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COMPARING PERFORMANCE OF CONSTRUCTION PROJECTS DELIVERED THROUGH DIFFERENT DELIVERY METHODS

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Abstract: When new delivery methods are introduced in public procurement, it is customary to analyze and compare their performance against traditional methods. Many early studies compared performance of different project delivery systems, and often developed decision support tools to help owners follow a structured path in measuring performance and, consequently, choose the most appropriate project delivery method. However, the measurement process adopted by these studies was mostly specific to the dataset to be analyzed. Only rarely, it took into account differences deriving from varying project characteristics, and, therefore was not generalizable. Building upon these studies, this study proposes a general framework for comparing performance of projects delivered through different delivery methods. A discussion of how the framework could also be adapted to every industry sector is included. This work can help owners choose a set of metrics to evaluate and compare the performance of project portfolios delivered with more than one delivery method and different industry sector.

Keywords: project delivery methods, construction project success evaluation, project performance metrics

1 INTRODUCTION

When in 1996 the U.S. Congress passed the “Clinger Cohen Act” authorizing public agencies to use the Design-Build (DB) project delivery method, the uncontested predominance of the traditional Design-Bid-Build (DBB) method was brought into question. Encouraged by results obtained on projects delivered through DB, a growing number of states passed legislation to allow other delivery methods including Construction Management at Risk (CMR), Design Build Operate (DBO), and Public-Private-Partnership (PPP). Early on, analyzing and comparing the performance of newly introduced delivery systems was required to allow public owners to assess and often justify their choice. Therefore, many early studies compared performance of different project delivery systems, and often developed decision support tools to help owners follow a structured path in measuring performance and consequently, choose the most appropriate project delivery method. However, the measurement process adopted by these early studies was mostly specific to the dataset to be analyzed, only rarely took into account differences deriving from varying project characteristics and size, and, therefore was not generalizable (Heisse et. Al. 2011).

Over the years, as the success of project management has become inextricably linked with cost, time and quality performance (Atkinson 1999), a number of relative, static and dynamic performance measurement metrics have been developed (Gransberg et al. 2003). Relative metrics are those independent from the size of the project, allowing for comparison among projects that consistently differ for size. Examples are time and cost growth metrics. Static metrics depend on project size, allowing comparison for those projects that have roughly the same size only. Examples are cost per square foot of constructed area or charge days per lane-mile of highways. Dynamic metrics vary according to both time and size; construction placement expressed in dollar is an example. However, despite the increasing availability of various types of metrics to compare and analyze performance of delivery systems, a general understanding of the metrics that may be applicable to compare project portfolios delivered using different methods in various industries is still missing. As an attempt to overcome this gap and enhance the understanding on how to perform internal benchmarking for delivering diverse project portfolios, we propose a framework developed through a critical analysis of previous studies.

Following a meta-analytical approach, we combined results from previous studies to identify patterns and sources of disagreement among results, or other interesting relationships that may help us formulate a general framework for evaluating the performance of a diverse project portfolio. A small set of projects was also used to narrate the application of the framework. The framework is presented as follows. Firstly, we analyze previous studies. Secondly, we propose the methodology and develop our framework. Then, we give an interpretation of results. Finally, we draw conclusions with future research directions.

2 LITERATURE REVIEW

As previously highlighted, this paper relies significantly on the studies of the main authors who analyzed project performance according to the delivery method adopted.

Konchar and Sanvido (1998) were the first authors to introduce a model of performance comparison among DBB, DB and CMR delivery methods in terms of cost, schedule and quality performance. A sample consisting of 351 building projects in the U.S. was used in their analysis. The model consisted of two t-tests to verify if the difference in means among the delivery systems was significant, as well as a Mood's median test for sample medians (95% confidence interval). Two multivariate regression analyses were performed, aimed to develop three models explaining the variability of unit cost, construction speed, and delivery speed, and the second for cost growth and schedule growth. This first empirical study on the performance of project delivery methods strongly concluded that DB provided cost and schedule advantages over DBB and CMR without sacrificing quality. Allen (2001) performed a study on 110 MILCON projects of the Southwest Division, Naval Facilities Engineering Command (SWDIV), from fiscal year 1996 to 2000 to compare performance of DBB and DB projects. Performance of DBB and DB projects were classified and compared in subcategories as vertical and horizontal projects, homogeneous projects and Bachelor Enlisted Quarters (BEQs) projects. Again, this study found DB to outperform DBB in terms of cost and schedule, but quality performance of the two delivery methods varied depending on the quality target being measured. Gransberg et al. (2003) analyzed 88 federal building projects that were developed under DB and DBB delivery methods. The aim of their work was to establish a framework for making programmatic decisions about the expected results delivered by the two project delivery methods exploiting performance metrics. Project performance was compared using cost growth, time growth, completed unit costs, design placement, construction placement, DB placement. They found that DB projects were completed with much lower cost and time growth than DBB projects.

