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Classification of Construction Projects

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***Abstract*—**In order to address construction project requirements and specifications, scholars and practitioners need to establish taxonomy according to a scheme that best fits their need. While existing characterization methods are continuously being improved, new ones are devised to cover project properties which have not been previously addressed. One such method, the Project Definition Rating Index (PDRI), has received limited consideration strictly as a classification scheme. Developed by the Construction Industry Institute (CII) in 1996, the PDRI has been refined over the last two decades as a method for evaluating a project's scope definition completeness during front-end planning (FEP). The main contribution of this study is a review of practical project classification methods, and a discussion of how PDRI can be used to classify projects based on their readiness in the FEP phase. The proposed model has been applied to 59 construction projects in Ontario, and the results are discussed.

***Keywords*—**Project classification, project definition rating index (PDRI), project goals alignment, risk.

I. INTRODUCTION

PROJECT classification schemes allow for scholars and experts to analyze construction projects by grouping them according to similar characteristics. Due to the unique aspects of construction project [1]-[3], it is especially challenging to classify the wide range of possible projects. Nonetheless, several authors within the construction management field have developed methodologies to achieve this. Each classification scheme has a specific domain of application depending on the method employed. The use of these schemes by EPCs (Engineering Procurement and Construction), governments, general contractors, and researchers is partially contingent on the project's phase, and the nature of the information being sought, as will be discussed below.

The PDRI is a comprehensive checklist of scope definition elements which are weighted relative to their potential impact on project success [4]. Project scope definition is the process by which a project's components are defined and prepared for implementation during FEP. This is a critical stage of the project where early designs and decisions are made, the specific project execution approach is developed, and the associated risks of the project are analyzed. Over a series of workshops, construction industry experts refined the weights of the PDRI's elements to enhance its utility as a front-end risk analysis tool [5]. Based on the perspective of project participants, comprehensive analysis of the definition level of elements can facilitate risk-assessment by highlighting a project's vulnerabilities. Project readiness can also be estimated as a function of PDRI scores by benchmarking them against the performance of past projects of a similar class. This requires classification, which is not trivial.

In addition to risk analysis, appropriate classification of construction projects can provide a number of benefits [6], [7]. According to CII, grouping of similar projects can enhance project effectiveness through the consistent management of project portfolios [8]. Once projects have been suitably grouped, firms can create or employ best practices to monitor and control them [8], [9].

Standardization of classification allows for consistency in FEP [10], cost estimation, schedule development, budget and human resources allocation, and technical documentation preparation [8]. For a portfolio of projects, this approach assists both owner and contractor firms in establishing prioritization criteria for project selection and managing processes related to their execution [11]. For each category of projects, weightings of various factors underlying project outcomes can also be determined in order to assist with multi-attribute decision making [12]. Project categorization can make it easier for experts to identify trends and pervasive issues [8], as well managerial variables critical to the performance and success of each project class [13], [14]. One highly cited issue in the fields of behavioral economics and projects management is optimism-bias when forecasting outcomes of major projects [15], [16]. In this instance, forecasts are adjusted by positioning the project in a distribution of historical outcomes of previous projects in its reference class.

One characteristic discussed extensively in the management literature is complexity [17]-[21], indicating a recognition that its effects impact the management of projects significantly. Project complexity can influence such features as the selection of expertise and experience requirements of personnel, clear definition of objectives, technology integration, budget allocation, the project organization's structure [17], as well as risk management processes such as interface management [12], [22]. Depending on the scale of project complexity, the construction management process must incorporate a

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corresponding set of tools to provide a suitable level of planning and control. Understandably, conventional systems applied to complex projects can be inappropriate for regular projects, and vice-versa [14], [23]-[24]. For example, the PDRI can be invaluable for the development of nuclear power plants, but cannot be typically justified for use in residential projects due to their required cost and technical expertise. In this case, the PDRI is used to simplify complexity and provide an understandable numeric score which is actionable.

The rest of the paper is arranged into three sections. Section II explores the body of work related to construction project classification, providing a summary of common methods. Section III presents a method for classifying projects by their PDRI score during the front end planning (FEP) phase. Section IV provides a case-study of 59 complex projects categorized by the PDRI classification approach. A conclusion section summarizes findings.

