi, 2009) and the State of Minnesota projects, Table 3, and the State of Oklahoma, Table 2, had an unexpected impact on performance information.

Table 2: State of Oklahoma Performance Metrics (PBSRG, 2020)

| Performance Measurements                                  | 2008-2012 |
|----------------------------------------------------------|-----------|
| State savings with best value projects (budget-actual)    | $29,887,034 |
| # of projects procured through BV                        | 15        |
| Value of Projects awarded through BV                      | $54,191,767 |
| Success Rate defending Bid Protests (# of protests won / # protested) | 100% (3/3) |
| Percent where BV Vendor was Lowest Cost                   | 92%       |
| Budget Deviation after award                              | -0.003%   |
| Schedule Deviation after award                            | 0.5%      |
| **Procurement Process Satisfaction**                      | All Projects |
| Using Agency Satisfaction with the Traditional Process    | 6.0/10    |
| Using Agency Satisfaction rating with BV process          | 9.5/10    |
| Vendor Satisfaction with the BV process                   | 9.8/10    |

Table 3: MEDCOM and Minnesota performance metrics (PBSRG, 2020)

| Division Overview          | MEDCOM          | Minnesota         |
|----------------------------|-----------------|-------------------|
| Original projects budget   | $ 973,939,615   | $ 495,094,925     |
| Estimated cost over budget | $ 53,595,264    | $ 38,828,396      |
| Original Project Duration  | 228,402         | 50,463            |
| Days Delayed              | 93,944          | 18,640            |
| Total Number of Projects   | 619             | 424               |
| **Average Project**        |                 |                   |
| % Over Awarded Budget      | 5.50%           | 7.84%             |
| % over budget due to owner | 4.13%           | 6.68%             |
| % over budget due to Designer | 0.06%        | 0.01%             |
| % over budget due to contractor | 0.00%       | 0.65%             |
| % over budget due to unforeseen | 1.31%       | 0.50%             |
| % Delayed                  | 41.13%          | 36.94%            |
| % Delayed due to owner     | 30.84%          | 26.93%            |
| % Delayed due to Designer  | 0.25%           | 2.00%             |
| % Delayed due to contractor | 1.48%          | 3.64%             |
| % Delayed due to unforeseen | 8.57%          | 4.36%             |
The four projects identified that over 90% of all project deviations were caused by the client’s professionals decision making. The risk caused by the contractor was less than 1%. The combination of the two metrics led to the following conclusions and changes in the definition of project performance and performance information:

1. The source of risk was client’s professional’s decision making.
2. The expert vendor who is required to have a detailed plan from beginning to end [preplanning], and a milestone schedule to identify and mitigate risk and track time and cost deviation from beginning to end has no risk.
3. If a project was non-performing, the probability that the non-performance was caused by the vendor was very low. Therefore, nonperforming project ratings were non-representative of a contractor’s performance and meaningless in predicting the contractor’s performance on a future project which the best value approach (BVA) was utilized.

The purpose of performance information is to minimize project risk. Project risk is minimized by expert contractors who can identify a detailed schedule of work from beginning to end, a milestone schedule to mitigate risk caused by stakeholder decision making and unforeseen events, and prove that they have successfully done similar projects with similar characteristics. The impact of these tests on the construction industry include:

1. Contractors should not be held liable for past project poor performance.
2. Contractors should not be prequalified.
3. Contractor performance information should come from the contractors and the information should have specific characteristics depending on the future project.
4. Contractor performance information is not the responsibility of the clients or the construction industry.
5. Contractor performance information is unique and should identify if contractors are qualified for a unique project.
6. Contractor performance information does not need to be verified until a contractor is being considered for award of a specific project.
Alpha Programs

A Sprayed Polyurethane Foam (SPF) roofing system manufacturer was introduced to the best value environment and the Industry Structure (IS) logic. The manufacturer did not participate in the first USAF SPF performance information project in 1982. The manufacturer produced an aromatic urethane coating Permathane which exhibited hail resistant characteristics. Aliphatic urethane coated roofs which were inspected at Texas A&M University in College Station Texas in the first research project. The aliphatic urethane roofs were erroneously identified by the professionals as the roof coating that performed due to its resistance against ultraviolet degradation. However, the aliphatic urethane roofs that were inspected exhibited reversion of its coating [the two-component urethane reverted to its original two liquid components] [Kashiwagi, 1996]. The urethane coating that performed was the manufacturer’s aromatic urethane coating. It had high performance with hail resistance and durability. The manufacturer approached ASU to do the following (Kashiwagi & Tisthammer, 2002):

