Application of Performance Based System in the Pavement Contracting

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Abstract

The demands and reliance upon the American pavement system for mobility and commerce have increased substantially over the past few decades. The pavement owners (mainly the public sector) are struggling with inefficient pavement management, decreasing budgets, inefficient work force, and increased risk. The pavement industry is usually run through the low bid contracting system, which has the built-in problems in meeting budget, time, and quality. The low bid contracting system has difficulty in addressing performance issues. Current contracting practices in the pavement industry were critically investigated. They were ranked according to their mode of practice. The Performance Information Procurement System (PIPS) and Design-Build-Maintain (Operate) came out as the two highest ranking contracting systems, respectively. Applicability of these two top ranking systems in the arena of the pavement industry was critically analyzed. It is envisioned that the pavement industry can improve paving quality by continuing to test and implement best-value systems.

Key Words: contracting, bid, quality, qualification, performance, best value, risk, information, PIPS.

Introduction

In combination with automobile and truck traffic, the 2.3 million mile-long interconnected paved road network of the U.S.A. provides the basis for America's economic prosperity. The demands and reliance upon the American pavement system for mobility and commerce have increased substantially over past few decades. During 1970 to 1997, the increase in number of drivers, vehicles, vehicle-miles, and travel by truck hauling freight are 61%, 87%, 131%, and 200%, respectively (Epps 2000). U.S. Federal Highway Administration (FHWA) forecasts the travel on national highways will increase by over 53% from 1997 to 2017 (APT Inc. 2001).

The pavement network is encountering new types of loading patterns (as different types of automobiles, trucks and trailers with different tire types and configurations are coming), higher loads (as load limits and tire pressure increased) and resulting more complex pavement distresses (e.g. various cracking, rutting etc.). The major challenges that the pavement community is facing today is to:

1. Construct high performing pavements.
2. Maintain pavements at preferred levels of performance (to optimize user satisfaction and minimize vehicle operating cost).

3. Minimize traffic delays during utility work and construction/rehabilitation/maintenance periods.
4. Maximize user's/worker's safety.
5. Minimize air/noise/other pollutions (it is noteworthy that the safety and pollution requirements have been tightened in recent years).

The physical condition of the U.S.A. pavements, as measured by International Roughness Index (IRI), is "Fair" (IRI = 125) (AASH&TO 2002). FHWA estimated that an average annual investment of $50.8 billion is required to maintain this average condition over a 20-year period (1998-2017) (HMA 2001).

In the U.S.A., the public sector, which includes the Federal Department of Transportation (DOT), State DOT, and local government, manages the majority of pavements. The DOTs, in corporation with FHWA, have been the public-sector leaders in defining contracting procedures, material and construction specifications, and facilities operating guidelines. Local governments and the private sector have typically followed the respective DOT/FHWA procedures. Similar to all other road agencies around the world, these U.S. pavement agencies are struggling with pavement management and work force, decreasing budget, increasing user requirements and increasing risk due to non-performance. Therefore, they must examine ways of cutting the cost of road maintenance and construction, as well as improving road conditions by practicing more efficient management, cost analysis, and very importantly, contracting practices.

Pavement Contracting System in the USA

Although innovative processes are being tested, the U.S.A. State DOTs/FHWA have predominately practiced the "low bid" contracting system for the procurement of pavement works. The foundation of this system is the principle of competitive sealed bids with award to the lowest responsive bidder who meets the specific conditions of responsibility. Over decades, it has effectively prevented the favoritism in spending public funds while stimulating competition in the private sector. For many years, until recently, it has also been believed by the users and a big portion of the pavement community that low bid contracting has provided taxpayers with an adequate, safe and efficient transportation product at the lowest price that responsible, competitive bidders can offer.

Recently, the "Contract Administration Task Force of the AASHTO Subcommittee on Construction" has commented that, "While the low bid system has served the public well, it has not always optimized the overall quality of the final product and it is not necessarily the most efficient way to procure services for all types of highway contracts" (AASHTO 2001). The low bid contracts often end in delay, change orders, increased cost, increased user-delay, and dissatisfaction, which all lead to unsatisfactorily performing pavement. But one must recognize that state and local transportation administrators are often subject to political forces. So a shift from low-bid system to a new, more efficient system must ensure that the subjective bias is not increased. With a view to find a better contracting system, the pavement community in the U.S.A. is currently examining a number of contracting systems, which will be briefly discussed.