II. Classification Schemes Review

A review was conducted to identify various methodologies for project classification relevant to construction management. The schemes include:

A. Rule-of-Thumb Classification
B. Classification by Complexity According to:
C. Function-Based Classification
D. Project Classification for Supply Chain Management
E. Project Parameters-Based Classification for Machine Scheduling
F. A Posteriori Project Classification Using Linear Discriminate Analysis
G. Project Classification for Strategic Portfolio Management
H. Reference Class Forecasting

Each methodology has its optimum domain of applicability, ranging from a general guide for rapid project classification, to detailed project characterization schemes for scheduling purposes. Some of these methods will be directly related to our proposed PDRI classification model, while others will only share a conceptual overlap.

A. Rule-of-Thumb Classification

The definition of a 'project' is interpreted differently between authors [25]-[31]. Santana defines construction projects in practical terms, as 'the sum of planned activities, material or otherwise, of an organization to convert an idea or a design for engineering or construction work to fulfill human or economic needs within limits of quality, cost and duration [9]. Santana breaks down construction projects into three categories: singular, complex, and normal. This hierarchy orders a project according to decreasing degrees of social, economic, and environmental impact, and decreasing numbers of specialists, consultants, and contractors employed.

Singular projects are unique, high impact endeavors undertaken by governmental or multinational institutions. These projects demand enormous capital, the most advanced technologies, and intricate systems of management and execution. Examples of such projects are the English Channel Tunnels linking England and France, the bridges joining the islands of Honshu and Shikokuh in Japan, and the Itaipli Dam on the Broil-Paraguay border [9]. A step down from singular projects is complex projects. The majority of industrial projects, public works, and town development schemes can be classified as complex. They share many of the same features as singular projects but lack uniqueness and involve more familiar problems. Examples range from airports, to railways, to oil and gas pipelines. The lowest class comprises normal construction projects such as buildings, roads, and earthworks. Their execution period is normally short, with planning and technical specifications completed before construction. One general contractor can normally handle this kind of work, usually involving only one type of engineering.

Once these categories have been established, features of the projects are subjectively evaluated on a scale from 0 to 10 according to importance. Santana uses two separate checklists of varying detail to assist in classifying projects. The score sheet in Fig. 1 allows for rapid project characterization, supplemented by a comprehensive inventory of features when a more conclusive rating is required [9].

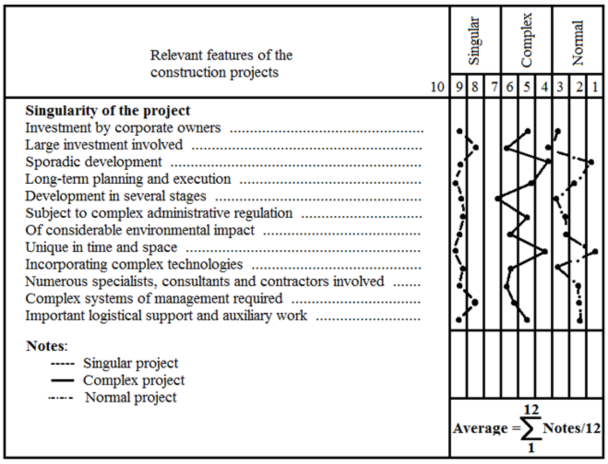


Fig. 1 Rapid Project Classification using rule-of-thumb criteria [9]

Projects with an average feature rating of 0 to 3 are considered normal, 4 to 6 complex, and 7 to 10 singular.

B. Classification by Complexity According to:

Complexity can be defined along various dimensions relevant to projects. Depending on the definition of complexity used, different elements become important to how a project is classified during analysis. Two methods based on separate and commonly cited dimensions are discussed below.

Organizational/technological differentiation and connectivity: Reference [17] operationalizes the definition of complexity in terms of two systems theory concepts: differentiation, and connectivity. Differentiation describes the number of varied elements (i.e. components, specialists, tasks), while connectivity expresses the interdependence of elements. This definition takes the view of projects as complex systems consisting of many dimensions such as organizational, technical, environmental, informational, and decision making. This methodology considers two project dimensions most commonly referenced in project management literature: organizational and technological complexity. These dimensions are then appropriately managed through integration once properly classified. For example, [22] extends [17] by classifying projects according to complexity, relative size, and organizational risk maturity level, among other factors. These can be qualitatively estimated through a weighted questionnaire. The authors then describe how a generic project risk management procedure can be adapted to project circumstances once its characteristics have been established.

The concept of organizational complexity is subdivided into its substituent components according to Baccarani's proposed definition. The organizational structure underpinning a construction project can be examined in terms of vertical and horizontal differentiation, as well as the interactions and interdependencies between organizational elements [32]. Vertical differentiation refers to the depth of an organization's hierarchical structure. Horizontal differentiation can be defined in terms of organizational units (i.e. departments, teams) and task structure, which can be achieved through the division of labour and/or through personal specializations. The level of organizational complexity can be classified in terms of three interdependencies: pooled, sequential, and reciprocal [28], with reciprocal interdependence introducing the most complexity and dominating the construction process [29], [30].