1. Create performance information based on performance periods and hail resistance. Use performance information [ability to resist hail stones] to differentiate their Permathane roofing system from other roofing systems. Conduct field hail tests with aged roofs to show that the Permathane system could resist Factory Mutual (FM) size hail without damage to the roofing system. Large hail was causing roofing failures, PBSRG was also requested to identify if the Alpha roofing system could possibly resist larger hailstones.
2. Create an education program for the manufacturer to educate best value clients. Use the Best Value Approach to identify clients who are looking for the best value solution. The alpha system performance information would be a unique marketing program.
3. Educate facility owners with the BVA technology and convince owners to use the Best Value procurement system to buy roofing and coating systems. The manufacturer would then respond to the owners with their best value options.
4. Create a new Alpha SPF contractor program based on performance. The contractors would go through an inspection of their installed SPF roof systems to show performance. The manufacturer hoped to get the best contractors in the country to join their program. The contractors would be key in the success of their Alpha program. Contractors would have to maintain a 98% of roofs not leaking and customer satisfaction to keep their Alpha certification in the program.
5. Risk reduction for the manufacturer and the contractors. The manufacturer wanted to increase their warranty period from 10 to 15 years for this program. The manufacturer increased the thickness of the urethane coating and added a layer of #11 granules in the topcoat of the coating. The Alpha manufacturer also required a high-quality SPF manufacturer to produce a 3PCF SPF and call it an Alpha SPF which was only available to Alpha contractors.

The manufacturer’s visionary was confident that the education would identify owners in the Best Value environment where competition would identify the Alpha roofing system and their other waterproofing systems as the best value product. The BVA education program by PBSRG/ASU identified or assisted the State of Hawaii, United Airlines, the University of Kentucky, L3 and DISD to install high performance waterproofing systems. One of the flaws of the Alpha program was the requirement for PBSRG to give all presentations to clients. The manufacturer did not
Development of the Use of Performance Information

have visionaries who understood the approach. This resulted in the termination of the program as the manufacturer’s personnel’s lack of understanding of the BVA led them to act in a traditional relationship manner with both contractors and clients.

The largest client who bought the Alpha roofing system was the Dallas Independent School District (DISD). DISD competed the Alpha roof system against the installation of new BUR systems or modified bitumen roof systems. The advantage of the Alpha system was it could be installed over the existing roof system, whereas the competing modified Bitumen systems required a complete removal and replacement. The DISD had two bond programs in 2005 and 2015.

The weakness of the Alpha SPF roof system was that it was a high-tech system that required contractor expertise. the Alpha contractors were scattered all over the country, and in the Dallas area, the Alpha manufacturer did not have enough high performing contractors to meet the DISD roofing demand. Instead of minimizing their risk and using the only experienced Alpha contractors, ensuring that the roof installations were high quality, the Alpha manufacturers allowed lower performing and low priced contractors with practices which increased the risk of premature failure of the Alpha roof system (Kashiwagi, Zulanas & Dhaval, 2017). the Alpha roof system manufacturers was also constrained by the following:

1. Weather constraints. The Alpha roof system could not be installed in wet, cold or windy environments.
2. Required expert SPF applicators who were highly trained and experienced.
3. SPF manufacturing production capability. The Alpha SPF manufacturer did not have the capacity to service all the contractors. Some of the lower performing contractors were forced to use substandard SPF.
4. Many of the DISD projects were controlled by general contractors. The SPF contractors did not have the capability to communicate their constraints and coordinate with the general contractors. They received no project management help from the Alpha manufacturer’s representative.
5. The president of the manufacturer was the visionary. However, he did not have visionary operations people supporting the Alpha program. The amount of roofing required by DISD overwhelmed the Alpha manufacturer’s representatives. They were paid a high commission for every gallon of material that was installed. They were not disciplined enough to maintain the Alpha specification and inspection requirements. The organization saw success as high sales and did not recognize the high risk of nonperformance.
6. The perfect storm was created when a new contractor was created from one of the existing Alpha contractors. The manufacturer accepted the new contractor if they had the same expertise as the contractor they came from. The new Alpha contractor started to bid a very low price and ended up installing 65% of all roofing applications, many of the roofs being substandard.
7. The DISD representatives were not blameless. Due to a lack of funding for their identified requirements, they lessened their requirement to cut costs. Instead of buying the Alpha system, they bought a ten-year Permathane system. They expected the same high quality and performance as the Alpha system. The manufacturer’s representatives did not ensure that the Alpha system level of quality was met.
Instead of the Alpha SPF roof systems lasting 20 years, roofing issues started occurring within 5 to 10 years. The roofing manufacturer was now faced with a situation with honoring the warranty and fixing the Alpha roofs that were damaged. The manufacturer did not have a cash reserve to handle problems. The manufacturer’s sales/warranty personnel had already been paid a generous commission without doing their responsibility. The low bidding contractor had formed a relationship with the manufacturer and stayed in business by fixing problems with the cash infusions from new projects. The client’s representative had a relationship with the Alpha manufacturer and the contractor. The Alpha program was now resembling a traditional supply chain where relationships were being used to resolve issues with low performance installation.

