Comparative Analysis of Project Delivery Systems Cost Performance in Pacific Northwest Public Schools

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Abstract: Alternative project delivery systems such as construction management at risk (CMR) are increasingly used in public school construction in the United States. CMR is expected to benefit owners with a guaranteed maximum price (GMP), decreased change order cost, and increased cost "certainty." This paper empirically compares cost growth performance of the CMR and design-bid-build (DBB) methods in Pacific Northwest public school projects. Data were collected from state records and previous studies on 297 completed schools in Oregon and Washington. The analysis of the data shows no statistically significant difference between CMR and DBB in construction change order costs, school project costs exceeding the GMP in 75% of the cases, and a statistically significant difference in cost growth between CMR and DBB projects during buy out, making CMR projects less efficient at controlling cost growth at buy out. These results counter some of the traditional expectations of the CMR delivery method.

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Introduction

The growing movement to allow alternative construction project delivery systems (PDS) in public construction nationwide is evidenced by recent and ongoing lobbying efforts in numerous states. Since 2001, at least five state governments have legislated alternative PDS. The most popular alternatives to the traditional design-bid-build (DBB) method are construction management at risk (CMR) and design-build (DB). The expected benefits of using alternative PDS include improved cost and schedule "certainty," reduced claims and litigation, improved project delivery speed, improved design and construction quality, and improved relationships among project stakeholders.

There is limited empirical research to date on completed projects to support such expectations. Published studies by the Construction Industry Institute (CII) (1997), Konchar and Sanvido (1998), and the State of Washington Office of Joint Legislative Review and Review Committee (JLARC) (2005) provide some evidence that CMR and DB have measurable benefits compared to DBB. However, other studies by Williams (2003) and Liu (2004) provide contrary evidence that CMR may not necessarily result in improved cost and schedule performance.

This paper presents research that empirically compares the cost growth performance of DBB to CMR in public school construction based on data from completed Pacific Northwest projects in Oregon and Washington. The goal of this research was to determine whether CMR has performed to cost expectations in school construction within the Pacific Northwest.

In Oregon, the CMR delivery method is referred to in legislative documents as Construction Manager/General Contractor, or CM/GC. In Washington, the CMR delivery method is called General Contractor/Construction Manager, or GC/CM. The origin of the term Construction Manager/General Contractor could not be determined, but it is also a general industry term used outside of Oregon. The Washington State designation GC/CM is reported to derive from the Oregon term (Roque 1998). This paper uses CM/GC for specific Oregon state references, GC/CM for specific Washington state references, and CMR for all other references to the delivery method. This is done to respect state designations, however, all of these designations refer to the same delivery method: CMR.

Differences between DBB, DB, and CMR

Public construction projects in the United States, including kindergarten through 12th grade (K–12) schools, have been traditionally procured with the DBB method for most of the 20th Century (AIA/AGC 2004). CMR is an alternative method to DBB that is increasingly used in the public sector. One reason there is little empirical research on alternative delivery methods is because they are new to much of the public sector. According to Cunningham (2005), most states that have passed alternative procurement legislation did so after the year 2000. This includes Arizona, Georgia, Massachusetts, New York, and Texas. Also, the AIA (2005) reported that Minnesota and Kentucky have allowed CMR. There is similar legislative activity in other states including Alaska, California, Minnesota, and New Mexico. Oregon has allowed "qualification based" contractor selection since 1976 and Washington since 1997. Thus, much of the available research on CMR in public school projects has been conducted in the Pacific Northwest. The design-build method is also allowed in Oregon on

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Table 1. Characteristics of Project Delivery Systems (Data from AIA/AGC 2004)

Project delivery system	Defining characteristics	Typical characteristics
DBB	• Three prime players: owner, designer, builder • Two separate contracts: owner-designer and owner-builder • Contract selection based on lowest responsible bid or total contract price	• Three linear phases: design, bid, build • Well-established and broadly documented roles • Carefully crafted legal and procedural guidelines • A lowest responsible bid that provides a reliable market price for the project • Contract documents that are typically completed in a single package before construction begins • Complete specifications that produce objective quality standards • Configuration and details of finished product agreed to by all parties prior to construction start
CMR	• Three prime players: owner, designer, builder • Two separate contracts: owner-designer and owner-builder • Contract selection based on aspects other than total cost	• Overlapping project phases are possible • Construction Manager (CM) is hired during design • Preconstruction services are provided by the CM • Specific contractual arrangement determines the role of players • Clear quality standards produced by the contract's prescriptive specifications
DB	• One contract between owner-design/builder	• Project-by-project basis for establishing and documenting roles • Continuous execution of design and construction • Overlapping phases: design and build • Two prime players: owner and design/build entity • Carefully crafted legal and procedural guidelines for public owners • Overall project planning and scheduling by the design/build entity prior to mobilization • Cost or solution is the basis for selection of the design/build entity

school projects, and on limited nonschool projects in Washington, but this research uncovered only one public school project between the two states that was actually procured with the DB method.

There is a limited body of research that empirically compares cost performance of different project delivery systems in public construction. Studies tend to fall into three variations: case study examinations of a limited number of projects, statistical comparisons of numerous sample projects, or a hybrid of the two. A study by the Construction Industry Institute (1997) and related journal article by Konchar and Sanvido (1998) are frequently cited in subsequent publications. Other studies include Thomas et al. (2002), Williams (2003), Liu (2004), and Septelka and Goldblatt (2005).

Table 1 illustrates the differences in delivery methods based on the AIA/AGC Primer (2004). The methods are first differentiated by defining characteristics. The two defining characteristics of DBB are that two prime contracts exist, one between the owner and the contractor and another one between the owner and the architect, and that contractor selection is based on the lowest responsible bid. CMR has the same contract arrangement but differs from DBB in that the contractor selection process is not necessarily the lowest price. The defining characteristic of DB is a single prime contract between the owner and the design/builder entity.