- Alternate Bids/Designs: More than one alternate is judged equal over the design life with the assumption that there is a reasonable possibility that the least costly design approach will depend on the competitive circumstances. FHWA, however, discourages it. It was initiated and evaluated by the Missouri DOT. The PA, and LA State DOTs were also evaluating it.
- Certified Producer Program: Indiana has initiated this program to certify aggregate and hot mix asphalt producers. A qualified mineral aggregate producer can supply material to Indiana DOT (INDOT) by assuming all of the plant site controls and a portion of the testing responsibility that had been previously assumed by INDOT. The program focused on production testing by the producer and a site-specific quality control (QC) plan that indicates how the producer proposes to control the materials at the plant.
- Constructability Reviews: The Kentucky DOT is utilizing a "Constructability Review Process" to obtain the construction industry's input during the design phase and to prequalify bidders. The concept is not design-build but rather a process whereby contractors interested in bidding must prequalify at the beginning of the project and then participate, with the State's designer (already under contract), in a constructability exercise to finalize the project design. When project contracts are advertised, only contractors who have been prequalified and have participated in the constructability exercise will be permitted to bid. Each contract will be awarded on the basis of the lowest competitive bid. The University of Washington and the Texas Transportation Institute are evaluating it. Others examining it include; NC, CA, CT, DE and WA state DOTs.
- Construction Manager at Risk: This process is becoming common in the vertical building industry. An owner selects a design and construction management consultant on the basis of qualifications, experience, fees for management services, and prices for the target cost of construction, as well as an estimated ceiling price. The consultant then proceeds with the preliminary design. In the mid-way of the design process the owner and the consultant will agree on a guaranteed maximum price for the construction of the project. Advantages of this process are the involvement of the contractor early in the design. The disadvantages of this process include two points of contact, lack of competition after the selection is made, and minimal incentive to perform. The Florida DOT is currently using this process.
- Contract Maintenance: Contract Maintenance contracts use the private sector forces to perform maintenance services that were previously done by the owners (e.g. DOTs). This may include both routine and preventive maintenance. Contracting agencies may use "means and methods" type contracts or "performance-based" contracts. Virginia and Florida are two states that have been leaders in this type of contracting. It is estimated that as of 1999, approximately $2.5 billion in maintenance work was contracted out to the private sector using this contracting practice.
- Cost-plus-Time (A+B) Bidding: This process involves time, with an associated cost, in the low bid determination. In A+B bidding, each bid submitted consists of two components, the "A" component (the traditional bid for the contract items and the dollar amount) and the "B" component (a "bid" of the total number of calendar days required to complete the project, as estimated by the bidder). The bid for award consideration is based on a combination of the bid for the contract items and the associated cost of the time, according to the following formula: (A)+(B x Road

User Cost/Day)

- This formula is used only to determine the lowest bid for award. The A+B bidding is sometimes used to reduce associated road user delay in selective critical projects. This contracting system is now being used by 28 state DOTs. A 1998 informal FHWA survey (with 37 responding Divisions) showed 18 states letting approximately 70 A+B contracts with I/D provisions in the past year (AASHTO 2001).
- Cost-plus-Time-plus-Quality (A+B+Q) Bidding: Similar to cost-plus-time (A+B) bidding, this concept envisions a contracting system where a bidder would bid the cost for completing the work (A), the time for completing critical work (B), and the level of quality or performance that would be achieved over a specified period of time (Q). A warranty bond or a method of making payment in future years would be necessary to implement this system.
- Design-Build: With design-build procurement, the contracting agency identifies the end result parameters and establishes the design criteria. The prospective bidders then develop design proposals that optimize their construction abilities. The submitted proposals may be rated by the contracting agency on factors such as design quality, timeliness, management capability, and cost. These factors may be used to adjust the bids for the purpose of awarding the contract. The advantage of the design-build process is the reduction of delivery time due to simultaneous design and construction. This process allows the contractor's flexibility for innovation in the selection of design, materials and construction methods. Other advantages include one point of contact and a rational factor-based selection rather than a price-based selection. Disadvantages include high bid preparation costs, locking in the project scope and price very early, and a lack of incentive to perform (on-time, on-budget, meet quality expectations) by the contractor. FHWA, however, still considers design-build contracts "experimental". FHWA is currently developing design-build regulations. Under SEP-14, FHWA has approved the use of the design-build contracting method for twenty-four states and several local public agencies.
- Design-Build-Warranty: Some agencies such as AK, MI and UT State DOTs have combined the conditions of a warranty clause with a design-build contract. Many owners want warranties tied with the contract. Typical ranges used are 1 to 2 years for chip sealing, 3 to 8 years for asphalt concrete, 5 years for PCC etc. Warranties are popular in Europe, where a few huge, often government controlled, companies dominate the construction industry. The situation is different in America, where the pavement industry consists of nearly 9,000 small construction companies (AASHTO 2001).
- Design-Build-Maintain (Operate): It deals not only with design and construction, but also with maintenance and/or operation of the road. The goals are set similar to that of the design-build contract with set performance levels to be achieved throughout the maintenance period. Several states have initiated design-build-operate-maintain projects. The Transportation Corridor Agencies in California is using this concept on the San Joaquin Hills, Eastern Transportation and Foothill Transportation Corridor projects. These corridors will provide more than 60 miles of new freeways at a cost of approximately $2.5 billion. The same concept has also been used in toll-road projects in Virginia, Colorado and Texas. Canada's Northumberland Strait Crossing Project is a design-build-maintain project that provides for the financing, design, construction and operation of a 12.9-km bridge

