A Construction Project Classification Framework: Mapping the Dimensions for Classification of Pacific Northwest Highway Project Types

FINAL PROJECT REPORT

by

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16. Abstract

In the construction industry, it is an accepted fact that not all projects are created equal, so analysis and evaluation of project performance should follow the same principle. Gaining insights into contract performance requires practitioners to compare project performance on various dimensions, look for patterns, and make generalizations. In contract administration, practitioners are interested in project performance as it relates to cost, time, quality of work, scope of work, and contract changes.

A standard project type classification framework that would allow such comparisons does not exist for use by practitioners working on highway projects. In the absence of a standard project type classification framework, practitioners have taken the pragmatic and ad hoc steps to classify projects to meet their specific needs. The lack of a standard project type classification framework makes it difficult for practitioners who administer highway projects to effectively gain insights, find patterns, generalize findings, extend knowledge, and transfer knowledge gained.

Following qualitative synthesis research and participation from Pacific Northwest (PNW) state departments of transportation (DOT), a project type classification framework was developed. The proposed project type classification framework captures the differentiating dimensions and corresponding measures that define highway projects. A data input wireframe was also developed for implementing the project type classification framework into a searchable database.

The significant contribution of this study was that basic project performance analytics can be enhanced by using the project type classification framework. In addition, the proposed project type classification framework would eliminate the use of ad hoc classification systems. It is recommended that future research focus on evaluating whether the proposed project type classification framework enables better visibility of and insights into contract administration.

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Executive Summary

In the construction industry and on highway projects, some key questions and problems are centered on practice and performance – what was done and what is the outcome. In contract administration, practitioners are concerned about project performances as they relate to time, cost, quality, scope of work, and contract changes. Specifically, they want to know why a project was or was not completed on time, why a project was or was not on budget, why the quality goals for a project were or were not met, and why the scope of work on a project changed or did not change. To answer these questions effectively, practitioners must have a framework that allows them to compare and contrast project types, look for patterns, and make generalizations that reflect reality. According to the Congressional Budget Office (CBO, 2015), in 2014 over $165 billion were spent by the federal, state, and local transportation agencies on highway projects, and the amount is projected to rise in coming years. With increasing expenditures come concerns about overruns, delays, and poor contract administration on highway projects. Regarding cost overruns, some notable cost overruns highlighted by Edwards and Kaeding (2015) include the Boston Big Dig that increased from $2.6 billion to $14.6 billion, the San Francisco-Oakland Bay Bridge that increased from $1.4 billion to $6.3 billion, the New York City WTC Rail Station that increased from $2.0 billion to $4.0 billion, and the Denver West Light Rail that increased from $250 million to $707 million. The lack of a standardized method to classify projects makes it difficult for practitioners to identify trends and patterns, and to use such information to inform and enhance practice. It is an accepted fact in the construction industry that not all projects are created equal; therefore, analysis and evaluation of projects should follow the same principle. However, a standard method for classifying highway project types does not exist. Hence, the objective of this research was to develop a classification

framework for highway project types based on several different dimensions of projects. Following a qualitative synthesis research method and participation from Pacific Northwest (PNW) state departments of transportation (DOTs), the researchers developed a framework, which was reviewed by the PNW state DOTs. Buy-in was obtained, and the framework was updated on the basis of the feedback received. The proposed project type classification framework captures projects' different dimensions and corresponding metrics. In addition, this project developed a data input wireframe (mock-up) for implementing the framework into a searchable database.

The proposed project type classification framework could help to focus research efforts and practices in the area of contract administration for state highway projects and programs. The significant contribution of this study was that state DOTs can enhance basic project performance analytics within and across states by using the standard project type classification framework. It is recommended that future research focus on evaluating whether the proposed framework will enable better visibility of project performance patterns and trends.

Chapter 1 - Introduction

1.1 Background and Overview

According to the Congressional Budget Office (CBO, 2015), in 2014 over $165 billion were spent by the federal, state, and local transportation agencies on highway projects, and the amount is projected to rise in coming years. With increasing expenditures come concerns about overruns, delays, and poor contract administration on highway projects. The construction industry's inability to control cost overruns and project delays may be due in part to practices that are not grounded in the understanding that not all projects are created equal. Given that no two projects are the same, it is easy to understand the limitations of research that seeks to understand the root causes of project overruns and delays when such evaluations are based on a mix of project types as opposed to a specific project type. Such research fails in design and method and may not truly represent the phenomenon that researchers seek to measure and understand. The problem is due in part to a lack of proper classification of project types for researchers to use. An in-depth classification of project types could help researchers pinpoint patterns and connections and identify key attributes that drive practice and performance. Classification is aimed at making things more manageable. It is "not only a way of representing entities but is also a way of imposing order on them" (Kwasnik 1992, p. 63). Kwasnik posited that knowledge representation in the form of classification enables knowledge creation and discovery.

Through research, people make sense of their environment and are better equipped to make decisions that enhance and shape their future. Researchers are continuously seeking answers to questions and finding solutions to problems that are all around them. In the construction industry and on state department of transportation (DOT) projects, some of the key questions and problems are centered on practice and performance—what was done and what is the outcome. In contract administration, practitioners are concerned about time, cost, quality, scope of work, contract changes, and performance. Specifically, they want to know why a project was or was not completed on time, why a project was or was not on budget, why the quality goals of a project were or were not met, and why the scope of work on a project changed or did not change. To answer these questions effectively, practitioners must have a framework that allows them to compare and contrast projects, look for patterns, and make generalizations on the basis of specific related cases. Such a framework must properly classify or categorize the projects to be evaluated. Incorrect categorization will lead to incorrect results, incorrect findings of patterns, and incorrect generalizations.

People classify things to make sense of them, compare and contrast them, find patterns and predict recurring characteristics and traits in them, and make generalizations reflective of reality. The ability to see patterns allows the construction environment to be predicted, and this is based on the understanding that patterns do not form by chance. A study by Crawford et al. (2002) pointed out that the need for a better understanding of project characteristics and their implications for practice has driven the need for classification of projects.

Construction projects are unique. They come in different sizes, shapes, and complexity, and they are undertaken by an array of people with varying impacts on the projects. Shenhar et al. (2002) argued that one of the fundamental misconceptions in the construction industry is that all projects are the same. However, it is common knowledge that not all roadway projects are the same, and not all bridge projects are the same. For example, a flat slab bridge is not the same as a box girder bridge. Similarly, the resurfacing of existing roadway is not the same as the construction of a new roadway alignment. Gidado (1996) explained that project complexity results from the inherent nature of individual parts of a project and the connection of those parts.

In contract administration, there are several areas of interest to practitioners whose understanding is obscured because of a lack of proper project classification and categorization. Valid and in-depth analyses of contract overruns, delays, designs, engineer's estimates, contractor bid amounts, project delivery methods, and realistic costs and time information could become possible if a standard classification of project types were available to practitioners. A few state DOTs have some form of project type classification system, but they are limited in structure, depth, and application. The importance of project type classification cannot be overemphasized, as it allows a more in-depth understanding of project phenomena.

Given the overwhelming number of cost overruns on public projects, Flyvbjerg et al. (2002) concluded that on most highway projects the engineers' estimates developed for the purpose of obtaining funds, evaluating bids, and projecting actual costs are inaccurate and outright misleading. Research by Hinze and Selstead (1991) and Cantarelli et al. (2012) showed that different categories of projects behave differently in terms of the level of overruns. However, each of these studies used different project type categories, making it difficult for practitioners to replicate the research and put it to use. Two areas that highlight the importance of proper categorization of projects are the understanding of cost overruns on state DOT projects and contingency allocations on projects.

Regarding cost overruns, some notable overruns highlighted by Edwards and Kaeding (2015) included the Boston Big Dig that increased from $2.6 billion to $14.6 billion, the San Francisco-Oakland Bay Bridge that increased from $1.4 billion to $6.3 billion, the New York City WTC Rail Station that increased from $2.0 billion to $4.0 billion, and the Denver West

Light Rail that increased from $250 million to $707 million. The tendency for a project to overrun in cost or to be delayed is related to several factors. A few of those factors include differing site conditions, design errors and omissions, project environment, poor oversight, and poor management (Ellis & Thomas 2003). The level at which these factors are prevalent could be dependent on the inherent nature of different types of projects. Research on contract overruns could benefit from a more objective evaluation based on project types. Such research would reflect the fundamental principle that a project is a complex, non-routine, unique effort, designed to meet specific objectives and constrained by time, budget, resources, and performance.

Regarding contingency allocations, state DOTs use a flat rate allocation method irrespective of project type. This practice fails to reflect the uniqueness of different types of projects. This may be largely due to a lack of evidence to suggest or justify the allocation of contingency on the basis of different types of projects. Contingencies are set up for unforeseen changes in a project during construction (WSDOT 2012), which include additional work, quantity over-runs, and additional items. For WSDOT, contingencies are currently limited to 4 percent of the total contract amount for all WSDOT contracts irrespective of project type or project complexity. Caltrans adds 5 percent to the final engineer's cost estimate (Caltrans 2016) irrespective of the type of project. Oregon DOT (2010) uses a 3.5 percent fixed rate for contingency allocations on all projects.

Given the uniqueness of projects, the case can be made that current contingency allocations are arbitrarily set and could benefit from a more objective evaluation based on different project types. Anderson et al. (2007) recommended that contingency be commensurate with the level of risk associated with a project. In other words, use of a flat rate allocation for contingencies should be avoided.

According to Crawford et al. (2002), “While a generic core of knowledge and practices [is] important in defining project management as a specific field of practice, discipline, or profession, recognition of differences in project types, contexts, and management approaches [is] vital to further growth and maturity.” The authors posited that use of project types, when classified, would enable practitioners to

- Share understanding of the nature of different projects and contexts
- Select project personnel and assign them to projects
- Select appropriate project management methodologies
- Select and establish project governance arrangements
- Use it for project management competence and career development
- Analyze the performance and outcomes of projects
- Analyze and manage an organization's portfolio of projects.

In the area of contract administration, there is a need to understand how well a program or a specific project is doing in terms of time, cost, quality, scope, and changes. Projects are unique, and there are inherent characteristics that differentiate projects of similar characteristics from another. Given this premise, identifying and grouping projects on the basis of their inherent dimensions should provide practitioners with the much-needed data to understand trends and focus their efforts in areas that most need their time.

Imagine the following questions that could be answered if a standard classification of project types existed:

1. Given the various dimensions of a project, such as type of construction, construction system, physical size, geographic location, materials, etc., are there fundamental

relationships between a project's level of complexity and contract cost or contract time?

2. On comparatively sized projects of similar scope, what are the trends in time to complete the projects, contract award amounts, cost overruns, or time delays?
3. When a medium-sized project (contract value) is found to be very complex, but the time to complete it is relatively short, could a simple evaluation be conducted to understand the major factors that informed the time to complete decision, and then can necessary steps be taken if such a decision could not be validated or was not well informed?
4. Is there a fundamental pattern aligned to different project types that would allow for ease of forecasting and predictive analysis?

A well defined project type classification, one that is based on the inherent dimensions of different types of projects, should allow limitless types of questions to be asked of the project data and answers to be derived from them.

Not all projects are created equal, and any premise different from this would be inappropriate for solving construction-related problems. This understanding was echoed by Shenhar et al. (2002): "One of the common myths and misconceptions about projects is that all projects are the same and you can use similar tools for all your project activities. We call this the *project is a project is a project syndrome*, and it often leads to project failure and delays when companies are using improper project management techniques for some of their project efforts."

The need for a standardized classification system for project types cannot be overemphasized. The main purposes for such system would be to improve efficiency, improve the validity of research findings, and greatly enhance research and practice on highway projects.

A standard classification would help practitioners in selecting the right methodology for the right project or problem.

It remains true that what worked in one type of project may not necessarily work in another type of project, which is why it is important to understand how individual types of projects behave before offering a generalization that cuts across all types of projects. Most state DOTs have loosely defined categories of project types that include bridges, roadways, resurfacing, major construction, and others. One of the most comprehensive classifications is one by New Jersey DOT (NJDOT). An in-depth categorization of highway projects was captured in NJDOT's AASHTOWare project cost estimation (CES) manual (2014). The grouping of project types included the following:

- New construction
- Reconstruction, widening and dualization
- Widening and resurfacing
- Resurfacing
- Bridge repair
- Intersection improvements
- Electrical, safety and traffic control
- Miscellaneous
- Unique
- Intelligent transportation systems (ITS)
- Landscaping
- Demolition
- Drainage.

Each state DOT has some form of project categorization; some have been in use for decades and have not been revisited to assess their relevance. A project type categorization and definition would be helpful and valuable to practitioners, as it would help them to better understand how specific types of project behave instead of how a mix of project types behave.

With proper categorization of construction projects based on types of projects, practitioners would be able to investigate how different types of projects perform in relation to time, cost, and other performance measures.

1.2 Problem Statement

A major concern raised by a program administrator within the Washington State DOT (WSDOT) was that, without a standardized framework to classify highway project types, it is difficult for program administrators on state DOT programs to effectively assess trends and patterns within the projects they deliver. The lack of proper classification of project types obscures and exaggerates research findings in the area of contract administration, resulting in generalizations that fail to reflect project differences. Without considering the effects of different project types, research conducted to understand factors that affect project time and cost have limited application in real-life situations. Such research fails to provide practical solutions to problems faced by state DOT agencies. This is wholly a result of overarching generalizations based on a mix of projects types. Such practice is not deliberate but results from the fact that proper project type classification does not exist for researchers to use. An in-depth classification system of project types would help practitioners pinpoint patterns and identify key attributes that drive practice and performance.

Having standard project types as a baseline would help practitioners evaluate and administer highway projects. In the absence of a standard classification system of project types, practitioners have taken pragmatic and ad hoc steps to classify projects to meet their specific needs, without much thought to how a standardized classification framework could improve understanding of contract administration.

1.3 Research Objectives

The objective of this study was to develop a classification framework for highway project types by using relevant data from Pacific Northwest DOTs and other state DOTs. The classification framework was intended to be based on key dimensions that drive project performance and to include the type of system, geographic location, controlling scope of work, level of complexity, contractual constraint, project delivery method, and other set parameters. Such a classification framework could improve efficiency, improve the validity of research findings, and greatly enhance how practitioners evaluate and administer highway projects within the Pacific Northwest DOTs and other state DOTs. In addition, the proposed study was intended to meet the PacTrans' theme of "data-driven solutions in transportation."

This research was data-driven (rather than driven by intuition or personal experience) by objective and qualitative data to improve the analysis and evaluation of highway project types. The study collected, analyzed, and synthesized data from the Pacific Northwest DOTs and other state DOTs on various classification systems in use. The resulting classification framework is data-driven and aims to provide new knowledge on how to classify highway project types to enhance how practitioners evaluate and administer highway project types with respect to time, cost, and other performance measures. This classification framework could offer another layer of information needed for safe transportation and could allow practitioners to safely evaluate and administer highway projects on the basis that projects differ.

1.4 Research Question

How should Pacific Northwest highway projects be categorized to enhance how practitioners evaluate and administer highway projects in the future in order to improve contract administration practices and performance?

1.5 Report Organization

This report is organized into six chapters.

Chapter 2 is the literature review, with a deep dive into understanding current state-of-the-art practices as they relate to project type classification. The eight sub-sections include

- An understanding of why people classify things
- The different ordering and classification systems around us
- Aligning classification principles with the research objective
- The various forms of categories related to highway work as captured in various state DOTs' documents
- Some context of overarching generalizations by researchers, where such generalizations have failed to achieve their set objectives because of incorrect levels of abstraction of project types
- The consequences of not having a standard classification system in place
- Examples of current attempts to classify highway projects
- Several key dimensions that help differentiate one set of projects from another.

Chapter 3 follows the literature review and covers the research methodology.

Chapter 4 describes the proposed classification framework as made available to PNW state DOTs for review and updated to reflect comments and suggestions received.

Chapter 5 is a discussion of the research findings and provides an implementation guide to help PNW state DOTs implement the proposed framework within their systems.

Chapter 6 includes conclusions and recommendations.

1.6 Research Scope Limitation

The objective of this research was to develop a classification framework of highway project types as a way to enhance the practice and performance of highway projects and programs within and across Pacific Northwest DOTs. As such, the research focused on classifying highway project types only at the construction phase. In other words, the classification framework does not include non-construction-related efforts such as planning, preliminary engineering, construction engineering, right-of-way acquisition, and all other activities that are not specifically related to the construction phase of a typical highway project.

Chapter 2 – Literature Review

2.1 Why People Classify Things

According to the Census of Marine Life (2011), there are about 8.7 million species on earth, and majority of them are yet to be described and cataloged. There is no doubt that our ability to describe, catalog, and classify the various species on earth has advanced our understanding of the environment. In the field of biological science, the need to classify things is informed by certain objectives. Some of those objectives include 1) the need to compare one group to other groups, 2) the need to store and retrieve information about things, 3) the need to recognize group affiliations, 4) the need to make inference and predict behavior based on known properties, and 5) as a baseline for comparative analysis (Ohl 2007; Mayr & Bock 2002).

2.2 Ordering and Classification Systems

Bowker and Star (2000, p. 16) stated that "classification systems are integral to any working infrastructure." Orders and classifications of things exist, and these taxonomies are all around us—from the classification of the tectonic plates to the classification of rocks, to the classification of different bodies of water. Some other classification systems include the periodic table, the human brain, and such things as classification of months in the calendar, days of the week, and period of time. From classification as basic as the color of things to systems as complex as the human brain, there is an endless universe of things that people have placed in an organized structure to reflect order, group, hierarchy, and classification (Kipfer 2001).

According to Kral (1884), the understanding of the scientific community is that there are order and reasons why things behave the way they do and that classifications indicate the uniqueness of phenomena and provide a framework of reference to evaluate them. The word classification comes from the term class, which relates to a group of items that have a specific set of attributes in common (Ohl 2007). Ohl (2007) stated that inconsistent classification of things causes miscommunication and confusion and limits effective understanding of the environment.

Mayr (1995) presented four systems of classification that included (1) special purpose classifications, based on specific features and specific context, (2) downward classifications by logical division, based on dichotomous splitting in two less inclusive groups (identification schemes), (3) upward or grouping classifications in more and more inclusive groups, based on observed characteristics (traditional), and (4) Hennigian phylogenetic systems, based on common descent (family). An example of type (1) classification would be the classification of building projects based on residential or commercial buildings, while an example of type (2) classification would be to start with all soils and group them on the basis of special attributes such as coarse-grained and fine-grained. An example of type (3) classification would be the construction industry and its sectors, as in residential, commercial, industrial, and infrastructure, and an example of type (4) classification would be the families of construction materials (soil, rock, concrete, wood, metal, masonry).

Mayr and Bock (2002) posited that our world is full of chaotic diversity of things, and it is the role of the researcher to make sense of all the diversity that would allow for better understanding of how things work. According to the authors, before a scientific explanation can be given of the chaotic diversity in life, a formal classification of things must be made to reduce the chaos to a more manageable state. Earthwork and foundation operations are typically the first few operations that start every construction project, and this is made possible from our understanding of soil mechanics, as evident in soil classifications and their properties. Soil classification is just one of the many classification systems that are used in the construction industry to simply the chaotic diversity of the construction process. It is important to note that these classification systems were developed for various purposes, and in the case of soil classifications, for better understanding of soil behavior and how it can be constructed using the right tools and techniques.

According to Afsari and Eastman (2016), Uniformat and MasterFormat classification systems are the most widely used classification systems for project breakdown. Uniformat II classification is based on functional elements (physical parts) of a construction facility called systems and assemblies. Currently, Uniformat II has been classified for a building project, for a bridge project, and for a highway project. MasterFormat is organized on the basis of typical construction work results, requirements, products, and activities. The main collections of related construction products and activities are level one titles or "divisions," and each division is made up of level two, level three, and often level four numbers. It is important to note that there is a difference in the level of detail required or resulting from the use of these two classification systems.

2.3 Aligning Classification Principles with the Research Objective

As in other industries, the construction industry maintains an array of construction-related classifications based on certain principles. In general, theories of classification are principles that can be used as a basis for classification. According to Hjørland and Nissen Pedersen (2005), each classification framework, whether explicit or implicit, is derived from the classifier's theories, perspectives, and purposes. The selection of classification criteria is always influenced by the underlying theory, individual knowledge, and expertise.

According to Niknzar and Bourgault (2017), each theory for classification sees the subject through its own lens. Therefore, a researcher who is a proponent of some theory or theoretical perspective (e.g., contingency theorist) can select the significant principles from that perspective as the classification criteria.

The field of natural sciences has led the way in developing theories for the classification of species. In biology, phyletics is a theoretical model of evolution, originating from the works of others such as Mayr and Ashlock (1969) and Ross (1974), that is based on the historical origin and evolution of lineages and species.

Even though phyletics as a theory for classification was intended to classify species, it is frequently applied to other areas such as organizational science for classification of organizational types. Some researchers in organizational science have used phyletics to classify organizations on the basis of how organizations evolve over time (McCarthy, 1995; McCarthy and Ridgway, 2000).

2.4 Various Categories of Work Related to Highway Work

Like other industries, the construction industry maintains an array of classifications for construction-related information and knowledge. Such classifications make it easy for practitioners to plan, design, contract, construct, and operate various built environment facilities. For various policy-related reasons, state DOTs maintain and use various design and construction practice standards that define various categories of highway work. Figure 2-1 provides a view of the various categories of work related to highway work that are in use within and across the state DOTs.

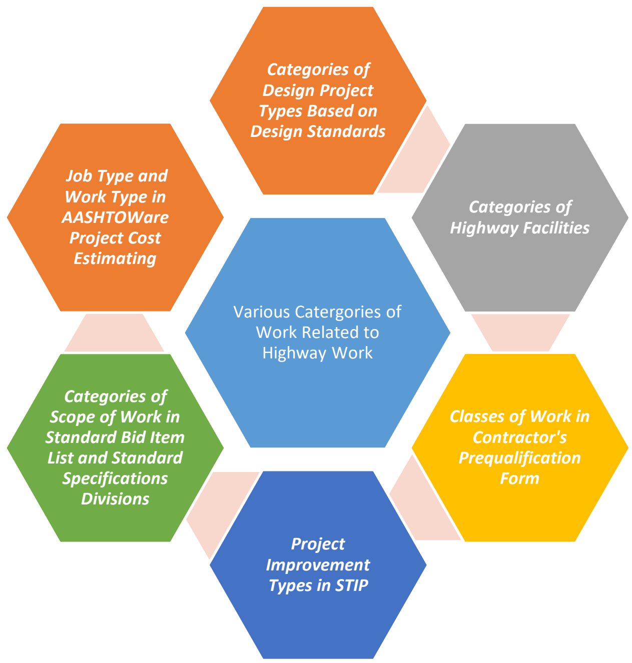

Figure 2-1 A view of various categories of work related to highway work

2.4.1 Categories of Highway Facilities

A bridge is a facility built to provide passage over physical obstacles without the need to close or remove the obstacles, which might include a body of water, gorge, roadway, and railway. Parsons Brinkerhoff and Engineering and Industrial Heritage (2005) used categories of bridge types that included trusses, arch, slab/beam/girder and rigid types, moveable spans, suspension, trestles and viaducts, and cantilevers. There are several types of bridges in the U.S., and as of 2006, the bridge counts captured by Farhey (2015) were classified as slab, stringer/multibeam or girder, girder and floor beam system, tee beam, box beam or girders-multiple, box beam or girders- single or spread, frame (except frame culverts), orthotropic, truss-deck, truss-thru, arch-deck, arch-thru, suspension, stayed girder, movable-lift, movable-bascule, movable-swing, tunnel, culvert (includes frame culverts), mixed type, segmental box girder, channel beam, and others. Such classification clearly suggests the inherent differences in different types of bridges. While the catalog of bridge types captured by Farhey was extensive, Zhao and Tonias (2017) indicated that some of the major types of bridges include slab-on-girder, one-way slab, steel and concrete box girder, cable-stayed, suspension, steel, concrete arch, and truss.