In addition to defining characteristics, the three different delivery methods have typical characteristics. The typical characteristics of DBB are three sequential phases of design, bid, and build with the selection of the contractor occurring after design is complete. CMR differs in that the project phases may overlap and the contractor is selected during design. The typical characteristic of DB is overlapping design and construction phases.

The AIA/AGC Primer (2004) does not mention one typical characteristic of the CMR method: That certain risks normally assigned to owners in DBB are transferred by contract to the CMR contractor. This risk may include change order costs due to bid exclusions, design errors and omissions, regulatory agencies, and inflation or escalation. The premise is that GC involvement during design should allow the contractor to assume more risk than in DBB.

Expected Owner Benefits of DBB and CMR

DBB is the traditional method for procuring public construction and there are well-established expectations associated with the method. The owner benefits typically include competition, a low initial construction price, transparency, fairness, and reduced chance of corruption and collusion. There are drawbacks inherent to DBB that are also well-documented in industry publications (CII 1997; Oregon Public Contracting Coalition 2002). Some of the most common issues include: The low bid is not necessarily the best value; the best contractor is not necessarily selected; the method is inflexible and sequential; design errors and omissions result in cost overruns and delays; lack of "teaming" or collaboration between project participants; and increased likelihood for claims and change orders.

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Opinions vary on the merits of the different delivery methods. Publications often obfuscate the defining and typical characteristics of delivery methods with expected results or benefits. The following list of CMR benefits provided by the State of Massachusetts (Massachusetts Division of Capital Asset Management 2004) illustrates this point:

1. The ability to prequalify and select your construction manager on the basis of its reputation and record in controlling costs, meeting deadlines, and satisfying customers.
2. The participation of the construction manager in design and phasing decisions so that ″unbuildable″ or costly design details or phasing plans may be avoided and design/drawing inconsistencies may be limited.
3. The construction manager's ownership of the construction budget through early cost estimating leading to a guaranteed maximum price (GMP) for the work.
4. The ability to "fast track" the start of construction by bidding early trade contracts which the construction manager will ultimately incorporate into the final GMP.
5. The right and responsibility to monitor and audit the construction costs of the project to ensure the city pays only the costs of the work plus the agreed fee to the construction manager.
6. A spirit of cooperation between the owner, architect, construction manager and trade contractors due to a defined allocation of project responsibilities and the construction manager's interest in obtaining strong references for future work.

An analysis of this list reveals that Item 1 is a defining characteristic of CMR. Item 2 lists a typical characteristic—GC participation in design—but also adds the expected benefits that this participation will necessarily result in reduced design errors and omissions. Item 3 states that the CMR contractor has "ownership" of the budget through early cost estimating which leads to a GMP. This is not necessarily true of CMR—the GC may have contractual preconstruction services, such as creating or validating cost estimates, but typically the owner controls budget decisions throughout the project and the GMP is a negotiated agreement between the two parties. Items 4 and 5 are not necessarily unique to CMR. In DBB, owners may be able to fast track work under multiple prime contracts, and the ability of owners to monitor and audit construction costs exists under any PDS, not just CMR. Item 6 is an expected benefit of CMR, but not necessarily a characteristic. Item 6 assumes that a "spirit of cooperation" between participants happens with CMR due to the GC's interest in obtaining future work. This list is a good example of prevailing opinions on CMR—namely, that characteristics of the delivery method necessarily result in various benefits.

In Washington State, school districts must apply for permission to the Office of Superintendent of Public Instruction (OSPI) School District Project Review Board to use the GC/CM method. In 2005, applications by six different districts were available on the OSPI website. The applications were at the stage where they had mostly completed the schematic design, and included a submission on the "Owner's Perspective." The following statements summarize the owner perspectives submitted in the applications:

1. *District A:*
   - GC involvement during design leads to improved budget management because project costs are "continually known."
   - Teaming improves the possibility for project success.
2. *District B:*
   - Good team atmosphere.
   - GC involvement during design leads to improved cost estimating.
   - GC involvement during design should reduce risk.
3. *District C:*
   - GC involvement during design provides constructability and value engineering services.
   - Unable to agree on an estimate for pricing of the mechanical work during maximum allowable construction cost (MACC) negotiations. Owner accepted an allowance for the mechanical package and assumed the risk for high bid prices, but the low mechanical bid was 10% more than the allowance.
   - Owner perceived low turnout during subcontract bidding; some were rebid.
   - Teaming relationship with project team and school staff.
   - High number of design coordination issues despite GC involvement during design; number of requests for information (RFIs) exceeded typical low bid projects.
4. *District D:*
   - GC involvement during design encourages team building.
   - Improved teamwork and communications.
   - GC involvement during design helps the contractor appreciate the owner's values and interests.
   - GC involvement during design contributed to site safety and opportunities to educate the students.
   - GC involvement during design allowed early input and resolution of issues.
   - Requires that the owner learn the process and acquire better ownership skills.
   - Guaranteed construction cost (GCC) is not a guarantee; assignment of risk and management of contingencies must be developed.
5. *District E:*
   - Estimate reconciliation at schematic design was lengthy.
   - Applicable for schools with numerous constraints and difficult urban sites.
6. *District F:*
   - GC involvement during design leads to improved cost estimating at schematic design.
   - Teaming.
   - GC involvement during design helps resolve issues that DB would fail to address.

These owner perspectives provide direct insight into school district expectations of the GC/CM method. District C submitted the application during the construction phase and the other five districts submitted these perspectives during design. Five of the six respondents linked GC involvement during design, a typical characteristic of CMR, with an expected benefit such as "improved budget management" or "improved cost estimating." Teaming was positively identified by five of the six respondents. Only three of the districts listed negative or cautionary perspectives. These included an observation that the GCC is not a guarantee, a difficulty with sufficient subcontractor bid coverage, and a difficulty with accurate contractor estimates.