Despite a lack of consensus on its definition, the broad meaning of the term 'technology' as the 'transformation processes which convert inputs into outputs' is cited [34]. Technological complexity by differentiation then refers to the variety in some aspect of a task completed during a project such as the number and diversity of inputs/outputs [35], number of separate actions to produce the end product of a project [36], and number of specialties involved [37]. There is some degree of overlap between technological and organizational complexity in this regard. As with organizational interdepencies, technological interdependencies in a project can be characterized as pooled, sequential, and reciprocal, between a network of tasks, teams, different technologies, and inputs [33]. The other dimension of technology referenced by Baccirini is uncertainty, which is covered by a related classification scheme in the following Section 2).

Scope and technological uncertainty: Assessing construction project complexity from the perspective of scope and technological uncertainty is also a classification scheme used in practice [38]. As shown in Fig. 2, the three levels of scope include assembly, system, and array. Assembly complexity represents a project that includes a collection of components and modules combined into a single unit. System complexity identifies a project that consists of a complex collection of interactive elements and subsystems within a single product, and array complexity signifies a program rather than a single project. In 2012, CII launched a research team to study project complexity. It is considered to be a project feature which drives the applicability of different management systems and processes such as interface and supply nexus management.

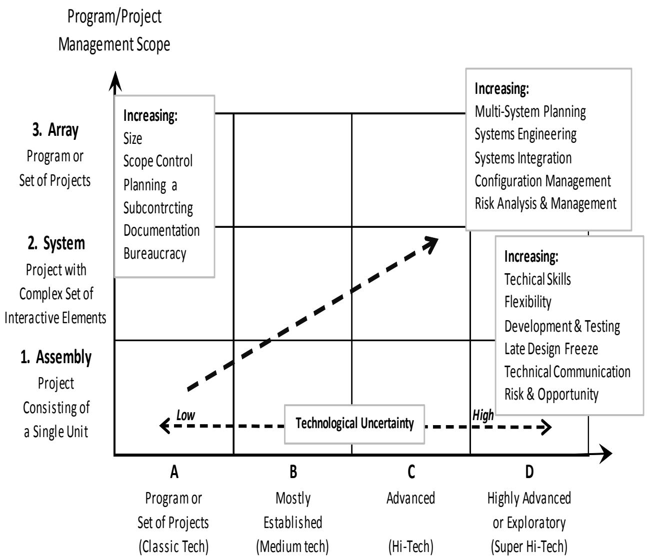


Fig. 2 Project Classification Systems Based on Complexity [38]

C. Function-Based Classification

The functional outcome of a project once construction is completed is also an important feature of a project. Reference [39] groups construction projects according to the type of construction work being completed, as follows:

GroupA. Roads, bridges, tunnels, railroads, rapid transit
GroupB. Petrochemical refineries, pipelines, power plants, etc.
GroupC. Steel plants, automobile plants, machinery shops, etc.
GroupD. Pharmaceutical plants, electronic plants, hospitals
GroupE. Food plants, textile plants, water plants, paper mills
GroupF. Additional types other than those listed above

D. Project Classification for Supply Chain Management

Reference [12] asserts that fully categorizing construction projects is impossible due to the numerous attributes that could be used to define classes, and the existence of unknown factors. This results in a lack of a generally agreed-upon framework for classifying construction projects because of their uniqueness and disparity in terms of size, time, investment, complexity, and technological content. The challenge is optimizing the selection of characteristics for defining the most ideal categories when applying a supply chain model [40] to the project. Safa classifies construction projects with respect to their size, complexity, and risk tolerance. Projects are categorized into four possible classes that have overlap but generally involve varying levels of detail:

1. Class I (megaprojects): refers to projects that have budgets exceeding $1B and require planning and execution over a very long term (more than three years). It includes government and national institutions have an enormous economic, social, and ecological impact.

2. Class II (large and unique): the investment in this class of project involves more than $100M as well as long-term planning and execution (more than two years). These projects can share many of the class I features but are unique, with complicated management and implementation systems. Numerous contractors, specialists, and consultants are employed, and the most advanced technologies are used.
3. Class III (complex): requires middle-level planning and execution within a shorter time frame (one to three years). These projects usually have budgets between $10M and $100M. A complex project is not unique, and the problems involved are not overly complicated. Most industrial projects and many public works are categorized as complex [9].
4. Class IV (basic and normal): an investment of up to $10M would be considered for this class of project. The projects are carried out with one year of planning or one budget period, with the use of measurable targets. Projects such as housing, earthworks, buildings, and roads can be considered class IV construction projects.