Ibbs et al. (2003) structured a model for performance comparison among DBB, DB and other available project delivery methods. A number of 67 projects from the Construction Industry Institute (CII)'s database were taken into account; and change cost, change schedule and productivity were the performance metric used in their study. This study confirmed previous studies when concluded that DB delivery results in time savings, but could not conclude that a method was better than the other in term of cost performance. Instead, the authors suggested that project management expertise and experience of the contractor impacted project performance more than project delivery strategy. Kuprenas et al. (2007) presented a comparison study of public sector municipal facilities projects delivered using DBB and In-House construction delivery method. Cost comparison was possible through 18 public sector municipal facilities projects completed for the Bureau of Engineering over two years. Project size, construction cost, change order value, design cost, construction management cost, total project cost, percentage breakdown by phase, and cost per square meter/square foot were the performance metrics utilized in this study. Results identified several benefits of the in-house delivery route over DBB, but also recognized that this approach was employed on smaller size projects.

In recent years, Hyun et al. (2008) set up a model for evaluating the level of design performance of DB and DBB multifamily housing projects begun in 2000, conducting a quantitative analysis on quality performance. Construction drawings and specifications of public multifamily housing projects were taken into account. Similarly to Allen (2001), Hale et al (2009) analyzed MILCON projects, but limited their analysis to BEQs projects. Thomas et al. (2009) used data from 617 projects from the CII, Benchmarking and Metrics (BM&M) database to compare performance of the DB and DBB delivery methods. This study relied on a set of performance metrics to evaluate performance in terms of cost, schedule, safety, changes, and rework. It also relied on a set of practice use metrics, including pre-project planning, constructability, project change management, design/information technology, team building, zero accident techniques, material management, planning for startup, quality management. Moreover, projects were compared by delivery system, sector, industry group, cost category and project nature, for both owners and contractors. Data were used to determine the relationship between practice use and performance. Practices that provided the greatest performance benefit for both owners and contractors of DB and DBB projects were identified. Moreover, Thomas et al. (2009) also analyzed the effects of fast tracking (i.e. difference between the actual construction phase start date and the actual detail design phase finish date) and schedule adherence (i.e. ahead/on time/behind) on safety performance for both owners and contractors of DB and DBB projects.

Shrestha et.al. (2007) performed an input-versus-output benchmarking approach to assess the performance of large DB highway projects, and found clear trends between project cost and schedule performance and 15 input factors, including location, pavement type, and nature of construction among others. Later, Shrestha et.al. (2012) compared and analyzed the relationship between DB and DBB project delivery methods and performance metrics of highway projects costing more than $50 million using a dataset of 130 projects, with the goal of developing a generic approach to compare performance of large highway construction projects. After normalizing the project for their size using per lane mile metrics, they found that DB projects were constructed and delivered significantly faster than DBB projects. Bogus et al. (2010) collected data from 100 water and wastewater projects with a total price of at least $3 Million to show the influence that project delivery method and contract payment provisions have on schedule and cost performance. As performance metrics, the authors utilized overall schedule growth, construction schedule growth, design and construction cost growth, and intensity. Three different statistical tests were performed during this study: a t-test to verify that the difference between the two population means exists, a Pearson goodness-of-fit to test for the difference between the two population medians, and a z-distribution test for the difference between two population proportions. The authors found that schedule or cost growth was more likely to appear when lump-sum contracts were used than when cost-plus-fee with a guaranteed maximum price (GMP) contract pricing provisions were used. Shane et al. (2013) collected data on 31 DB projects and 69 DBB projects through a survey from municipal water/wastewater facility owners. The aim was to compare performance of DBB over DB delivery method on cost (i.e. growth, unit, total) and schedule (i.e. growth, duration, construction speed, delivery speed). Finally a hypothesis testing to check for a difference between two population means was performed by treating the variable rating as a quantitative variable. These analyses led to quantify that schedule growth under DB was about fifty percent that under DBB. Similarly, DB led to better performance in terms of cost growth. Still, quality of projects delivered through the two delivery methods was comparable.