Few examples of negative expectations for CMR were identified in the literature. Henry (2005) questioned whether the Washington GC/CM method was meeting expectations. Based on anecdotal evidence that some GC/CM projects resulted in large claims and change orders, Henry (2005) listed the following issues:

- GC/CM may not result in efficiencies that benefit the public.
- GC/CM may not promote competitive construction pricing.
- GC/CM may not promote fairness to subcontractors.

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Table 2. Expected Owner Benefits of the CMR Delivery Method

Benefit to owner	Characteristics
Select the most qualified contractor, not the lowest bidder	• Qualifications-based selection
Reduction of design errors and omissions	• GC participation in design • Terms of the contract (GC assumes more risk)
Improved phasing plans	• GC participation in design
GC assumes more risk	• GC participation in design • Terms of the contract. • Potential for future work
Cost certainty during design (more accurate estimating during design)	• GC participation in design
Cost certainty during bidding and construction (guaranteed maximum price)	• GC participation in design
Reduced change orders	• GC participation in design • Terms of the contract (GMP)
Owner pays only cost of work plus fee	• Flexibility (CMR allows different contract pricing)
Improved schedule: Fast-track, phased bidding, etc.	• GC participation in design • Flexibility (multiple bid packages)
Collaboration, cooperation, team spirit, etc.	• GC participation in design • Potential for future work
GC better comprehends and supports Owner expectations	• GC participation in design • Potential for future work

- GC/CM may not reduce claims.

The expected owner benefits of CMR, as stated in various publications (CII 1997; Konchar and Sanvido 1998; Liu 2004; Massachusetts Division of Capital Asset Management 2004; Oregon Public Contracting Coalition 1997; Septelka and Goldblatt 2005) are summarized in Table 2. Table 2 also illustrates relationships between CMR characteristics and expected benefits.

Studies on Alternate Project Delivery Performance

There are a limited number of studies that empirically compare the performance of different delivery systems. Love (2002) considered the effect of PDS on rework costs on Australian projects and found no significant difference between traditional and alternative PDS. Ernzen and Schexnadyer (2000) analyzed two similar highway projects and found 10–15% labor cost savings on a DB versus DBB project. Riley et al. (2005) studied the effects of the PDS on change orders in mechanical construction and concluded that "unforeseen" change orders were less frequent on DB projects than DBB. Bender (2003) analyzed two case study projects from Washington State, a DBB and CMR project, and concluded that different project conditions warrant different delivery methods.

CII has sponsored several studies that compare PDS performance. Konchar and Sanvido (1998) empirically compared cost, schedule, and quality performances of projects that used the CMR, DB, and DBB delivery methods. Konchar and Sanvido used a survey document to gather post project performance data from owners and contractors on 351 completed projects. The authors concluded that DB was superior to DBB in terms of cost and schedule performance, and DB was superior to both CMR and DBB in terms of quality.

The results from Konchar and Sanvido (1998) are often cited as evidence that DB is superior to the other delivery methods. The sample data include a large variety of projects including public and private owners, six different project types, traditional building and nonbuilding (e.g. industrial) project types, project sizes from 500 to $200{,}000\ \mathrm{m}^2$, and unit construction costs from under $\$600/\mathrm{m}^2$ to over $\$1{,}800/\mathrm{m}^2$. Williams (2003) questioned whether the Konchar and Sanvido (1998) results were valid for a particular project type, owner, or delivery system. For example, Konchar and Sanvido (1998) concluded that DBB projects had the highest average unit cost at $\$1{,}291/\mathrm{m}^2$ compared with $\$861/\mathrm{m}^2$ for DB. Yet the authors acknowledged that high technology projects accounted for the "majority of high unit costs, while light industrial facilities accounted for most of the low-unit-cost facilities." The authors' conclusions on PDS performance did not take into account inherent differences in the source data.

Williams (2003) also questioned the validity of the Konchar and Sanvido (1998) statistical analysis. First, Williams noted that the principal cost growth and schedule growth differences in the study were not statistically significant. Second, Williams questioned the results on "construction speed" and "delivery speed" because the study compared "fast track" DB projects against CMR and DBB projects that are not necessarily fast-track. Williams noted that the study conclusions on quality performance were based on a survey of owner perceptions rather than measurable, quantitative data, and the results were not statistically significant. DBB was rated lower than DB and CMR on four quality metrics in the study, but the difference in scores were not statistically verified and appear to be within 1% of each other. Finally, Williams observed that the study analyzed differences in medians as opposed to arithmetic means, which could have yielded results that favored the sample with larger variances.

Another CII study by Thomas et al. (2002) compared the impact of the DB and DBB methods on performance. Thomas et al. (2002) utilized the CII Benchmarking and Metrics (BM&M) database, which contained quantitative information on more than 1,000 projects gathered from owner and contractor questionnaires. The BM&M data included standard performance metrics such as cost, schedule, safety, changes, rework, and productivity, plus "practice use" metrics such as preproject planning, constructability, team building, zero accident techniques, project change management, design/information technology, materials management, planning for startup, and quality management. The authors

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Table 3. Standard GC/CM GMP Components

Item	Description	Typical pricing method
Maximum allowable construction costs (MACC)	Direct cost of work, comprised of competitively bid work packages (self-perform or subcontracted)	Fixed cost lump sum
Specified general conditions	GC's cost for general conditions requirements	Fixed cost lump sum or reimbursable
Fee and profit	Contractor's overhead and profit	Percentage of the MACC, fixed cost lump sum
Preconstruction Services	Cost for preconstruction services such as constructability reviews, estimating, scheduling and phasing, value engineering, meeting attendance, etc.	Fixed cost lump sum or Time and Materials
GC/CM contingency	Optional change order contingency, usually jointly managed by the contractor and owner	Reimbursable

selected 617 DBB and DB projects with sufficient information for analysis. Like Konchar and Sanvido (1998), the Thomas et al. (2002) data were widely varied. Project types included domestic and international, industrial and building, public and private owners, and information from both owners and contractors. Thomas et al. (2002) performed bivariate statistical comparisons of the DB and DBB delivery systems for the above-listed performance and practice-use metrics. The authors concluded that DB significantly outperformed DBB in terms of cost, safety, changes, and rework. The study did not include CMR projects.