The DISD roofing representative expected the manufacturer to fix their performance issues. The low performing Alpha contractor did not meet their obligations [went bankrupt]. Because of the issue with the SPF roofs, the DISD decided to remove all SPF roofs when repairs were required. The Alpha manufacturer was forced to terminate the Alpha program. The contractor who had caused the most problems declared bankruptcy. At the time of termination, there was three contractors who were still highly successful. Only one of the high performing contractors was in the Dallas area.

The three contractors did not depend on the Alpha program for their success. They used the Alpha program to get better product and performance from the Alpha manufacturers and they used the information system of the Alpha program to minimize the risk of their installed roofing systems. The other contractors depended on the Alpha program for business opportunities. Two of the high-performance contractors did not participate in the DISD roof opportunities in Dallas and California.

The Alpha program was terminated because of the following issues:

1. All contractors were treated the same by the manufacturers. PBSRG recommended numerous times to use the performance of the vendors to differentiate the contractor performance and quality which would motivate the high performing contractors due to the recognition and minimized cost of the manufacturer’s warranty for the performing vendors. The manufacturer refused.
2. The manufacturer’s representatives could not tell the difference. The personnel in charge of sales, inspection of contractor quality and warranty were not skilled or professional. They were not project managers who could implement a BVA system. They did not do their quality assurance of the BVA. They could not identify and utilize expertise. They did their business based on relationships. Yet they were rewarded with high commissions of the Alpha program.
3. The manufacturer could have protected themselves against the risk of nonperformance of the contractors by doing their quality assurance, requiring a weekly risk report (WRR). They should also have created a risk fund instead of paying the high commissions to the sales representatives. The manufacturer thought that the success would change the representatives to learn the Alpha program and become more professional in their approach. IMT identified this as an error in the manufacturer’s approach.
4. The poor performing contractors could not tell the difference. They did not price their product as a performing product. They were financially unsound. They also did not mitigate
Development of the Use of Performance Information

risk with a milestone schedule and Weekly Risk Report (WRR). Their project management was ineffective and low performing. PBSRG recommended to the manufacturer, that it would be worth the investment to assist the contractors in their project management practices. The manufacturer did not see the value of the advice until the manufacturer’s financial risk increased.

5. Some contractors which met the Alpha program requirements, and who were perceived as good contractors by the industry, did not put their most experienced and performing people on Alpha projects. On one project, a client selected the Alpha roofing system based on the performance information. They installed a decent roofing system, however there were roof issues which the contractor did not efficiently resolve. The contractor wanted the Alpha coating and Alpha SPF manufacturer to pay for the materials [even though they erred in the application]. On the subject project that they did not respond in a timely manner, the Alpha program ended up losing a project worth upwards of $2M. PBSRG was forced to find another performing manufacturer to set up a similar program to the Alpha program to provide for the nationwide client.

PBSRG identified the reasons for the lack of the sustainability of the Alpha program:

1. Manufacturer could not tell the difference in levels of performance of the Alpha contractors.
2. Lower performing contractors could not tell the difference between the value Alpha system and their regular installations. They charged the same price for both.
3. Clients who used the BVA to procure Alpha systems could not tell the difference in performance between the high performing and low performing Alpha contractors. They assumed that all the contractors would perform to the same level of high performance.
4. Manufacturer’s representatives were getting commissions that they did not earn. They did not enforce the Alpha system requirements on the contractors by doing their quality assurance responsibilities.
5. Manufacturer of the SPF did not meet their requirement of providing product to the contractors they did not have a good relationship with.
6. PBSRG did not have the authority to enforce the Alpha program requirements on the manufacturer’s representatives.