E. Project Parameters-Based Classification for Machine Scheduling

Reference [41] proposes a notation and classification scheme for project scheduling which is compatible with what is commonly accepted in machine scheduling. The classification scheme describes the resource environment, activity characteristics, and objective function of the project. This approach allows for a project schedule to be modeled in terms of stochastic activity durations, which account for hard-to-predict factors or events which can introduce uncertainty in a project schedule (i.e. weather conditions, resource usage obstruction, supply chain delays, contractor disputes, etc). Each stochastic model requires a tailored method to manage inherent computational complexity within the problem. Proper project classification based on relevant parameters allows for the appropriate machine planning method to be applied. The specific project parameters are detailed in the authors' research paper, and are beyond the scope of this review.

F. A Posteriori Project Classification Using Linear Discriminate Analysis

Reference [13] researches a more natural, empirical project classification scheme by using linear discriminant analysis. This allows for project success factors to be identified for different project classes, which in turn influence decision making by project managers. Three major classification constructs emerged from this analysis: pure software vs. hardware projects, project scope (or complexity), and project outcome (i.e. a new facility, building renovation, etc). From the construction management viewpoint, the first construct can be ignored as all construction projects are primarily hardware projects with varying degrees of software integration. The paper's classification scheme assesses project characteristics in terms of managerial variables which are detailed across several tables (a sample is provided below).Consequently, managerial variables critical to project success emerges from this analysis.

TABLE I
LIST OF MANAGERIAL VARIABLES AND MANAGERIAL FACTORS [13]

Organization of Managerial Variables	
Managerial Groups	Managerial Factors
Project initiation and pre-contract activities	Definition of operational need
	Urgency of need
	Alternative Solutions
	Definition of technical and operational specs.
	Pre-contract activities
	Customer follow-up team
Project preparation and design quality, Technological infrastructure and design methods	Pre-project preparation
	Management Policy
	Technological Infrastructure
	Prototypes
	Number of design cycles
	Design freeze timing
	Design considerations
Planning and control processes	Project milestones
	Project control
	Effectiveness of project control
	Budget management
	Discussions and reports
Organizational and managerial environment	Organization environment
	Manger style
	Communication style
	Flexibility in management
	Delegation of authority
	Organizational learning
	Team characteristics
	Manager qualifications

G. Project Classification for Strategic Portfolio Management

Project classification within portfolio management depends on the overall portfolio formation strategy of the firm in question [8] interviewed a set of owners and contractors to extract the most common grouping approaches. Each type of firm is motivated by different considerations, although overlaps exist. The authors report that all contractors interviewed group their portfolio projects according to client first, then by geographic location. Conversely, owners typically group their projects by different business lines, taking size and geography as secondary considerations. This approach is probably motivated by profit and loss centres being arranged along business lines. The purpose of project grouping by industry/technology/product is that projects in each class share similar expertise, and generally involve the same construction activities.

Project priority is an alternate project classification scheme used to manage portfolios [8]. A formal method can be employed with criteria covering project maintenance, environmental and safety concern, and cost/strategic considerations. As reported by contractors, prioritization is usually client and/or resource driven for contractors. This is due to the fact that client turn-around dates; construction windows, operating priorities, budgets, and human resources are significant determinants of a project's schedule.

H.Reference Class Forecasting

In reference class forecasting, project classification encourages management to consider an "outside view" of planned actions when forecasting project outcomes. By framing the project in terms of previously completed projects in its reference class, an experience-based estimate of a project's performance can be formed. Reference [15] introduced this method as a means of counteracting the effects of optimism-bias and strategic misrepresentation on project decision making under risk. In addition to other findings, the work demonstrates how errors in judgment are systematic and predictable instead of random. Undue optimism in project forecasts is likely a result of bias from organizational pressure and overconfidence, rather than confusion alone. Distributional information, or experience/data regarding the completion of past, similar actions is often ignored in favor of a more singular approach focused on the unique characteristics of the current task. Termed the "planning fallacy" [42], this judgment error manifests itself in project planning when costs, completion dates, and risks, are underestimated while the benefits of planned actions are overestimated. To help curb impartiality, the authors suggest a three-step process:

1. Classify the project by identifying a relevant class of reference projects that is extensive enough to be statistically significant, and narrow enough to warrant comparison with the project being analyzed.
2. Ascertain the probability distribution of the selected reference class based on credible, empirical data from a sufficient number of projects within the class.
3. Position the specific project in the distribution and adjust predictions of the most likely outcome for the specific project.