Washington GC/CM

Washington State has allowed alternative PDS in public projects since 1991 under the Revised Code of Washington (RCW) Chapter 39.10 "Alternative Public Works Contracting Procedures." The law was modified by Substitute House Bill (SHB) 2239 in 1994 and SHB 1425 in 1997. GC/CM was initially enacted for a select group of public projects but has since been expanded by various actions of law. As of October 2006, the following agencies could utilize GC/CM:

- State Department of General Administration.
- University of Washington.
- Washington State University.
- Cities with population greater than 70,000 and any public authority chartered by such cities.
- Counties with population greater than 400,000.
- Port districts with total annual revenues greater than $15 million.
- Public hospital districts, subject to district project review board approval.
- Public utility districts with total annual revenues from energy sales greater than $23 million.
- School districts, subject to district project review board approval.
- State ferry system.

With few exceptions, GC/CM was only authorized for projects $10 million or larger. RCW 39.10 also authorized limited use of DB for nonschool agencies and job order contracting (JOC). JOC was expanded to include school districts in 2005.

GC/CM is an increasingly popular method in Washington. According to Septelka and Goldblatt (2005), the use of GC/CM increased statewide from 2 projects in 1991 to 11 in 2004, with a peak of 13 in 2003. It could not be determined whether GC/CM was increasing as a share of overall projects. Through 2005, Septelka and Goldblatt (2005) identified at least 108 GC/CM projects valued at $6.6 billion.

In 2002, the Washington Legislature passed Substitute Senate Bill (SSB) 6597 allowing public school districts limited use of GC/CM. RCW 39.10.067 currently governs the GC/CM process for public schools and the legislation is more restrictive for school districts than for other state agencies. The following is a list of the principal K-12 GC/CM restrictions:

- Each GC/CM school project must receive approval by a special review board established by RCW 39.10.115.
- Originally limited to 10 demonstration projects statewide.
- At least eight projects must be more than $10 million.
- Two projects may be between $5 million and $10 million.
- Authorizing legislation expires July 1, 2007.

In 2003, SHB 1788 was passed to enlarge the school pilot program to 18 projects. As of October 2006, three known school districts rejected the GC/CM method prior to the start of construction. One of these projects was bid and awarded under the traditional DBB method. The status of the other two projects could not be determined. In 2006, SHB 3024 was passed, enlarging the school GC/CM pilot program to 23 projects.

The GC/CM legislation contains some other key requirements. The cost components of the contract are described in Table 3. All work packages, including self-performed work, must be competitively bid with public bid openings. The GC may bid on subcontract work if the process is managed by the public agency, the work is customarily performed by general contractors, the packages are advertised to the public, and the combined value of all self-performed work does not exceed 30% of the negotiated MACC. Washington legislation also requires performance and payment bonds for all subcontract work packages greater than $300,000, and allows the general contractor to require performance and payment bonds from any other subcontractors on a package regardless of the dollar amount.

Septelka and Goldblatt (2005) published a comprehensive survey of GC/CM projects in Washington State. The results were delivered to the State of Washington JLARC, a committee that "carries out independent performance audits, program evaluations, sunset reviews, and other policy and fiscal studies" for the state. JLARC subsequently published a report in 2006 to the legislative body based on the study.

The Septelka and Goldblatt (2005) data were collected from written surveys sent to representatives of the state agencies that utilized GC/CM. By 2005, only four–six GC/CM school projects were completed. The authors collected data about cost growth using the industry change order ratio (COR) metric. COR, which is expressed as a percentage, is calculated by dividing the difference between final contract amount and original contract amount by the original contract amount. Septelka and Goldblatt (2005) received 46 valid responses on change order performance and determined the mean COR for these GC/CM projects was 11%.

Septelka and Goldblatt (2005) theorized that GC/CM should result in reduced change orders and reduced litigation relative to DBB projects due to GC involvement during design. The authors

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did not gather data on non-CMR projects, so four other studies were cited for comparative purposes. Septelka and Goldblatt (2005) first cited a previous study by Septelka (1997) that determined the mean COR on DBB projects was 109% and the median COR was 4%; on private negotiated-cost-plus-fixed-fee projects the mean COR was 247% and the median 7%. These change order ratios are far above the industry standard of 5–10% and the large difference between mean and median suggests the means were radically skewed by outliers. The cited results were based on projects from a single design firm and thus not necessarily indicative of typical change orders in DBB or CMR public projects. Septelka and Goldblatt (2005) also cited a report by Engan (1996) that found the mean COR for renovation-only DBB projects under $10 million to be 15% and the median 9%. Finally, Septelka and Goldblatt (2005) cited a 1986 government report (NRC Committee on Construction Change Orders 1986) on tens of thousands of private, public, and federal projects which concluded that change order increases of 5–10% was reasonable. Septelka and Goldblatt (2005) concluded that the Washington GC/CM projects "experienced less change than WA public and private projects," yet this conclusion was not supported by the results of their study. The GC/CM COR was not compared to the COR for similar projects, and the mean GC/CM COR of 11% actually exceeded the ratios in the cited reports, with the exception of the Septelka (1997) study.

Oregon CM/GC

Oregon has allowed alternative public construction procurement since 1976 and CM/GC since the early 1980s. The use of alternative PDS is allowed by the Oregon Revised Statute (ORS) 279.015 and can be granted as an exemption through an administrative process. According to Williams (2003), Oregon had used alternative PDS on over 136 projects valued at $2.9 billion through 2002.

The Oregon legislation is generally less prescriptive than in Washington. For example, Oregon does not explicitly list the public agencies, types of projects, or project sizes that are eligible for alternative PDS consideration. Washington is more explicit in defining the process vis-à-vis selection criteria, public notice requirements, evaluation/selection criteria, proposal contents, elements of the GMP, ability to self-perform work, and allowed incentives. It is not known if the differences in legislation between the states correlate with project performance.