Similar to the bridge classification system, there are also different highway and street classification systems, referred to as functional classifications. The highway and street classification system proposed by Stamatiadis et al. (2017) considered both the geographic context (based on density, land use, and setback) and the roadway types. The geographic context included rural, rural town, suburban, urban, and urban core, while the roadway types included interstates/freeways/expressway, principal arterials, minor arterials, collectors, and locals. A similar classification of highways and streets provided by Findley et al. (2016) was based on the amount of mobility and access they provided (with higher mobility and less access and vice versa), and they included arterials, collectors, and local streets.

Retaining walls as facilities have been also classified and grouped on the basis of inherent characteristics that differentiate one retaining wall from another. The variations in the classification of retaining wall are not different from the variations in classification for bridges and highways. According to the Florida DOT (FDOT) (2009), retaining wall types include conventional cast-in-place walls, pile-supported walls, mechanically stabilized earth (MSE) walls, precast counterfort walls, steel sheet pile walls, concrete sheet pile walls, temporary MSE walls, soil nail walls, soldier pile/panel walls, modular block walls, and permanent-temporary wall combinations. This classification is different from that defined by Caltrans (2004), which classifies retaining walls as gravity, semi-gravity, and non-gravity cantilevered and anchored walls. According to Caltrans, the gravity wall type includes rigid gravity walls, mechanically stabilized earth (MSE) walls, and prefabricated modular gravity walls. The semi-gravity walls rely on their structural components to mobilize the dead weight of backfill to derive their capacity to resist lateral loads, and gabion walls and crib walls are examples of semi-gravity walls. Non-gravity cantilevered walls are constructed of vertical structural members consisting of partially embedded soldier piles or continuous sheet piles. Anchored walls are typically composed of the same elements as non-gravity cantilevered walls but derive additional lateral resistance from one or more levels of anchors. The classification of retaining walls used by Brockenbrough, (2009) was a blend of the classification used by FDOT and Caltrans, and Brockenbrough's categories of retaining walls included rigid retaining walls, MSE walls, non-gravity cantilever walls, anchored walls, soil nail walls, and prefabricated modular walls.

2.4.2 Categories of Scope of Work Captured in Standard Specifications and Standard Bid Item Lists

To design, construct, and operate these infrastructure facilities, practitioners implement design practices, estimating practices, scheduling practices, project execution practices, project monitoring practices, and facility management practices. The effectiveness of these practices is dependent on the industry's ability to develop and use various classification systems that help aggregate scopes of work. Classification systems include CSI MasterFormat, UniFormat, and OmniClass, which are predominantly used for private projects and a few state DOT projects. Most highway projects are designed and constructed following the scope of work described in the contract specification, contract plan, and bid/pay items. For example, WSDOT (2014) specifications are classified into divisions that include 1) general requirements, 2) earthwork, 3) aggregate production and acceptance, 4) bases, 5) surface treatment and pavement, 6) structures, 7) drainage structure, storm sewer, sanitary sewer, water mains, and conduits, 8) miscellaneous construction, and 9) materials. In contrast, Caltrans (2015) specifications are classified under the following divisions: 1) general provisions, 2) general conditions, 3) earthwork and landscape, 4) subbase and bases, 5) surfacing and pavements, 6) structures, 7) drainage facilities, 8) miscellaneous construction, 9) traffic control devices, 10) electrical work, 11) materials, and 12) building construction. To further highlight the different classifications used by various DOTs for their specifications, Oregon DOT (2015) specifications are classified in parts. The specification parts include 1) general conditions, 2) temporary features and appurtenances, 3) roadwork, 4) drainage and sewers, 5) bridges, 6) bases, 7) wearing surfaces, 8) permanent traffic safety and guidance devices, 9) permanent traffic control and illumination systems, 10) right-of-way development and control, 11) water supply systems, and 12) materials. Idaho DOT (2012) specifications are broken into 1) general provisions, 2) earthwork, 3) bases, 4) surface courses and pavement, 5) structures, 6) incidental construction, and 7) materials. Alaska DOT&PF (2017a) classification is identical to that of Idaho DOT with the exception of the name for division (4) as asphalt pavements and surface treatments and for division (6) as miscellaneous construction.

All state DOTs maintain a master list of approved bid items (pay items) that are standardized and categorized for data collection, historical records on costs, definition of scope of work, cost estimating, development of plans and specifications, performance measurement and payments, and several other uses. However, like the specifications categorization, the standard list of bid items and sections of the bid items differ from one state DOT to another. For example, table 2-1 shows FDOT's (2017a) "pay items/specification sections" found in chapter 10 of FDOT's basis of estimate, WSDOT's (2016) grouping of bid items into sections, Wisconsin DOT's (2016) grouping of bid items based on standard specification parts, Alaska DOT&F's groups of bid items, and Caltrans' groups of pay items.

Table 2-1 Example of how different state DOTs organize standard bid/pay items in groups

WSDOT Bid Item Group	Alaska DOT & PF Pay Item Group - Per Subsection of the Standard Spec.	Florida DOT Pay Item Group/Standard Specifications Section	Wisconsin DOT Pay Item Group/Standard Specifications Parts and Sections	Caltrans Pay Item Group/Standard Specifications Section
Preparation,	201 - CLEARING AND GRUBBING	101 - Mobilization	Part 12. Earthwork	Division II, Sections 10-15 - General Construction
Grading,	202 - REMOVAL OF STRUCTURES AND OBSTRUCTIONS	102 - Maintenance of Traffic	Part 3. Bases and Subbases	12 TEMPORARY TRAFFIC CONTROL
Stockpiling,	203 - EXCAVATION AND EMBANKMENT	104 - Erosion Control	Part 4. Pavements	13 WATER POLLUTION CONTROL
Drainage,	204 - STRUCTURE EXCAVATION FOR CONDUITS AND MINOR STRUCTURES	107 - Litter Removal and Mowing	Part 5. Structures	15 EXISTING FACILITIES
Storm sewer,	205 - EXCAVATION AND FILL FOR MAJOR STRUCTURES	110 - Clearing and Grubbing	Part 6. Incidental Construction	Division III, Sections 16-23 - Grading
Sanitary sewer,	206 - FILTER BLANKET	120-175 - Excavation, Embankment, and other Earthwork	Part 7. Quality Management Program	16 CLEARING AND GRUBBING
Water lines,	301 - AGGREGATE BASE AND SURFACE COURSE	200s - Base Courses		17 WATERING
Structure,	302 - SUBGRADE MODIFICATION	300-341 - Bituminous Mixtures, Milling, Superpave, Friction Courses		19 EARTHWORK
Surfacing,	303 - RECONDITIONING	346-347 - Portland Cement Concrete		21 EROSION CONTROL
Liquid asphalt,	304 - SUBBASE	350-353 - Concrete Pavement		22 FINISHING ROADWAY
Bituminous surface treatment,	305 - STOCKPILED MATERIAL	400 - Concrete Structures		Division IV, Sections 24-36 -Subbases and Bases
Cement concrete pavement,	306 - ASPHALT TREATED BASE COURSE	415 - Reinforcing Steel		24 STABILIZED SOILS
Hot mix asphalt,	307 - EMULSIFIED ASPHALT TREATED BASE COURSE	425-449 - Drainage: Inlets, Manholes, Junction Boxes, Pipe, Trench Drain, Underdrain, French Drain, Edgedrain		25 AGGREGATE SUBBASES
Seal coat,	308 - CRUSHED ASPHALT BASE COURSE	450 - Precast, Prestressed Concrete		26 AGGREGATE BASES
Irrigation and water distribution,	401 - HOT MIX ASPHALT PAVEMENT	455 - Structures Foundations: Piling, Drilled Shafts		27 CEMENT TREATED BASES
Erosion control and roadside planting,	402 - TACK COAT	470 - Timber Structures		28 CONCRETE BASES
Traffic,	403 - PRIME COAT	508-510 - Movable Bridges: Navigation Lights, Machinery		29 TREATED PERMEABLE BASES
Building,	404 - SEAL COAT	520s - Concrete Gutter, Curb, Barriers, Traffic Separator, Sidewalk		Division V, Sections 37-45 - Surfacing and Pavements
Superstructure, and	405 - SURFACE TREATMENT	523 - Patterned/Textured Pavement		37 BITUMINOUS SEALS
Other items.	406 - RUMBLE STRIPS	530 - Riprap		39 HOT MIX ASPHALT
	501 - CONCRETE FOR STRUCTURES	534 - Sound Barriers		40 CONCRETE PAVEMENT
	502 - PRESTRESSING CONCRETE	536-538 - Guardrail		41 CONCRETE PAVEMENT REPAIR
	503 - REINFORCING STEEL	550 - Fencing		42 GROOVE AND GRIND CONCRETE
	504 - STEEL STRUCTURES	555-557 - Directional Bore, Vibratory Plowing, Jack & Bore		Division VI, Sections 46-60 - Structures
	505 - PILING	570-580 - Grassing, Seeding, Sodding, Landscaping, Trees, Plants		46 GROUND ANCHORS AND SOIL NAILS
	506 - TIMBER STRUCTURES	600s - Signalization: Conduit, Mast Arms, Detectors, Cabinets		47 EARTH RETAINING SYSTEMS

WSDOT Bid Item Group	Alaska DOT & PF Pay Item Group - Per Subsection of the Standard Spec.	Florida DOT Pay Item Group/Standard Specifications Section	Wisconsin DOT Pay Item Group/Standard Specifications Parts and Sections	Caltrans Pay Item Group/Standard Specifications Section
	507 - BRIDGE BARRIERS AND RAILING	700-705 - Signing, Delineators		48 TEMPORARY STRUCTURES
	508 - WATERPROOFING MEMBRANE	710-714 - Pavement Markings: Paint, Thermo		49 PILING
	509 - MICROSILICA MODIFIED CONCRETE OVERLAY	715 - Lighting: Poles, Conduit (see also 630 for conduit)		50 PRESTRESSING CONCRETE
	510 - REMOVAL OF CONCRETE BRIDGE DECK	800s - Mass Transit		51 CONCRETE STRUCTURES
	511 - MECHANICALLY STABILIZED EARTH (MSE) WALL	900s - Special, Developmental, Trial Items		52 REINFORCEMENT
	512 - FORMS AND FALSEWORK			53 SHOTCRETE.
	513 - FIELD PAINTING OF STEEL STRUCTURES			54 WATERPROOFING
	515 - DRILLED SHAFTS			55 STEEL STRUCTURES
	516 - EXPANSION JOINTS AND			57 WOOD AND PLASTIC LUMBER STRUCTURES
	520 - TEMPORARY CROSSINGS			58 SOUND WALLS
	550 - COMMERCIAL CONCRETE			59 PAINTING
	600 - 670 - MISCELLANEOUS CONSTRUCTION			Division VII, Sections 61-71 - Drainage
	603 - CULVERTS AND STORM DRAINS			61 CULVERT AND DRAINAGE PIPE JOINTS
	604 - MANHOLES AND INLETS			65 CONCRETE PIPE
	605 - UNDERDRAINS			66 CORRUGATED METAL PIPE
	606 - GUARDRAIL			68 SUBSURFACE DRAINS
	607 - FENCES			69 OVERSIDE DRAINS
	608 - SIDEWALKS			Division VIII, Sections 72-81 - Miscellaneous Construction
	610 - DITCH LINING			72 SLOPE PROTECTION
	611 - RIPRAP			73 CONCRETE CURBS AND SIDEWALKS
	612 - SACKED CONCRETE SLOPE PROTECTION			80 FENCES
	614 - CONCRETE BARRIER			Division IX, Sections 82-86 - Traffic Control Facilities
				83 RAILINGS AND BARRIERS
				84 TRAFFIC STRIPES AND PAVEMENT MARKINGS
				86 ELECTRICAL SYSTEMS
				Division XI, Section 99 - Building Construction

2.4.3 Categories of Project Improvement Types in STIP

Each state DOT is required to document and report its statewide transportation improvement program (STIP) expenditure. The STIP is the state's transportation preservation and capital improvement program. It takes on transportation projects using federal, state, and local government transportation funds. The Tri-State Transportation Campaign (TSTC, 2012) found that different DOTs categorize their projects differently, which makes it difficult to aggregate, report, and compare expenditures across all state DOTs. A common list of project improvement types/codes does not exist. For example, WSDOT (2011), New Mexico DOT (2016), Virginia DOT (VDOT) (2007), and the Mid-Region Metropolitan Planning Organization (2010) include different categories of improvement types/codes. Alaska DOT&PF's (2017b) primary work type category, as used in its searchable eSTIP database, is different from the other PNW state DOTs, as shown in table 2-2.

Decision making for highway transportation projects is carried out at several levels of government, which include the USDOT, state DOTs, metropolitan planning organizations (MPOs), and regional transportation planning organizations (RTPOs), which include counties and cities. The operations of these agencies are interwoven and connected through funding and administering of highway projects. For example, the MTO and RTPO prepare the transportation improvement program (TIP) that gets added to the statewide transportation improvement program, which is eventually used in obtaining portions of transportation funding that come from the federal government. In that way, the state DOTs get a portion of their funding from federal sources, and the others from state and local sources. The funds are then used to fund the construction, operation, and maintenance of transportation systems. These funds typically come in the form of federal and state grants, cooperative agreements, loans, and revenue sources such as gas taxes, registration fees, etc. (Caltrans, 2017; FDOT, 2017b). The inherent relationships among the agencies involved in highway projects should enable consistent data collection, sharing, analysis, and reporting.

A review of the Iowa DOT (2017) format for reporting on its TIP showed that even though the data from the TIP are incorporated into the STIP data, the agency does not include the type of work in the required data from the metropolitan and regional agencies that produce the TIP. The format includes project location, route identification, project termini/location, work description, project sponsor, FHWA structure numbers, total project costs by year, and expected federal-aid funds by year.

WSDOT (2013) training on its TIP indicates that the metropolitan and regional agencies are required to include improvement type/code (45 types – see table 2-2) as one of the project data. To be specific, the reporting format also includes project descriptions, improvement type, total project length, beginning and ending termini, environmental type, and right-of-way required.

Walla Walla Valley is a town between Oregon and Washington, and it maintains a bi-state metropolitan and sub-regional transportation planning organization that is partly financed by both states. A Walla Walla MPO report (2016) showed that for projects that fall under Washington state, the MPO is required to include improvement type/code, whereas for projects that fall under Oregon, it is required to use "work type." However, the classifications are different.

In contrast, Oregon DOT's (2006) document on STIP scoping includes 1) new construction, 2) restoration, 3) resurfacing, 4) rehabilitation, 5) bridge, 6) reconstruction, 7) safety, 8) operations, 9) enhancement, and 10) modernization.

Idaho Transportation Department's report (2016) on transportation investments planned for 2017-2021 has different categories of program types, as shown in table 2-2.

Maryland DOT's STIP report (2017) has a clear definition of the different types of projects that fall into each project category, and the main categories include the following:

- Environmental projects
- Safety and spot improvements
- Resurfacing and rehabilitation
- Bridge replacement and rehabilitation
- Urban reconstruction and revitalization and
- Congestion management.

Table 2-2 Categories of project improvement types used by various state DOTs in STIP reporting

Improvement Types Used by WSDOT in STIP Reporting	Work Type Used by Oregon DOT in STIP Reporting	Primary Work Type Used by Alaska DOT in STIP Reporting	Program Type Used by IDAHO DOT in STIP Reporting
1. New Construction	BIKPED - Bike/Ped Grant Program only	Bridge Rehabilitation	State Highways
2. Code Not Used	BR-CLV - Non-NBI Culverts	Bridge Replacement	Pavement Preservation (Commerce) Program
3. Reconstruction- Added Capacity	BR-MBM - Major Bridge Maintenance	Congestion	Pavement Preservation (Non-Commerce) Program
4. Reconstruction- No Added Capacity	BR-SCR - Bridge Overpass Screening	Debt Service	Pavement Restoration Program
5. 4R Maintenance-Resurfacing	BRIDGE - Bridge Program	Environmental Only	Bridge Preservation Program
6. 4R Maintenance-Restoration & Rehabilitation	CMAQ - New code for CMAQ Projects	Ferry Boats	Bridge Restoration Program
7. 4R Maintenance-Relocation	EM-REL - Emergency Relief Projects	Gasoline	Local Highway
8. Bridge New Construction	ENHANC - Enhancement Program	ITS	Safety – Federal Rail Program
9. Code Not Used	ENVIRO - Env. Projects (Soundwall, etc.)	New Bridge Access	Safety - State Rail Program
10. Bridge Replacement-Added Capacity	EXCHNG - Jurisdictional Exchange	New Construction	Recreational Trails
11. Bridge Replacement-No Added Capacity	IOF - IOF Program (Special Programs)	Other	Local Highways
12. Code Not Used	MAINT - Maintenance (Non STIP)	Planning	STP – Local Urban Program
13. Bridge Rehabilitation- Added Capacity	MISCEL - Will be removed w/ 02-05 STIP	Rail/Highway Crossing	STP – Local Rural Program
14. Bridge Rehabilitation- No Added Capacity	MODERN - Modernization (add capacity)	Railroad	Bridge – Local Program
15. Preliminary Engineering	MODIOF - IOF counting against MOD target	Reconstruction	Bridge – Off-system Program
16. Right of Way	OP-ITS - Operation ITS	Rehabilitation	Highways Other Federal Programs
17. Construction Engineering	OP-SLD - Slides and Rockfalls	Research	Emergency Relief Program
18. Planning	OP-SSI - Signs, Signals, Illumination	Resurface	Miscellaneous Federal Program
19. Research	OP-TDM - Transportation Demand Managmt	Safety	Indian Reservations Road Program
20. Environmental Only	OPERAT - Operations (ITS, TDM, etc.)	Safety Corridor	
21. Safety	OPERTN - Transit Operations	System Preservation	
22. Rail/Highway Crossing	PLANNG - Planning Limitation	Traffic Management Operations	
23. Transit	PRESRV - Pavement Preservation	Training	
24. Traffic Management Engineering (ITS & TSM)	PURCHS - Transit Purchase	Transit	
25. Vehicle Weight Enforcement Program	RAILRD - Highway Rail Crossing Program	Transportation Enhancements	
26. Ferry Boats	SAFETY - Highway Safety	Youth Conservation/Service	
27. Administration	SALMON - Salmon Recovery Projects		
28. Facilities for Pedestrians & Bicycles	SCENBY - Scenic Byway Projects		
29. Acquisition of Scenic Easements & Scenic of Historical Sites	SPPROG - Special Program (Limitation)		
30. Scenic or Historic Highway Programs	TRANST - Transit Program/Project		
31. Landscaping & Other Scenic Beautification			
32. Historic Preservation (non-transportation buildings)			
33. Rehabilitation & Operation of Historic Transportation Building/Structures/Facilities			
34. Preservation of Abandoned Railway Corridors			
35. Control & Removal of Outdoor Advertising			
36. Archaeological Planning & Research			
37. Mitigation of Water Pollution Due to Highway Runoff			
38. Safety & Education for Pedestrians/Bicyclists			
39. Establishment of Transportation Museums			
40. Special Bridge			
41. Youth Conservation Service			
42. Training			
43. Utilities			
44. Other (SRTS, SIB Loan Repayments)			
45. Debt Service			

2.4.4 Categories of Design Project Types Captured in Design Standards

State DOTs' design manuals provide guidance for the design of different project types, and each state DOT has its own manual. Oregon DOT (2012) uses four design standards that include 4R standard, 3R standard, 1R standard, and AASHTO's *A Policy on Geometric Design of Highways and Streets – 2011.* These four standards guide the design of nine different design project types, as depicted in *Table 1-1: Design Standards Selection Matrix* of the Oregon DOT design manual. The different design manuals from the state DOTs cover specific project types, and table 2-3 captures the differences in the project types identified by some of the state DOTs.

Table 2-3 Design project types found in state DOT design manuals

OREGON DOT - Design Manual	IDAHO DOT - Design Manual	ALASKA DOT - Design Manual	WSDOT - Design Manual
Modernization [New Construction/Reconstruction (4R)]	Short Projects	New Construction	New Construction
Preservation [Interstate Maintenance/Resurfacing, Restoration, and Rehabilitation (3R)]	Special Projects	Reconstruction	Reconstruction
Bridge	New Construction	Rehabilitation (3R)	Improvement projects
Safety	Reconstruction		Preservation projects
Operations	Resurfacing, Restoration, Rehabilitation		
Maintenance	Pavement Rehabilitation		
Miscellaneous/Special Programs	Pavement Preservation		
Single Function	ST (State Funded) Projects		
ODOT Resurfacing 1R	Rest Area/Port of Entry Caretaker Services		
	Building and Yard Projects		
	Minimal Contract Maintenance Projects		
	Multifaceted Contract Maintenance Projects		
	Congestion Mitigation and Air Quality Projects		
	Non-Bid Projects		

2.4.5 Categories of Work Classes Captured in Contractor's Prequalification Forms

On some state DOT projects, contractors must go through a qualification process before they can bid on a project. Through this process, the area of expertise and bonding capacity of a contractor is known, making it possible for the agencies to properly qualify the contractor for each project that is let out for bid or proposal. WSDOT (2015a) uses a standard work class, which is part of the Washington Administrative Code for prequalification of contractors, and it is part of the standard questionnaire that contractors need to fill out and submit before being prequalified. There are 58 classes of work item, as shown in table 2-4, and these include items such as clearing, grubbing, grading and drainage; bridges and structures; tunnels and shaft excavation; demolition; earth retention and anchoring; and railroad construction. In most cases, WSDOT projects involve a combination of several work classes. Like WSDOT, Oregon DOT's (2016) prequalification form has 15 classes of work, as shown in table 2-4.

For bidding purposes and qualification of contractors, South Dakota DOT (2014) has the following work type classification:

- Major grading
- Minor grading
- Portland cement concrete paving
- Portland cement concrete repair (spall repair, joint repair, or pavement grinding)
- Asphalt concrete paving and microsurfacing
- Asphalt surface treatment and asphalt crack sealing
- New bridge construction
- Bridge rehabilitation (deck overlays, fatigue retrofit, steel and concrete repair, epoxy chip seal, or rail retrofit)

- Minor structure construction (cast-in-place box culverts, pre-cast multi-beam deck bridges, or mechanically stabilized earth (MSE) large panel retaining walls)
- Lighting and signals
- Signing, delineation, and pavement marking
- Underground and utilities (storm sewer, sanitary sewer, waterline, drainage pipe, or precast box culvert)
- Incidental construction (fencing, guardrail, railroad crossings, MSE modular block retaining walls, gravel surfacing, base course, landscaping, or erosion control)
- Miscellaneous concrete construction (sidewalk, bike path, multi-use path, or curb and gutter)
- Bridge painting.