for 35 years following construction. Similarly, Canada is currently constructing the Toronto Toll Highway 407 project under this concept. In August 2000, the Massachusetts Highway Department awarded a design-build-operate-maintain contract to Modern Continental to reconstruct Route US-3 from the I-95/Route 128 interchange in Burlington, MA to the New Hampshire border. This $385 million, 30-year contract will widen the existing 21-mile, two lane highway to include three lanes. It will provide for the replacement of 47 bridge structures and the upgrade of 13 interchanges.

- Incentive/Disincentive (I/D) Provisions for Early Completion: I/D provisions for early completion are intended to motivate the contractor to complete the work on or ahead of schedule. It allows a contracting agency to compensate a contractor a certain amount of money for each day identified that critical work is completed ahead of schedule and assess a deduction for each day the contractor overruns the I/D time. The I/D amounts are based upon estimates of such items as traffic safety, traffic maintenance and road user delay costs. In February 2000, the Michigan DOT (MDOT) reported that out of its 26 I/D projects, 65% were completed early, 12% were on time and 23% were late. MDOT found that the average net reduction in contract days was 19% in comparison with similar projects that were let with an expedited schedule clause requiring the contractor to work a six calendar-day week, but without the use of an I/D provision. The average project user delay savings was $610,500. MDOT indicated that I/D provisions will result in an average expenditure of 1.5% of the contract amount. Now 35 State DOTs are using the I/D provisions to some extent.
- Indefinite Quantity/ Indefinite Delivery (ID/IQ): Michigan and some municipalities are currently using this contracting method (also known as job order, task order, area-wide, county-wide, city-wide and open ended contracting). Under this method, contractors bid a contractor coefficient on estimated work based on unit work items from a unit price book. An estimate of the total work over the life of the contract is provided in each contract. Florida DOT calls this “push-button” contracting and has been using it for maintenance and traffic operations activities for many years. JOCs usually have a guaranteed minimum amount of work, and motivate the contractor to perform with the incentive of more work orders. The advantages of ID/IQ include the ability to prequalify, and the minimizing of procurement actions. The disadvantages include limiting of the competition by the owner’s specification and the lack of incentive to continually improve. MI, DE, MD and FL State DOTs are primarily using this method.
- Lump Sum Bidding (No Quantities): While lump sum bidding is not new to the highway industry, Florida has developed several lump sum projects under SEP-14 with a new variation. The contractor is provided with a set of bid documents and is required to calculate quantities and develop a lump sum bid for all work. The contractor bears the responsibility for any change in the estimated quantities. Any costs associated with changed or unforeseen conditions as well as added or deleted work will be negotiated using standard practices.
- Performance Information Procurement System (PIPS): PIPS is a request for proposal process that considers both performance (past and current capability) and price. Contractors are asked to identify the risk of the project (on-time, on-budget with no contactor cost change orders, and meeting quality expectations), how to minimize their risk, and how they would add value to the project. An artificial intelligence (AI) processor prioritizes the bidders by using preset formulas that show how close each bidder is from the best. Each bidder is represented by

performance information on the general contractor, the paving contractor, other critical subcontractors, and key personnel (Kashiwagi 2003). The top prioritized contractor then reviews the project in detail, coordinates the project with the critical subcontractors, seeks clarification, and then signs a contract to perform the construction to their stated expectation. The contractor takes the risk of not performing, knowing that a low performance will affect future work opportunities because the performance from the current project impacts the future performance lines by 25%. The Hawaii Department of Transportation (HDOT) implemented PIPS on a $3.5M pavement contract that included resurfacing the pavement, reconstructing weakened areas, modifying traffic signals, adjusting manholes, improving ADA, markings, sign replacement and installing traffic control. So far, PIPS has shown promising success in the vertical construction industry.