3 RESEARCH METHODOLOGY

3.1 Metric collection

The main objective of this research is to provide construction project owners and stakeholders with an unbiased and structured overview of the tools available for evaluating performance of project portfolios executed via different delivery methods and in different industry sectors. Starting from the broad concepts of project delivery and project performance, an articulated research was performed to identify previous studies that had compared the performance of project delivery methods or compared project performance in relation to the delivery method.

A thorough literature search process was carried out. This initially relied on the “snowballing” technique, but later moved toward a more systematic approach. In the first stage, the authors initially analyzed a sample of about 60 papers. Then, a more structured process was established that exploited standard searches in various research databases, including “Google Scholar”, “Engineering Village” and “JSTOR.” These searches relied on keyword strings, such as “project delivery method comparison”, “project delivery method performance comparison”, “project delivery method construction” and “project delivery method using performance metrics”. This search allowed analyzing work by the most influential authors, which led to identify a subset of 21 papers, named the project delivery method (PDM) sample that was further analyzed to retrieve the metrics that the authors utilized in their work. This subset included papers from authors who had analyzed the project performance in relation to the project delivery method. The set of metrics extracted from this subset was named PDM metrics sample. Table 1 provides examples of how the information was collected and organized.

Table 1: PDM metric collection format

ID-#	Full Reference	Metric	Industry
PDM-1	Konchar, B. M., and Sanvido, V. (1998). “Comparison of U.S. Project Delivery Systems.” *Journal of Construction Engineering and Management*, 124(December), 435–444.	Unit Cost,Cost Growth, Intensity, Construction Speed, Delivery Speed, Schedule Growth, Start up, Call backs, Operation and maintenance, Envelope, roof, structure and foundation system, interior space and layout, environmental system, equipment	Residential Buildings, Other Buildings, Heavy Industrial
PDM-2	Molenaar, K. R., Songer, A. D., and Barash, M. (1999). “Public-Sector Design/Build Evolution and Performance.” *Journal of Management in Engineering*, 15(April), 54–62.	Cost growth, Schedule Growth, Conformity to expectations, Administrative burden, Overall owner satisfaction	Buildings, Infrastructure, Heavy Industrial
PDM-3	Allen, L. N. (2001). “Comparison of Design-Build to Design-Bid-Build as a Project Delivery Method.” Master’s Thesis, Monterey, CA	Award Schedule Growth, Cost Growth, Schedule Growth, Construction cost growth, Design Construction placement, Unit Cost, Start up, Call backs, Operation and maintenance, Envelope, roof, structure and foundation system, interior space and layout, environmental system, equipment	Buildings, Infrastructure

An ID number was assigned to all 21 papers taken into account; the full reference of the work with author, year and related source was listed together with the metrics utilized in their studies. An additional field was dedicated to the industry sector of the project samples. Table 2 highlights how the industry sector division was performed.

Table 2: Industry sector division

A. RESIDENTIAL BUILDINGS	Individual Homes, Small Condominiums, Small Apartment Complexes
B. OTHER BUILDINGS	Offices, Hospitals, MILCON Projects, Schools, Large Apartment Complexes, Barracks , Light Industrial
C. INFRASTRUCTURE	Highways, Highways Paving, Bridges, Water/Wastewater
D. HEAVY INDUSTRIAL	Steel Mills, Automobile Production Facilities, Chemical Processing Plants

While reviewing the 21 papers to extract the relative metrics, we underwent a classification into either measurable (i.e. metrics or variables) or abstract in nature (i.e. constructs) factors. Any factors that could not be measured because they were abstractions intended to conceptualize latent variables were excluded from the metric sample because they were not suited for this work. Following this approach, factors, such as administrative burden, conformity to expectations, operation and maintenance, system quality and satisfaction (Owner/Overall) were deleted from the metric list because they were intended as constructs. At the end of this operation, the PDM database consisted of 43 metrics.