Table 2-4 Categories of work classes found in contractors' prequalification forms

Oregon DOT - Contractor Prequalification Work Class	WSDOT - Contractor Prequalification Work Class
(AB) Aggregate Bases	Class 1 Clearing, grubbing, grading and draining - Removal of tree stumps, shrubs, modification of the ground surface by cuts and fills, excavating of earth materials, placement of drainage structures, and construction of structural earth walls.
(AC) Rock Production (Aggregate Crushing, Sanding Rock)	Class 2 Production and placing of crushed materials - Production and placing crushed surfacing materials and gravel.
(ACP) Asphalt Concrete Paving and Oiling (Paving, Chip Sealing, Crack Sealing, Slurry Sealing, Fog Sealing)	Class 3 Bituminous surface treatment - Placing of crushed materials with asphaltic application.
(BLD1) Buildings (Toilets, Bathhouses, Maintenance, Sand Sheds)	Class 4 Asphalt concrete paving - Production and placing Asphalt Concrete Plant Mix Pavement.
(EART) Earthwork and Drainage (Clearing, Earthwork, Blasting, Riprap, Culverts, Manholes, Inlets, Storm Sewers, Sanitary Systems	Class 5 Cement concrete paving - Production and placing cement concrete pavement.
(ELEC) Electrical (Traffic Signals, Illumination, Ramp Meters, Roadway Weather Information Systems (RWIS), Variable Message Signs (VMS), Traffic Cameras	Class 6 Bridges and structures - Construction of bridges and other major structures of timber, steel, and concrete.
(LS) Landscaping (Roadside Seeding, Lawns, Shrubs, Trees, Irrigation Systems, Topsoil, Temporary and Permanent Erosion Control)	Class 7 Buildings - Construction of buildings and related structures and major reconstruction and remodeling of such buildings.
(MHA) Miscellaneous Highway Appurtenances (Guardrail, Barrier, Curbs, Walks, Fences, Protective Screening, Impact Attenuators, Cold Plane Pavement Removal, Rumble Strips)	Class 8 Painting - Painting bridges, buildings, and related structures.
(PAI1) Painting (Bridges and Buildings	Class 9 Traffic signals - Installation of traffic signal and control systems.
(PAVE) Pavement Markings (Permanent - Painted, Durable, Markers, Delineators	Class 10 Structural tile cleaning - Cleaning tunnels, large buildings and structures and storage tanks.
(PCP) Portland Cement Concrete Paving	Class 11 Guardrail - Construction of a rail secured to uprights and erected as a barrier between, or beside lanes of a highway.
(REIN) Bridges and Structures (Concrete, Steel, and Timber Bridges, Retaining Walls and Soundwalls; Seismic Retrofit; Box Culverts; Structural Plate Pipe, and Pipe Arches	Class 12 Pavement marking (excluding painting) - Thermoplastic markings, stripes, bars, symbols, etc. Traffic buttons, lane markers, guide posts.
(SIGN) Signing (Permanent)	Class 13 Demolition - Removal of timber, steel, and concrete structures and obstructions.
(TTC) Temporary Traffic Control (All Temporary Traffic Control Items Including Flaggers and Pilot Cars)	Class 14 Drilling and blasting - Controlled blasting of rock and obstructions by means of explosives.
(OTH1) Other, (List specific class)	Class 15 Sewers and water mains - Draining, pipe jacking, water systems, pumping stations, storm drainage systems, sewer rehabilitation, sewage pumping stations, pressurized lines.
	Class 16 Illumination and general electrical - Highway illumination, navigational lighting, wiring, junction boxes, conduit installation.
	Class 17 Cement concrete curb and gutter - Sidewalks, spillways, driveways, monument cases and covers, right of way markers, traffic curbs, and gutters.
	Class 18 Asphalt concrete curb and gutter - Sidewalks, spillways, driveways, monument cases and covers, right of way markers, traffic curbs, and gutters.
	Class 19 Riprap and rock walls - Mortar, rubble, and masonry walls; rock retaining walls, and placing of large broken stone on earth surfaces for protection against the action of water.
	Class 20 Concrete structures except bridges - Cast-in-place median barrier, prestressing, post-tensioned structures, footings, prefabricated panels and walls, retaining walls, and ramps, foundations, rock bolts, and concrete slope protection.
	Class 21 Tunnels and shaft excavation - Tunnel excavation, rock tunneling, and soft bore tunneling.
	Class 22 Piledriving - Driving concrete, steel, and timber piles.
	Class 23 Concrete surface finishes - Architectural concrete surface finishes (fractured fin, random board, exposed aggregate, etc.). Waterproofing concrete surfaces (clear or pigmented sealer).
	Class 24 Fencing - Wire and metal fencing, glare screens.
	Class 25 Bridge deck repair - Bridge expansion joint repair and modification, bridge deck resurfacing and repair, deck seal.
	Class 26 Not used
	Class 27 Signing - Sign structures and sign foundations.
	Class 28 Drilled large diameter slurry shafts - Drilled shafts 4' diameter or larger and greater than 15' deep when excavation is performed utilizing the wet method and concrete is placed by tremie methods under slurry.
	Class 29 Slurry diaphragm and cut-off walls - Slurry excavation and the construction of structural concrete walls and slurry cut-off walls.
	Class 30 Surveying - Highway construction surveying.

Oregon DOT - Contractor Prequalification Work Class	WSDOT - Contractor Prequalification Work Class
	Class 31 Water distribution and irrigation - Irrigation systems and heavy duty water distribution.
	Class 32 Landscaping - Landscape irrigation, planting, sodding, seeding, fertilizing, mulching, herbicide application, insecticide application, weed control, mowing, liming, soil binder, topsoil.
	Class 33 Engineering - Work other than surveying, including engineering calculations, drawing and other related work for highway construction.
	Class 34 Erosion control - Seeding, fertilizing, mulching, slope protection, topsoil application, hydro-seeding, soil stabilization, soil sampling.
	Class 35 Precast median barrier - A concrete barrier that is cast and cured in other than its final position used to divide the median of two adjacent highways or temporarily placed to divert traffic in construction zones.
	Class 36 Earth retention and anchoring - Installation of permanent soil nails, soldier piles, timber lagging and micropiles. Soldier pile tie-back anchor wall construction.
	Class 37 Impact attenuators - Installation of approved protective systems filled with sand, water, foam, or other substances which prevent errant vehicles from impacting roadside hazards.
	Class 38 Paint striping - Painted bars, letters, symbols, and striping.
	Class 39 Slope protection - The installation of a zinc coated steel wire mesh anchored by wire rope and reinforced concrete posts or anchor rods. Used for dampening the effects of rolling rocks onto the highway. Slope scaling, horizontal drains, rock dowels, and rock bolts for slope stabilization.
	Class 40 Gabion and gabion construction - Construction of walls made with containers of galvanized steel hexagonal wire mesh and filled with stone.
	Class 41 Intelligent transportation systems (ITS) - Traffic sensors systems, highway advisory radios, environmental sensing stations, variable message signs, nonfiber optic based closed circuit television, and video systems.
	Class 42 Electronics - Fiber optic based communications systems Design and installation of fiber optic based communication systems.
	Class 43 Mechanical - Plumbing work and the installation of heating or air conditioning units.
	Class 44 Asbestos abatement - Asbestos abatement (L & I certified workers).
	Class 45 Hazardous waste removal - The containment, cleanup, and disposal of toxic materials. Companies seeking this classification shall have full-time personnel with current hazardous waste training (certifications).
	Class 46 Concrete restoration - Pavement subseal, cement concrete repair, epoxy coatings, epoxy repair, masonry repair, masonry cleaning, special coatings, epoxy injection, gunite, shotcrete grouting, pavement jacking, gunite repair, and pressure grouting.
	Class 47 Concrete sawing, coring, and grooving - Concrete sawing, concrete planing, grinding, grooving, bump grinding, joint repair, concrete coring and rumble strips.
	Class 48 Dredging - Excavating underwater materials.
	Class 49 Marine work - Underwater surveillance, testing, repair, subaquatic construction, anchors, and cable replacement, floating concrete pontoon repairs and modifications, disassembly and assembly of floating concrete pontoons.
	Class 50 Ground modification - Pressure grouting, blast densification, stone column, jet grouting, compaction, dynamic compaction, soil mixing, gravel drain.
	Class 51 Well drilling - Drilling wells, installing pipe casing and pumping stations.
	Class 52 Sewage disposal - Hauling and disposing liquid and solid wastes.
	Class 53 Traffic control - Providing piloted traffic control, traffic control labor, and maintenance and protection of traffic.
	Class 54 Railroad construction - Construction of railroad subgrade, placing of ballast, ties, and track and other items related to railroad work.
	Class 55 Steel fabrication - Welding of steel members, heat straightening steel.
	Class 56 Street cleaning - Street sweeping with self-propelled sweeping equipment.
	Class 57 Materials transporting - Truck hauling.
	Class 58 Sand blasting and steam cleaning - Steam cleaning, sand blasting, shot blasting, and water blasting.

2.4.6 Job Type and Work Type Captured in AASHTOWare Project Cost Estimation Application

The NJDOT uses the AASHTOWare Project Cost Estimation software for preparing construction cost estimates, and several other state DOTs use the same software. AASHTOWare is a suite of applications designed by and used by state DOTs. AASHTOWare provides for standardization and, as such, some level of integration and collaboration. In addition, the applications allow the state DOTs to share best practices and conduct comparative analyses, aimed at improving performance. The AASHTOWare Project software comes with modules that include a project estimating module. Three data points captured within the project estimating module are job type, work type, and bid item groups. However, there is no alignment within the state DOTs in their classification of job type, work type, or bid item classes. For example, table 2-5 shows the classification of job type and work type used by NJDOT (2014).

Table 2-5 Job type and work type used in New Jersey DOT AASHTOWare project cost estimation

NJDOT Project/Job Type Classification in AASHTOWare Project Cost Estimation	NJDOT Work Type Classification in AASHTOWare Project Cost Estimation
1. New construction	ASPH - Primarily asphalt work
2. Reconstruction, widening, and dualization	BRPT - Bridge painting and cleaning
3. Widening and resurfacing	CONC - Primarily Portland cement concrete work
4. Resurfacing	CURB - Curbs, sidewalks, and gutters
5. Bridge Repair	DRNG - Drainage work and erosion control
6. Intersection improvements	ERTH - Earthwork
7. Electrical, safety and traffic control	FENC - Fencing
8. Miscellaneous	GRDL - Guiderail
9. Unique	GENC - General construction
10. Intelligent transportation systems (ITS)	INTC - Interchange
11. Landscaping	ITS - Intelligent transportation systems
12. Demolition	JNTS - Joints
13. Drainage	LAND - Landscaping
	LTNG - Lighting
	MISC - Miscellaneous
	PVMK - Pavement marking
	RMVL - Removal of buildings
	SGNL - Signals
	SIGN - Signs
	SRFP - Surface prep
	STRL - Structures - large
	STRS - Structures - small
	UTIL - Utility work

2.4.7 Others

Other areas in which different categories of highway work were found in the literature include work by Hinze and Selstead (1991) and WSDOT (2017a).

Hinze and Selstead's (1991) analysis of WSDOT cost overruns were conducted using six types of projects, and their classification included the following:

- Type 1 – New construction
- Type 2 – Roadway resurfacing

- Type 3 – Bridge projects only
- Type 4 – Safety improvements
- Type 5 – Landscaping only
- Type 6 – Unique projects.

WSDOT (2017a) provided an advance schedule of contracts to be let out in the near future, and the list had project types that included 1) bridges, 2) major construction, 3) resurfacing, 4) safety, and 5) unique projects.

It is noticeable that among the state DOTs there is a lack of consistency in the classification of highway work types. Most of these classifications were developed to meet policy needs but without much consideration for how they might align with project performance. There is a need for a standardized classification framework for highway project types.

2.5 Generalizations on Construction Performance with and without Consideration to Project Types

Generalizations made in research that are not anchored in a specific level of abstraction are not helpful in practice, as they do not tell practitioners which unit of analysis (i.e., project type) they reference. For example, some researchers have come up with findings that show that some highway projects are constructed at a cost higher than the original bid price (e.g., Flyvbjerg et al. 2002; Edwards and Kaeding 2015). Such research should be founded on a specific level of abstraction, such as the type of construction (new construction, reconstruction, etc.), or which system and type (flat slab bridge, beam/girder bridge, collector roadway, etc.), or the type of material (concrete, asphalt concrete, precast, structural steel, etc.), or other dimensions.

Abstraction helps to make sense of a complex system, by creating structure and different levels and making it easy to explain a system at the right level of abstraction. According to Budd

(2002), the map of a country could be distilled to states, from states to counties, from counties to cities, and from cities to major features, with each level representing a level of abstraction.

The work by Korde et al. (2005) recognized that construction performance could be measured at different levels of project definition. From previous research conducted over a 20-year period, Korde et al. cataloged the various factors that affect construction performance at the overall project level, at the project participant level, and at the activity level.

Construction is a system made up of several interrelated elements and components, which operate at different levels of abstraction, from the program level, to the project type level within the programs, to the project level within each variant project type, to the activity level, and the project participant level. Each of these levels presents different experiences and phenomena, requiring an in-depth understanding of the factors that make them behave the way they behave. Therefore, a more in-depth understanding is required to define project types, allowing practitioners to make generalizations that reflect reality.

Following the findings from the research on cost overruns on federal projects, Edwards and Kaeding (2015) offered some suggestions to help reduce cost overruns. One of the generalizations made by the authors was that cost overruns would be reduced when projects were benchmarked against similar past projects. Their research looked at various construction projects that included defense projects, energy projects, and transportation projects in general. Such a recommendation was founded on the grounds that not all projects are created equal and that, in this case, generalizations must be specific to a project type. Such project types should be categorized on the basis of project dimensions.

Flyvbjerg et al. (2002) posited that engineers' estimates are highly misleading, given the level of project overruns. The authors' findings and generalizations were based on evaluations of

258 transportation projects, which they agreed was not large enough to allow for further subdivision. The problem with such generalization is that it does not specify which project type (bridges, roadways, tunnels, etc.), and asking transportation agencies to make improvements without being specific about the areas of focus makes it difficult for such improvements to occur. To make such a generalization, the projects could have been grouped by project type and then analyzed to determine whether the phenomenon was found across all project types or only on specific project types. Projects are peculiar, and each group of similar projects tends to have peculiar behavior that may not necessarily be found in other types of projects.

A more recent and extensive study by Okere (2017) on the accuracy of engineers' estimates used 4,062 transportation projects from a Washington State DOT log of completed/active/yet to be executed projects. The research found that the engineers' estimates were within range 50 percent of the time. However, the author did not find the engineers' estimates to be misleading or deceptive. The research was designed to evaluate the engineers' estimates within different clusters, which included 1) overall projects, 2) bridge projects vs. roadway projects, 3) small size projects vs. medium size projects, 4) time range 1992 – 2004 vs 2005-2016, 5) bridge contractor vs. paving contractor, and 6) design-bid-build projects vs. design-build projects. There is no doubt the research could have provided a better understanding of the accuracy of engineers' estimates had they been evaluated on the basis of different types of projects. This would also help engineers to focus their efforts on the types of projects for which their estimates are not within range.

There are different dimensions to measure project performance, most of which center around time, budget, safety, quality, scope, and other parameters. However, these measures are seen as measures that cut across all types of projects without much thought that the results could be different when one looks at one project type or another. Such level of abstraction and analysis could provide better appreciation for the inherent nature of different project types and how to manage them effectively.

Research by Nassar (2009) extended the analysis of project performance to an integrated project performance model that evaluated project performance on eight dimensions, including cost, schedule, progress billing, profitability, safety, quality, team satisfaction, and client satisfaction. Project owners could use such metrics to evaluate individual project performance. However, to determine whether patterns exist, the evaluation would have to be conducted at the project type abstraction level. At that point, it would become easy to determine whether differences occurred within project types and seek indicators that could point to areas for improvement.

Crossett and Hines' (2007) study analyzed a large data set of nine state DOTs for projects from 2001 to 2005. The study compared the state DOTs' performance on the basis of cost and time and found that large projects were more likely to have cost overruns and time delays, and maximum cost overruns were within 10 percent in most cases. This was an important evaluation of state DOT projects that could have benefited from an in-depth review of the level of time delays and cost overruns associated with different project types.

Cantarelli et al. (2012) evaluated Dutch infrastructure projects on the basis of cost overruns and how they could be driven by project types (road, rail, and fixed link projects), contract amount at award, and contract duration. Their research sought to understand how different types of projects could factor in project behavior and performance. A level of overrun on a roadway project could be different from that of a rail project or a bridge project. Interestingly, the study found that average cost overruns on Dutch projects were 10.6 percent for rail, 18.6 percent for roads and 21.7 percent for fixed links. This is a very good example of why it is important to categorize and standardize highway project types. Such classification would help practitioners in evaluation and analysis aimed at understanding the relationships that exist (if any) between project types and several project parameters.

Okere (2018) conducted a similar study on project types, cost overruns, and allocation of contingency on state DOT projects. The study similarly found that the pattern of cost overruns was different for different types of projects and therefore helped to provide the basis for state DOTs to re-evaluate their current practice of allocating contingencies by using a fixed percentage. The approach of making recommendations and generalizations at the project type level would be a better approach than generalizing for all construction projects without reference to different project types that in most cases behave differently.

Bikson et al. (1996) posited that one of the most important factors in facilitating the implementation of research findings is the participation of key parties. It is not a secret that industry practitioners apply only a very small percentage of research findings and recommendations. The goal of all research is to help solve problems. Some research efforts fail because the generalizations and recommendations are not made at the appropriate unit of analysis and level of abstraction. Work by Ibbs (2012) evaluated the likelihood and severity of construction change and their impacts on productivity, and the author found that in general contract changes do have impacts on cost, time, and productivity. The research used 226 projects in the analysis. However, the implementation of such research could have been facilitated if the study had been designed with the projects abstracted to different project types, knowing that different types of projects behave differently.

The ability to see patterns in the universe of things allows the environment to be predicted, and this is based on the understanding that patterns do not form by chance. Just as there are natural orders and classifications of things, there are patterns that exist around us. However, some of those patterns are easy to see, while some of them require a better tool to make them evident. The use of project types on highway projects could be the much-needed tool to determine the patterns that are inherent in the construction process. Which project type is susceptible to more contract changes, or which project type is best suited for the design-build delivery method, or what level of design effort is required? Such questions could be better answered by looking at projects through the lens of project types. Gransberg et al. (2003) posited that there are key project characteristics that could speak to the use of one delivery method or another.

WSDOT developed an extensive guide on design-build contracting. WSDOT (2004a) detailed the processes required for the selection, design, and construction of a design-build project. According to State of Washington law, to be considered for design-build, a project must be greater than $10 million and provide the opportunity for one of the following: 1) highly specialized construction activities requiring significant input into the design; 2) greater innovation and efficiencies between the designer and the builder; or 3) significant savings in project delivery time. All three of these criteria could easily be identified by looking at different project types and the patterns that emerge from them. The guide also stated, “Projects that are complicated present more challenges and therefore more potential benefits from a design-build approach” (WSDOT 2004a, p. 19). The development and use of project types could enhance and provide justification for the selection of one delivery method or another.

A small design-build pilot project evaluation for WSDOT (2015b) aimed to determine whether small projects that were less than $10 million could benefit from design-build contracting. The study found that different types of projects would benefit from design-build. The research also posited that the small projects that would benefit from design-build were 1) projects with critical phasing and timing, 2) projects with performance specifications allowing innovation/specialty work, and 3) projects with significant risks that can be managed effectively through the design-build project delivery. The study by WSDOT highlighted the benefits of classifying projects by project types. If a project type classification system had been available for the agency to use, it would have aided the study. Such a tool would have created additional benefit by indicating what types of small projects were best suited for design-build contracting. In addition, by classifying the results on the basis of specific project types, a pattern might have emerged in comparison to a database of completed/active/yet to be executed projects and could have helped improve decision making and the re-evaluation of contracting practices.

It is important that any analysis on project performance be evaluated on the basis of different project types, thereby providing a focus for resources and the use of management techniques that are aligned to the specific project types.

2.6 The Gap – Aligning Project Performance Patterns and Trends with Project Types

There is gap in our understanding of how to categorize Pacific Northwest highway project types to enhance future investigative studies on contract administration practices and performance. Three key problems highlight these gaps:

First, from the literature, it is obvious that a consistent and standardized classification of project types does not exist within state DOTs.

Second, there is an increasing amount of research on construction performance. However, most of those studies are based on a mix of projects or ad hoc project classifications that are inconsistent across research related to contract administration.

Third, without a standard classification of project types, the PNW state DOTs and others working to help understand and improve contract administration practices find it difficult to uncover some of the inherent relationships and patterns that exist.

In general, it is difficult to find consistency in the analysis of contract performance when such efforts are not aligned with the reality that "not all projects are created equal." Such efforts fail in design and method, and they may not help practitioners to see patterns that are evident in the unique nature of projects. This gap is also caused in part by the lack of a standard classification of project types. An in-depth classification of highway project types could help practitioners to determine performance trends and patterns of connections and be able to identify key attributes that drive practice and performance.

2.7 Current Attempts to Categorize Highway Projects

There are ongoing efforts to develop project classification systems for highway projects, and this section presents a few of those efforts. There is evidence that state DOTs have made efforts to categorize highway projects, and a study by Hancher et al. (1992) addressed that. Their research aimed to determine the required time to complete a construction contract for different types of highway projects, as classified by Texas DOT, for design management. It included the following 14 categories of project types:

- SC Seal Coat
- OV Overlay
- RER Rehabilitate Existing Road

- CNF Convert Non-Freeway to Freeway
- WF Widen Freeway
- WNF Widen Non-Freeway
- NLF New Location Freeway
- NNF New Location Non-Freeway
- INC Interchange
- BWR Bridge Widening/Rehab
- BR Bridge Replacement
- UPG Upgrade Freeway to Standards
- UGN Upgrade Non-Freeway to Standards
- MS Miscellaneous Construction.

Like the work of Hancher et al., the research by Werkmeister et al. (2000) provided Kentucky DOT with a scheduling tool for determing contract times for various project types on the basis of predefined controlling activities. The contract time templates were developed for six different project types, as defined in table 2-6 below:

Table 2-6 Project type classification used by Kentucky DOT in Werkmeister, et al. 2000

Project Template	Project Description
Reconstruction Limited Access	This is a project that utilizes the existing alignment but may revise the profile grade for an overlay.
Reconstruction Open Access	This is a project where a road is being rebuilt that has either "Access by Permit" or "Partial Control" while utilizing the existing right-of-way.
New Route	This is a project being built from point "A" to point "B."
Relocation	This is a project that a section of road is being rebuilt on new alignment and grade.
Bridge Rehabilitation	This is a project that a lane on a bridge would be closed for reconstruction or widening the deck part width.
Bridge Replacement	This project's main focus would be to build a new bridge.

In order to develop a comparative report of infrastructure spending across all state DOTs, a common classification was developed in a study by the Tri-State Transportation Campaign (TSTC, 2012). The authors then used the project type classification to conduct a line-by-line analysis of transportation spending. In the study, the authors developed a project classification system for the purpose of tracking and comparing state DOT transportation dollars as captured under the STIP. The classification included nine groups of project types:

- New road capacity
- Bridge capacity expansion
- Road maintenance/minor widening
- Bridge maintenance/replacement
- Road or bridge project with bicycle/pedestrian components
- Bicycle/pedestrian
- Safety
- Transit and
- Other.

In a recent study, Okere (2018) developed a project type classification for highway projects. The author then used the data to evaluate whether the current state DOTs' practices for allocating contingency needed re-evaluation. Given the different categories of projects used by researchers and state DOTs, the author analyzed 537 WSDOT projects out of 1,731 projects that had been completed between 2005 and 2016. The 537 projects had contract values ranging from $2.1 million to over $500 million. The 1,194 projects that were not analyzed had contract values below $2 million. Focusing on the 537 projects and based on the projects' description of work and the contract title, the researchers mapped and classified the project types on the basis of their main work features, their level of complexity, and whether the projects involved construction on new or existing alignment. The project types classification included the following:

- New roadway alignment
- Reconstruct existing roadway alignment
- Rehab existing roadway alignment
- Tunnel roadway
- New bridge alignment
- Remove/replace/widen existing bridge alignment
- Rehab/retrofit existing bridge alignment
- Retaining and sound wall
- Slope stabilization
- Utilities – ITS, electrical, several
- Utility relocation
- New/Replace culvert
- Erosion control/drainage system
- New and rehab building facility
- New and rehab waterfront structure
- Safety and traffic control
- Riverbank restoration
- Wetland mitigation.

An in-depth categorization of highway projects was captured in the NJDOT AASHTOWare project cost estimation (CES) manual (2014). The grouping of project types used for estimating purposes included the following:

- New construction
- Reconstruction, widening, and dualization
- Widening and resurfacing
- Resurfacing
- Bridge Repair
- Intersection improvements
- Electrical, safety and traffic control
- Miscellaneous
- Unique
- Intelligent transportation systems (ITS)
- Landscaping
- Demolition
- Drainage.

For segmenting, grouping, and clustering a set of items such as projects (with attributes) into a class based on similarities and dissimilarities, there are a handful of statistical analysis and modeling tools to use. Some of the options include 1) hierarchical cluster analysis, 2) *k*-Means cluster analysis, and 3) latent class analysis (LCA). Latent class analysis is used to identify unobservable (latent) subgroups of related cases within a larger set of items. For example, an unobservable (latent) pattern or trend might emerge on the performance of a specific contractor or resident engineer working on similar types of projects but at different locations, different size projects, and different project delivery methods.