- Performance-Related Specifications (PRS): These are quality assurance specifications that describe the desired levels of key materials and construction quality characteristics that have been found to correlate with the fundamental engineering properties that predict performance. These quality characteristics (for example, strength of concrete cores) are amenable to acceptance testing at the time of construction. True PRS not only describe the desired levels of these quality characteristics, but also employ the quantified relationships containing the characteristics to predict subsequent pavement performance. They thus provide the basis for rational acceptance and/or price adjustment decisions. In other words, PRS are simply improved quality assurance specifications that use improved acceptance plans with rationally derived performance-related price adjustments. As in conventional QA specifications, it is the desired product quality rather than the desired product performance that is specified. PRS are in various stages of research and development mostly by FHWA, State DOTs of New Jersey, Iowa, New Mexico, Missouri and Kansas.
- Public-Private Partnerships / Toll Roads: In these contracts, private entities finance or invest in a transportation project by developing, designing, building and/or maintaining a roadway or bridge for a specified duration in return for monetary compensation, toll revenues or development rights. Many of the first U.S. roadways were privately financed by associations and the automotive industry. In some countries, concessionaires are used to allow corporations with mixed capital structure or privately owned corporations to finance, design, build and operate toll roads. States using this contracting method include CA, CO, MO, VA and Denver.
- Quality Assurance Specifications Contracting: AASHTO defines “quality assurance” as “all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality.” Quality Assurance (QA) specifications (previously referred to as QC/QA specifications) are mathematical probability (statistically) based specifications that recognize variability of construction materials. They assign quality control sampling, testing and inspection responsibility to the contractor and include some level of acceptance sampling, testing, and inspection by the owner. These specifications identify specific quality characteristics to be measured for acceptance and typically provide for price adjustments related to a defined quality level of the work. Currently at least 44 states in the U.S. and 3 Provinces in Canada use Hot Mix Asphalt (HMA) QA specifications; about a dozen U.S. states use Portland Cement Concrete (PCC) pavement and/or structural QA specifications; and a few states use QA specifications for embankments and aggregate base.

Quality, Qualification and Performance in Contracting

As U. S. highway agencies are moving toward improved quality assurance and performance-based specifications under "23 CFR 637.205" (Title 23, Volume 1, Code of Federal Regulations, Sec. 637.205), contractors, either by necessity or mandate, are taking more responsibility for quality control. To ensure product quality, U.S. state DOTs use some combination of following contractor qualification processes:

1. Prequalification,
2. Post-qualification,
3. Performance Bonds,
4. Contractor Licensing,
5. Third Party Certification (usually the ISO 9000),
6. Project Audit etc.

A recent research project to develop a "Quality-Based Performance Rating" (QBPR) system conducted by NCHRP (*National Cooperative Highway Research Program*) concluded that although the term "quality" is used frequently to relate with the contractor qualification process, there is, to date, no evidence of any data, or model found that established or proposed relationships between product quality and the contractor qualification rating (Minchin 2001). It should be understood that conventional qualification ratings have many sources of bias, and hence, such contractor qualification process alone cannot assure sustained high performance.

"Performance Based Contracting" is a term that is increasingly being used in the pavement community, but which often means different things to different users. It can, however, be safely said that a performance based contract should describe the owner's requirements in terms of performance rather than the methods of performance (i.e. specifications, design etc.) of the work. In the case of pavement contracts, usually the aim of performance requirements is to minimize total system cost, including delivery cost, the long-term cost of preserving the roads, as well as the cost to the road user. Typical performance measures are:

1. International Roughness Index (IRI) to measure the roughness of the road surface, which affects vehicle operating cost;
2. Absence of potholes and control of cracks and rutting;
3. Minimum amount of friction between tires and the road surface for safety reasons.

In terms of expectation, the owner's expectation is on-time, on-budget and good quality work. During the work-phase, the user's expectation is minimum traffic delay (i.e. user cost) and the workers' expectation is maximum work-zone safety. After completion of work, some of the user's expectations are to have a smooth ride (minimum pavement distress such as rutting, potholes and cracking), adequate friction between tire and pavement for safety against accident, properly installed and maintained, and minimum noise. The contractor's expectation is to maximize profit with promising probability of getting future contracts. In general, for a healthy contracting system to prevail the owners and users are supposed to get the "best value" of their investment and the contractors are supposed to perform their "best practice" by continuously improving their own performance. Figure 1 shows typical

construction industry structure, which is very much similar to the existing structure of the U.S. pavement contracting system (Kashiwagi 2001).

Figure 1: Structure of the Pavement Contracting Systems

The low-bid system clearly fits into the first quadrant (Quadrant-I). Here contractors attempt to satisfy the "minimum" requirements set by the specifications while submitting the lowest possible bid. In order to become competitive, they reduce their price, profit, number of trained personnel, and quality of work to meet the minimum standards and specifications. Thus, specifications actually set the maximum level of performance, minimize contractor's risk and maximize risk to the owner and designer. Once awarded the contract, the lowest bid contractor looks for possible change orders and forces the skilled craftsmen to work for the same salary as untrained craftsmen. Thus there is little incentive for training and improvement in quality. Finally, the whole system becomes non-performing. One of the most negative results of Quadrant I is that the buyer or user becomes very bureaucratic, their delivery system becomes one of confused liability, having the following characteristics:

1. The designer's design is reviewed and checked by another designer, confusing the liability issue because a second professional corrects the design.
2. The user directs, manages, and controls the contractor, confusing the liability if there is a performance issue.
3. The user has a design section and a construction management section, which operate as separate entities, each refusing to solve the others problems. The confusion is then forced on the contractor who is held up by the lack of cooperation.
4. It is not in the best interest of the designer and contractor to minimize the risk of the owner.