Williams (2003) published a Ph.D. dissertation that compared DBB and CM/GC performance of 215 Oregon public projects. Williams analyzed basic cost and schedule performance metrics using statistical significance testing similar to Konchar and Sanvido (1998), and Williams used data envelope analysis (DEA) to compare overall project efficiencies based on multiple input and output variables. The author restricted the analysis to the public building construction sector in Oregon. Some of Williams' findings challenge expectations of the perceived benefits of CMR. The following is a list of the principal conclusions from the Williams study:

- CM/GC projects do not significantly "outperform" DBB projects solely in terms of cost and schedule.
- CM/GC projects correlate with a higher $/SF unit cost than DBB.
- CM/GC projects may not reduce an owner's overall risk compared to DBB.
- CM/GC projects achieve a higher DEA "technical efficiency" score than DBB based on the ability to fast track.

To obtain completed project data on Oregon construction projects from 1997 to 2002, Williams (2003) utilized five data sources: Surveys of contractors, owners, and architects; websites of contractors, owners, and architects; direct information provided by panel and nonpanel members; archival information from the Seattle Daily Journal of Commerce (www.djc.com); and Oregon legislative reports. He compiled information on 407 projects and reduced the data to 215 projects with sufficient information, composed of 111 CM/GC and 104 DBB projects. The results indicated that CM/GC projects experienced 5.35% average change order cost growth, which was observably lower average than 7.77% for DBB. This outcome met initial expectations, but hypothesis testing using a *t*-test determined the results were not statistically significant at 95% confidence. CM/GC projects experienced an average schedule growth of 10.46%, which was observably greater than 9.40% for DBB, but this was also not statistically significant with 95% confidence.

Williams (2003) used DEA to compare PDS performance for multiple variables including cost and schedule growth. DEA is useful for analyzing monetary and nonmonetary variables and multiple inputs and outputs. Williams concluded that CM/GC, as measured by DEA technical efficiency, achieved a statistically significant higher result than DBB. The author concluded that the CM/GC method had beneficial outcomes that could not be measured by cost or schedule growth metrics alone.

Methodology

The primary objective of this research is to determine whether the CMR delivery method is meeting cost control expectations on Pacific Northwest public school projects. To accomplish this objective, three research questions are formulated:

1. Does the CMR project delivery method experience significantly lower change order growth than DBB?
2. Is the GMP an effective controller of cost growth?
3. Does the CMR project delivery method experience significantly lower project cost growth than DBB?

   The secondary objective of this research is to consider how the results address relevant issues encountered in other cited studies. To accomplish this objective, two secondary research questions are formulated:

4. Do public school projects experience significantly different change order performance than nonschool projects?
5. Is there a difference in change order performance between Oregon and Washington?

Projects are limited to the DBB and CMR delivery methods, public owners, building projects, and geographically constrained to the Pacific Northwest to minimize the potential effects of variables unrelated to PDS. The expectation is that any observed differences between PDS performance measurements are less likely to be affected by non-PDS variables such as geography, laws, market conditions, etc.

Oregon Data

The Oregon database (Williams 2003) contains information on 407 projects, including 153 projects classified as schools. The information was originally compiled by Williams (2003) and his assistants through various methods including written surveys, online research, and direct access. In order to generate our data set, 86 higher education projects identified as schools and 254 non-

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school projects were removed. Additionally, another 59 projects were removed due to incomplete information. This resulted in a data set of 67 Oregon public school projects.

The Oregon database comprised projects that were completed through 2002. The Oregon database was assembled over a 5 year time period. A comparable period of time to collect project information after 2002 was not feasible for this research.

Washington Data

In Washington, a convenient and comprehensive data source of school project information was found. The OSPI administers the state matching fund process for all eligible public school projects. As part of the state match process, OSPI collects and retains budget and cost data for all state match school projects.

The Washington school data set initially consisted of 235 projects, of which 234 were provided by OSPI. It should be noted that the information provided by OSPI did not constitute all public school projects for the given time period because not all projects were eligible for state match funding. The Seattle Daily Journal of Commerce reported that 72% of school projects were eligible for state match funding (Marsh 2002), which means the Washington school data set excludes approximately 94 nonmatch public school projects for the time period. This research also identified and collected information for an additional GC/CM school project completed in summer 2005 that was not available from OSPI.

Pacific Northwest School Database and Nonschool Projects Database

The Pacific Northwest School database (PNWSD) includes the Oregon and the Washington data sets and it is comprised of 8% CMR and 92% DBB projects. This makeup is to be expected because DBB is still the dominant delivery method for school projects in both states. The PNWSD contains the following input data:

- Data source.
- Year completed.
- Project name.
- Project size (SF).
- Prebid estimate ($).
- Original contract ($).
- Final contract ($).
- Contract type.
- State.

The following variables were added to the PNWSD to calculate cost ratios based on the input data:

- $/SF=Final contract ($)/SF.
- Bid growth ($)=Original contract ($)−Prebid estimate ($).
- Bid growth ratio (%)=Bid growth ($)/Prebid estimate ($).
- Change order growth ($)=Final contract ($)−Original contract ($).
- Change order ratio (%)=Change order growth ($)/Original contract ($).
- Project growth ($)=Final contract ($)−Prebid estimate ($).
- Project growth ratio (%)=Project growth ($)/Prebid estimate ($).

The nonschool project database (NSPD) has 126 CMR and 51 DBB projects. The greater ratio of CMR projects in the NSPD is mainly due to the makeup of the contributing data sets (Williams 2003; Septelka and Goldblatt 2005). The data in this database have the same structure as in the PNWSD.