By using a well-structured questionnaire to capture data from state DOTs on four project characteristics that included complexity, award cost, facility type, and project type, Antoine and Molenaar (2016) used LCA to develop the project categorization framework shown in table 2-7.

Table 2-7 Project type classification framework as developed by Antoine and Molenaar (2016)

Variables / Classes	Descriptions			
	Complexity	**Award Cost**	**Facility Type**	**Project Type**
Class 1	Most Complex	Over $10M	Road & Drainage	New Const. & Resurf.
Class 2	Mod. Complex	$0 - $50M	Bridge	Rehab.
Class 3	Non-Complex	$0 - $10M	ITS & Ancillary	Maintenance

2.8 The Differentiating Dimensions and Measures of Project Types

It is common knowledge that not all roadway projects are the same, not all bridge projects are the same, and neither is a flat slab bridge the same as a box girder bridge. How does one project type differ from another, or in other words, what parameters can be used to distinguish one project from another? The focus here is to answer the question, How is one project type different from another project type? How could roadway resurfacing projects be different from new roadway projects, and what parameters should be used to cluster and classify different highway project types?

Projects are unique, and there are certain dimensions that set one type of project apart from another. Those parameters originate from the scope of work and the project settings. Those are what differentiate a bridge project from a roadway project, and a flat slab bridge constructed in a rural town to one constructed in an urban core area. It is common knowledge that the same scope of work in a different setting will behave differently, and different scopes of work in the same setting will behave differently.

Wideman (2002) posited that an understanding of the fundamental differences among different types of projects could enable adoption of successful management practices for a specific project type. Therefore, it is important to know the main factors that differentiate one project type from another.

Having a standardized classification of highway project types is critical for practitioners to make sense of the inherent nature of different project types. It allows for in-depth analyses that seek to find relationships that may exist between different project types and other contract performance parameters such as time, cost, safety, resource allocation, delivery methods, etc. Therefore, the development of a standard classification could be a way to change behavior and practice. For example, Pennsylvania DOT (2015) used the following dimensions to combine multiple projects of similar work as a way to deliver those projects effectively: 1) type of work, 2) size, 3) location, 4) timeline, 5) level of impact, 6) construction material, 7) threshold to ensure competitive bids, etc. Shenhar et al. (2002) used three dimensions to distinguish among projects: uncertainty, complexity, and pace.

Simply put, what differentiates one type of project from another has most to do with the scope of work and the project settings. These two factors aggregate the dimensions detailed below. Each of these dimensions has corresponding measures (metrics) defined on the basis of the literature.

2.8.1 Type of Construction

State DOTs' design efforts include different types of construction. The type of construction is the starting point for understanding how one type of highway project may differ from another highway project. Some of the themes that emerge from state DOT design manuals and other literature as they relate to various types of construction designed and constructed by state DOTs include the following:

- A new construction project; according to the USDOT (2007), new construction is defined as roadways that are built on new alignment
- A modernization project
- A replacement project
- A retrofit project; add a component or accessory to something that was not present at initial construction
- A safety improvements project
- A widening project
- A preventive maintenance project
- An emergency repair projects
- A reconstruction project; according to USDOT (2007), reconstruction is defined as roadways that are rebuilt primarily along existing alignment. Reconstruction normally involves full-depth pavement replacement. Other work that would fall into the category of reconstruction includes adding lanes adjacent to an existing alignment, changing the fundamental character of the roadway (e.g., converting a two-lane highway to a multi-lane divided arterial), or reconfiguring intersections and interchanges
- A resurfacing project
- A restoration project
- A rehabilitation project
- A preservation project.

What is in a name? The Wisconsin DOT's (n.d.) *Highway Improvement Type Definitions* manual provides definitions for some of the above-listed types of work.

According to USDOT (2007), the term ***3R*** stands for resurfacing, restoration, and rehabilitation projects. *3R* projects typically involve pavement improvement work (short of full-depth replacement) and targeted safety improvements. *3R* projects generally involve retention of the existing three-dimensional alignment.

DOT design manuals for the Pacific Northwest states (Washington, Alaska, Idaho, and Oregon) provide some definition for the project types listed above. For example, Alaska DOT&PF's (2005) *Highway Preconstruction Manual* chapter on "Highway Design," and Oregon DOT's (2012) *Highway Design Manual* chapter on "Design Standard Policies and Processes" provide definitions for some of the above and refer to them as project types. In addition, Caltrans' (2012) *Highway Design Manual* provides definitions for some of the types of construction listed above.

NJDOT's (2001) manual for developing construction schedules provides a very good example of how highway projects differ by type of work/construction. The manual reflects specific project conditions and captures the differences in production rates for items of work related to new construction projects, reconstruction projects, resurfacing projects, or intersection projects. In addition, the manual presents the differences in production rates for reconstruction on an existing alignment vs. construction on a new alignment, and for bridge superstructure replacement vs. bridge deck replacement or deck overlay.

To identify a common type of construction across state DOTs, the definitions of the types of work shown in the design manuals were aggregated. Following the definitions, a list was developed that captures all the types of construction that are typically found on state DOT projects. As seen in table 2-8, it is obvious that the definitions are not consistent.

Table 2-8 Definitions of types of construction as used by various state DOTs

TYPE OF CONSTRUCTION	Definitions from Washington State DOT Design Manual	Definitions form State of Idaho DOT Design Manual	Definitions from State of Oregon DOT Design Manual	Definitions from State of Alaska DOT & PF Design Manual	Definitions from Caltrans Design Manual
A new construction project,	New construction projects address the construction of a new roadway, interchange, or other transportation facility where none existed before.	This action involves the construction of a new highway facility where nothing of its type currently exists.	New construction projects are projects constructed in a new location, new alignments, major additions such as interchanges and safety rest areas, or rebuilding an existing facility with major vertical or horizontal alignment changes.		New construction is the building of a new facility. This includes new roadways, interchanges or grade separation crossings, and new parking lots or safety roadside rest areas.
A modernization project,			Modernization projects generally improve transportation safety, add capacity to the highway system to facilitate existing traffic and/or accommodate projected traffic growth. Modernization projects also include new construction activities such as construction of a new segment of highway on new alignment.		
A replacement project,			Bridge replacement - Improvements to rebuild or extend the service life of existing bridges and structures beyond the scope of routine maintenance.		
A safety improvements project,			Safety projects address the Region's prioritized high crash locations and corridors, including the Interstate system, in order to reduce the number of fatal and serious injury crashes. Projects funded through this program typically meet benefit/cost criteria of 1.0 or greater or are on the top 10% SPIS list.	Highway Safety Improvement Program (HSIP) projects are different from other projects. Because HSIP projects are intended to be cost-effective solutions to specific safety problems, project scope should be limited to that which was HSIP-approved by the FHWA.	
A widening project,					Widening projects involve the construction of additional width to improve traffic flow and increase capacity on an existing highway facility. Widening may involve adding lanes (including transit or bicycle lanes), shoulders, pullouts for maintenance/transit traffic; or widening existing lane, shoulder or pullouts.
A preventive maintenance project,			Preventive Maintenance is a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system without significantly increasing the structural capacity.	Preventive Maintenance Program projects include asphalt surface treatments, rut filling, profiling, and similar work and may be done either by DOT&PF maintenance or contractors.	Preventive maintenance projects are used to provide preventive treatments to preserve pavements in good condition. These projects are typically done by Department Maintenance forces or through the Major Maintenance Program.
An emergency repair project,		Emergency Relief projects are funded with emergency funds authorized for the repair or reconstruction of highways and bridges which have suffered serious damage as the result of acts of nature.	The Emergency Relief (ER) program is intended to assist the States and local agencies in repairing disaster damaged highway facilities and returning them to their predisaster condition.		

<table>
<tr><th>TYPE OF CONSTRUCTION</th><th>Definitions from Washington State DOT Design Manual</th><th>Definitions form State of Idaho DOT Design Manual</th><th>Definitions from State of Oregon DOT Design Manual</th><th>Definitions from State of Alaska DOT & PF Design Manual</th><th>Definitions from Caltrans Design Manual</th></tr>
<tr><td>A reconstruction project,</td><td rowspan="4">ALTERATION PROJECTS - Alteration projects include, but are not limited to, renovation; rehabilitation; reconstruction; historic restoration; resurfacing of circulation paths or vehicular ways; and changes or rearrangement of structural parts or elements of a facility. Where existing elements or spaces are altered, each altered element or space within the limits of the project shall comply with the applicable accessibility requirements to the maximum extent feasible.
The following are some examples of project types that are classified as alteration projects and can potentially trigger a variety of ADA requirements:
HMA overlay or inlay
Traffic signal installation or retrofit
Roadway widening
Realignment of a roadway (vertical or horizontal)
Sidewalk improvements
PCCP panel repair/replacement
Bridge replacement
Raised channelization</td><td>This typically involves a major change to an existing facility within the same general right of way corridor. Reconstruction may involve making substantial modifications to horizontal and vertical alignment in order to eliminate safety and crash problems or making substantial modifications to the pavement section to correct structural deficiencies. These projects can be as complex as new construction and they can present more challenges because of the constraints involved with work within the existing facility and under traffic.</td><td>These projects upgrade the facility to acceptable geometric standards and as a result, provide a greater roadway width. The improvements may be in the form of additional lanes and/or wider shoulders and produce an improvement in the highway's mobility. Reconstruction projects normally include the following types of work: Projects which alter the original subgrade; those that construct major widenings that result in the addition of a new continuous lane; the addition of passing lanes or climbing lanes; channelization for signals or left turn refuges; structure replacement; and similar projects. Other modal projects on state highways and bridges such as light-rail, bus-rapid transit, streetcar, and alike are to use 4R standards.</td><td>A major highway improvement that completely rebuilds an existing roadway or constructs a roadway on new alignment, to the contemporary design requirements</td><td>Pavement reconstruction is the replacement of the entire existing pavement structure by the placement of the equivalent or increased pavement structure. Reconstruction usually requires the complete removal and replacement of the existing pavement structure utilizing either new or recycled materials. Reconstruction features typically include the addition of lanes, as well as significant change to the horizontal or vertical alignment of the highway.</td></tr>
<tr><td>A resurfacing project,</td><td rowspan="3">3R Projects (NHS and Interstate) are intended to extend the service life of the existing highway and, at the same time, improve highway safety by making selective improvements to highway geometry and roadside features. The integrity of the existing ballast is maintained. The types of improvements to existing federal aid highways include: resurfacing, cold-mill-inlay/overlay, overlay, bridge deck rehabilitation, modifying bridge rail, pavement structural and joint repair, minor lane and shoulder widening, minor alterations to vertical grades and horizontal curves, and removal or protection of roadside obstacles.</td><td rowspan="3">These are projects that preserve and extend the service life of existing highways and enhance safety, using cost-effective solutions. Improvements include extending pavement life by at least 8 years, safety enhancements, minor widening (minor widening considered to be widening at spot locations, widening at curves, etc.), improvements in vertical and horizontal alignment, improvement in superelevation, flattening of sideslopes and removal of roadside hazards. The scope is influenced by factors such as: roadside conditions, funding constraints, environmental concerns, changing traffic and land use patterns, surfacing deterioration and crash type and rate. 3R projects are not constructed with the intent of improving highway mobility; however, it is sometimes an automatic incidental benefit as a result of improving the riding surface and improving safety.</td><td rowspan="3">Rehabilitation (3R) projects consist of the resurfacing, restoration, and rehabilitation of an existing roadway on the same alignment or modified alignment. The principal objective of 3R projects is to restore the structural integrity of the existing roadway, thereby extending the service life of the facility. In addition, the safety and capacity of the facility should be enhanced, if required.</td><td rowspan="3">The primary purpose of roadway rehabilitation projects is to return roadways that exhibit major structural distress, to good condition. Many of these structural distresses indicate failure of the surface course and underlying base layers. Roadway rehabilitation work is generally regarded as major, non-routine maintenance work engineered to preserve and extend the service life as well as provide upgrades to enhance safety where needed. Roadway rehabilitation projects are divided into 2R (Resurfacing and Restoration) and 3R (Resurfacing, Restoration and Rehabilitation). Roadway rehabilitation projects should address other highway appurtenances such as pedestrian and icyclist facilities, drainage facilities lighting, signal controllers, and fencing that are failing, worn out or functionally obsolete. Also, unlike pavement preservation projects, geometric enhancements and operational improvements may be added to roadway rehabilitation work if such work is critical or required by FHWA standards.</td></tr>
<tr><td>A restoration project,</td></tr>
<tr><td>A rehabilitation project,</td></tr>
</table>

2.8.2 The Controlling System/Work

Even when highway projects fall under the same type of construction, they may differ by the type of system that forms the design basis of the project. The controlling features (systems) of work may fall under various civil engineering areas of specialization. According to Cheah et al. (2005), over the years, the field of civil engineering has grown to include several areas of specialization, such as

- Environmental Engineering
- Geotechnical Engineering
- Hydraulic and Water Resources Engineering
- Structural Engineering
- Transportation Engineering
- Construction Technology and Project Management.

State DOT highway infrastructures or systems can be categorized on the basis of civil engineering specialization areas. Therefore, one way to differentiate one highway project from another would be by the controlling feature (system) of work corresponding to a specific area of civil engineering specialization.

A review of ASCE journals in these areas of specialization showed that the following:

1. Environmental engineering relates to **wastewater** collection and treatment.
2. Geotechnical engineering relates to foundations, **retaining structures**, soil dynamics, the engineering behavior of soil and rock, site characterization, **slope stability**, **dams**, rock engineering, earthquake engineering, etc.
3. Hydraulic engineering relates to **closed conduits** to free-surface flows (canals, rivers, lakes, and estuaries) and to environmental fluid dynamics, etc.

4. Structural engineering relates to **bridge** engineering and issues related to bridge materials, design, fabrication, construction, inspection, evaluation, safety, performance, management, retrofitting, rehabilitation, repair, and demolition.
5. Transportation engineering relates to **road** engineering, bridge engineering, tunnel engineering, **intelligent transportation systems (ITS)** and traffic engineering, automobile engineering, environmental engineering, and transport economics, etc.

The controlling feature (system) of work represents the main product delivered/improved, which represents another way to differentiate one highway project from another. Youker (2017) posited that the project product (deliverable) provides the most important classification for a project type. The research showed that further abstraction can be made on the basis of the degree of uncertainty, the level of specialty/uniqueness of the personnel (labor, supervision, subcontractors), the level of time pressure, the importance of meeting budget, degree of new technology involved, and level of scope detail/stability. For example, on highway projects the products delivered or improved could include but not be limited to the following:

- Roadway system
- Roadway interchange system
- Tunnel system
- Bridge system
- Retaining system
- Highway drainage and erosion control system
- Building structure/highway facilities
- Rail transit (RT)
- Utilities to support highway facilities

- Utilities –others
- ITS/Electrical systems
- Landscape architecture systems
- Marine structures and facilities.

The main product delivered/improved reflects an instance of a typical highway project of the same product irrespective of the size, location, price of the project, or other factors to qualify the project.

In addition to the main system being delivered or improved, it is also important to indicate the type of system. For example, in the case of a bridge system, there are various types of bridges, as detailed in Farhey (2015). In the case of a roadway system, there are various types of roadways, as detailed in Stamatiadis et al. (2017). The same applies to the other systems.

2.8.3 Controlling Material for the Highway Project

The type of material is a dimension that makes one highway project differ from another even when the projects fall under the same type of construction and system of work. There are a few unique construction materials used on highway projects, and they are key factors in differentiating highway projects because they require different tools and techniques. A review of the state DOT (Alaska, Idaho, California, Washington, Oregon) standard specifications pointed to several construction materials used on highway projects. A few of the predominant materials found in the specification include the following:

- Timber and lumber
- Concrete
- Asphalt concrete
- Structural steel and related materials

- Masonry units
- Geomaterials as they relate to cut/fill materials (processed and unprocessed soils and rocks) and/or soil improvement material
- Illumination, signal, electrical, and related materials.

2.8.4 Number of Combined Systems/Works within the Project

Some projects may involve only one type of system of work, while some others may include more than one system of work. For example, the Presidio Parkway Project in San Francisco included roadway systems, bridge systems, tunnel systems, retaining wall systems, drainage and erosion control systems, utilities, building structures, and other features. Wideman (2002) proposed a project typology that helps to show the level of technological uncertainty based on the extent of the level of the project scope mix. The levels are defined by

1. An array of different systems (multi-system)
2. A system - complex set of interactive elements
3. An element(s) of a system.

2.8.5 Physical Size (Scale) of the Project

There is a fundamental relationship between the size of a project and the associated cost, time, or resources needed. The larger the size of a project, the more resources and time it takes. The physical size (scale) of a project captures how much work is involved. For example:

- Length of a bridge
- Contact surface area of a bridge deck
- Lane or lane-mile of a roadway
- Weight of structural steel
- Volume of concrete or earthwork

- Contact surface area of roadway pavement
- Exposed surface area (face) of a retaining wall
- Contact top area (length x width) of culvert.

2.8.6 Size of Contract Value

Even when two highway projects are of the same type of construction, the same system, the same construction material, and are the same size, the contract value would likely not be the same. WSDOT's (2002) *Highway Construction Cost Comparison Survey* showed that the same scope of work could result in different contract values. Therefore, an understanding of the projects could start with the project value. On the basis of the Surety Information Office's (SIO) contractors' guide to surety bonding (2015), construction projects are classified as follows:

- Small – less than $10 million
- Middle (medium) - $10 million - $100 million
- Large - $100M - $250 million
- Mega – more than $250 million.

2.8.7 Contract Time

Contract time represents how long it takes to complete a project. Contract time is driven by many factors that include the type of construction, system of work, material type, size, location, and several other factors. Contract time is a dimension that differentiates highway projects. To analyze projects on the basis of time requires an understanding of whether the projects were constructed within the following time frame:

1. Number of working days within one construction season
2. Number of working days within two construction seasons
3. Number of working days within three construction seasons

4. Number of working days within four construction seasons
5. Number of working days within five construction seasons
6. Number of working days within six or more construction seasons.

2.8.8 Geographic Location of the Project Site

All highway projects are constructed on either a new alignment or an existing alignment located somewhere in some part of the country. Geographic location is needed to understand project setting and the level of traffic-related constraint that might be placed on a project. Stamatiadis et al.'s (2017) work on a classification system for highways and streets provided the following improvements to the location classification:

- Rural
- Rural Town
- Suburban
- Urban
- Urban Core.

To further show the relationship between the location context, functional classification, and level of usage by different users (drivers, bicyclist, and pedestrian), the authors created the matrix below in figure 2-2.

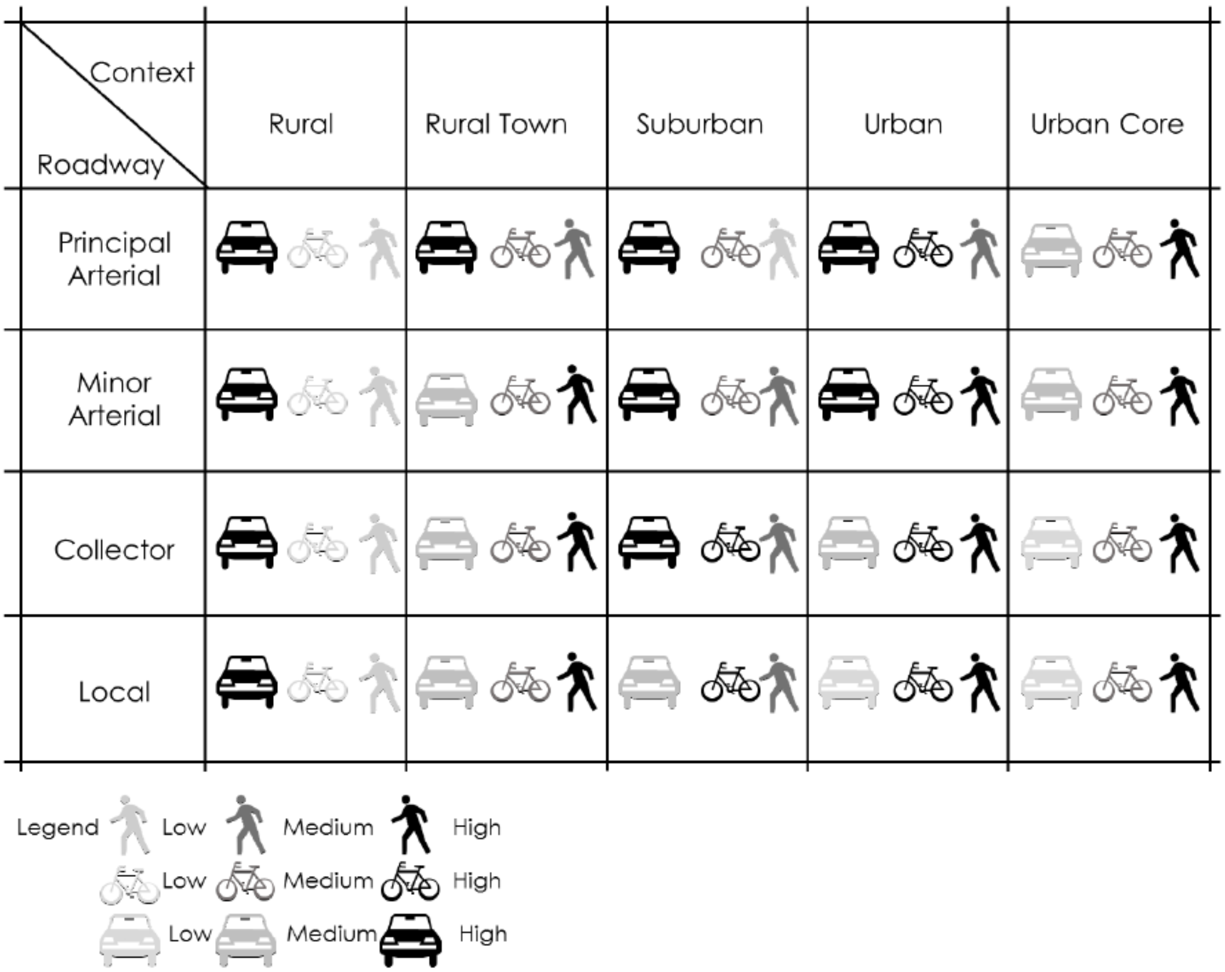

Figure 2-2 Expanded functional classification system matrix captured from Stamatiadis et al. (2017)

Some states have mapped out their road network on the basis of functional classification and context related to the geographic location of the roadway. For example, Appendix A of Oregon DOT's (2012) design manual has a comprehensive list of functional classification for all the state's road network.

In addition, the physical location should indicate whether the work is being done on a new alignment or an existing alignment.

WSDOT's (2004b) comparative cost evaluation study showed that location is a major factor when it comes to the cost of highway construction project. Two similar projects constructed at two different locations showed wide variations in cost resulting from location factors such as right-of-way acquisition, environmental impacts, and existing soil and site conditions.

Work by Yi and Wu (2007) showed that production rates can be affected by the location of a project, as in rural areas or urban areas.

2.8.9 Project Risks and Complexity

According to Gidado (1996), project complexity results from the inherent nature of individual parts of a project and the interrelationships between those parts. Turner (1995) presented three levels of project complexity that included low complexity, medium complexity, and high complexity. Luo et al. (2017) showed the trends in research on complexity factors, impacts, measures, and management. The authors' recommendation was that future research on complexity should focus on different types of construction projects and how to manage them. The work by Luo et al. (2017) also showed that there was no consensus on how to measure project complexity. Gransberg et al. (2013) developed one of the project complexity measurement methods that were adopted by Wisconsin DOT and USDOT. The model is called the complexity footprint, and it is based on complexity ratings in five dimensions, cost, schedule, technical, context, and finance. Wisconsin DOT (2014) utilizes this model to rate projects on five dimensions using a scale of 0 to 100, with 100 representing the greatest possible complexity and 50 representing an average level. This number is then plotted on a spider chart, and the interior angle of the pentagon is combined with the rating to find the area. Whereas this is a subjective measure of project complexity, Virginia DOT's (2012) categorization of project complexity, presented in figure 2-3, is a preferred option, as it removes subjectivity and provides a better definition of what types of projects fall under each category of project complexity.