TABLE II
CATEGORIES AND TYPES OF PROJECTS USED AS BASIS FOR REFERENCE CLASS FORECASTING [13]

Category	Types of Projects
Roads	Motorway , trunk roads, local roads, bicycle facilities, pedestrian facilities, park and ride, bus lane schemes, guided buses on wheels
Rail	Metro, light rail, guided buses on tracks, conventional rail, high speed rail,
Fixed links	Bridges, tunnels
Building projects	Stations, terminal buildings
IT projects	IT system development
Standard civil engineering	Included for references purposes only
Non-standard civil engineering	Included for references purposes only

Selecting an appropriate reference class of projects is not always possible. It is more difficult when precedents cannot easily be found for the project outcome being forecast, which can occur if the project incorporates new and unfamiliar technologies [43]. When conditions in steps (1) and (2) are met, however, the method can be employed to mitigate over-optimism during the appraisal of major capital projects. Reference [16] demonstrates this approach in practice in its recommendations to the UK Department of Transport and HM Treasury regarding forecasts of transportation infrastructure projects. Table II outlines the possible categories of projects used for step (1) of this implementation.

Probability distributions were established for each category in Table III from available data of projects in its class, fulfilling step (2) of the procedure. A curve is produced comparing "Cost overruns vs. budget" against "Share of projects with given maximum cost overrun", as seen in Fig. 3.

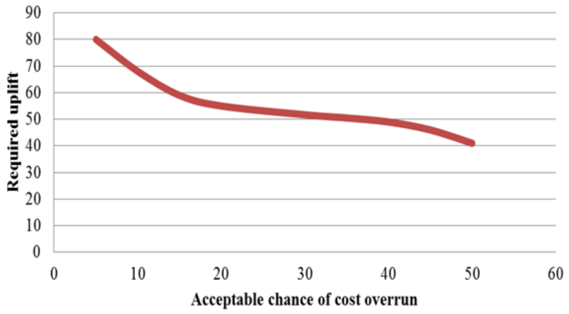


Fig. 3 Required uplift for rail projects as function of the maximum acceptable level of risk for cost overrun, constant prices [16]

In order to estimate the required budgetary uplift for the project, the acceptable risk tolerance for the project must be determined. On the basis of the probability distribution seen in Fig. 3, if a rail project is willing to take on a 40% risk of cost overrun, the required uplift would be 50%. If only a 5% risk of cost overrun is acceptable, then the required uplift is 80%. However, if a reserve fund is set up, cost control measures must be put in place to ensure accurate quantified risk assessment and efficient use of financial resources [16], [43].

In this instance of project classification, a project is categorized so that historical data of projects in its class can be used to unbias forecasts of its outcome. In Section 3, a method is presented which classifies projects according to their PDRI score. This scheme allows for a comprehensive classification to be made, based on the sum of weighted scope definition elements which quantify project readiness during FEP. This provides a structured approach for the project management team to uncover project risk factors during the planning phases of the project. In addition reference class forecasting, this method is also used as a benchmarking tool to adjust alignments of expectations for project performance. The details of this process are discussed below.

III. PROJECT CLASSIFICATION BY LEVEL OF DEFINITION USING PDRI

Critical to any controlled approach to managing elements of a construction project is detailed documentation relating to FEP, internal and external risks, and ongoing management. The process of using the PDRI for classifying capital projects is information intensive, multidisciplinary, and time consuming. Therefore, the first step for project classification by PDRI is gated evaluation. In this step, a general assessment is made of the applicability of the PDRI to the specific project, and whether it should be considered for the final score calculation process. Gated evaluation includes key criteria such as cost, schedule, quality, safety, scope, reputation, operations, environmental, regulatory, visibility, expertise, and complexity. Quality in this context can be described as meeting the projects' legal, aesthetic, and functional requirements [44]. If a project is determined to be simple, and critical project data is unambiguous, FEP can be easily and effectively performed without a PDRI evaluation. This step is conducted by project managers and experienced project stakeholders who subjectively decide whether the FEP process is successful. If the management team decides to follow through with a PDRI evaluation, the project is assessed at various stages during FEP [45], however, the authors recommend the PDRI be used in all three stages of the FEP process.