Table 4. Change Order Ratio Metrics by PDS

PDS	Number of projects	Mean COR (%)	Median COR (%)	Standard deviation (%)
DBB	273	6.29	4.98	5.34
CMR	24	4.74	4.50	5.90
Total	297	6.19	4.98	5.39

Results

Change Order Performance

The first research question is whether CMR public school projects experience lower average construction contract cost growth than DBB in the Pacific Northwest, as measured by the industry standard COR metric. Using Microsoft EXCEL's Descriptive Statistics function, univariate analysis of COR by PDS is summarized in Table 4. The results show that CMR projects did experience lower average change order growth than DBB. The mean COR for CMR projects is 4.74 versus 6.29% for DBB. The CMR standard deviation is only slightly larger than DBB, suggesting the two samples are similarly distributed. The sample medians are also shown in Table 4 to illustrate how the data are distributed. The median COR for CMR is closer to its mean than in the DBB sample, suggesting that the DBB mean may be upwardly skewed by outliers.

Statistical hypothesis testing is used to determine if the observed difference in COR was statistically significant or due to chance. An EXCEL unpaired two-sample t-test, with a confidence level of 95% ($\alpha=0.05$), was used to calculate the p value. The results indicate the observed difference in COR values is not statistically significant and may be the result of chance, $t(26)=-1.24$ and $p=0.23$.

As CMR can only be used on projects larger than $10 million in Washington, project size as measured by cost may be a contributing factor to the average change order ratios. The average CMR final construction cost is $17.3 million versus $9.6 million for DBB. To compare change order performance for similar-sized projects, all projects less than $5 million in final construction contract cost were omitted for both PDS. This resulted in a new reduced data set of 22 CMR projects and 156 DBB projects. The mean COR for large DBB projects increased compared to the mean of all DBB projects from 4.74 to 5.30%. The mean COR for large CMR projects decreased slightly from 6.29 to 6.13%. The observed difference in COR is not statistically significant, $t(26)=-0.63$ and $p=0.53$. By reducing the data to similar-sized projects, the difference in the mean COR for each delivery system was actually reduced.

GMP Performance

The second research question evaluates the effectiveness of the GMP as a controller of cost growth. The initial observation of the PNWSD, shown in Table 5, is that only 6 of the 24 CMR school projects, or 25%, finished at or below the GMP. This observation does not support the expectation that the GMP is a guarantor, and thus few CMR projects would exceed the GMP. The analysis shows that the average CMR school project exceeded the GMP by 4.74% by the end of construction.

The observation that only 25% of school projects were completed at the GMP was unexpected and led to another question: Was this result atypical for public school construction? Table 6

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Table 5. GMP Performance of School Projects

Final construction cost type	Number of projects	Percentage
Lower than the GMP	2	8.3
Equal to the GMP	4	16.7
Greater than the GMP	18	75.0
Total	24	100.0

shows that only 21% of nonschool projects were completed under or at the GMP, similar to what was uncovered for schools.

The GMP was a guarantor of maximum construction cost on less than 21% of projects in this data set. There are two principal reasons the final construction price would exceed the GMP, depending on the project circumstances. First, the GMP is typically set prior to completion of design and "buy out" of the work packages. There is a risk that the negotiated GMP will be exceeded during actual buy out, which could entitle the contractor to compensation if the contract allows. Septelka and Goldblatt (2005) noted that the earlier a GMP is established in design, the more risk the contractor would assume due to the potential for inflation, changing market conditions, and design changes.

The PNWSD does not have information on when the GMP was negotiated, but results from Septelka and Goldblatt (2005) can be used for reference. Table 7 illustrates the results of 40 responses regarding the timing when the GMP was negotiated. Septelka and Goldblatt (2005) asked owners to report when the MACC was negotiated relative to completion of overall design, measured as a percentage. This does not translate directly to the typical design phases of schematic design (SD), design development (DD), and construction documents (CD). To make this translation, the State of Washington guidelines for determining architect/engineering fees were used to correlate level of design with percentage complete. All of the 40 GC/CM projects in the Septelka and Goldblatt (2005) study reported negotiating the GMP at 50% design or later, which correlates with the CD design phase. Of these projects, 35% reported negotiating the GMP prior to 80% of design completion and the remaining 65% established the GMP at 80% design completion or later. These results suggest that the typical GC/CM GMP is established very late in design, which should mitigate some of the contractor's risks identified previously, yet the GMP is consistently exceeded nonetheless. These results also suggest that an expected benefit of the CMR may not be materializing in practice. When the GMP is established so late in design the owner essentially adopts all of the risk of cost growth during the design phase, despite the GC involvement.

Another explanation for the low percentage of projects completed under their GMP is that CMR contracts often allow for compensable change orders. Although CMR contracts often shift more risk to contractors during the construction phase, the contract terms may allow for compensation due to owner requests, design or scope creep, unforeseen conditions, force majeure, and potentially design errors and omissions. The PNWSD does not

Table 6. GMP Performance of Nonschool Projects

Final construction cost type	Number of projects	Percentage
Lower than the GMP	20	15.9
Equal to the GMP	6	4.8
Greater than the GMP	100	79.4
Total	126	100.0

Table 7. Typical Project Design Phase when GMP Is Negotiated (Data from Septelka and Goldblatt 2005)

Design phase	Design complete (%)	Number of projects	Percentage of projects
Schematic design	0 to 19	0	0
Design development	20 to 50	0	0
Contract documents	50	8	20.0
	60	2	5.0
	70	4	10.0
	80	16	40.0
	90	5	12.5
	100	5	12.5
Total		40	

have information on change order types, but Septelka and Goldblatt (2005) gathered more specific change order data on 46 school and nonschool CMR projects. Based on these projects, owner's scope accounted for 52% of change cost, design errors and omissions accounted for 18%, unforeseeable conditions accounted for 15%, the contractor accounted for 11%, code/regulatory agencies and other accounted for the remaining 4%. This information suggests that half of all change order costs on CMR projects are attributable to "owner's scope," which would explain why CMR projects are exceeding the GMP. It is not clear whether these owner-caused changes occur before or after buy out.

Owners typically budget a contingency for additional costs during the design and construction phases. As a project progresses, owners may choose to expend funds from these contingencies for project enhancements or other purposes. There is no data to compare the two delivery methods to determine if CMR experiences more or less owner-requested changes than DBB.