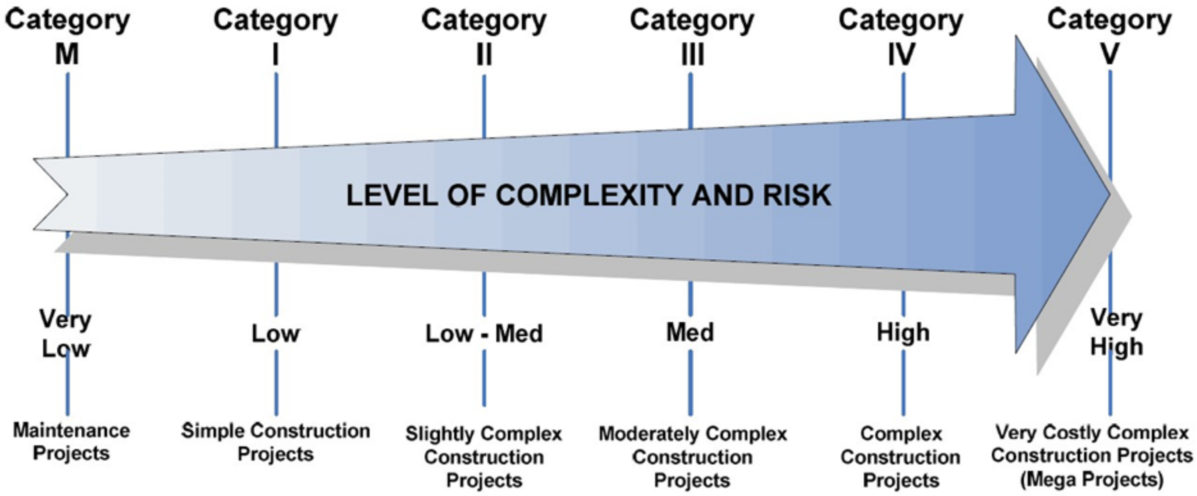

Figure 2-3 Categories of project complexity and risk captured from VDOT (2012)

As shown in table 2-9, VDOT (2012) included an extensive list of project types that fall into each category of project complexity and risk.

Table 2-9 VDOT list of project types under different categories of project complexity and risk

COMPLEXITY CATEGORY	EXAMPLES OF PROJECT TYPES UNDER EACH PROJECT COMPLEXITY CATEGORY
Category M	
	Pavement schedules (Asphalt overlay, surface treatments & slurry seals);
	Bridge joint repairs;
	Bridge painting (minimum traffic impact);
	Guardrail improvements;
	Curb and gutter repair/replacement;
	Raised pavement marker installation, lens replacement;
	Pavement marking schedules;
	Minor Bridge repair (District wide, minor miscellaneous);
	Rumble strip installation;
	Slope slide repair, scour repair;
	Ground mounted sign maintenance/replacement;
	Incidental concrete repair;
	Pipe culvert rehabilitation;
	Bridge cleaning;
	Retaining wall/ Sound wall repair;
	Signal maintenance & repair (District wide).
Category I	
	Rural grade, drain, & pave of unpaved roads (may include minor horizontal & vertical alignment changes and rural rustic projects with drainage work);
	Minor bridge deck repair & concrete overlay (may include multiple bridges);
	Break, seat, & overlay concrete pavement;
	Spot improvements (multiple locations any of: incidental concrete, minor widening, enhanced pavement marking, & sign installation);
	Building demolition in advance of construction projects;
	Retaining wall installation or extensive repair;
	Minor bridge substructure repairs (with traffic impact);
	Bridge painting (multiple locations or with traffic impact);
	Minor urban reconstruction & improvement (could include curb & gutter and sidewalks; new or extended turn lanes);
	Surface reclamation, sub-grade stabilization & overlays;
	Bridge steel repair (with traffic impact);
	Signal installation – Site specific (w/o intersection improvements, no regional on-call installations);
	Overhead sign installation & lighting installations (multiple locations & or significant amount of lighting);
	Simple concrete pavement repair and/or asphalt overlay (major corridor, minimum traffic impact).
Category II	
	Urban grade, drain, & pave projects of low to medium complexity;
	Rural new construction or reconstruction grade separation roadway and bridge projects (low to medium size and complexity);
	Complex reconstruction and improvements, including widening and multiple turn lanes that may include utility adjustments;
	Major bridge substructure repairs (with low to medium traffic impact);
	Bridge deck replacements, such as multi-span or over railroads;
	Major bridge deck repair & concrete overlay (multi-span or over railroads);
	Intersection improvements with lighting and/or signal installation;
	Bridge & drainage structure replacements (frequently single span with limited approach work);
	Major drainage improvements;

COMPLEXITY CATEGORY	EXAMPLES OF PROJECT TYPES UNDER EACH PROJECT COMPLEXITY CATEGORY
	Complex concrete pavement repair and/or asphalt overlay (major corridor, significant traffic impact);
	Multi-season bridge painting (with low to medium traffic impact).
Category III	
	Intersection improvements, including widening and multiple turn lanes with utilities, lighting and/or signal installation (with medium complexity and traffic impact);
	New roadway/bridge construction or extension projects (medium size, complexity, and traffic impact);
	Bridge deck replacements (multi-span, medium traffic impact);
	Bridge & drainage structure replacements (limited span with approach work);
	Bridge reconstruction/widening projects (medium size, complexity, and traffic impact).
Category IV	
	Major urban intersection improvements, including widening and multiple turn lanes with utilities, lighting and/or signal installation (medium to large size, complex, and significant traffic impact);
	Rural/Urban new construction or reconstruction grade separation roadway and bridge projects (medium to large size, complex, major corridor);
	Major bridge deck replacements (substructure repairs, multi-span, multi-lane, major corridor, with significant traffic impact);
	Major bridge & drainage structure replacements (multi-span with extensive approach work);
	Major widening projects (medium to large size and complexity, major corridor, with significant traffic impact).
Category V	
	Major rural/urban new construction or reconstruction grade separation roadway and bridge projects (large size, complex, major corridor, significant traffic impact);
	Major widening projects (large size, complex, major corridor, significant traffic impact);
	Major interchange projects (large size, complex, major corridor, significant traffic impact);
	Major bridge deck replacement projects (large size or multiple bridges, complex, major corridor, significant traffic impact);
	Individual Category III or IV level projects that are included in multiple-contract mega-projects like Woodrow Wilson, Springfield Interchange, etc.).

Another take on project complexity, by Pennsylvania DOT (2015), is presented in table 2-10 and documented in Penn DOTs *Design Manual: Part 1 – Transportation Program Development and Project Delivery.*

Table 2-10 Penn DOT list of project types under different categories of project complexity

PROJECT TYPES	EXAMPLE OF PROJECTS UNDER EACH PROJECT COMPLEXITY CATEGORY
	NON-COMPLEX (MINOR) PROJECTS
Roadway	
	Maintenance Betterment projects.
	3R (Resurface, Restore, Rehabilitate) projects.
	Intersection improvement projects with minor or no signal layout changes or un-signalized.
	Construction of turn lanes at intersections.
	Overlay projects, simple widening.
Structures	
	Bridge resurfacing or repairs which do not require re-analysis of bridge capacity.
	Replacement with minimal approach work.
	Pipes, box culverts, or minor culvert replacements.
	Sign structures, including Dynamic Message Sign structures.
	Noise walls or retaining walls for which the design can be picked directly from the standards or using design computer software.
Highway Safety Improvements	
	Guide rail elimination, replacement, or updating.
	Slope flattening.
	Traffic operations with minor or no roadway work (e.g., signalization including retiming, signing, pavement markings and roadway lighting).
	23 U.S.C. Sections 130 and 148 Highway 130 Safety Projects.
	Truck escape ramps.
Miscellaneous	
	Transportation enhancement projects (e.g., pedestrian and bicycle paths).
	Transportation corridor fringe parking facilities.
	Rehabilitation of truck weigh stations, rest areas, or tourist information facilities.
	Rehabilitation of bus storage and maintenance facilities.
	Rehabilitation or reconstruction of existing rail and bus facilities.
	Rehabilitation of rail storage and maintenance facilities.
	Construction of replacement wetlands.
Traffic Control	
	Single traffic control/management projects (i.e., projects with no traffic control phasing or with a single detour).
	Non-ITS but minor safety improvements.
Right-of-Way	
	Involve minor right-of-way way acquisitions with no controversial or only minor displacements and maintain or reduce existing access control.
Utilities	
	Minor adjustments/relocations.
Environmental	
	Categorical Exclusion (Level 1A or 1B), Environmental Documentation, or NEPA Programmatic Agreement.
	Minimal interaction with environmental and permitting agencies.
	Minor environmental impacts.
	Minimal or no involvement with cultural resources or hazardous waste.
	No substantial flood plain encroachments.
Stakeholders	
	No public controversy on environmental grounds.

PROJECT TYPES	EXAMPLE OF PROJECTS UNDER EACH PROJECT COMPLEXITY CATEGORY
	MODERATELY COMPLEX PROJECTS
Roadway	
	4R (Resurface, Restore, Rehabilitate, Reconstruct) projects that do not add capacity.
	Minor relocations and/or reconstructions.
	Minor sections of new alignment.
	Intersection improvement projects with additional through lanes.
	Intersection improvement projects with significant signal layout changes.
Structures	
	Non-complex (straight geometry with minimal skew; designs using AASHTO distribution factors; minimal seismic analysis; footings on rock or conventional piles and abutments) bridge replacements.
	Bridge rehabilitation that requires re-analysis of bridge capacity.
	Bridge mounted signs.
	Tie back walls.
	Sound barriers.
	Proprietary/non-proprietary walls.
Traffic Control	
	Minor-ITS projects, such as non-corridor spot improvements.
	Major safety improvements.
	Interconnected traffic control/management projects.
Right-of-Way	
	Less than 20 moderate to significant claims, and minimal relocations or displacements.
Utilities	
	Some utility relocations, most of it prior to construction, but no major utility relocations.
Environmental	
	Categorical Exclusion (Level 1B or 2).
	Cultural resources (historical, archeological, etc.). Coordination with PHMC, FHWA, and/or Advisory Council.
	Water and air pollution mitigation.
	Major coordination with PA Game or Fish and Boat Commissions.
	Endangered Species Act, Section 7 Consultation.
Stakeholders	
	Involvement of public and public officials is moderate due to non-controversial project type.
	General communication about project progress is required.
	MOST COMPLEX (MAJOR) PROJECTS
Roadway	
	New highways.
	New interchanges.
	Major Relocations, including signal relocations that influence/change a coordinated system.
	Capacity adding/major widening.
	Major reconstruction.
Structures	
	Replacement, new or rehabilitation of:
	Unusual (non-conventional such as, segmental, cable stayed, major arches or trusses, steel box girders, movable bridges, etc.).
	Complex (sharp skewed (less than 70 degree) superstructure, non-conventional piers or abutments, horizontally curved girders, three dimensional structural analysis, non-conventional piles or caisson foundations, complex seismic analysis, etc.).
	Major (bridge cost of $15 Million or more - Federal definition).
	Unusual geology (i.e., mines, karst, etc.).

PROJECT TYPES	EXAMPLE OF PROJECTS UNDER EACH PROJECT COMPLEXITY CATEGORY
Traffic Control	
	Multi-phased traffic control for highway or bridge construction that would mandate CPM during construction.
	Major ITS (Electronic surveillance, linkages) corridor project.
Right-of-Way	
	Numerous relocations of residences or displacements of commercial and/or industrial properties are required.
	Major involvement of environmental clean-up.
Utilities	
	Major utility (transmission lines, substations) relocations or heavy multi-utility coordination is involved.
Environmental	
	Level 2 Categorical Exclusion Evaluations, Environmental Impact Statements, or Environmental Assessments are required.
	Continued public and elected officials' involvement in analyzing and selecting alternates.
	Other agencies (such as FHWA, COE, PHMC, Game Commission, Fish & Boat Commission, DEP, DCNR, EPA, Agricultural Board, etc.) are heavily involved to protect air; water resources; gamelands, game fish, threatened and endangered species; cultural resources (historical and archaeological); parks; wetlands; etc.
Stakeholders	
	High profile projects (Fast track design/construction, high public impact, high interaction of elected officials, etc.).
	Controversial projects (Lack of consensus).
	Major coordination among numerous stakeholders is required.

2.8.10 Traffic Control Level

Traffic maintenance is always of major concern on every highway project, and the level of traffic control can be classified on the basis of traffic maintenance, staging, and phasing of work. British Columbia Ministry of Transportation (MOT) (2001) developed a classification scheme for the MOT that reflects conditions on similar highway projects executed in the U.S. The categories include the following:

CATEGORY 1

- Two-way traffic at all times
- Work on the shoulder, or work requiring single or multi-lane closures
- All lane closures removed and traffic operations normalized at the end of each work period.

CATEGORY 2

- Single lane alternating traffic or temporary total road closures
- All lane closures removed and traffic operations normalized at the end of the daily work period
- Duration of the work is typically between one day and two weeks.

CATEGORY 3

- Detours or traffic diversions with two-way traffic at all times
- Duration of the project is typically less than two weeks.

CATEGORY 4

- Long duration work requiring staged traffic control plans
- Work zone is linear and contained within a transportation corridor

- Primary impact on traffic operations is limited to the transportation corridor containing the work zone.

CATEGORY 5

- Long duration work requiring staged traffic control plans
- Work zone located at a node in the transportation network
- Primary impact on traffic operation extends beyond the work zone onto alternative routes.

2.8.11 Level of Contractor's Project Safety Effort and Performance

The construction industry has a very high accident rate. Several researchers have contributed to our understanding of site safety, and some have developed measures of safety performance based on several factors. Fang et al. (2004) indicated that the nature of a project is related to safety accidents and management. Therefore, the level and intensity of construction activities and the project setting drive the potential for accidents, as well as the level of safety management provided. Mohamed (1999) developed a safety management index (SMI) designed to measure the level of safety management commitment and attitude on a project. The resulting SM intensity classes include the following:

1. High safety management intensity (SMI of 1)
2. Medium safety management intensity (SMI of 0.588)
3. Low safety management intensity (SMI of 0.304)
4. Very low safety management intensity (SMI of 0.102).

While the intensity rating provides a way to measure how well a project is been managed, the safety performance of a contractor will vary through the lifecycle of a project. One metric that might be of use in defining project type could be the experience modification rate (EMR) generated by insurance companies on workers' compensation insurance policies. Contractors are required to provide information regarding their safety performance during the prequalification stage, and this allows the owner to get a better understanding of the level of risk they might be taking should they engage the select contractor. Hinze et al. (1995) posited that EMR is a good measure of a contractor's safety performance.

However, others have argued that EMR is not the best measure of safety performance for a specific project with unique challenges. Hoonakker et al. (2005) argued that EMR is based on worker classifications and not on jobs, which makes it difficult for use in predicting performance on a specific project.

Given the limitations of using the EMR as a true measure of project-specific safety performance, Imriyas et al. (2008) proposed a new premium-rating model. The model was developed specifically for building construction projects and has been tested in the Singapore general insurance industry. The proposed model provided an optimal premium based on structured analyses of project-specific hazards, contractors' safety management systems, market conditions, and the insurers' internal factors.

2.8.12 Level of Environmental Control Needs

Project environmental considerations begin with the project location. According to the Massachusetts DOT (2006), roadway design usually starts with the environmental context, which considers nearby natural resources, the terrain, and man-made environment. Classification follows area type: rural areas, suburban areas, and urban areas. Environmental needs are specific to project setting and go beyond classification by area type.

To be in compliance for construction of highway projects, all state DOTs are required to follow environmental regulations enacted at both the federal and state levels. WSDOT (2017b) considers environmental issues related to water; wetlands; habitats; flood plains or ways and groundwater; air quality; noise; social or public involvement; cultural resources/historical properties; tribal consultation; parks, recreation areas, wildlife refuges, scenic rivers/byways, and public lands; resource lands; and, hazard and problem waste. According to the agency, project classification based on environmental issues depends on the National Environmental Policy Act (NEPA) and State Environmental Policy Act (SEPA). NEPA classification includes class I – environmental impact statement (EIS), and class II – categorically excluded (CE). SEPA classification includes 1) determination of significance (DS), 2) determination of non-significance (DNS), and 3) categorically exempt (CE).

The project site conditions related to environmental needs are evaluated on the basis of site topography and site features, soil or rock type, presence of surface or groundwater near construction areas, presence of underground or overhead utilities, presence of hazardous waste, and weather. Cunningham (2013) explained how physical site conditions affect the cost of a project. Dewberry and Matusik (1996) provided an extensive breakdown of environmental factors, with a list including the following:

- Water resources
- Wetlands
- Vegetation preservation
- Wildlife preservation
- Topography and soils
- Historical preservation and archeology
- Chemical contamination
- Underground storage tanks

- Asbestos
- Radon
- Air quality
- Noise abatement.

Environmental factors are a major differentiator of project types and can be captured by using the SEPA classification of environmental conditions for a specific project, as in DS, DNS, and CE.

2.8.13 Project Delivery Method

A major differentiator of projects is the delivery method chosen. This is because the delivery method has an impact on project outcome. This fact is well understood, and some state DOTs have developed guidelines for the use of different delivery methods. For example, WSDOT has developed an extensive guide on design-build contracting. WSDOT (2004a) detailed the processes required for selection, design, and construction of a design-build project. It is also common knowledge that a project constructed with the design-build process is less adversarial than one constructed with the design-bid-build process. The resulting contracting environment created by different delivery methods has an impact on project performance and project outcome. According to West Virginia DOT (2017), some typical project delivery methods used on highway projects include the following:

- DBB – Design-bid-build
- DB – Design-build
- P3 – Public-private partnership
- CMGC – Construction manager, general contractor
- Performance specification

- Multi-parameter contracting – also called A+B+C approach. A represents cost, B represents time, and C could be quality, safety, or warranty.
- Another contracting method that has been used on state DOT projects is the multiple contract method.

2.8.14 The Contractor

A major differentiator of project performance is the contractor. Some contractors do better than others; some learn from their experience while others fail to learn. It is common knowledge in the construction industry that the success or failure of any construction project is largely dependent on the contractor chosen to build the project. Alhumaidi (2015) posited that because contractors play a big role in any construction project, they have a major influence on the overall success of any project. The importance of an experienced and capable contractor on a construction project cannot be overemphasized because contractors play a big role in delivering projects on time and on budget. The overall performance of a project depends on selecting the right contractor for the right project (Cristobal 2012). Both Alhumaidi (2015) and Cristobal (2012) agreed that some of the key determinants of capable contractors include experience, availability of resources with technical capability, financial stability, good safety record, and ability to complete project on time. Work by Yi and Wu (2007) showed that for different items of work, the production rates differs by contractors.

Table 2-11 Summary of project types differentiating dimensions (categories) and measures (classes)

Type of Construction
- New construction
- Reconstruction
- Rehabilitation (includes resurfacing and restoration)
- Retrofit (structural systems)
- Safety improvements
- Emergency relief
- Preventive maintenance
- Preservation

Controlling System/Work
- Roadway systems (Functional Classification: principal arterial; minor arterial; collector; local and street)
- Road interchange systems (diamond, partial cloverleaf, full cloverleaf, trumpet, three-leg directional, one quadrant, single-point urban interchange, all directional four leg)
- At-Grade Intersection/Junctions
- Tunnel systems (cut and cover; mined/bored; immersed)
- Bridge systems (flat slab; beam/girder; truss; arch; suspension; cantilever; cable-stayed; movable; floating; railroad)
- Retaining, sound, and slope stabilizing wall (gravity, semi-gravity, cantilever; MSE; soil nail; sheet pile; soldier pile and lagging); (rock anchor; netting)
- Drainage systems
- Utilities - others
- ITS/Electrical systems
- Building structures/highway facilities
- Rail transit - RT
- Landscape architecture systems
- Marine structures and facilities
- Miscellaneous

Controlling Material Used
- Geomaterial; Concrete; Structural Steel; Wood; HMA; Prestressing Concrete; Masonry; Drainage Conduits and Structures, Traffic Marking, Paints, Erosion control, Waterproofing and dampproofing, Illumination, Signal, Electrical and Related Materials, etc.

Number of Combined System/Work on the Project
- 1; 2; 3; 4; 5; 6; 7; 8; 9; 10; 11

Physical Size (scale) of Project
- Physical quantities : abutment to abutment span in FT, contact surface area in SF, volume in CY, length in miles, weight in Tons

Size of Contract Value
- Small; Medium; Large; Mega Project

Contract Time
- Construction Season - 1; 2; 3; 4; 5 or more

Geographical Location
- Rural roadways (new alignment or existing alignment)
- Rural town roadways (new alignment or existing alignment)
- Suburban roadways (new alignment or existing alignment)
- Urban roadways (new alignment or existing alignment)
- Urban core roadways (new alignment or existing alignment)

Traffic Control Category
- Category 1; 2; 3; 4; 5

Project Risks and Complexity Category
- Caterory M; I; II; III; IV and; V

Prime Contractor's Experience Modification Rating
- Experience modifcation rate - EMR

Site Environmental Assessment Class
- EIS; SEPA classification includes 1) determination of significance (DS), 2) determination of non-significance (DNS), and 3) categorical exempt (CE)

Project Delivery Method
- DBB; DB; P3; CMGC

Contractor's Years of Experience on Controlling System/Work
- Number of years of experience on controlling system/work

Chapter 3 – Methodology

This section details the research design and method. In addition, this section introduces the classification principles adapted for the classification framework that was developed and the basis for selecting them.

3.1 Research Design and Method for the Project Types Classification Framework

The objective of this research was to develop a classification framework for highway project types by gathering, reviewing, and synthesizing relevant data from Pacific Northwest DOTs and other state DOTs. The classification framework was to be based on several dimensions, such as the type of system, geographic location, controlling scope of work, level of complexity, contractual constraint, project delivery method, and other set parameters. Such a classification framework would improve efficiency, improve the validity of research findings, and greatly enhance how practitioners evaluate and administer highway projects within the Pacific Northwest DOTs and the other state DOTs. In addition, the objective of this research was to contribute to PacTrans' theme of "data-driven solutions in transportation."

This research followed a qualitative synthesis (qualitative systematic review) research design (Schick-Makaroff et al. 2016). It involved the collection and analysis of relevant state DOT documents and databases of active and completed projects. In addition, the research collected and analyzed other published work on the topic. The resulting classification framework follows the classification principles adapted for this research.

A formal Institutional Review Board (IRB) exempt application #16238 was made pursuant to this study, and it was determined through the review that the study did not require IRB oversight. This determination followed the understanding that this research was not about living individuals; rather, it was about publicly available data from PNW transportation agencies.

The following approach and procedures defined the research design and method. The procedures were as follows:

1. This research started by making contact with the Pacific Northwest state DOTs about the research project, seeking their participation, and requesting their availability (if any) for a focus group. One person was identified as a point of contact at each agency, and all communication were channeled through that point of contact. Unfortunately, participation from the agencies became a challenge, and there were not enough participants to form a focus group. However, even with limited participation from the agencies, the study was able to obtain the required data, reviews, and inputs.
2. In addition to an in-depth and extensive review of literature on the dimensions and differentiators of project types, the study gathered and analyzed over 50 documents related to state DOTs' policies and procedures on various forms of highway project work categorization. The documents gathered from the various state DOTs were those that informed the research about the various forms of categorization used in describing and differentiating highway project work or types. A larger number of documents were examined, but only relevant documents were retained and referenced for this study. Data extracted from the documents related to the following:
    a. Categories of type of work captured in STIP documents [gathered from six data sources]
    b. Categories of design project types captured in design manuals [gathered from five data sources]

c. Categories of highway improvement types captured in FHWA documents [gathered from one data source]
d. Categories of project types captured in a state DOT AASHTOware project cost estimation manual [gathered from one data source]
e. Categories of highway facilities and systems captured in various state DOT documents [gathered from eight sources]
f. Categories of work types captured in contractor prequalification forms [gathered from three data sources]
g. Categories of scope of work captured in master lists of bid/pay items [gathered from six data sources]
h. Categories of site environmental conditions captured in site environmental impact assessments [gathered from two data sources]
i. Categories of site traffic impact levels captured in maintenance of traffic documents, [gathered from two data sources]
j. Categories of geographic locations of roadways captured in roadway functional classifications [gathered from three data sources]
k. Categories of construction materials captured in standard specifications [gathered from five data sources]
l. Categories of project complexity [gathered from three data sources]
m. Categories of project delivery systems [gathered from three data sources].