3.2 Metric Validation

Since the PDM metrics sample relied on only 21 papers (i.e., PDM sample), we underwent a validation task to verify if any additional relevant metrics adopted in the construction industry to assess project performance were missing. A structured research was carried on the SCOPUS database with the following key-words: “Project Success” AND “Construction” AND “Cost”, “Project Success” AND “Construction” AND “Price”, “Project Success” AND Construction” AND “Time”, “Project Success” AND “Construction” AND “Schedule”, “Project Success” AND Construction” AND “Safety”, “Project Success” AND “Construction” AND “Quality.” Since construction literature on these topics mostly builds upon previous work, only the last three years were taken into account (i.e. 2012, 2013, 2014). This search resulted in the identification of about 80 papers that were analyzed to extract the metrics used by the authors in their project performance evaluation.

The validation process is based on the concept that the metrics found in our PDM sample are representative of the vast majority of the “metric population” in the construction industry. The objective of the database consultation was to highlight the fact that the PDM metric database is sufficiently reliable and no important metrics were excluded. A set of 28 factors was identified, of which, four (i.e. formality, phase schedule factor-design, profitability, and integration) were not present in the PDM databases, but with a frequency lower than 6%, and 6 that were considered constructs, so they were not included in this study.

After the filtering, the frequency of each of the 22 remaining metrics was computed in relation to the total occurrence in each paper (59), in relation to the number of papers containing the specific metric (15) and over the total number of metric appearance (71).

Once PDM metrics were separated from constructs and validated through the triangulation with the SCOPUS database, Table 3 below, was created with the relative metrics, occurrence of the latter with respect to all the papers in the sample and the relative frequency in relation to the total occurrence in each paper (21) and in relation to the number of papers containing the specific metric. An additional computation was made to obtain the frequency of appearance of each single metric, among all 21 papers, in the specific industry sector.

Table 3: PDM metric sample classification and industry sector occurrence

Metric	Frequency (Paper)	Frequency (Metric)	Industry Sector			
			A	B	C	D
Cost Growth	95%	16%	3	14	11	6
Unit cost	38%	6%	2	8	2	2
Phase Cost Growth-Design	10%	2%	0	0	2	0
Phase Cost Growth-Construction	19%	3%	0	2	3	1

4 RESULT INTERPRETATION

Figure 1 shows the frequency distribution of PDM metrics. The mean value of the frequencies equals 2%; in particular, it can be observed that 21% of the metrics distribution is above the mean value, as follows: (a) Cost Growth (16%); (b) Schedule Growth (14%); (c) Unit Cost (6%); (d) Call Backs, Delivery speed, Intensity and Start-up costs (4%); (e) Change Order Cost, Phase Cost Growth-Construction (3%).

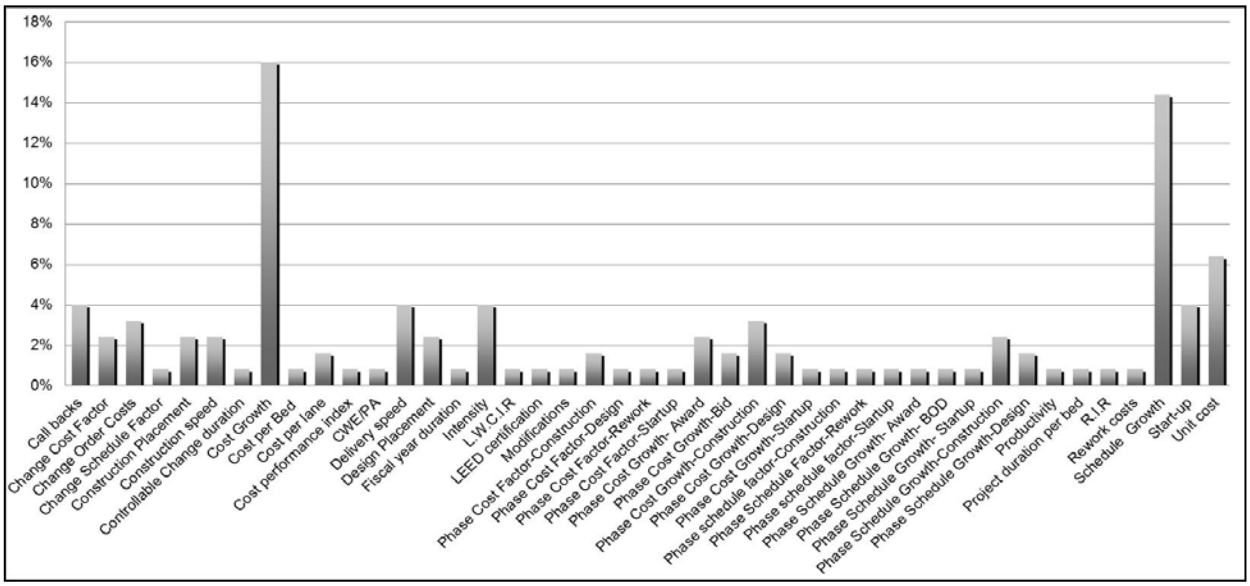

Figure 1: PDM metric frequency

Four main industry sectors have been identified though the analysis of the PDM metrics sample, as shown in Table 2. Figure 2 presents the Industry sectors distribution for each single PDM metric.