When the project management team decides to apply the PDRI for project classification, the characteristics of each project is carefully considered in order to select the most appropriate PDRI version. This may be established based on the project's primary designers, in addition to the main design/construction expenditures of the project. Depending on which category fits best, the project should be categorized as Building, Industrial, or Infrastructure, as elaborated below [46]:

- *PDRI Building projects:* normally designed by architects, the space involved is typically developed for living, working, and social interaction. The building and its systems often comprise the majority of project costs. This can include offices, schools, medical facilities, banks, shopping centres, and warehouses.
- *PDRI Industrial projects:* usually designed by process engineers (mechanical/industrial/ chemical), these projects include costs with extensive piping and mechanical equipment often comprising more than 50% of the project cost. Examples are: power plants, water treatment plants, manufacturing plants, refineries, and steel mills.
- *PDRI Infrastructure projects*: often designed by civil engineers, these projects primarily perform a function that is integral to the effective operation of a system. Infrastructural projects provide capacities such as transportation, transmission, distribution, collection, and the interaction of goods, services, or people [47]. In terms of scale, these projects generally span a broad geographical region; affect multiple jurisdictions and stakeholder groups. Examples include: pipelines, electrical transmission/distribution, fiber optic networks, highways, railroads, and canals.

It is also possible for the project to be classified as a hybrid of the three PDRI versions with a hierarchy of types. For example, the overall project may fall under Industrial, while the related subprojects could be categorized as Building and Infrastructure. In this case, the appropriate PDRI version should be applied on an individual project basis, which is beyond the scope of this work. For the general case, PDRI project classification is illustrated in Fig. 4.

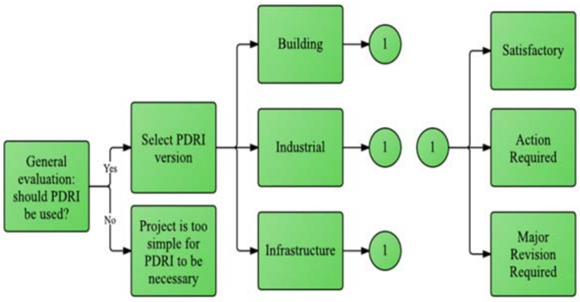


Fig. 4 Flowchart of PDRI project classification process

Once the specific version of the PDRI has been selected, a facilitator team is matched to project needs based on the project industry, asset type, project size, and FEP stage. The facilitator team uses a comprehensive checklist of approximately 70 scope definition elements. As mentioned, these elements were weighted to underscore their potential impact on project readiness. Since the PDRI score relates to risk, vulnerable areas that need to be addressed can easily be isolated [48]. Fig. 5 illustrates the FEP intervals at which the PDRI is applied.

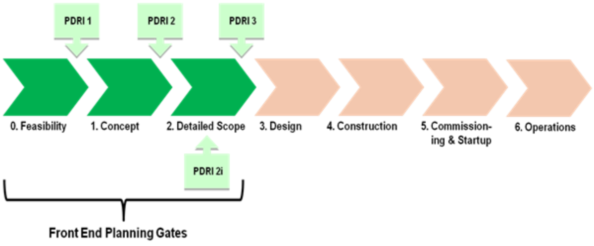


Fig. 5 Gated Front-End Planning Process

As shown in Fig. 5, PDRI 1 is used after the feasibility phase of FEP as a high level assessment of the project. This assessment is usually held at the kickoff meeting of projects when meeting with an architect/engineering firm early on. PDRI 2 is a high level assessment of the project following the Concept Development phase of the project. The PDRI 2 review evaluates the alignment of project objectives with stakeholder needs, identifies high priority project deliverables, helps anticipate late project surprises, and facilitates communication across the project team and stakeholders. PDRI 2i is an intermediate (i) assessment of the project during the Detailed Scope phase of FEP, held at its midpoint. It further assures the alignment of project objectives with stakeholder needs, confirms efficient deployment of resources, verifies scope in relation to original project goals, and identifies and plans remaining activities necessary to proceed to the next FEP phase. PDRI 3 is the final assessment of the project during FEP, where risk issues have been identified and mitigation plans prepared. Usual scores for this evaluation are between 150 to 250, with a preferred score between 200 or less. The acceptable PDRI score ranges for the various phases of FEP are summarized in Table III. The ranges are contained in Table III is employed in the last stage of the proposed classification scheme [39].