3. The researchers then gathered and analyzed the database of over 2,000 projects from the Pacific Northwest state DOTs. The data from these projects were organized in Excel tables, and they contained completed and active projects within the past 10

years. Analyses of the data related to these projects were conducted to understand current project type differentiators used, their limitations, and whether they could be used in this research. The database of active and completed projects used in this research came from Washington State DOT, Alaska DOT&PF, and Oregon DOT. Some of the typical project type differentiators found in the database of over 2,000 projects analyzed included the following:

- Contract number
- Contract value
- Project name
- Project description and scope of work
- Project delivery method
- Contract amount
- Contract duration
- State route number where each project is located
- Others.

4. As a follow-up, for documents not publicly available online, the Pacific Northwest state DOTs were contacted. For example, Alaska DOT&PF was contacted for a copy of the contractor's prequalification form, and the agency responded, noting that the agency does not maintain or use a contractor's prequalification form. Alaska DOT&PF and Oregon DOT were contacted and asked whether they aggregated their cost estimates on the basis of project types (similar to the format used in AASHTOware for cost estimate), and they responded noting that they did not aggregate cost estimates on the basis of project types.

5. The study then synthesized the data gathered to understand the key dimensions that differentiate one project type from another.
6. The study evaluated and adapted an appropriate theory and principles of classification. Following the synthesis of data on various project differentiators, the study produced the initial design for the classification framework. In order to objectively develop the initial design, a set of guiding principles was followed and aligned to the research objective. The fundamental principles described in the work of Arnold (2007) were adapted as the foundation and basis for this research. In general, the theory proposed the following eight classification principles: 1) purpose, 2) domain, 3) identity, 4) differentiation, 5) prioritization, 6) diagnostics, 7) membership, and 8) certainty. These guiding principles were adapted for this research because they were realistic, explicit, universal, and not specific to any field of study. In addition, the principles provided an important and objective basis for developing the classification framework.
7. The Pacific Northwest state DOTs were then contacted for review comments and inputs to the highway project classification framework that was developed. Two of the agencies responded with comments and suggestions. One agency noted that because of workload and strategic issues, the agency would not have the resources to participate in the review.
8. On the basis of the review comments, the initial design of the project classification framework was modified, and a final design was produced to meet comments and suggestions provided by the agencies.

9. The final step was a review of the classification framework. The purpose of the review was twofold. The first objective was to check whether project type differentiators for a given project could be easily and completely mapped with the classification framework. This would mean that using the classification framework would make it easy to associate a project to one specific project type (and not two or more project types), that is, that the classification framework would provide mutually exclusive project type categories for highway projects. The second objective was to evaluate whether the resulting project type differentiators developed for the classification framework met the research objective, to enhance how practitioners evaluate and administer highway project types with regard to time, cost, and other performance measures.

3.2 Classification Principles Adapted for This Research

From the work of Arnold (2007), the classification principles adapted for this research were as follows:

Setup

1. The principle of **Purpose,** that is, the reasons for wanting to organize knowledge about PNW highway *project types*.
2. The principle of **Domain,** that is, the universe of *project dimensions* (categories) relevant to the purpose.
3. The principle of **Identity,** that is, the individual *measures* (classes) by which the *project dimensions* are defined and named.

Organization

4. The principle of **Differentiation,** the protocol-guided hierarchical structure of a system with categories and classes within categories.
5. The principle of **Prioritization,** the priority of knowledge determined by sequencing categories and sequencing classes within categories.
6. The principle of **Diagnostics,** the quantification and use of *project type* properties, sets of properties, and selected features (diagnostics) that provide objectivity.
7. The principle of **Membership,** the class membership for individuals based on quantified class limits and described central tendencies.

<u>Future</u>

8. The principle of **Certainty,** the recognition that change is inevitable and the need for continual testing of a system.

These principles were adapted and used to guide this research because they aligned with the premise of this research. The premise was that all projects, all project types, and all programs are not created equal. Project types have certain inherent characteristics that can be organized into a hierarchical framework following the levels, categories (dimensions), and classes (measures) within each category.

1. **Purpose** - Given the unique and inherent characteristics of different project types, it is a general understanding in construction that "all projects are not created equal." The purpose of this research was to create a classification framework that could categorize projects on the basis of their inherent characteristics. Such a classification system would enhance the evaluation and administration of highway projects. An in-depth classification of project types could help researchers pinpoint patterns of connections and identify key attributes that drive practice and performance.

2. **Domain** – As pointed out above, the objective was to provide a classification framework that would allow for evaluation of projects at the project type level. The domain of interest in this research included the universe of highway project types, which extended to different highway products or facilities with different project type dimensions that included parameters such as project complexity, project delivery methods, geographic location of the project, project risk level, traffic control level, level of environmental control needs, controlling system/work, and others.
3. **Identity** – Given the domain of interest, which related to the various project type dimensions, the measures for each dimensions were detailed. For example, the measure for the dimension of controlling system/work would include such systems as bridges, roadways, drainage systems, retaining walls, building facilities, tunnels, and others.
4. **Differentiation** – Practitioners are always seeking to understand differences and similarities among several phenomena. The dimensions (categories) and measures (classes) could be organized into a hierarchical structure, designed to provide differentiation within different types of highway projects.
5. **Prioritization** – Projects involve so many dimensions and measures that it is important to identify and prioritize what dimensions and measures to consider. This process was guided by an understanding of how projects behave.
6. **Diagnostics** – For analysis of project phenomenon within the realm of project types, measurable dimensions and measures are needed. Such provisions for quantification provide a much-needed tool for practitioners to understand the situations surrounding various project types. Each of the dimensions used for this research had specific

measures (values informed by literature) that could be used to diagnose how well a project type was doing.

7. **Membership** – The classification tool provides for categorizing a group of projects into project types (membership) bounded by dimensions and measures. Understanding what project would fall under what group could help to create the basis for evaluating projects that belong to the same group or membership.
8. **Certainty** – Construction projects and the construction environment are dynamic systems that change continuously. Therefore, any classification system developed today should be easy to modify and extend in the future as new knowledge becomes available.

Chapter 4 – Results

This section details the dimensions and measures selected form the in-depth review of relevant state DOT documents, the initial design of the classification framework, the review comments received from the PNW state DOTs, and the final design of the classification framework in response to comments received.

Through an in-depth review of available data from state DOTs, and following qualitative synthesis research, the study synthesized relevant and current state DOT data representing differentiators and dimensions of project types.

The resulting classification framework identified 14 dimensions (*categories*), with each dimension further broken down into corresponding measures (*classes*), giving practitioners a synthesized, data-driven tool that can enhance how practitioners evaluate and administer highway projects.

A hierarchical structure was developed to show that, given the dimensions chosen, several top-down evaluations could be conducted. The levels proceeded from type of construction to controlling system of work, to controlling materials, and to all the other dimensions. The proposed hierarchical structure was used in this research to show that one of the options available for organizing the proposed framework would be a hierarchical structure. One of the principles of a classification system is the principle of differentiation, as different levels may be structured hierarchically. In addition, a hierarchy of project levels would provide a way to drill down and categorize a project on the basis of the levels indicated. A project could be easily categorized by asking and answering questions about the types of construction, the project's controlling systems/work, the project's controlling materials, and other differentiating dimensions.

4.1 Definitions of Dimensions and Measures Selected for the Classification Framework

Definitions are presented in this section to provide clarification and consistency for the terms used for dimensions and measures. These definitions reflect the definitions found in the literature and described in the literature review.

4.1.1 Type of Construction

The definitions below are based on state DOTs' design manuals and categories of types of construction

a. *New construction* - New construction projects address the construction of a new roadway, interchange, or another transportation facility where none existed before.
b. *Reconstruction* - This typically involves a major change to an existing facility within the same general right-of-way corridor.
c. *Rehabilitation* - Rehabilitation (3R) projects consist of the resurfacing, restoration, and rehabilitation of an existing roadway on the same alignment or a modified alignment.
d. *Retrofit* – Addition of components to a highway facility, where the added components did not exist when the facility was initially constructed and are required to bring the facility up to standard.
e. *Safety Improvement* - Safety projects address prioritized high crash locations and corridors, including the Interstate system, to reduce the number of fatal and serious injury crashes.
f. *Emergency Relief* - The Emergency Relief (ER) program is intended to assist state DOTs and local agencies in repairing disaster-damaged highway facilities and returning them to their pre-disaster condition.

g. *Preventive Maintenance* - Preventive maintenance projects include asphalt surface treatments, rut filling, profiling, and similar work. These projects are typically done by department maintenance forces or through the major maintenance program.

h. *Preservation* - Historical preservation and archeological work

4.1.2 Controlling System/Work or Controlling Material

Controlling system/work or controlling material relates to portions of a project that are significant to project completion, to the extent that their progress relates to project cost, time, and influence on subsequent work. For example, on a rigid pavement roadway project, concrete is the controlling material, and it would likely consume a significant portion of the project cost and time, as well as influence subsequent work such as pavement markings.

Controlling system/work

- Roadway systems
- Road interchange systems
- At-grade intersection/junctions
- Tunnel systems
- Bridge systems
- Retaining, sound, and slope stabilizing wall
- Drainage systems
- Utilities - others
- ITS/electrical systems
- Building structures
- Rail transit - RT
- Landscape architecture systems

- Marine structures and facilities
- Miscellaneous

Controlling material used

- Demolition and removal material
- Plain concrete
- Reinforced concrete
- Structural steel
- Timber
- Hot mix asphalt
- Geomaterial (soil and rock- exc/fill) and/or soil improvement material
- Masonry
- Prestressing concrete
- Storm drain material
- Bridge expansion joint and bearings
- Piles
- Landscape materials
- Rock slope protection material
- Electrical/ITS material

4.1.3 Number of Combined System/Work on the Project

This measure was based on work by Wideman (2002) on the level of technological uncertainty based on the extent of project scope mix.

Most highway projects are a combination of various systems. For example, the controlling system/work might be a bridge project, but other system/work might include the roadway, drainage, and a retaining wall. In such cases, it is important to note the number of combined systems/work to understand the project mix and the level of complexity of the project.

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8.

4.1.4 Physical Dimensions and Scale of the Project

The physical dimensions/scale of a project represent the size of a project in terms of length, surface area, weight, and volume of the specific controlling systems/work.

- End-to-end length in “LF”
- Contact surface area in “SF”
- Concrete volume in “CY”
- Asphalt concrete weight in “TON”
- Length of roadway in “Mile”
- Roadway in “Lane-Miles”
- Structural steel weight in “TON”
- Geomaterial volume in “CY.”

4.1.5 Size of the Contract Value

This measure was based on Surety Information Office (SIO 2105) data on classifying project size on the basis of surety capacity.

The size of contract value refers to contract value at project completion.

- *Small* – less than $10 million
- *Middle* (medium) - $10 million - $100 million
- *Large* - $100M - $250 million
- *Mega* – more than $250 million

4.1.6 Contract Time

The contract time refers to project duration in working days based on contract time allowed for project completion**.**

- Working days within one construction season
- Working days withing two construction seasons
- Working days within three construction seasons
- Working days within four construction seasons
- Working days within five construction seasons
- Working days within six or more construction working seasons.

4.1.7 Geographic Location of theProject Site

This measure was based on work by Stamatiadis et al. (2017) on an Expanded Functional Classification System Matrix. Within the context of highway project alignments, the terms “rural,” “rural town,” “suburban,” “urban,” and “urban core” are used to express the level of development (density, land use, and setback) related to a specific highway alignment where a highway project is located. The range is from low density to highest density areas. Table 4-1 represents the five categories for differentiating a project based on geographic location.

Table 4-1 Context categories for the expanded functional classification system, by Stamatiadis et al. (2017)

Category	Density	Land Use	Setback
Rural	Lowest (few houses or other structures)	Agricultural, natural resource preservation and outdoor recreation uses with some isolated residential and commercial	Usually large setbacks
Rural Town	Low to medium (single family houses and other single purpose structures)	Primarily commercial uses along a main street (some adjacent single family residential)	On-street parking and sidewalks with predominately small setbacks
Suburban	Low to medium (single and multi-family structures and multi-story commercial)	Mixed residential neighborhood and commercial clusters (includes town centers, commercial corridors, big box commercial and light industrial)	Varied setbacks with some sidewalks and mostly off-street parking
Urban	High (multi-story, low rise structures with designated off-street parking)	Mixed residential and commercial uses, with some intuitional and industrial and prominent destinations	On-street parking and sidewalks with mixed setbacks
Urban Core	Highest (multi-story and high rise structures)	Mixed commercial, residential and institutional uses within and among predominately high rise structures	Small setbacks with sidewalks and pedestrian plazas

4.1.8 Traffic Control Categories

These measures were based on British Columbia MOT (2001) classifications.

CATEGORY 1

- Two-way traffic at all times
- Work on the shoulder, or work requiring single or multi-lane closures

- All lane closures removed and traffic operations normalized at the end of each work period.

CATEGORY 2

- Single lane alternating traffic or temporary total road closures
- All lane closures removed and traffic operations normalized at the end of the daily work period
- Duration of the work is typically between one day and two weeks.

CATEGORY 3

- Detours or traffic diversions with two-way traffic at all times
- Duration of the project is typically less than two weeks.

CATEGORY 4

- Long duration work requiring staged traffic control plans
- Work zone is linear and contained within a transportation corridor
- Primary impact on traffic operations is limited to the transportation corridor containing the work zone.

CATEGORY 5

- Long duration work requiring staged traffic control plans
- Work zone located at a node in the transportation network
- Primary impact on traffic operation extends beyond the work zone onto alternate routes.

4.1.9 Project Risk and Complexity Category

These measures were based on VDOT's (2012) classification. Table 4-2 shows the grouping of projects into different project risk and complexity categories.

Table 4-2 Project complexity and risk categories, per VDOT (2012)

COMPLEXITY CATEGORY	EXAMPLES OF PROJECT TYPES UNDER EACH PROJECT COMPLEXITY CATEGORY
Category M	
	Pavement schedules (Asphalt overlay, surface treatments & slurry seals);
	Bridge joint repairs;
	Bridge painting (minimum traffic impact);
	Guardrail improvements;
	Curb and gutter repair/replacement;
	Raised pavement marker installation, lens replacement;
	Pavement marking schedules;
	Minor Bridge repair (District wide, minor miscellaneous);
	Rumble strip installation;
	Slope slide repair, scour repair;
	Ground mounted sign maintenance/replacement;
	Incidental concrete repair;
	Pipe culvert rehabilitation;
	Bridge cleaning;
	Retaining wall/ Sound wall repair;
	Signal maintenance & repair (District wide).
Category I	
	Rural grade, drain, & pave of unpaved roads (may include minor horizontal & vertical alignment changes and rural rustic projects with drainage work);
	Minor bridge deck repair & concrete overlay (may include multiple bridges);
	Break, seat, & overlay concrete pavement;
	Spot improvements (multiple locations any of: incidental concrete, minor widening, enhanced pavement marking, & sign installation);
	Building demolition in advance of construction projects;
	Retaining wall installation or extensive repair;
	Minor bridge substructure repairs (with traffic impact);
	Bridge painting (multiple locations or with traffic impact);
	Minor urban reconstruction & improvement (could include curb & gutter and sidewalks; new or extended turn lanes);
	Surface reclamation, sub-grade stabilization & overlays;
	Bridge steel repair (with traffic impact);
	Signal installation – Site specific (w/o intersection improvements, no regional on-call installations);
	Overhead sign installation & lighting installations (multiple locations & or significant amount of lighting);
	Simple concrete pavement repair and/or asphalt overlay (major corridor, minimum traffic impact).
Category II	
	Urban grade, drain, & pave projects of low to medium complexity;
	Rural new construction or reconstruction grade separation roadway and bridge projects (low to medium size and complexity);
	Complex reconstruction and improvements, including widening and multiple turn lanes that may include utility adjustments;
	Major bridge substructure repairs (with low to medium traffic impact);
	Bridge deck replacements, such as multi-span or over railroads;
	Major bridge deck repair & concrete overlay (multi-span or over railroads);
	Intersection improvements with lighting and/or signal installation;
	Bridge & drainage structure replacements (frequently single span with limited approach work);
	Major drainage improvements;
	Complex concrete pavement repair and/or asphalt overlay (major corridor, significant traffic impact);
	Multi-season bridge painting (with low to medium traffic impact).
Category III	
	Intersection improvements, including widening and multiple turn lanes with utilities, lighting and/or signal installation (with medium complexity and traffic impact);
	New roadway/bridge construction or extension projects (medium size, complexity, and traffic impact);
	Bridge deck replacements (multi-span, medium traffic impact);
	Bridge & drainage structure replacements (limited span with approach work);
	Bridge reconstruction/widening projects (medium size, complexity, and traffic impact).
Category IV	
	Major urban intersection improvements, including widening and multiple turn lanes with utilities, lighting and/or signal installation (medium to large size, complex, and significant traffic impact);
	Rural/Urban new construction or reconstruction grade separation roadway and bridge projects (medium to large size, complex, major corridor);
	Major bridge deck replacements (substructure repairs, multi-span, multi-lane, major corridor, with significant traffic impact);
	Major bridge & drainage structure replacements (multi-span with extensive approach work);
	Major widening projects (medium to large size and complexity, major corridor, with significant traffic impact).
Category V	
	Major rural/urban new construction or reconstruction grade separation roadway and bridge projects (large size, complex, major corridor, significant traffic impact);
	Major widening projects (large size, complex, major corridor, significant traffic impact);
	Major interchange projects (large size, complex, major corridor, significant traffic impact);
	Major bridge deck replacement projects (large size or multiple bridges, complex, major corridor, significant traffic impact);

COMPLEXITY CATEGORY	EXAMPLES OF PROJECT TYPES UNDER EACH PROJECT COMPLEXITY CATEGORY
	Individual Category III or IV level projects that are included in multiple-contract mega-projects like Woodrow Wilson, Springfield Interchange, etc.).

4.2.10 Site Environmental Assessment Type

Environmental assessment was based on SEPA classification, which included

- determination of significance (DS)
- determination of non-significance (DNS) and
- categorically exempt (CE).

4.2.11 Contractor's Experience Modification Rating (EMR)

A contractor's experience modification rating is an indication of how well it manages projects. The rating changes from year to year. Ratings below 1 indicate good safety record, and ratings above 1 indicate a bad safety record. If a contractor is on a project for more than a year, the average rating should be computed on the basis of the yearly rating for the period of the project.

4.2.12 Number of Years of Experience of the Prime Contractor on Controlling System/Work

This dimension aimed to capture the contractor's experience with, qualification for, and knowledge about the work.

4.2 Initial Design of the Proposed Classification Framework

Given the project differentiators identified, each highway project could be associated with corresponding project dimensions and corresponding measures. Table 4-3 shows the proposed project type classification framework with its differentiating dimensions and corresponding measures. Table 4-3 shows all possible dimensions that a project could take, as well as all possible measures that could be associated with a project for use in project data collection, reporting, and analysis.

The dimensions and measures used in the table, supported by references as discussed in the literature review, are as follows:

- *Type of Construction* is based on a synthesis of various state DOT's *design manuals,* including those of the Pacific Northwest states (Washington, Alaska, Idaho, and Oregon).
- *The Controlling System/Work* is based on different civil engineering systems as captured in various literature.
- *The Controlling Material* is based on the different construction materials used in civil engineering projects, as captured state DOT contract specifications.
- *Number of Combined System/Work Involved* is based on work by Wideman (2002), who proposed a project typology to show the level of technological uncertainty based on the level of the project scope mix.
- *Physical Dimension/Scale of Project* is based on the fact that the size of a project's scope will affect budget and time and therefore does have a significant impact on performance.
- *Size of Contract Value* is based on Surety Information Office (SIO) data (2015) on classification of project size based on surety capacity.
- *Contract Time* in working days is based on the time it takes to contractually complete a project.
- *Geographic Location of Project Site* is based on the Expanded Functional Classification System Matrix by Stamatiadis et al. (2017).

- *Traffic Control Category of Project Site* is based on the British Columbia Ministry of Transportation (2001) classifications, which reflect traffic conditions for different highway projects.
- *Project Risk and Complexity Category* is based on Virginia DOT's (2012) work on complexity and risk categories.
- *Site Environmental Assessment Type* is based on the SEPA (State Environmental Policy Act).
- *Project Delivery Method* is based on West Virginia DOT's (2017) list of typical project delivery methods used on highway projects.
- *Experience Modification Rate (EMR)* is based on the safety record rating of the prime contractor.
- *Number of Years of Experience of the Prime Contractor on the Controlling System of Work* is based on contractor experience with and knowledge about the work the contractor is hired to do.

Table 4-3 Initial design of the proposed project types classification framework showing the differentiating dimensions and measures

PROJECT ID	PROJECT NAME	PROJECT DESCRIPTION	TYPE OF CONSTRUCTION	CONTROLLING SYSTEM/WORK	CONTROLLING MATERIAL TYPE	NUMBER OF COMBINED SYSTEM/WORK INVOLVED	DIMENSION AND SCALE OF PROJECT PER	SIZE OF CONTRACT VALUE	CONTRACT TIME IN WORKING DAYS	GEOGRAPHIC LOCATION OF PROJECT SITE	TRAFFIC CONTROL CATEGORY OF PROJECT SITE	PROJECT RISK AND COMPLEXITY CATEGORY	SITE ENVIRONMENTAL ASSESSMENT TYPE	PROJECT DELIVERY METHOD	EXPERIENCE MODIFICATION RATE (EMR) OF PRIME CONTRACTOR	NUMBER OF YEARS OF EXPERIENCE OF PRIME CONTRACTOR ON CONTROLLING SYSTEM OF WORK
			NEW CONSTRUCTION PROJECT	ROADWAY	PLAIN CONCRETE	2	END-TO-END LENGTH, LF	SMALL	WORKING DAYS WITHIN ONE CONSTRUCTION SEASON	Rural Roadway - New Alignment	TRAFFIC CONTROL CATEGORY 1	CATEGORY M	DS - Determination of Significance	DBB – Design-bid-build		
			RECONSTRUCTION PROJECT	INTERCHANGE	REINFORCED CONCRETE	3	CONTACT SURFACE AREA, SF	MEDIUM	WORKING DAYS WITHIN TWO CONSTRUCTION SEASONS	Rural Roadway - Existing Alignment	TRAFFIC CONTROL CATEGORY 2	CATEGORY I	DNS - Determination of Non-significance	DB – Design-build		
			REHABILITATION PROJECT	INTERSECTION	STRUCTURAL STEEL	4	CONCRETE VOLUME, CY	LARGE	WORKING DAYS WITHIN THREE CONSTRUCTION SEASONS	Rural Town Roadway - New Alignment	TRAFFIC CONTROL CATEGORY 3	CATEGORY II	CE - Categorical Exempt	P3 – Public-private partnership		
			RETROFIT PROJECT	BRIDGE	TIMBER	5	ASPHALT CONCRETE WEIGHT, TON	MEGA	WORKING DAYS WITHIN FOUR CONSTRUCTION SEASONS	Rural Town Roadway - Existing Alignment	TRAFFIC CONTROL CATEGORY 4	CATEGORY III		CMGC – Construction manager, general contractor		
			SAFETY IMPROVEMENT PROJECT	RETAINING, SOUND, ROCK SLOPE STABILIZATION WALL	CONCRETE PAVEMENT	6	LENGTH OF ROADWAY, Mile		WORKING DAYS WITHIN FIVE CONSTRUCTION SEASONS	Suburban Roadway - New Alignment	TRAFFIC CONTROL CATEGORY 5	CATEGORY IV				
			EMERGENCY RELIEF PROJECT	TUNNEL	ASPHALT CONCRETE	7	ROADWAY, Lane-Miles		WORKING DAYS WITHIN SIX OR MORE CONSTRUCTION SEASONS	Suburban Roadway - Existing Alignment		CATEGORY V				
			PREVENTIVE MAINTENANCE PROJECT	STORM DRAINAGE	GEOMATERIAL AND/OR SOIL IMPROVEMENT MATERIAL		STRUCTURAL STEEL WEIGHT, TON			Urban Roadway - New Alignment						
			PRESERVATION PROJECT	UTILITIES (NOT STORM DRAIN)	MASONRY		GEOMATERIAL VOLUME, CY			Urban Roadway - Existing Alignment						
				ELECTRICAL/ITS	PRESTRESSING CONCRETE					Urban Core Roadway - New Alignment						
				BUILDING FACILITY	STORM DRAIN MATERIAL					Urban Core Roadway - Existing Alignment						
				RAIL TRANSIT	PILES (drilled & driven)											
				LANDSCAPE	ROCK SLOPE PROTECTION MATERIAL											
				MARINE STRUCTURE & FACILITY	ELECTRICAL/ITS MATERIAL											
				MISCELLANEOUS	BRIDGE EXPANSION JOINTS AND BEARINGS											
					DEMOLITION AND REMOVAL MATERIAL											
					LANDSCAPE MATERIAL											
					OTHERS											

Figure 4-1 shows the hierarchical structure used to organize and break down the classification framework into different levels given the previously defined dimensions.