Quadrant-II indicates a performance and value-based environment. Here, competition among high performers will force continuous improvement. Performing contractors are motivated by profit to increase the value (price and performance) of the owner. They are encouraged to train their personnel and improve quality thus encouraging innovation and human development. True performing contractors know how to do their work. They reduce their risk by hiring the best people and equipment possible.

Quadrant-III is when the owner subjectively minimizes competition by identifying a minimal amount of performers, and either negotiating a contract or awarding on the

lowest bid after prequalification. Problems of the low bid are minimized due to the monopolistic contracting system. Quadrant-IV is not stable because it refers to both low quality and a low competition environment.

Best Value Selection

The Federal Acquisition Streamlining Act of 1994 states that the use of past performance information is legal. This permits the Federal Government to move in the direction of best value contracting. However, the difficulty or inability of procurement agencies to compare performance, due to a lack of methodology, reduces the effectiveness of best value selection. Many construction and procurement personnel still think that the best value is the lowest price. For many similar misconceptions, the use of A+B+Q, Design-Build, ID/IQ, PRS, QA etc. contracts often do not deliver the best value due to their inability to consider differential in performance and price. Modern business theorists, working in the arena of the construction business, such as Buckingham et al, Crosby, Deming, Drucker, Rasiel et al, Trout, Welch et al, and Womack et al have identified the following successful business practices that are essential for a shift from the current price-based system towards a best-value procurement system (Buckingham 1999, Crosby 1980, Deming 1982, Drucker 1994, Rasiel 2001, Trout 1996, Welch 2001, Womack 1991):

1. Break down barriers (team orientation);
2. Competition is required;
3. Contractor minimizes risk;
4. Do not award on price alone;
5. Encourage innovation;
6. Improve continuously;
7. Increase performance instead of dropping price;
8. Maximize (contractor's) responsibility;
9. Minimize owner's control, direction and inspection (management);
10. Minimize standards;
11. Pay for the best more, because it minimizes total cost;
12. Use customer satisfaction to mean quality;
13. Use feedback loop for incremental improvement;
14. Use maximum information to reduce uncertainty;
15. Use the best past performers.

The authors propose to compare the 18 identified contracting systems, including the low-bid system, based on these 15 successful business practices required for the best value selection. Table 1 shows a ranking based on a rating of 0 to 2, where a system scored a “2” for always having the criteria, a “1” if the process could possibly have the criteria if managed by an experienced manager, or a “0” if the system cannot accommodate the best practice. As shown in Table 1, the final ranking is as follows:

Rank	Name of Pavement Contracting System
1	Performance Information Procurement System (PIPS)
2	Design-Build-Maintain (Operate)
3	Design-Build-Warrant
4	Design-Build
5	Public-Private Partnerships / Toll Roads

6 Cost-plus-Time-plus-Quality (A+B+Q) Bidding
7 Performance Related Specifications (PRS)
8 Quality Assurance (Former QC/QA) Specifications Bidding
9 Certified Producer Program
9 Contract Maintenance
10 Constructability Reviews
10 Incentive/Disincentive (I/D) Provisions for Early Completion
11 Alternate Bids/Designs
12 Indefinite Quantity/ Indefinite Delivery (ID/IQ)
13 Construction Manager at Risk
13 Cost-plus-Time (A+B) Bidding
14 Low Bid
15 Lump Sum Bidding (No Quantities)