Bid and Buy out Performance

The third research question compares the project cost growth for CMR public school projects to DBB projects, where project cost growth is defined as the difference between the final construction contract cost and the prebid owner's estimate. Prebid cost estimates were only available for Washington school projects so the Oregon data were omitted from this analysis. The Washington data were comprised of 228 projects, of which 6 were CMR and 222 were DBB.

Table 8 shows the results of the bid growth ratio (BGR) and project growth ratios (PGR). The observable results indicated that DBB projects averaged −3.09% cost growth from the owner's prebid estimate to actual contract award (BGR), and 3.25% total cost growth from the prebid estimate to the final construction cost (PGR). CMR projects averaged 10.5% BGR and 19.4% PGR.

Table 8. Cost Growth Metrics for Washington Schools by PDS

		Bid cost growth		Project cost growth	
PDS	Number of projects	Mean (%)	Standard deviation (%)	Mean (%)	Standard deviation (%)
DBB	222	−3.09	12.00	3.25	13.00
CMR	6	10.50	11.40	19.40	14.90
Total	228				

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Table 9. Cost Growth Metrics for Washington Schools by PDS for Projects Greater Than $7 Million

PDS	Number of projects	Bid cost growth: Mean (%)	Bid cost growth: Standard deviation (%)	Project cost growth: Mean (%)	Project cost growth: Standard deviation (%)
DBB	97	−2.35	10.50	4.35	11.30
CMR	6	10.50	11.40	19.40	14.90
Total	103				

The bid growth results in Table 8 suggest that CMR is not as effective at containing costs at buy-out in public schools as DBB. The DBB construction contracts were awarded, on average, 3.09% under the prebid estimates, whereas CMR experienced an average 10.5% growth for the same period. The *t*-test yielded a statistically significant result, $t(5)=2.88$ and $p=0.03$. With 95% confidence, the results indicate that DBB averages significantly less cost growth at bid/buy out than CMR.

The project cost growth results shown in Table 8 also suggest that CMR is not as effective at containing costs from the estimate to construction completion as DBB is. DBB projects averaged 3.25% growth from the prebid estimate to construction completion (PGR), while CMR averaged 19.4% growth. These results are statistically significant, $t(5)=2.62$ and $p=0.05$.

The expanded cost growth comparisons show how cost growth ratios change over the life of the project. The DBB school projects averaged −3.09% cost growth from the prebid estimate to contract award and 6.29% cost growth during construction. This suggests that owners experience cost savings from low bid results but pay more in change orders during construction. Such an observation is consistent with industry expectations that low bid construction typically yields a low initial construction price and increased change order costs. The CMR projects averaged 10.5% cost growth from the prebuy out estimate to negotiated GMP and 4.74% cost growth during construction. This suggests that project owners experience significant cost growth at buy out but pay less change order costs during construction. Thus, the reason why CMR projects in this study are exceeding the GMP is more likely the result of cost growth prior to start of construction.

The BGR results in Table 8 suggest that CMR correlates with higher cost growth from estimate to construction completion, but this does not necessarily mean that CMR causes the higher cost growth. Other variables besides the PDS could account for the difference in cost growth. The CMR projects in this data set are all more than $7 million, which may contribute to the observed difference in project cost growth ratios, so the same analysis was performed on projects $7 million or larger. This reduced the DBB data set to 97 DBB projects. Table 9 illustrates that for projects larger than $7 million, DBB still experienced significantly lower mean budget and project cost growth than CMR. However, the BGR for DBB decreased from −3.09 to −2.35% and PGR increased from 3.25 to 4.35% when projects smaller than $7 million are omitted. The results in Table 9 are statistically significant, $t(5)=2.69$ and $p=0.04$ for BGR and $t(5)=2.42$ and $p=0.05$ for PGR. This suggests that when projects of similar size are compared, the mean cost growth ratios for the two delivery systems are closer together. Project size is a contributing variable to bid and project cost growth ratios.

Table 10. Cost Growth Comparison of CMR Projects for Schools versus Nonschools

Database	Project type	Number of projects	Average cost growth (%)	Standard deviation (%)
PNWSD	Schools	24	4.74	5.90
NSPD	Nonschools	126	7.61	9.56
Total		150		

Cost Performance Comparisons to Nonschools

Our fourth research question relates to CMR and DBB public school projects as compared to nonschool projects in terms of construction cost growth. For this comparison, the industry standard COR metric from the PNWSD was compared to the nonschools data (NSPD). Using the EXCEL descriptive statistics function, the mean COR and standard deviations were calculated for each PDS and differentiated by schools or nonschools and summarized in Tables 10 and 11.

Initial observation of the data in Table 10 suggests an observable difference between the 24 CMR school projects and the 126 nonschool projects. CMR schools averaged 4.74% COR versus 7.61% for nonschools. The standard deviation for nonschools CMR projects is almost 80% greater than schools, which suggests more variation in change order ratios for nonschool projects. Initial observation of the data in Table 11 suggests an observable difference between the 273 DBB schools and the 51 DBB nonschool projects, although this difference is not as great as CMR projects. DBB school projects averaged 6.29% COR versus 7.04% for nonschools. The standard deviation for nonschool DBB projects is 35% larger than school projects, which suggests more variation in change order ratios for nonschools. For CMR projects shown in Table 10, the *t*-test resulted in a statistically significant difference $t(49)=2.00$ and $p=0.05$. Therefore, in Washington and Oregon, school projects experienced a lower average COR than nonschool projects with 95% confidence.

The *t*-test for DBB projects shows a nonstatistically significant difference, $t(60)=-0.71$ and $p=0.48$. Therefore, the change order ratios for DBB projects are not significantly different between schools and nonschools.

Cost Performance Comparisons between Washington and Oregon

The fifth research question explored a secondary issue: Whether differences in Oregon and Washington school CMR legislation resulted in observable differences in change order growth. A total of 18 Oregon and 6 Washington CMR school projects were compared. Although Oregon experienced observably lower COR as shown on Table 12, the results were not statistically significant at 95% confidence, $t(8)=-1.58$ and $p=0.13$.