The highest level of the structure is the the type of construction, followed by the controlling of system/work, and then by the controlling material. All other dimensions are applied at the lowest level.

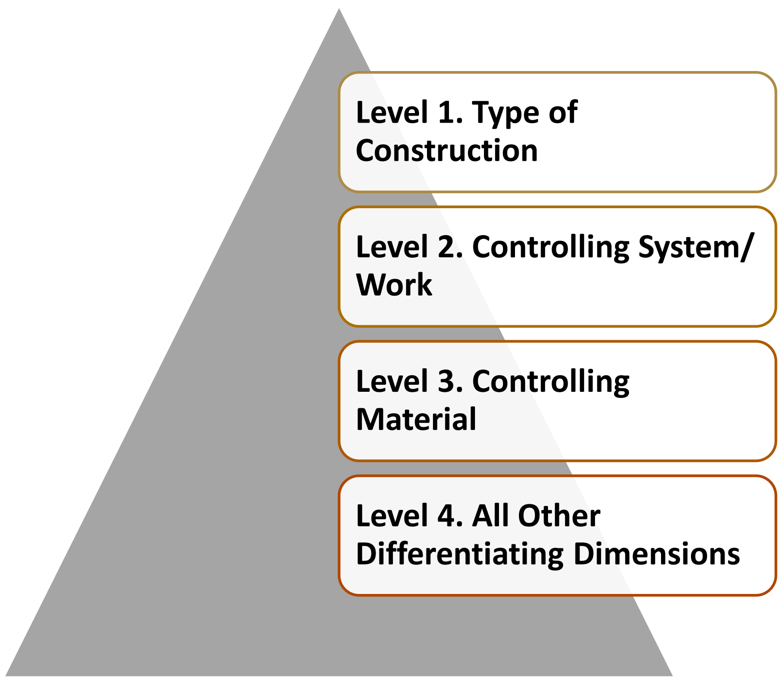

Figure 4-1 Proposed hierarchical structure for organizing project types

The chart in figure 4-2 provides an example of the hierarchical structure of a typical highway project. In this case, the project includes two types of construction, which then cascade to controlling system/work, and controlling material and all other dimensions.

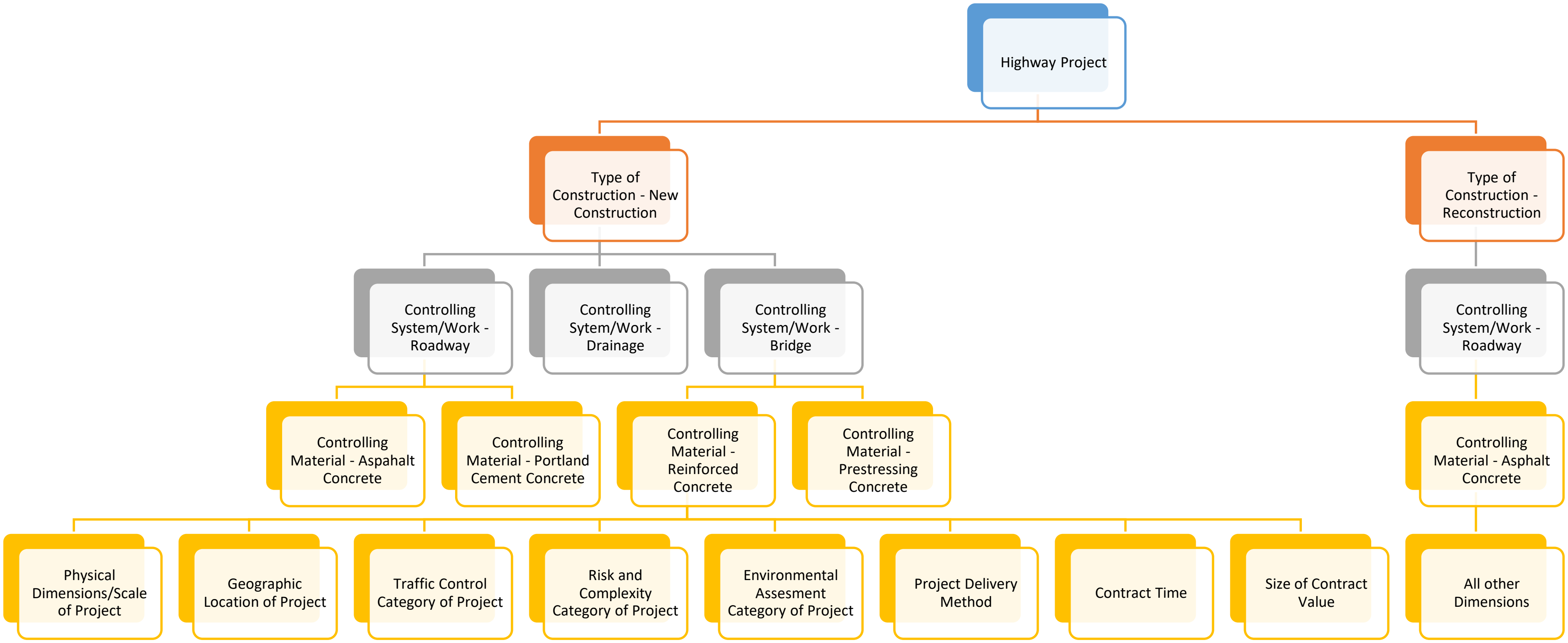

Figure 4-2 Proposed hierarchical structure and levels for organizing project types

4.3 Mapping of PNW State DOT Projects Using the Proposed Classification Framework

Table 4-4 and table 4-5 are examples of mapping some PNW DOT projects using the proposed project type classification framework. The figures show how each project is associated with and mapped to the dimensions (categories) and their corresponding measures (classes). The mappings clearly show that projects do differ, and that the use of this framework could help in the analysis of project trends, patterns, and performance.

Table 4-4 Using the proposed project type classification framework to map Alaska DOT&PF projects

PROJECT ID	PROJECT NAME	PROJECT DESCRIPTION	PROJECT TYPES CLASSIFICATION DIMENSIONS	TYPE OF CONSTRUCTION	CONTROLLING SYSTEM/WORK	CONTROLLING MATERIAL TYPE	NUMBER OF COMBINED SYSTEM/WORK INVOLVED	DIMENSION AND SCALE OF PROJECT PER	SIZE OF CONTRACT VALUE	CONTRACT TIME IN WORKING DAYS	GEOGRAPHIC LOCATION OF PROJECT SITE	TRAFFIC CONTROL CATEGORY OF PROJECT SITE	PROJECT RISK AND COMPLEXITY CATEGORY	SITE ENVIRONMENTAL ASSESSMENT TYPE	PROJECT DELIVERY METHOD	EXPERIENCE MODIFICATION RATE (EMR) OF PRIME	NUMBER OF YEARS OF EXPERIENCE OF PRIME
67285	SGY REPLACE CAPT. WILLIAM HENRY MOORE BRIDGE	The project will build a replacement bridge on a new alignment and realign one half-mile of the Klondike Highway. Project will consist of replacing the existing Captain William Henry Moore (CWHM) bridge with a Roller Compacted Concrete (RCC) embankment over an arch culvert.		NEW CONSTRUCTION	ROADWAY	GEOMATERIAL	2		MEDIUM		Rural Roadway - New Alignment	TRAFFIC CONTROL CATEGORY 1	CATEGORY II				

Table 4-5 Using the proposed project type classification framework to map WSDOT projects

PROJECT ID	PROJECT NAME	PROJECT DESCRIPTION	PROJECT TYPES CLASSIFICATION DIMENSIONS	TYPE OF CONSTRUCTION	CONTROLLING SYSTEM/WORK	CONTROLLING MATERIAL TYPE	NUMBER OF COMBINED SYSTEM/WORK INVOLVED	DIMENSION AND SCALE OF PROJECT PER	SIZE OF CONTRACT VALUE	CONTRACT TIME IN WORKING DAYS	GEOGRAPHIC LOCATION OF PROJECT SITE	TRAFFIC CONTROL CATEGORY OF PROJECT SITE	PROJECT RISK AND COMPLEXITY CATEGORY	SITE ENVIRONMENTAL ASSESSMENT TYPE	PROJECT DELIVERY METHOD	EXPERIENCE MODIFICATION RATE (EMR) OF PRIME CONTRACTOR	NUMBER OF YEARS OF EXPERIENCE OF PRIME CONTRACTOR ON CONTROLLING SYSTEM OF WORK
7984	Sr 105, Norris Slough Culvert Replacement	Construct New Bridge On Sr 105: Grade, Pile Drive, Excavate, Cement &Asphalt Pvmt, Guardrail, Pvmt Marking, Bridge Structure And Other.		RECONSTRUCTION PROJECT	BRIDGE	REINFORCED CONCRETE	2		SMALL						DBB		
7999	Sr 99, Bored Tunnel Alternative - Design-Build Pro	Grading, Surfacing, Retaining Walls, Structures, Tunneling, Electrical, Ventilamitigation, Traffic Control, And Other Work To Perform Bored Tunnel Alternative		NEW CONSTRUCTION	TUNNEL	REINFORCED CONCRETE	3		MEGA						DB		
8033	Us 12, Sr 124 Intersection - Build Interchange	Realign Sr 124, Frontage Roads, 2 Roundabouts, 2 Concrete Girders, Geo-Synthetic Retaining Walls, Curb/Gutter, Landscape, Storm Drainage, Illum, Other		RECONSTRUCTION PROJECT	BRIDGE	REINFORCED CONCRETE	5		MEDIUM						DBB		
8812	Sr224 & Sr225, Benton City-Construct Intersection	Construct Roundabouts At Sr 224 & Sr 225 W/Adj I-82 Wb Ramp		NEW CONSTRUCTION	INTERSECTION	REINFORCED CONCRETE	3		SMALL						DBB		

PROJECT ID	PROJECT NAME	PROJECT DESCRIPTION	PROJECT TYPES CLASSIFICATION DIMENSIONS	TYPE OF CONSTRUCTION	CONTROLLING SYSTEM/WORK	CONTROLLING MATERIAL TYPE	NUMBER OF COMBINED SYSTEM/WORK INVOLVED	DIMENSION AND SCALE OF PROJECT PER	SIZE OF CONTRACT VALUE	CONTRACT TIME IN WORKING DAYS	GEOGRAPHIC LOCATION OF PROJECT SITE	TRAFFIC CONTROL CATEGORY OF PROJECT SITE	PROJECT RISK AND COMPLEXITY CATEGORY	SITE ENVIRONMENTAL ASSESSMENT TYPE	PROJECT DELIVERY METHOD	EXPERIENCE MODIFICATION RATE (EMR) OF PRIME CONTRACTOR	NUMBER OF YEARS OF EXPERIENCE OF PRIME CONTRACTOR ON CONTROLLING SYSTEM OF WORK
		Term, Upgrade Elect& Illum System, Drainage, Signing & Relocation The Park & Ride Lot															
8126	Sr 3, Judy Lane Vicinity - Drainage	Install Hwy Cross Culvert, Install Drainage Structures & Catch Basin, excavation, Grading, Plugging & Filling A Pipe, Remove/Dispose Of Asbestos Pipe		NEW CONSTRUCTION	STORM DRAINAGE	STORM DRAIN MATERIAL	1		SMALL						DBB		
7074	Sr 2, North Wenatchee Area, Paving	Pavement Resurfacing From Maple St. To Baker Flats Industrial Park.		REHABILITATION PROJECT	ROADWAY	ASPHALT CONCRETE	1		SMALL						DBB		
8280	I-5, 48th St To M St Bridge Concrete Pavement Reha	Replace Concrete Panels, Pavement Grinding, Plane Bituminous Pvmt, Hma Placemeninstall Guardrail, Pvmt Marking, Traffic Control And Other Work.		REHABILITATION PROJECT	ROADWAY	REINFORCED CONCRETE	1		SMALL						DBB		
8282	Sr 706, E Of 182nd Ave Ct E To W Of 314th Ave Ct E	Rehabilitate Existing Pvmt W Pvmt Repair And Bituminous Surface Trmt, Rumblestrips, Guardrail, Pvmt Marking, Permanent Signing And Other Work.		REHABILITATION PROJECT	ROADWAY	ASPHALT CONCRETE	1		SMALL						DBB		

PROJECT ID	PROJECT NAME	PROJECT DESCRIPTION	PROJECT TYPES CLASSIFICATION DIMENSIONS	TYPE OF CONSTRUCTION	CONTROLLING SYSTEM/WORK	CONTROLLING MATERIAL TYPE	NUMBER OF COMBINED SYSTEM/WORK INVOLVED	DIMENSION AND SCALE OF PROJECT PER	SIZE OF CONTRACT VALUE	CONTRACT TIME IN WORKING DAYS	GEOGRAPHIC LOCATION OF PROJECT SITE	TRAFFIC CONTROL CATEGORY OF PROJECT SITE	PROJECT RISK AND COMPLEXITY CATEGORY	SITE ENVIRONMENTAL ASSESSMENT TYPE	PROJECT DELIVERY METHOD	EXPERIENCE MODIFICATION RATE (EMR) OF PRIME CONTRACTOR	NUMBER OF YEARS OF EXPERIENCE OF PRIME CONTRACTOR ON CONTROLLING SYSTEM OF WORK
8204	I-405, Ne 6th St To I-5 Widening And Express Toll	Add One Lane In Ea Direction On I-405 Fr Ne 6th St To Sr 522 To Create A 2-Lanetem-Completing Addl Lane Started On Stage 1, Re-Stripe I-405 Hov Lane To Creat		RECONSTRUCTION	ROADWAY	ASPHALT CONCRETE	1		LARGE						DB		
8004	Sr 21, 1 Mile N Of Manila Creek Rd - Slope Stabili	Tree Removal,Slope Scaling, Rock Bolts, Rock Dowels, Horizontal Drains, Wiremesh Slope Protection, Traffic Control, Other Work		NEW CONSTRUCTION	RETAINING, SOUND, SLOPE STABILIZATION WALL	SLOPE PROTECTION MATERIAL	1		SMALL						DBB		

4.4 Getting Buy-in and Feedback from PNW State DOTs on the Proposed Classification Framework

One of the most important aspects of this research was support adoption by the state DOTs. This required buy-in by and participation of key parties to confirm that the findings met user needs and to provide a better implementation experience (Bikson et al. 1996). This study sought to verify and validate how well the proposed framework would reflect and fit real-world experience within the PNW state DOTs. To do that, a copy of the proposed framework was provided to the PNW state DOTs.

Below are summaries of the comments received.

1. It is difficult to associate a project to one specific type of construction because most projects involve one or more types of construction. "*Using these definitions, I would classify most of our projects as hybrids. For example, consider the I-405/SR 167 Connectors DB project that is currently under construction. For the type of construction, this includes a new bridge (new construction), widening an existing bridge (reconstruction), seismic retrofit of a bridge (Retrofit) and also provides some safety improvement. I foresee lots of challenges if we are supposed to select one type of construction for every project*."
2. It is difficult to associate a project to one controlling system/work because most projects involve one or more controlling systems/work. "*For some unique projects like the AWV Tunnel, it would be easy to select "Tunnel systems" as the controlling system. For most of our projects, it would be difficult to determine which of these are controlling.*"
3. It is difficult to associate a project to one controlling material because most projects involve one or more controlling materials

4. It is difficult to decide which quantity is relevant because all projects involve quantities. "*Since all major projects involve quantities in each of these categories, would data be entered for every applicable category? There are lots of other categories that could be considered. For example, tons of reinforcing steel, area of fish habitat improved, cubic yards of cut/fill, acres of habitat restoration, etc.*"
5. It is difficult to place a project within one geographic location because most projects span more than one geographic location. "*Some projects span multiple geographic locations. As an example, WSDOT Regions on the eastern side of the state usually have annual pavement preservation contracts each summer that fix stretches of pavement across the region. Any given project could improve ten or twenty separate locations falling across multiple categories*."
6. It is difficult to map the respective information because the required data are gathered from different systems, and in some cases, some of the data are not captured by the agency.
7. It is difficult to decide on which traffic control category to use since most projects involve several traffic control categories.
8. Regarding the use of contractor experience modification rate (EMR), a comment indicated that this metric is not typically collected.
9. A suggestion for the type of construction was to indicate the percentage associated with a specific type of construction. For example, a project could be associated with 60 percent new construction, 30 percent reconstruction, and 10 percent retrofitting.

10. A suggestion for controlling system/work was to indicate the percentage associated with a specific controlling system/work. For example, a project could involve 10 percent roadway, 50 percent bridge, and 40 percent tunnel work.
11. Suggestions for controlling material were to indicate the percentage associated with a specific controlling material. For example, a project could be associated with 80 percent asphalt concrete and 20 percent Portland cement concrete.

<u>4.5 Final Design of the Proposed Classification Framework Based on Suggestions Received</u>

After review comments and suggestions had been received, the framework was reworked. The changes included the following:

1. Allow a project to be mapped with one or more types of construction, and the use of percentages to indicate how much each type of construction contributes to the total value of a project.
2. Allow a project to be mapped with one or more controlling systems/work, and the use of percentages to indicate how much each controlling system/work contributes to the total value of a project.
3. Allow a project to be mapped with one or more controlling materials, and the use of percentages to indicate how much each material contributes to the total value of the project.
4. A project may include several systems/work and resulting physical dimensions/scales. Allow the association of one or more physical dimensions resulting from the controlling systems. For example, if a project includes a roadway, bridges, and storm drainage, then the physical dimension/scale could reflect miles of roadway, length of bridge, cubic yards of concrete, length of storm drain, and other quantities.

5. Because a project could span more than one geographic location, allow a project to be mapped to more than one geographic location.
6. Because a project could require more than one category of traffic control, allow a project to be mapped to more than one traffic control category.
7. Remove contractor experience modification rate from the dimensions.
8. Update the prime contractor's experience to indicate years of experience in one or more of the controlling systems/work.

Table 4-6 is the updated version of the project type classification framework following the review comments and suggestions received from the PNW state DOTs.

4.5.1 Dimensions with Multiple Option Selection

- *Type of Construction* - The updated framework shows that a project could be associated with more than one type of construction. The revised framework allows the use of percentages to indicate how much of the scope could be associated with each type of construction.
- *Controlling Systems/Work* - Similarly, a project could be associated with one or more controlling systems/work, so the revised framework allows the use of percentages to indicate how much of the scope could be associated with each controlling system/work.
- *Controlling Material* – In addition, a project could be associated with one or more controlling material, so the revised framework allows for the use of percentage to indicate how much of the scope could be associated with each controlling material.

- *Physical Dimension and Scale of Project* - A project captures various physical dimensions that indicate the scale of the project and corresponding quantities captured for the controlling systems/work.
- *Geographic Location of Project Site –* A project could span through various functional classifications, so the revised framework allows the selection of one or more location type.
- *Traffic Control Category of Project Site –*A project could also span through various traffic control types, so the revised framework allows the selection of more than one traffic control category.

4.5.2 Dimensions with Single Option Selection

All the other dimensions allow the selection of only one option. For example, only one option is available for size of contract value.

Table 4-6 shows the final design of the proposed project type classification framework with 13 differentiating dimensions and corresponding measures. In addition, table 4-7 provides a data input sheet that can be used as a wireframe (mock-up) for implementing this classification framework into a searchable database.