The Alpha program was not aligned to the best value environment. It had some of the characteristics of the best value program, but many of the characteristics of a client centric, price-based system. PBSRG did not think that the Alpha program had a future in the SPF roofing industry. However, they were surprised by one of the performing Alpha contractors.

**New Alpha Program**

At the time of the termination of the Alpha program, the researcher identified that three of the six contractors had the following practices (Kashiwagi, Zulanas & Dhaval, 2017):

1. Serviced all their clients.
2. Could meet the 98% roofs not leaking and customers satisfied.
3. Keeps an information system.
4. Was not participating in the Alpha program to generate work.

Only one of the Alpha contractors understood the value of the Alpha program performance information structure and approached PBSRG to change the Alpha Program from a manufacturer controlled program to a contractor centric program [Insulated Roofing Contractors, IRC, located in Indiana]. They wanted the following characteristics in their program (https://cibw117.org/certified-alpha-contractors/):

1. Contractor based program.
2. Increased investment in time [in business for ten years] and performance [tracked their performance of installed roofing] for contractors.
3. Contractor controlled.
4. Contractor is responsible for tracking information and using the Alpha program for quality assurance.
5. High performance: 98% contractor satisfaction and roofs not leaking.
6. Contractor is responsible for warranty whether the warranty is being offered by the manufacturer or the contractor. Contractor is the single point of responsibility to the client and responsible for fixing any problem.
7. The focus is on customer satisfaction and value. IRC understood that this was the definition of transparency.
8. Tracking the performance information is a requirement for the contractor. The contractor is responsible for setting up the system and responding to any issues. The cost of posting the information on the Internet by a third party would be the responsibility of the contractor.

IRC knew that in order to be sustainable, they had to get a fair profit for their product. It would have to be a performing product, and it would have to be supported by the capability to constantly and consistently install the product. IRC was interested in scale. Instead of competing with other vendors where there was no competitive advantage and a very costly procurement process, they were interested in setting up a best value environment where they had the competitive advantage. The competitive advantage was:

1. Performance.
2. Price.
3. Customer service utilizing the internet, information systems and virtual integrated applications.
4. Efficiency, effectiveness and customer satisfaction.
5. Information based.
6. Scalable, repeatable, high performing.
7. They picked the market of roofing for schools as the primary marketplace.
8. They participated in a cooperative procurement group, marketplace where they identified the level of performance [which included the price].

IRC identified the cooperative marketplace where schools could go to the cooperative and buy roofs directly. Other roofing contractors could also be listed; however, they must meet the requirements of the Alpha program listed above. It cuts out the risk, complex and professional based procurement systems, and allowed guaranteed delivery of high quality every time. Their
development of the use of performance information. IRC used the highest quality products and is responsible for the funding to set up their information-based customer service and the quality assurance by an independent third party.

The figures below are the latest performance information that all clients have access to on the internet. The new Alpha program [IRC] shows the optimal use of performance information, and gives the best value, with risk mitigated by their expert service. This is the latest and most accurate use of performance information in the delivery of service.

IRC discovered that the traditional procurement process is too expensive and filled with decision making by professionals [technical designers and procurement professionals] for performing expert contractors to participate on a regular basis. They moved to the best value quadrant. To move into the best value environment, they required high performance [and performance information]. They realized that they needed to act as the expert vendor who takes responsibility for any errors in application. IRC does all the quality control and has an independent third party [PBSRG] doing the quality assurance. They have eliminated the decision making of professionals in this supply chain.

Table 4: IRC Annual Performance (https://cibw117.org/certified-alpha-contractors/)

| No | Survey Results                           | Unit | 2019   | 2017   | 2015   | 2013   |
|----|------------------------------------------|------|--------|--------|--------|--------|
| 1  | Total number of different clients        | #    | 40     | 12     | 27     | 24     |
| 2  | Total number of roofs surveyed           | #    | 293    | 72     | 90     | 89     |
| 3  | Total roof area                          | SF   | 21,634,918 | 7,915,423 | 2,286,230 | 5,428,887 |
| 4  | Largest roof area                        | SF   | 1,037,600 | 1,037,600 | 140,000 | 759,500 |
| 5  | Average roof area                        | SF   | 73,839  | 109,936 | 25,403 | 60,999 |
| 6  | Oldest roof                              | Years| 44     | 31     | 16     | 31     |
| 7  | Average age of roofs                     | Years| 15     | 13     | 8      | 7      |
| 8  | Age sum of all projects that never leaked| Years| 2,661   | 804    | 680    | 688    |
| 9  | Age sum of all projects that do not leak | Years| 4,201   | 944    | 698    | 858    |
| 10 | % of roofs that do not leak              | %    | 100%   | 100%   | 100%   | 100%   |
| 11 | % of roofs with satisfied clients        | %    | 100%   | 100%   | 100%   | 100%   |
| 12 | % of roofs with clients that would purchase again | % | 100% | 98% | 100% | 100% |