TABLE III
ACCEPTABLE PDRI SCORES FOR STAGES OF FEP

Stage	PDRI 1: Feasibility	PDRI 2: Concept	PDRI 2i: Detailed Scope	PDRI 3: Detailed Scope
Typical Min	550	450	300	150
Typical Max	800	600	450	250

Once the PDRI score is calculated, if it falls below the acceptable range for the evaluated FEP phase shown in Table III, it can be classified as being Satisfactory. If The PDRI score falls within the acceptable range, it should be classified as Action required, if it is above this range, then it should be classified as Major Revision Required. This classification scheme can be used in risk analysis where poorly defined scope elements can be identified. Generally, a lower PDRI score corresponds to a well-defined scope definition package, resulting in better performance and a higher probability of project success. This classification also assists project managers in evaluating whether work under their supervision is ready to continue to the next step. The following section demonstrates this classification method by presenting how it was applied to 59 construction projects.

IV. RESULTS AND DISCUSSION

The PDRI scores were collected from PDRI users involved in projects of various types and sizes in North America, in the period between 2011 and 2014. The professional PDRI facilitators were able to guide PDRI sessions to produce a quality scope definition package in a limited amount of time. In approximate terms, the resources and time used for a PDRI scope definition package per project are: one facilitator and one co-facilitator per PDRI session with a total of six, four hours per session, and three PDRIs during front-end planning (feasibility, concept, and detailed scope phase gates).

They applied the best industry practices along with their experience for conducting PDRI sessions. Due to confidentiality restrictions, neither the actual names of the construction companies nor the projects can be mentioned in this paper.

The first step of the PDRI classification scheme necessitates a subjective assessment of whether the PDRI is applicable to the specific project or not. In this study, only the projects which were determined to require a PDRI evaluation are considered. As shown in Fig. 4, the second step in the classification process is determining the PDRI version depending on project characteristics. This step was applied to the sample data, categorizing the projects as either for Building, Industrial, or Infrastructure projects. The result is summarized by Fig. 6, which shows the distribution of PDRI versions present in the sample data set.

Out of the 59 projects assessed using PDRI, 96.61% were categorized as Industrial projects, while the remaining projects were divided evenly under Infrastructure and Building types.

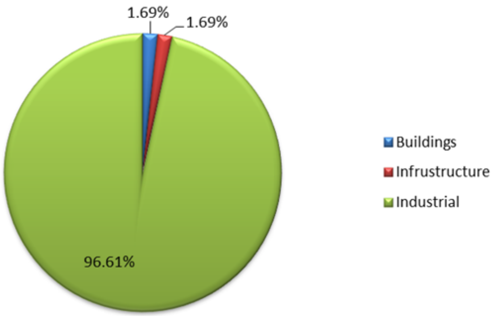


Fig. 6 Percentage distribution of project types

The third step of the classification process uses the normalized final PDRI scores to classify projects into three separate categories: Satisfactory, Action required, and Major Revision Required. As illustrated in Fig. 7, only three projects were classified as Major Revision Required for the sample data studied. The practical recommendation for these three projects is not to proceed any further until all FEP elements are evaluated and corrective actions applied. 24 of the projects were classified under Action required, meaning that FEP should continue while PDRI session comments and action items are addressed in parallel.

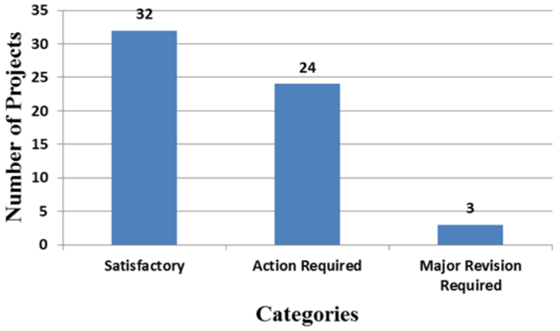
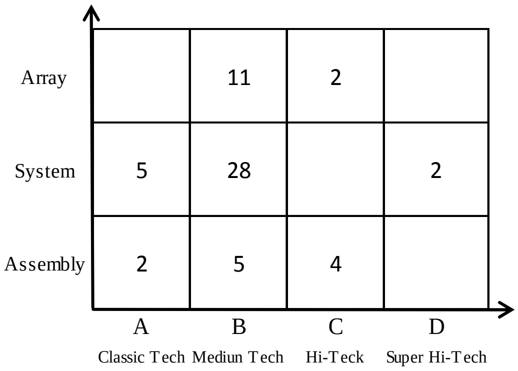


Fig. 7 Classification of projects by PDRI



	A Classic Tech	B Mediun Tech	C Hi-Teck	D Super Hi-Tech
Array		11	2	
System	5	28		2
Assembly	2	5	4	

Fig. 8 Project classification systems based on complexity

The result shows 32 projects are categorized as satisfactory, not obligating any major corrective actions. However, 27 of the projects are considered to be 'at risk' under this classification scheme.