In particular, it can be observed how the maximum percentage value of the Residential building factor (25%) is at rework costs metric where the remaining factors cover the same percentages; the lower values of the same factor are recorded at schedule growth and cost growth metrics (9%). Nearly 79% of the total PDM metrics do not involve the residential building sector.

Some PDM metrics are representative for the building sector only; in particular, it has been observed how Phase Cost Factor-Design, Cost per Bed, Cost performance index, Fiscal year duration, Project duration per bed, LEED certification characterize only this industry factor. The lower values are recorded at Rework costs, Phase Cost Growth-Award, Change Cost Factor, Phase Schedule Growth-Construction, Phase Cost Growth-Design (9%). Nearly 7% of the total PDM metrics do not involve the building sector.

Some PDM metrics are representative for the infrastructure sector only; in particular, it can be observed how Phase Cost Growth-Design, Cost per lane, Phase Schedule Growth-Design are specific to this sector. The lower value is at unit cost (14%). Nearly 42% of the total PDM metrics do not involve the infrastructure sector.

As far as the Heavy Industrial sector is concerned, the maximum percent value (50%) is for the Phase Cost Growth-Startup, Phase Cost Factor-Startup, Phase Cost Factor- Rework, Change Schedule Factor, Phase Schedule Growth- Startup, Phase Schedule Factor-Rework, Phase schedule factor-Construction,

Phase schedule factor-Startup, Recordable Incident Rate (RIR), Lost Workday Case Incident Rate (LWCIR). The lower value of this sector is at unit cost (14%). Nearly 14% of the total PDM metrics don't involve heavy industrial sector.

When comparing the PDM metrics, filtered from the constructs, with the SCOPUS database, just 21 PDM overlapping metrics, appearing in both samples, have been studied over a total of 43 PDM metrics.

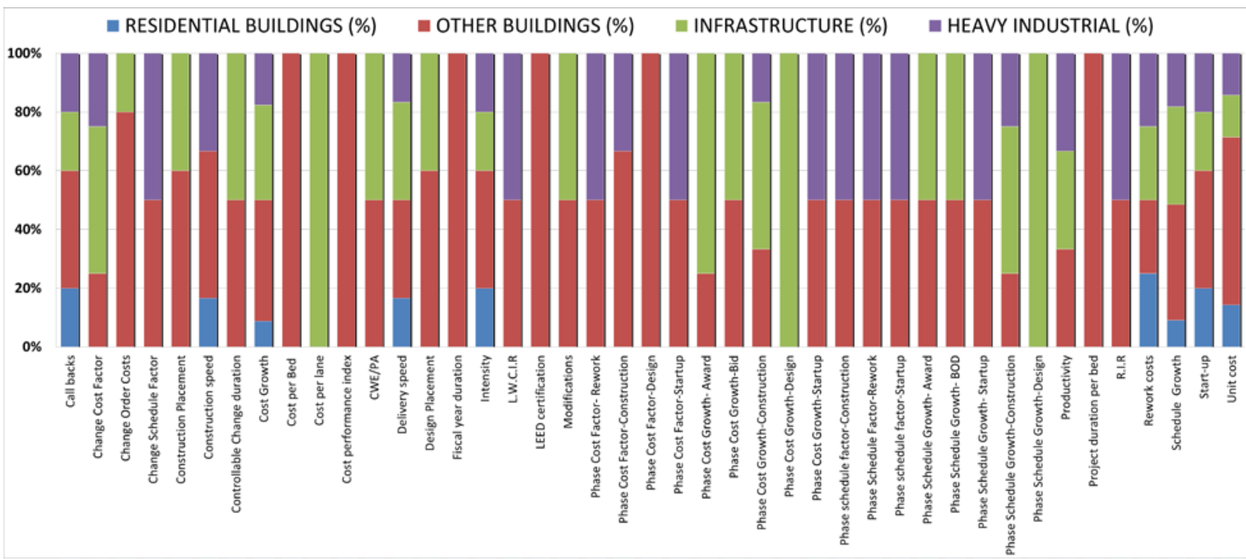

Figure 2. Industry Sector Distribution by metric

Figure 3 shows the frequency distribution of the overlapped metrics. It can be observed how the maximum and the minimum values in the two different datasets are found at the same metrics.