Table 11. Cost Growth Comparison of DBB Projects for Schools versus Nonschools

Database	Project type	Number of projects	Average cost growth (%)	Standard deviation (%)
PNWSD	Schools	273	6.29	5.34
NSPD	Nonschools	51	7.04	7.20
Total		324		

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Table 12. Change Order Growth Comparison between Oregon and Washington for CMR Projects

State	Projects	Average change order growth (%)	Standard deviation (%)
Oregon	18	3.67	5.60
Washington	6	7.94	6.07

Conclusions

State governments are liberalizing project delivery systems in public school construction. CMR is a popular alternative to DBB that has been allowed by Oregon and Washington in school construction for several years. Alternative PDS are expected to mitigate perceived shortcomings associated with the DBB method and to improve project cost performance. The primary intent of this research effort was to determine whether the CMR method has met cost performance expectations in Pacific Northwest public schools when compared to DBB.

Cost data on completed school projects were collected for Oregon and Washington from two sources. Information on 235 Washington school projects was assembled from forms maintained by the state, and information on 67 Oregon school projects was gathered from the Williams (2003) study. Information on 177 nonschool projects was also used for a comparative database. This nonschool project data set was assembled from the Williams (2003) study and the Septelka and Goldblatt (2005) study. The data consisted of basic project information and construction cost figures including prebid estimate, awarded contract amount, and final contract amount. Industry-standard cost growth metrics were generated. Finally, the results were validated with statistical testing (*t*-test) to determine if the differences were statistically significant.

The first research issue was whether CMR resulted in less change order cost growth than DBB in public school construction, as expected. Data on 273 DBB and 24 CMR projects were analyzed. The mean COR for CMR was observably lower than DBB, but the results were not statistically significant at 95% confidence. The same analysis was performed on projects larger than $5 million and yielded analogous results.

The second research issue was whether school district owners benefited from a GMP with the CMR method. A total of 24 school projects were analyzed and only 25% were completed at or below the GMP. Data on 126 nonschool Pacific Northwest projects were similarly analyzed to test whether schools were abnormal and only 21% of nonschool projects were completed at or below the GMP. This research concluded that the GMP is not necessarily an effective guarantee of maximum construction cost.

The third research issue was whether CMR school projects experienced lower construction cost growth than DBB prior to construction. A total of 6 CMR and 222 DBB projects were analyzed from Washington. The mean bid cost growth and the overall project construction cost growth for CMR projects were observably higher than DBB, which was unexpected. Statistical t-tests found that DBB had a statistically significant lower mean BGR and lower mean PGR than CMR with 95% confidence. Project size did not significantly affect these results.

The fourth research question was whether public school change order performance is comparable to industry standard for either DBB or CMR delivery method. 24 CMR school projects data were compared to 126 CMR nonschool projects data. The CMR school projects experienced a statistically significant lower COR than nonschools with 95% confidence. This research did not determine why schools in OR and WA experienced lower change orders than nonschools, but this result provides support for allowing CMR for schools. The data from 273 DBB school projects were compared to 51 DBB nonschool projects data. Although schools had an observably lower mean COR, the result was not statistically significant with 95% confidence. This research concluded that CMR school projects were more effectively controlling change order costs compared to nonschool CMR projects, and DBB school projects were comparable to DBB nonschools at controlling change order costs.

The fifth research question explored whether differences in Oregon and Washington CMR legislation resulted in observable differences in school change order growth. A total of 18 Oregon and 6 Washington CMR school projects were compared. Although Oregon experienced observably lower COR, the results were not statistically significant at 95% confidence.

The findings of this research challenge assumptions that the CMR method necessarily controls construction cost growth more effectively than DBB in public school construction in the Pacific Northwest. Expectations of CMR project performance are based on unique delivery method characteristics including the use of a GMP, the ability to select the GC for reasons other than lowest price, the involvement of the at-risk GC in design, the shifting of certain contractual risks from the owner to the GC, and the use of fiscal incentives during construction. In spite of these characteristics, CMR did not result in significantly lower change order cost ratios than DBB, 75% of CMR school projects exceeded the GMP, and CMR actually resulted in higher cost growth after the estimate. Alternative PDS are increasingly popular in public construction nationwide, yet this study shows that CMR is not necessarily more effective than DBB in controlling cost growth. Although CMR certainly has other benefits outside the scope of this study, owners should not necessarily expect improved control of bid and change order costs.

This study does not suggest the CMR method is necessarily "better" or "worse" than the DBB method at change order performance in public schools. The average change order percentage experienced on GC/CM and CM/GC school projects was comparable to DBB, and owners should budget appropriate contingency funds. This research concludes that the CMR GMP is not an effective guarantee of maximum construction costs in approximately 75% of school projects and 79% of nonschool projects. This research did not explore why the GMP was exceeded so often, but the process does not appear to be having the intended result, which may necessitate changes to the GC/CM legislation.

Like any body of empirical research, this study is bound by numerous limitations. First, the study scope was limited to Pacific Northwest school building projects in the public sector from 1987 to 2005. The findings may not be applicable to projects outside these confines. Second, the data were obtained from OSPI forms and prior studies. The raw information is subject to various potential issues including bias and errors. Sample sizes varied depending on the hypothesis tested, but the CMR schools data were limited to 24 projects. This sample may not be an accurate representation of the population as a whole—more projects are needed to generate more confident statistical results. In addition, the statistical tools such as the *t*-tests rely on the central limit theorem (CLT) which states that the distribution of an average tends to be normal regardless of the population distribution type as the sample size is increased. However, the CLT has limitations when sample sizes are less than 30, such as in parts of the analysis in this study.

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Finally, project data do not represent a truly random sampling. The data are essentially a sample of convenience. Therefore, the data collection process may bias the results. For example, this research excluded school projects in Washington that did not receive state matching funding.

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