In many cases, it can be challenging to determine the optimal scheme for classifying a set of construction projects. Classification schemes are by no means mutually exclusive, or one-size-fits-all. The same projects may be classified using different schemes depending on the purpose for categorizing the project. As discussed, the proposed method can be used to classify construction projects in terms of associated risks identified during their FEP phase. For example, the 59 projects discussed have also been grouped from the viewpoint of project complexity, displayed in Fig. 8.

By aggregating PDRI results and considering other factors at a portfolio level, new insights can be gained. This includes risk monitoring based on the aggregate profile of the projects at each of the FEP gates as they transition into the execution phase. Table IV illustrates how a sample portfolio of 14 projects can be mapped based on their definition level, and other factors such as cost, duration, and change orders. These values have been normalized and do not represent actual project data. Visualization software [49] can be used here to provide the project management team with a summary of the status of projects in terms of risks and other dimensions. This enhances their ability to make quick assessments of portfolio's condition, so that a judgment can be made on where to prioritize the management team's actions.

The software can then transform the information from Table IV into a parallax view to help visualize the distribution of project data in terms of the dimensions discussed.

Fig. 10 gives a view from our visualizer which summarizes the status of projects according to four metrics: PDRI on the X-axis, Cost on the Y-axis, Duration by circle color, and Change Orders by circle size.

TABLE IV
NORMALIZED DATA FOR 14 PORTFOLIO PROJECTS

Project (#)	PDRI Score (normalized)	Total Cost (m$)	Duration (month)	Change Order (#)
1	106	6.1	16.5	235
2	134	5.2	5.5	340
3	182	6.6	11.0	304
4	209	2.4	5.5	124
5	106	2.2	0.6	60
6	132	3.8	11.0	104
7	138	7.9	0.4	334
8	161	3.3	0.6	50
9	86	1.8	5.5	145
10	157	7.0	16.5	502
11	100	2.0	5.5	144
12	165	32.8	5.0	618
13	834	3.7	11.0	284
14	183	15.2	5.5	393

PDRI classification allows for risk factors to be quantified, and the visualization software provides the opportunity for the management team to prioritize project risks according to cost and duration. In addition to these factors, projects can be visualized and compared in terms of other dimensions such as project complexity.

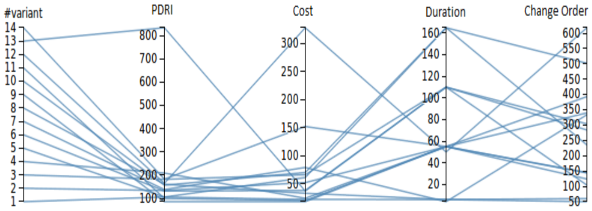


Fig. 9 Parallax view

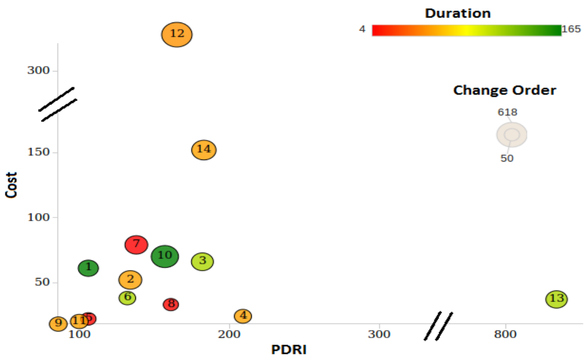


Fig. 10 Bubble chart

The presented method exploits results of over two decades of research by CII members who are senior project managers and scholars with years of research experience in the area. The industry risk metrics of the method is based on a large number of industrial projects [46]. Therefore, this method could be considered as one of the best approaches to classification of projects in terms of the risk.

V. CONCLUSION

This study provides a concise review of selected methods for construction project classification. A new classification method using PDRI is introduced, measuring overall project readiness during FEP. This proposed classification can help project managers address risk and decide to commit resources to maximize project performance and the probability of project success. Facilitation sessions are time-consuming for the key members of project management teams; however, ignoring any deficiencies in FEP can potentially incur significant costs and delays on the project. In terms of the range of classification schemes discussed, project classification by PDRI is comprehensive and useful as either a stand-alone method, or in conjunction with other schemes.

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