Table 1 Ranking of Pavement Contracting Systems

Pavement Contracting Systems		**Scores for Successful Business Practices[1,2]**															**Total Score**	**Rank**
No	**Name**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**		
1	Alternate Bids/Designs	0	0	1	2	0	1	0	0	0	0	1	0	0	1	0	6	11
2	Certified Producer Program	1	0	0	1	0	2	1	2	1	0	1	0	0	0	0	9	9
3	Constructability Reviews	2	0	0	0	1	1	1	0	0	0	0	0	0	1	1	7	10
4	Construction Manager at Risk	0	0	0	0	2	0	0	0	1	0	1	0	0	0	0	4	13
5	Contract Maintenance	1	0	1	1	1	0	0	1	1	1	0	0	0	1	1	9	9
6	Cost-plus-Time (A+B) Bidding	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	4	13
7	Cost-plus-Time-plus-Quality (A+B+Q) Bidding	1	1	2	2	1	1	1	1	0	0	1	0	2	1	0	14	6
8	Design-Build	1	1	1	2	2	1	1	2	2	2	0	0	0	1	1	17	4
9	Design-Build-Maintain (Operate)	2	2	2	2	2	1	1	2	2	1	2	2	1	1	1	24	2
10	Design-Build-Warrant	1	1	2	2	2	1	1	2	2	2	1	1	1	1	1	21	3
11	Incentive/Disincentive (I/D)	1	0	1	0	1	1	1	0	0	0	1	1	0	0	0	7	10
12	Indefinite Delivery / Indefinite Quantity (ID/IQ)	1	0	1	0	1	0	0	1	0	0	0	0	0	1	0	5	12
13	Low Bid	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	3	14
14	Lump Sum Bidding (No Quantities)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	15
15	PIPS	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	29	1
16	Performance Related Specifications (PRS)	1	0	2	2	1	1	1	2	0	0	1	1	0	1	0	13	7
17	Public-Private Partnerships / Toll Roads	2	0	2	0	2	1	1	2	1	1	1	1	1	1	0	16	5
18	Quality Assurance	1	0	2	2	1	1	1	2	0	0	0	0	0	1	0	11	8

1. A “2” represents the system always has the criteria

A “1” represents the system could possibly have the criteria

A “0” represents the system cannot accommodate the best practice criteria.

2. The codes A-O represent the following successful business practices:

A. Break down barriers (team orientation);

B. Competition is required;

C. Contractor minimizes risk;

D. Do not award on price alone;

E. Encourage innovation;

F. Improve continuously;

G. Increase performance instead of dropping price;

H. Maximize (contractor's) responsibility;

I. Minimize owner's control, direction and inspection (management);

J. Minimize standards;

K. Pay for the best more, because it minimizes total cost;

L. Use customer satisfaction to mean quality;

M. Use feedback loop for incremental improvement;

N. Use maximum information to reduce uncertainty;

O. Use the best past performers.

Implementation of a Best Value System

One of the most important issues that led to the government favoring the low-bid contracting process (including other pseudo-performing contracts QA/QC, A+B, A+B+Q, I/D, PRS etc.) was that they always wanted to avoid possible sources of bias. So, to replace one of these pseudo-performing or non-performing systems, a better and unbiased procurement system must be identified and validated. As noted, the Performance Information Procurement System (PIPS) and Design-Build-Maintain (Operate) proved their potential to be future candidates in the arena of pavement contracting.

Performance Information Procurement System (PIPS)

The Performance Based Studies Research Group (PBSRG) at Arizona State University has conducted over $3M in research, developing and testing the Performance Information Procurement System (PIPS) over 300 times in the past 8 years on over $150M of construction contracts. PIPS uses a best value procurement system schematically shown in Figure 2, as previously described. Points A, B, C, and D do not have to be subjectively set, but are the result of the flow of information and the information environment. The major users of PIPS include Motorola, Honeywell, IBM, Boeing, United Airlines, the States of Wyoming, Utah, Hawaii and Georgia, the University of Hawaii, and the Dallas Independent School District. On average, all PIPS contracts were 98% on-time and on-budget and had 100% customer satisfaction with 9.5 construction rating (out of 10) and no contractor generated cost change orders (Kashiwagi 2003).