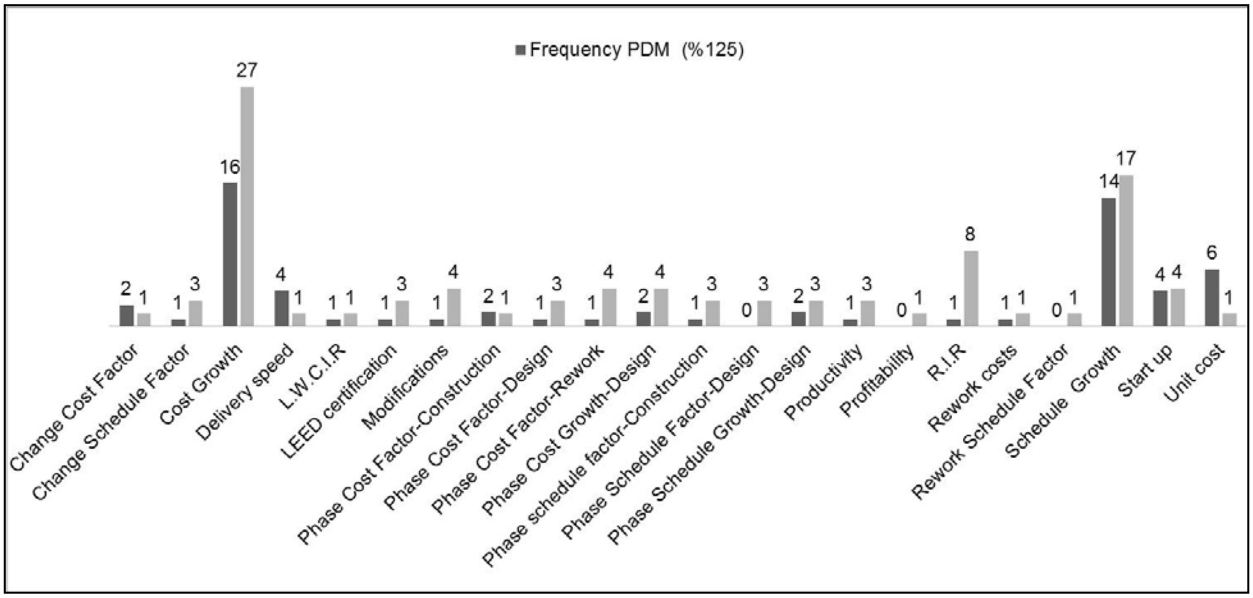

Figure 3: PDM and SCOPUS metric frequency

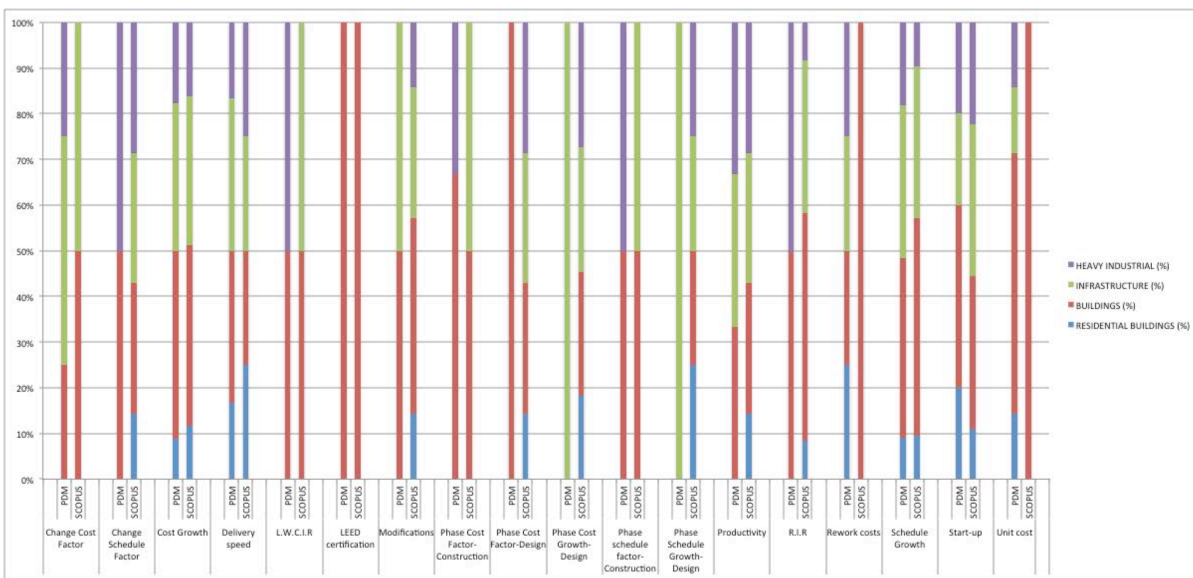

Figure 4: PDM and SCOPUS industry sector distribution

Figure 4 shows the industry sector distribution for the metrics found in both PDM and SCOPUS database. In both SCOPUS and PDM the LEED certification metric is exploited only in the building sector. Regarding the three most frequent metrics: Cost Growth appears in all four categories as well as Schedule Growth. Figure 4 shows that, as per the SCOPUS database, the Unit Cost metric is only present in the Building sector.

5 CONCLUSIONS AND FUTURE PERSPECTIVES

Recent advances in contracting approaches, delivery methods and technology have been making the construction industry more complex. Inefficient and biased evaluations about the project performance deriving from the involving technology, blurring geographical borders, green products or high quality requirement, and vague identification of roles may lead to worsening management of construction projects. Apparently, owners tend to evaluate performance through personal preferences or previous experience rather than exploiting a systematic approach; these biases could result in misevaluation, subjective measurements or ultimate failure in generating the right motivations for the involved parties.

Based on a thorough research on previously used metrics, this paper is proposed as a support for selecting the appropriate metrics that optimize evaluations and help owners efficiently make better and more objective decisions. This work is intended to provide owners of construction projects with: (1) an objective and exhaustive overview on the metrics adopted by the most influent authors in the field; and (2) a structured selection approach for choosing the most suited set of metrics for the evaluation of their projects and project portfolios.