| No | Inspection Results                      | Unit | 2019   | 2017   | 2015   | 2013   |
|----|-----------------------------------------|------|--------|--------|--------|--------|
| 1  | Total number of different clients        | #    | 10     | 6      | 12     | 6      |
| 2  | Total number of roofs inspected          | #    | 52     | 28     | 30     | 33     |
| 3  | Total roof area                          | SF   | 8,037,065 | 7,154,944 | 2,095,986 | 4,025,462 |
| 4  | Average roof area                        | SF   | 154,559 | 255,533 | 69,866 | 121,983 |
| 5  | Oldest roof                              | Years| 44     | 31     | 26     | 27     |
| 6  | Average age of roofs                     | Years| 21     | 24     | 11     | 10     |
| 7  | % of inspected roofs with < 5% ponded water | %   | 100.00% | 100%   | 100%   | 97%    |
| 8  | % of inspected roofs with < 1% deterioration | %  | 100.00% | 100%   | 100%   | 97%    |
| 9  | % of inspected roofs with > 1/4" slope  | %    | 96%    | 79%    | 97%    | 94%    |
| 10 | % of inspected roofs’ area blistered    | %    | 0.06%  | 0.03%  | 0.02%  | 0.02%  |
Conclusion

In the last 28 years, research on performance information has resulted in the development of the Best Value Approach (BVA) that identifies and utilizes the expertise of expert vendors. The research has also developed the Information Measurement Theory (IMT) concepts that explain why the performance of the construction and other industries has not met expectations over such a long period of time. The BVA and the IMT research has led to the following conclusions:

1. 90% of all project risk (time and cost deviation) is caused by the client and their representatives.
2. A performing industry is expert vendor centric [the expert vendor is the most important and leads the project].
3. An expert vendor makes fewer decisions [decisions cause risk].
4. Performance is the identification and utilization of experts who mitigate risk, lower cost and higher value.
5. True competition increases quality and lowers cost. Most competition is not fair or accurate competition. It requires professionals to make decisions and is relationship based. This is the biggest source of risk in projects.
6. The existing industry environment is a client centric, where the client uses professionals [who meet education, certification and experience requirements] where the professionals attempt to identify the project requirement, select the best option via low price, and then manage, direct, control and inspect the vendor’s work to mitigate the risk.
7. The change from a client centric to a vendor centric environment minimizes the need for professionals who represent the client to do any project management or quality control. Professionals should only be technical experts in their area of expertise. Professionals must minimize their decision making which causes project risk.
8. Professionals do not use or understand performance information. Their environment is technical. Their environment cannot distinguish the difference between performing entities. It is a structure which identifies minimum requirements that results in all entities being the same.
9. Professionals are identified by a minimum requirement of education, certification and experience. They include designers, architects, quantity surveyors, procurement managers and project managers.
10. Professionals will resist the change from a client centric to an expert vendor centric environment despite research tests identifying their decision making, management and control as the greatest source of risk.
11. Performance information increases transparency, accountability and performance.
12. Performance information are metrics used in communicating the capability of experts on specific projects.
13. The amount of performance information should be minimized to create transparency.
14. Performance information should be the responsibility of the expert vendor.
15. Communications in the supply chain should be minimized to the language of metrics that do not require decision making.

PBSRG is working with the first Alpha general contractor and service distributor using the same concepts of performance information. PBSRG also utilizes the BVA to compete vendors to
identify the best value for any service. The greatest lesson learned is that one vendor can create competition by themselves by utilizing performance information and transparency. The number of visionaries who can see into the future, make things simple [transparency], and can tell the difference between options, in the industry is limited, and the identification and use of these expert services always results in the best value.

**Recommendation**

Further research is required using industry tests to identify examples of performance information that leads to transparency. The future of project management and risk management and the utilization of automation [reduction of human functions] is also recommended.

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