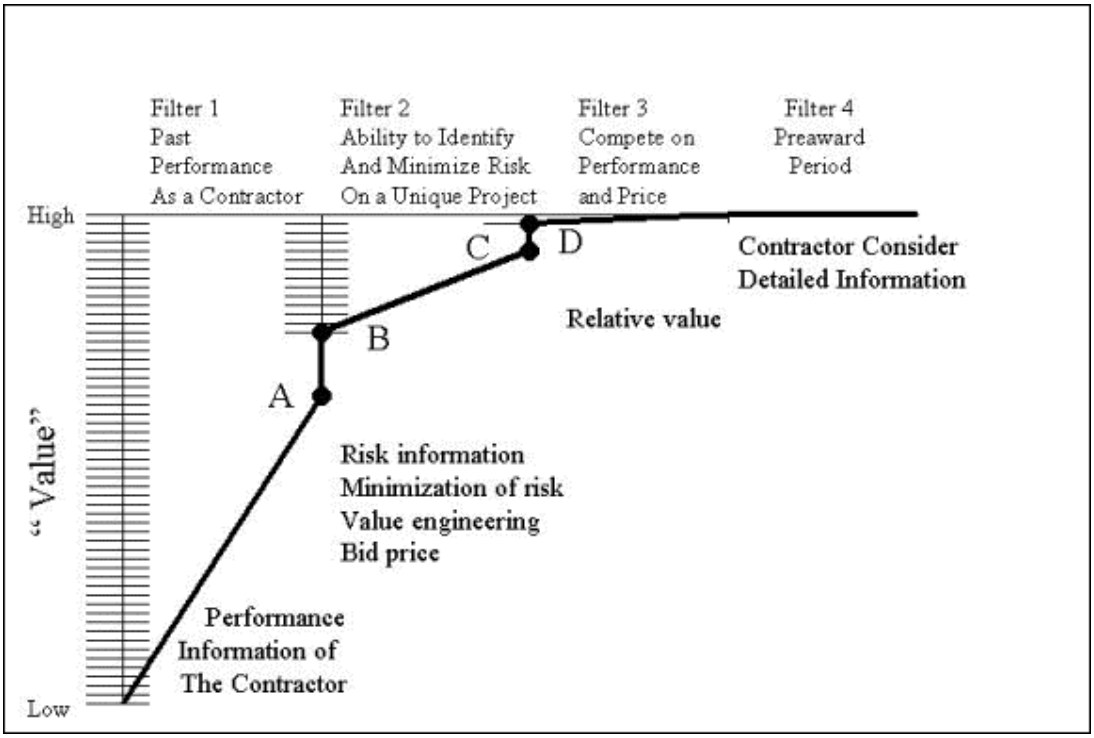

Figure 2: PIPS Schematic

The Hawaii Department of Transportation used PIPS in its "Nimitz Highway Resurfacing Rodgers Boulevard to Ahua Street" project, which had a project budget of $5M and a contract award price of $3.5M. As noted, the contract included resurfacing the pavement, reconstructing weakened areas, modifying traffic signals, adjusting manholes, improving ADA, applying markings, replacing signs and installing traffic control. Out of three performance requirements (on-time, within-budget, quality), the project met two (within-budget and quality). There were issues that were brought up after the award (scope changes on landscaping and striping issues), which extended the construction time. The contractor performed well in the areas of quality (smoothness and customer satisfaction) and price (contractor

generated change orders). Smoothness of the pavement was measured in the following methods:

1. Comparison with other paving projects using IRI (International Roughness Index) measurements.
2. Reduction of roughness of the project (5%.)
3. Comparison with what competitor would have provided (surface roughness of 30% lower than competitor.)
4. IRI of middle lanes of a business area (with intersections and handicapped access ramps which increase the surface roughness due to differential of elevations) compared against freeway construction.

Drawbacks to the PIPS test included the following:

6. As identified by the industry structural analysis, the DOT is a very bureaucratic organization, which is heavy with management, control, and inspection.
7. In Hawaii, the paving sector of construction is conditioned by the low bid environment of confused liability. The contractors did not coordinate, manage, and control their own projects. The DOT inspectors managed the projects. Subcontractors did not always go through the general contractor on the project, but were oftentimes directed by the DOT inspector.
8. The procurement system is engrained in the unit price based system. The majority of subcontractors were still selected based on price. Contractors had a difficult time breaking low bid practices on the jobsite.
9. A specification was used, hampering the contractors from innovating.
10. PIPS has shown promising success in the vertical construction industry, but has not been sufficiently tested in the horizontal construction sector. Due to the current Quadrant I environment, implementation will be slow. Since it has the best practices, which identify best value to the owner, implementation may assist in the stabilization and increase in the value of horizontal construction.

Design-Build-Maintain (Operate) Contracting

With the traditional specification based method of contracting, all risk for the quality and performance of the final product rests with the road authority. This is because the road authority sets the methods, material quality, and minimum standards and enforces the directives by management and inspection. However, due to the Quadrant I attributes of the delivery mechanism, the risk remains with the road authority or user. In Design-Build-Maintain (Operate) contacting, the risk is transferred to the contactor, as they are in control of the design, materials, construction process, standards and maintenance of the road. The contractor is also required to provide a minimum standard of quality throughout the life of the contract, while in a traditional specification based contract, the contractor is only required to meet a minimum standard at the time of the completion of construction. The single point of liability consolidates the risk to the decision maker, and forces consideration of value (performance and cost.) Such transfer of risk forces the contractor to complete risk

assessment and measure the sensitivity of those risks on the final performance. This sensitivity study allows the contractor to focus on the variables that will most affect the performance of the pavement and thus the contractor focuses on the precise quality control of those sensitive products. To lower the risk, the contractor is forced to produce the highest quality pavement at the beginning of the contract life to minimize risk for major rehabilitation during the contract life. The use of a long-term contract, as in the Design-Build-Maintain (Operate), also provide the contractor with a better incentive to use new technologies and even to undertake some research on how to adapt these technologies to the very specific conditions at hand. At present, however, this incentive is reduced by contract specifications that either are prescriptive or if performance based, require that only materials and pavements test results meet minimum levels (Johnston 2000).