A set of definitions is proposed for all the identified metrics, which highlights what they measure and how they properly work as an instruction booklet. With this aided selection tool, the choice of the right metrics set requires only few simple steps. After the definition of the industry sectors involved in the project portfolio, a list of metrics, previously validated through the SCOPUS database, will be identified. The result is a subset of metrics, taken from the PDM database, that have been successfully exploited in the analysis of project involving the same industry sectors.

As a practical example presented in Figure 5, a hypothetical project owner could aim to compare the effectiveness and efficiency of a project portfolio, ranging from residential buildings, infrastructure, to heavy industrial. Using the results of our work, this owner could timely access to the list, and develop his own subset of metrics, which includes nine available metrics to choose from. This guide not only saves time for owners, but also produces a more objective outcome for projects in cross-sector evaluations.

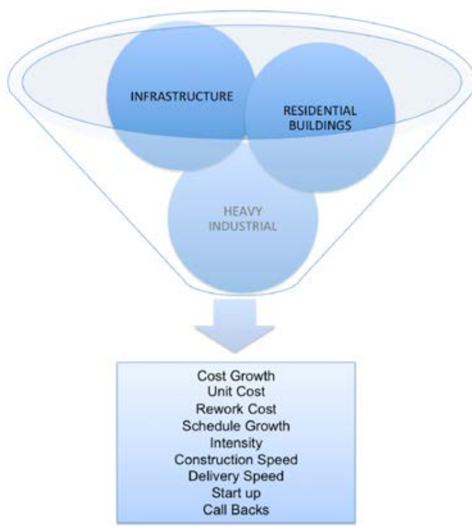

Figure 5: Structured metric selection approach

In this study, the small dimension of the PDM metric sample could be source of reduced results accuracy. Whereas the cross-validation against the SCOPUS database was designed to reduce this issue, it may be the risk that the literature on this topic may not be mature enough to encompass all possible metrics to evaluate project performance. These suggestions can be the basis for new studies in the project evaluation and delivery system field. Trying to consider in the analysis each project delivery method analyzed by the authors could lead to more accuracy.

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