Table 4-6 Final design of the proposed project types classification framework updated to reflect comments and suggestions received

CONTRACT ID	PROJECT TITLE	CONTRACT DESCRIPTION

TYPE OF CONSTRUCTION								CONTROLLING SYSTEM/WORK													
NEW CONSTRUCTION PROJECT	RECONSTRUCTION PROJECT	REHABILITATION PROJECT	RETROFIT PROJECT	SAFETY IMPROVEMENT PROJECT	EMERGENCY RELIEF PROJECT	PREVENTIVE MAINTENANCE PROJECT	PRESERVATION PROJECT	ROADWAY	INTERCHANGE	INTERSECTION	BRIDGE	RETAINING, SOUND, ROCK SLOPE STABILIZATION WALL	TUNNEL	STORM DRAINAGE	UTILITIES (NOT STORM DRAIN)	ELECTRICAL/ITS	BUILDING FACILITY	RAIL TRANSIT	LANDSCAPE	MARINE STRUCTURE & FACILITY	MISCELLANEOUS

CONTROLLING MATERIAL TYPE																
PLAIN CONCRETE	REINFORCED CONCRETE	STRUCTURAL STEEL	TIMBER	CONCRETE PAVEMENT	ASPHALT CONCRETE	GEOMATERIAL AND/OR SOIL IMPROVEMENT	MASONRY	PRESTRESSING CONCRETE	STORM DRAIN MATERIAL	PILES	ROCK SLOPE PROTECTION MATERIAL	ELECTRICAL/ITS MATERIAL	BRIDGE EXPANSION JOINTS AND BEARINGS	DEMOLITION AND REMOVAL MATERIALS	LANDSCAPE MATERIAL	OTHERS

DIMENSION AND SCALE OF PROJECT PER								GEOGRAPHICAL LOCATION OF PROJECT SITE										TRAFFIC CONTROL CATEGORY OF PROJECT SITE				
END-TO-END LENGTH, LF	CONTACT SURFACE AREA, SF	CONCRETE VOLUME, CY	ASPHALT CONCRETE WEIGHT, TON	LENGTH OF ROADWAY, Mile	ROADWAY, Lane-Miles	STRUCTURAL STEEL WEIGHT, TON	GEOMATERIALS CUT/FILL VOLUME, CY	Rural Roadway - New Alignment	Rural Roadway - Existing Alignment	Rural Town Roadway - New Alignment	Rural Town Roadway - Existing Alignment	Suburban Roadway - New Alignment	Suburban Roadway - Existing Alignment	Urban Roadway - New Alignment	Urban Roadway - Existing Alignment	Urban Core Roadway - New Alignment	Urban Core Roadway - Existing Alignment	TRAFFIC CONTROL CATEGORY 1	TRAFFIC CONTROL CATEGORY 2	TRAFFIC CONTROL CATEGORY 3	TRAFFIC CONTROL CATEGORY 4	TRAFFIC CONTROL CATEGORY 5

NUMBER OF COMBINED SYSTEM/WORK INVOLVED	SIZE OF CONTRACT VALUE	CONTRACT TIME IN WORKING DAYS	PROJECT RISK AND COMPLEXITY CATEGORY	SITE ENVIRONMENTAL ASSESSMENT TYPE	PROJECT DELIVERY METHOD	NUMBER OF YEARS OF EXPERIENCE OF PRIME CONTRACTOR ON ONE OR MORE OF THE CONTROLLING SYSTEM/WORK
2	SMALL	WORKING DAYS WITHIN ONE CONSTRUCTION SEASON	CATEGORY M	DS - Determination of Significance	DBB – Design-bid-build	
3	MEDIUM	WORKING DAYS WITHIN TWO CONSTRUCTION SEASONS	CATEGORY I	DNS - Determination of Non-significance	DB – Design-build	
4	LARGE	WORKING DAYS WITHIN THREE CONSTRUCTION SEASONS	CATEGORY II	CE - Categorical Exempt	P3 – Public-private partnership	
5	MEGA	WORKING DAYS WITHIN FOUR CONSTRUCTION SEASONS	CATEGORY III		CMGC – Construction manager, general contractor	
6		WORKING DAYS WITHIN FIVE CONSTRUCTION SEASONS	CATEGORY IV			
7		WORKING DAYS WITHIN SIX OR MORE CONSTRUCTION SEASONS	CATEGORY V			

Table 4-7 Proposed data input sheet for database development

PROJECT ID AND DESCRIPTION DATA		
Contract ID Number		
Project Title		
Contract Description		
PROJECT COST AND TIME DATA		
Engineer's Estimate Amount		
Contract Amount at Award		
Contract Amount at Completion		
Contract Working Days as Awarded		
Authorized Contract Working Days at Completion		
Number of Contract Changes		
TYPE OF CONSTRUCTION (Select one or more as applicable)		**Indicate % of types of construction applicable (total of all not to exceed 100%)**
NEW CONSTRUCTION	☐Y ☐N	[%]
RECONSTRUCTION	☐Y ☐N	[%]
REHABILITATION	☐Y ☐N	[%]
RETROFIT	☐Y ☐N	[%]
SAFETY IMPROVEMENT	☐Y ☐N	[%]
EMERGENCY RELIEF	☐Y ☐N	[%]
PRVENTIVE MAINTENANCE	☐Y ☐N	[%]
PRESERVATION	☐Y ☐N	[%]
CONTROLLING SYSTEM/WORK (Select one or more as applicable)		Indicate % of *controlling* system/work applicable (total of all not to exceed 100%)
ROADWAY	☐Y ☐N	[%]
INTERCHANGE	☐Y ☐N	[%]
INTERSECTION	☐Y ☐N	[%]
BRIDGE	☐Y ☐N	[%]
RETAINING/SOUND/STABILIZATION WALL	☐Y ☐N	[%]
TUNNEL	☐Y ☐N	[%]
STORM DRAINAGE	☐Y ☐N	[%]
UTILITIES (NOT STORM DRAINAGE)	☐Y ☐N	[%]
ELECTRICAL/ITS	☐Y ☐N	[%]
BUILDING FACILITY	☐Y ☐N	[%]
RAIL TRANSIT	☐Y ☐N	[%]
LANDSCAPE	☐Y ☐N	[%]
MARINE STRUCTURE & FACILITY	☐Y ☐N	[%]
CONTROLLING MATERIAL (Select one or more as applicable)		Indicate % of *controlling* materials applicable (total of all not to exceed 100%)
PLAIN CONCRETE	☐Y ☐N	[%]
REINFORCED CONCRETE	☐Y ☐N	[%]
STRUCTURAL STEEL	☐Y ☐N	[%]
TIMBER	☐Y ☐N	[%]
CONCRETE PAVEMENT	☐Y ☐N	[%]
ASPHALT CONCRETE	☐Y ☐N	[%]
GEOMATERIAL (soil and rock-exc/fill) AND/OR SOIL IMPROVEMENT MATERIAL	☐Y ☐N	[%]
MASONRY	☐Y ☐N	[%]
PRESTRESSING CONCRETE	☐Y ☐N	[%]
STORM DRAINAGE MATERIAL	☐Y ☐N	[%]
PILES	☐Y ☐N	[%]
SLOPE PROTECTION MATERIAL	☐Y ☐N	[%]
ELECTRICAL/ITS MATERIAL	☐Y ☐N	[%]
EXPANSION JOINTS AND BEARINGS	☐Y ☐N	[%]
DEMOLITION AND REMOVAL MATERIAL	☐Y ☐N	[%]
LANDSCAPE MATERIAL	☐Y ☐N	[%]
OTHERS	☐Y ☐N	[%)

NUMBER OF COMBINED SYSTEM/WORK INVOLVED ON THIS PROJECT (should correspond to the number of controlling systems/work checked above)			
Does project involve more than one controlling system/work	☐Y ☐N	How many?	#

PHYSICAL DIMENSIONS AND SCALE OF PROJECT

System - *ROADWAY*	Size	System - *INTERCHANGE*	Size	System - *INTERSECTION*	Size	System - *BRIDGE*	Size
☐ End-to-end Length	X	☐ End-to-end Length		☐ End-to-end Length		☐ End-to-end Length	
☐ Contact Surface Area	X	☐ Contact Surface Area		☐ Contact Surface Area		☐ Contact Surface Area	
☐ Concrete Volume	X	☐ Concrete Volume		☐ Concrete Volume		☐ Concrete Volume	
☐ HMA Tonnage	X	☐ HMA Tonnage		☐ HMA Tonnage		☐ HMA Tonnage	
☐ Length of Roadway	X	☐ Length of Roadway		☐ Length of Roadway		☐ Length of Roadway	
☐ Roadway Lane-Miles	X	☐ Roadway Lane-Miles		☐ Roadway Lane-Miles		☐ Roadway Lane-Miles	
☐ Structural Steel Weight		☐ Structural Steel Weight		☐ Structural Steel Weight		☐ Structural Steel Weight	
☐ Geomaterial (cut/fill) Volume	X	☐ Geomaterial (cut/fill) Volume		☐ Geomaterial (cut/fill) Volume		☐ Geomaterial (cut/fill) Volume	

PHYSICAL DIMENSIONS AND SCALE OF PROJECT

System – RETAINING *WALLS*	Size	System - *TUNNEL*	Size	System – *STORM DRAINAGE*	Size	System – *UTILITIES (Not Storm Drainage)*	Size
☐ End-to-end Length	X	☐ End-to-end Length		☐ End-to-end Length		☐ End-to-end Length	
☐ Contact Surface Area	X	☐ Contact Surface Area		☐ Contact Surface Area		☐ Contact Surface Area	
☐ Concrete Volume	X	☐ Concrete Volume		☐ Concrete Volume		☐ Concrete Volume	
☐ HMA Tonnage		☐ HMA Tonnage		☐ HMA Tonnage		☐ HMA Tonnage	
☐ Length of Roadway		☐ Length of Roadway		☐ Length of Roadway		☐ Length of Roadway	
☐ Roadway Lane-Miles		☐ Roadway Lane-Miles		☐ Roadway Lane-Miles		☐ Roadway Lane-Miles	
☐ Structural Steel Weight	X	☐ Structural Steel Weight		☐ Structural Steel Weight		☐ Structural Steel Weight	
☐ Geomaterial (cut/fill) Volume	X	☐ Geomaterial (cut/fill) Volume		☐ Geomaterial (cut/fill) Volume		☐ Geomaterial (cut/fill) Volume	

PHYSICAL DIMENSIONS AND SCALE OF PROJECT

System – *ELECTRICAL/ITS*	Size	System – *BUILDING*	Size	System – *RAIL TRANSIT*	Size	System - *LANDSCAPE*	Size
☐ End-to-end Length	X	☐ End-to-end Length		☐ End-to-end Length		☐ End-to-end Length	
☐ Contact Surface Area		☐ Contact Surface Area		☐ Contact Surface Area		☐ Contact Surface Area	
☐ Concrete Volume	X	☐ Concrete Volume		☐ Concrete Volume		☐ Concrete Volume	
☐ HMA Tonnage		☐ HMA Tonnage		☐ HMA Tonnage		☐ HMA Tonnage	
☐ Length of Roadway		☐ Length of Roadway		☐ Length of Roadway		☐ Length of Roadway	
☐ Roadway Lane-Miles		☐ Roadway Lane-Miles		☐ Roadway Lane-Miles		☐ Roadway Lane-Miles	
☐ Structural Steel Weight		☐ Structural Steel Weight		☐ Structural Steel Weight		☐ Structural Steel Weight	
☐ Geomaterial (cut/fill) Volume	X	☐ Geomaterial (cut/fill) Volume		☐ Geomaterial (cut/fill) Volume		☐ Geomaterial (cut/fill) Volume	

SIZE OF CONTRACT VALUE (Select one)

☐Small Project [less than $10m]	☐Medium Project [$10m to $100m]	☐Large Project [$100m to $250m]	☐Mega Project [more than $250m]

CONTRACT TIME IN WORKING DAYS

Number of Working Days Allowed in the Contract

GEOGRAPHIC LOCATIONS OF PROJECT SITE (Select one or more as applicable)

RURAL ROADWAY – New Alignment	☐Y ☐N
RURAL ROADWAY – Existing Alignment	☐Y ☐N
RURAL TOWN ROADWAY – New Alignment	☐Y ☐N
RURAL TOWN ROADWAY – Existing Alignment	☐Y ☐N
URBAN ROADWAY – New Alignment	☐Y ☐N
SUBURBAN ROADWAY – Existing Alignment	☐Y ☐N
URBAN ROADWAY – New Alignment	☐Y ☐N
URBAN ROADWAY – Existing Alignment	☐Y ☐N
URBAN CORE ROADWAY – New Alignment	☐Y ☐N
URBAN CORE ROADWAY – Existing Alignment	☐Y ☐N

TRAFFIC CONTROL CATEGORIES OF PROJECT SITE (Select one or more as applicable)

TRAFFIC CONTROL CATEGORY 1	☐Y ☐N
TRAFFIC CONTROL CATEGORY 2	☐Y ☐N
TRAFFIC CONTROL CATEGORY 3	☐Y ☐N
TRAFFIC CONTROL CATEGORY 4	☐Y ☐N
TRAFFIC CONTROL CATEGORY 5	☐Y ☐N

PROJECT RISK AND COMPLEXITY CATEGORY (Select one)					
☐ CATEGORY M [very low]	☐ CATEGORY I [low]	☐ CATEGORY II [low–med]	☐ CATEGORY III [med]	☐ CATEGORY IV [high]	☐ CATEGORY V [very high]
SITE ENVIRONMENTAL ASSESSMENT TYPE (Select one)					
☐ DS – DETERMINATION OF SIGNIFICANCE	☐ DNS – DETERMINATION OF NON-SIGNIFICANCE	☐ CE – CATEGORICAL EXEMPT			
PROJECT DELIVERY METHOD (Select one)					
☐ DESIGN-BUILD	☐ DESIGN-BID-BUILD	☐ P3	☐ CMGC		
NUMBER OF YEARS OF EXPERIENCE OF CONTRACTOR ON ONE OR MORE OF THE CONTROLLING SYSTEM/WORK					
# of Years					

Chapter 5 – Discussion

In this section, formal definitions based on the developed classification framework are presented. This section details what was found, what the results indicate, and how practitioners could implement the results.

5.1 Project Type Definitions

As depicted in Table 4-6, a highway project type could be defined by one or more contributing types of construction, one or more contributing systems/work corresponding to the type of construction, and one or more contributing materials corresponding to the systems/work. A highway project type could be further defined by the size of project by contract value, the project contract duration, the physical sizes of various systems and components, the categories of traffic control required for the project site, the categories of geographic locations of the project site, and the site environmental assessment type. In addition, a highway project type could be defined by the project risk and complexity level, the project delivery method used, the experience of the prime contractor related to the systems and components, and the number of combined systems involved.

5.2 Research Method Used

The use of the qualitative synthesis research method was found to be a good fit for this research because it allowed an in-depth but systematic approach. The qualitative synthesis research method provides for contextual richness that enhances relevance and understanding. The research method included reviewing, selecting, combining, integrating, and synthesizing across diverse study designs and data types.

5.3 Project Types Differentiators

The literature review indicated that various dimensions help describe and differentiate one project type from another. The research found that because of the inherent nature of projects, several factors are needed to classify project types. Some of the key dimensions identified from the literature included the construction type, type of system, type of material, location, physical size of the project, and traffic control category of the project.

5.4 PacTrans Theme on Data-driven Solution

This research was data-driven (rather than by intuition or personal experience) by objective and qualitative data to improve analysis and evaluation of highway project types. The study collected, analyzed, and synthesized data from Pacific Northwest DOTs and other state DOTs on various classifications in use. The resulting classification framework is data-driven and provides new knowledge on how to classify highway project types. The classification framework provides knowledge and understanding of the different highway project types available. The results of this research offer another layer of information needed for safe transportation. They could allow practitioners to safely evaluate and administer highway projects on the basis that projects differ, and safe transportation could be informed by a data-driven solution.

5.5 Aligning the Classification Framework to Uniformat and MasterFormat

In construction, the Uniformat and MasterFormat classification systems are the most widely used classification system for project break down, and both were found to be fundamental to this research. For example, the proposed framework classification considered controlling materials that are similar to some of the Level 1 products captured in MasterFormat. Similarly, the controlling systems are in line with some of the systems captured in Uniformat II for bridges and Uniformat II for transportation surface elements.

5.6 Review of PNW Database of Over 2,000 Projects

An analysis of over 2,000 projects (completed and active) categorized in a PNW database found that the database was not suitable for use in developing a highway project type classification framework. This is because the project types were not clearly defined and could not be differentiated easily following the broad description of the scope of work. The narrative that defines the project scope of work was not organized or written in such a way as to make it possible to easily isolate and differentiate one specific type of project from the other.

5.7 Lack of Standard Classification Framework within State DOTs

The classification framework developed from this research does not exist within the PNW state DOTs, and does not exist within other state DOTs in the U.S. The PNW state DOTs capture and maintain various data on project that they execute. In reference to the data gathered from the PNW state DOTs, the study found that the agencies maintained some form of project type classification for different purposes. However, a formally synthesized classification of highway project types does not exist. For example, a look at contractors' prequalification forms from WSDOT and Oregon DOT showed different work classifications. Similarly, a look at STIP reports from all four agencies showed different classification formats. In addition, the design manuals developed by all four agencies classify design for various construction types by using different criteria. Pennsylvania DOT and Virginia DOT have also developed different classifications of project types on the basis of project complexity and risk. What was found to be lacking was a formal classification framework for highway projects.

5.8 Classification Principles and Research Objective

Given the adopted classification principles, the proposed classification framework was found to be aligned with the research objective. The proposed classification framework captures various dimensions (categories) of highway project types as the domain of interest, and it defines each category further defined by measures (classes). The fundamental principles captured in the work of Arnold (2007) were adapted to provide the foundation and basis for this research. In general, Arnold's theory proposed the following eight classification principles: 1) purpose, 2) domain, 3) identity, 4) differentiation, 5) prioritization, 6) diagnostics, 7) membership, and 8) certainty. The classification framework developed in this study was informed by these principles. These classification principles allowed the framework to be organized into a hierarchical format, and the framework is suited for objective analysis (diagnosis) of project performance. In addition, the proposed framework leaves room for future modifications as new knowledge become available.

5.9 Meeting the Need for a Mutually Exclusive and Exhaustive Classification Framework

One of the key recommendations from the reviewers, which was implemented, is that the proposed classification framework should allow practitioners to easily associate a project with a specific project type – it should be mutually exclusive and exhaustive in allowing practitioners to capture all applicable dimensions and measures. Mutually exclusive means that the project types captured with the classification framework would not overlap, while exhaustive means that all possible project types would be captured with the classification framework. The classification framework would allow agencies to select one or more types of construction, one or more types of systems/work, and one or more types of materials, as well as to aggregate their contributing percentages. Irrespective of the way the state DOTs organize their bid/pay items, the proposed framework should allow agencies to select and aggregate the contributing percentages of the types of construction, the types of systems/work, and the types of materials.

Most state DOTs aggregate project bid/pay items on the basis of similar items of work (refer to table 2-1). which is different from organizing the bid/pay items separately on the basis of different systems or sub-systems of work. One of the state DOTs that organizes pay/bid item on the basis of the systems and sub-systems of work is Ohio DOT. Ohio DOT's schedule of bid/pay items is broken into sections, with each section representing a different system or sub-system of work. For example, a recent project by Ohio DOT for the "Reconstruction of I-75 Mainline, Ramps, and Local Roads" included several bid/pay items organized and aggregated on the basis of project systems and sub-systems. The following systems and sub-systems were included in the project: roadways, erosion control, drainage, pavements, water works, sanitary sewers, lighting, traffic control, traffic surveillance, traffic signals, building demolition, noise barriers, maintenance of traffic, retaining walls, bridges, pedestrian tunnels.

Implementing the proposed framework to reflect the contributing percentages of individual systems of work should not be difficult, even when bid/pay items are not currently organized by systems and sub-systems as in the case of Ohio DOT. Even for state DOTs whose current practice is to aggregate bid/pay items by similar items of work, the practice still involves defining the items of work for the systems or sub-systems of work and then organizing and aggregating them by similar items of work. Implementing the proposed framework to reflect the contributing percentages from the types of construction would require mapping the applicable systems and subsystems to the type of construction. Also, irrespective of the project delivery method, this approach could work because the scopes of work for all project delivery methods are defined by bid/pay items. However, aggregating and proportioning the work items would become difficult to accomplish if the contract payment method for the entire project was a lump sum payment method.

In addition, the proposed framework should be easy to implement as it relates to the contributing percentages of various construction materials. The bid/pay items define the scope of work, the product and materials of the contract, and the corresponding quantity or amount needed to derive the contributing percentage.

5.10 Previous Attempts to Categorize Highway Project Types

Several researchers have pointed to the need to develop a project type classification system, and a few researchers have developed project type classification systems but with a limited focus.

The ability to describe, catalog, and classify the various aspects of the environment has advanced understanding of the environment. Within the construction industry, there are different aspects of classifications, some of which include construction materials, construction trades, contract pay items, construction tasks, contract specifications, project delivery methods, and others. According to Mayr and Bock (2002), in a diverse, dynamic, and chaotic environment, classification helps in making sense of the environment and allows for better understanding of how things work. Understanding construction requires an understanding of how things work, and classification of different types of projects is integral to the process.

Hancher et al. (1992) used 14 categories of project types that were previously developed by Texas DOT. The 14 categories compared to some of the types of construction and controlling systems/work developed in this study.

Werkmeister et al. (2000) used categories of project type that were previously developed by Kentucky DOT. The six categories compared to some of the types of construction developed in this study.

TSTC (2012) developed a project type classification system to allow comparative evaluation of funding under STIP across all state DOTs. The classification system included nine groups, which compared to some of the type sof construction and controlling systems/work developed in this study.

Work by Okere (2018) resulted in the classification of WSDOT project types into 18 categories. Those categories had some similarities to the types of construction and controlling systems/work developed in this study.

Antoine and Molenaar (2016) developed a project classification framework based on four key variables that included complexity, award cost, facility type, and project type. The proposed project type classification framework developed in this study extended the work of Antoine and Molenaar by considering other dimensions.

The common theme found in these classification frameworks was that they were not all-inclusive. The proposed project type classification framework developed in this study is all-inclusive and would allow the framework to be extended and modified as new knowledge become available.

5.11 Suggestions for Implementing the Proposed Project Type Classification Framework

Moving from research to practice is not always easy. To help PNW state DOTs and other DOTs implement the proposed framework, this section outlines some of the benefits and applications of this research.

Benefits of using the project type classification framework extend to, and are not limited to, evaluation of the following:

1. Project types and rate/*trends in* project cost overruns
2. Project types and rate/*trends in* project time delays
3. Project types and level/*trends in* the accuracy of the engineer's estimate
4. Project types and range/*trends in* bid amount submitted

5. Project types and design completeness – the level of/*trends in* design error and omissions
6. Project types and sources/*trends in* contract changes
7. Project types and level/*trends in* types of management resources needed
8. Project types and completeness/*trends in* contractual language and clauses
9. Project types and impact on/*trends in* project delivery method
10. Project types and the percentage of/*trends in* contingency allocated
11. Project types and effectiveness of/*trends in* contract administration practices
12. Project types and rate of/*trends in* safety performance during construction
13. Project types and applicable work breakdown structure (WBS)/construction work tasks
14. Project types and nature of/*trends in* project risk and complexity
15. Project types and conceptual method for determining contract time and cost
16. Project types and *trends in* the bid submitted by a specific contractor.

A standardized framework for classification of highway project types could provide insights into trends and patterns that might not be evident in current practice when project type differentiators are not classified. In addition, standardized classification of highway projects should provide the basis to compare and contrast projects.

Another benefit resulting from this study is that the framework could be used to ask questions and conduct analyses and project evaluations to understand various aspects of a specific project type performance.

Inconsistent metadata make basic project analytics difficult. The use of the project type dimensions and measures developed in this study should provide consistent metadata that will allow practitioners to conduct basic or complicated analytics.

Also, the use of this framework should provide a baseline for evaluating project performance and gain lessons learned across PNW state DOTs. For example, an analysis of a specific project type could be conducted across two or more state DOTs if those state DOTs implemented the same project type classification framework in their programs. The implementation of this research will allow highway construction cost and time comparison surveys across state DOTs. Work by WSDOT (2002) on its *Highway Construction Cost Comparison Survey* is a good example of the benefits that could result from this research. Comparisons of project cost or time across state DOTs could become a basic process if the agencies implemented the project type classification framework.

In addition to implementation of the project type classification framework, a common database could be created for use by state DOTs. The aim would be for agencies to adopt a common database system. A common database of highway project types would allow agencies to review their practices as well as easily compare their practices to those of other state DOTs. Such a database could be designed to allow the agencies to enter project type data and import additional data such as project costs, contract time, contract change orders, project claims, etc.

Given the benefits gained from state DOT participation in the AASHTOWare Project software, it would be beneficial to expand the AASHTOWare applications to capture project types and other project-related data by using the classification framework developed in this study.

One of the major purposes of the proposed project type classification framework is to facilitate the transfer of knowledge about highway projects from one area of construction to another. For example, knowledge gained about how different project types behave could extend to and become the basis for planning, preliminary engineering, right-of-way acquisition, and transportation research on highway projects.

Some of the existing systems and applications into which this framework could be incorporated are the following:

- An *estimating database* to allow analysis and evaluation of project cost estimates based on different highway project types
- A *database of active and completed projects* to provide publicly accessible data that could allow practitioners and the public to view highway project type uniqueness, reduce over-generalization, and improve expectations for project performance
- A *statewide transportation improvement program report* to allow consistency in aggregating and in-depth reporting on statewide improvements, thereby providing transparency and clarity
- A *database of project schedules* to aggregate and analyze different project schedules based on highway project types, thereby making data available to objectively estimate contract time on the basis of known patterns from specific project types
- A *database of contract change orders* to aggregate and analyze contract changes associated with various highway project types.

5.12 Research Limitation

A limitation in this research was the limited participation from the PNW state DOTs, which meant that the focus group was not used as initially proposed. Some of the PNW state DOT personnel who were contacted in this study did not have the time to participate in this study.

Chapter 6 – Conclusions and Recommendations for Future Work

The lack of a standardized classification system for highway project types obscures and exaggerates practitioners' understanding in the area of contract administration, resulting in practices and overarching generalizations that fail to reflect reality. In the absence of a standard system for classifying project types, practitioners have taken pragmatic and ad hoc steps to classify projects to meet their specific needs. The proposed classification framework provides a much-needed tool for classifying highway projects. A standardized classification framework could improve efficiency and greatly enhance how practitioners evaluate and administer highway projects within the Pacific Northwest and the entire U.S.

The research objective was to develop a classification system for highway project types based on several differentiating dimensions. Following qualitative synthesis research and participation by PNW state DOTs, a framework was developed, and reviewed by the PNW state DOTs. On the basis of the review comments and feedback received, the framework was updated. The research outcome is a classification framework that would allow practitioners to effectively evaluate and administer highway projects. The proposed project type classification framework could help to focus practices and performance related to contract administration on highway projects. Suggestions and guidance for implementation of the classification framework were provided, and a wireframe was developed to help practitioners implement the framework into searchable database applications.

The significant contribution is that basic project performance analytics could be conducted to enhance how practitioners evaluate and administer highway projects within and across agencies if the framework is implemented by state DOTs. For future research on this topic, the recommendation is be to focus on evaluating how well the proposed classification framework enables better visibility of and insight into contract administration.

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