Results of Some Design-Build-Maintain and Performance Based Contracts

In New South Wales (NSW), Australia, the Road Transport Authority (RTA) first tested the Design-Build-Maintain concept in 1995. The initial trial of these contracts has been so successful that they are now the preferred delivery strategy for major projects in NSW. In Western Australia, Main Roads (MRWA) has moved 100% of its road network to performance based contracting. Their first 8 are expected to deliver cost savings between 15-35%, without compromising standards and with a corresponding improvement in the overall asset value. In 1999, Transit New Zealand awarded the first of their 10-year performance based contracts and to date, that has been regarded as a complete success. The New Zealand News reported, "… … long-term Performance Based Maintenance contracts such as the one being proposed in the Western Bay of Plenty are cutting costs and resulting in better roads. For example the State Highway 5 to New Plymouth showed clear improvements in the quality of the road surface, drainage, signage and pavement rehabilitation" (New Zealand News 2000). In USA, the first performance based contract was awarded by Virginia DOT, which estimated a savings of $22 million over the course of the five and one-half year contract.

The Design, Build, Maintain delivery system may be easier to implement than the PIPS system due to the clear cut transfer of control of construction. PIPS is a methodology that out sources the construction but still allows the owner or buyer to control the contractor through the use of performance information. It is the requirement for the buyer to change from an expert making subjective decisions, to an information worker who uses performance information and best practices, which makes it difficult to implement PIPS.

Conclusion

True performance based pavement contracting provides incentive for improvement and innovation, reduces overall system loss and gives the best value for our roads. The Performance Information Procurement System (PIPS) and Design-Build-Maintain (Operate) theoretically have the potential to be the future candidates in performance based contracting systems in the arena of pavement contracting. Due to the current "controlling" environment, performance-contracting success is limited. To get the best value for the roads, the procuring agencies (mostly, government transportation departments e.g. DOTs) should:

1. Release control of the construction and maintenance of the pavements.
2. Minimize standards, means and methods specifications, inspection, and construction management.
3. Allow contractors to bid in design, build, and maintenance of the pavements.
4. Identify performance criteria, which may include performance periods, level of pavement smoothness and skid resistance (for example, IRI, skid number etc.), control of rutting, cracks and potholes, user satisfaction and other performance criteria.
5. Maximize the use of information.
6. Award contracts based on unbiased processing of performance information.
7. Educate both procuring personnel and contractors about their responsibilities in a performance based contracting environment.

References

Buckingham, M. and Coffman, C. (1999). *First, Break All the Rules*. New York: Simon & Schuster.

Cost of Road Maintenance Climbs. (2000, November 15). *New Zealand News.*

Crosby, Philip B. (1980). *Quality is Free: The Art of Making Quality Certain*. New York: Penguin Group.

Deming, Edward W. (1982). *Out of the Crisis*. Massachusetts Institute of Technology, Cambridge.

Drucker, P. (1994). *Post Capitalist Society.* New York: Harper Business.

Epps, J., Witczak, M., Decker, D., and Acott, M. (2000). Hot Mix Asphalt Visions. *National Asphalt Pavement Association; Lanham, MD.*

HMA Pavement Evaluation and Rehabilitation. (2001). Reference Manual. *Applied Pavement Technology, Inc.* 3001 Research Road, Suite C, Champaign, IL.

Johnston, I. (2000). *Asphalt Technology Development - Whose Responsibility?* 1st World of Asphalt Pavements Conference, Sydney.

Kashiwagi, D. T. (2003) Information Measurement Theory (IMT). *Encyclopedia of Information Systems,* 2, 599-610. Elsevier Science (USA).

Kashiwagi, D. T. (2001). *2001 Information Measurement Theory*. Performance Based Studies Research Group, Del E. Webb School of Construction, Arizona State University, Tempe, AZ.

Minchin Jr., R. E. and Smith, G. R. (2001). *Quality-Based Performance Rating of Contractors for Prequalification and Bidding Purposes*. National Cooperative Highway Research Program: Project 10-54. Transportation Research Board. National Research Council. Washington D.C.

Primer on Contracting for the Twenty-first Century. (2001). *A Report of the Contract Administration Task Force of the AASHTO Subcommittee on Construction. 4th Edition.* American Association of State Highway and Transportation Officials (AASHTO), Washington D.C.

Rasiel, E. and Friga, P. (2001). *McKensie Mind.* New York: McGraw-Hill.

Transportation Invest in America. (2002). *American Association of State Highway & Transportation Officials (AASHTO).* 444 North Capitol Street N.W., Suite 249, Washington, D.C.

Trout, J. (1996). *The New Positioning.* New York: McGraw-Hill.

Welch, J. and Byrne, J. (2001). *Straight from the Gut*. Warner Books Inc.

Womack, J. P., Jones, D. T., and Roos, D. (1991). *The Machine that Changed the World: The Story of Lean Production.* New York: Harper Perennial.