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INTRODUCING THE CONCEPT OF FOUNDATIONAL ATTRIBUTES OF CONSTRUCTION PROJECTS

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Abstract: A construction project is considered to be unique due to the process of delivering a customer-designed product, diverse stakeholders involved, the unique location and timeframe of construction, and specific social, economic, and environmental constraints attached to it. The uniqueness of construction projects brought great challenges to the construction industry professionals as well as researchers and educators in the construction discipline. If a method or a model can be developed to assess the similarity between projects and make project comparison more science than art, we can increase the confidence level of researchers when they conduct analyses and make conclusions. We can help industry professionals make better decisions by providing more accurate information. This paper introduces the concept of Foundational Attributes of construction projects. A literature review is conducted to create the framework, and case study projects are applied to the framework to demonstrate how this concept helps with project comparison. A spider chart is chosen to host the concept of Foundational Attributes, and two case study projects are selected to demonstrate how to quantify project similarity using the concept of Foundational Attributes and a spider chart. Last but not least, lessons learned and future research directions are discussed at the end of this paper.

1 INTRODUCTION

A construction project is considered to be unique due to the process of delivering a customer-designed product, the involvement of diverse stakeholders, the unique location and timeframe of construction, and specific social, economic, and environmental constraints attached to it. All those factors acting together make a construction project unique (Zhang, 2016).

The uniqueness of construction projects has brought great challenges to construction industry professionals as well as researchers and educators in the construction discipline. This characteristic brings limitations to researchers when they try to compare multiple projects and make inferences, as well as to industry professionals when they try to make decisions based on previous projects. The current common practice is to ignore differences between projects and assume that they are similar enough so people can go on with their analysis and make conclusions. Sometimes people address this issue by only comparing projects that fit certain criteria. It is better than no standard at all, but the confidence level is low.

If a method or a model can be developed to assess the similarity between projects and make project comparisons more science than art, we can increase the confidence level of researchers when they conduct analyses and make conclusions, and we can help industry professionals to make better decisions based on better information. Considering the example of a research study to evaluate the effectiveness of a new safety procedure mentioned in the previous section, if some kind of tool can be used to justify the researchers' assumption and to prove that the projects are similar enough to be compared, it could significantly boost the confidence level, and it will be a big contribution to the construction research community.

A thorough literature search was conducted to locate any past and current studies directly related to construction project comparison, and unfortunately, none have been found. As mentioned above, researchers compare projects in their research studies with or without acknowledging the fundamental differences between projects. One of the reasons for why there has been no effort on making a more justified comparison between projects is that the uniqueness of construction projects is a commonly accepted fact, and it is not possible to make an apples-to-apples comparison between projects. Another reason for the lack of research effort on this subject could be because the construction management research community is used to doing qualitative research, and this kind of research is more of an art than a science, so there is no need to address seemingly small differences between projects. Unlike doing research in a controlled lab, doing research on a construction project is too complicated and contains too many variables, so there is no need to know to what extent the projects being compared are similar.

As discussed previously, solving this problem is worthwhile and will have a significant impact on both the research community and the construction industry. Therefore, the lack of previous research efforts presents a chance and a challenge. The author is determined to make the initial effort to work on this subject.

This is a complicated problem, with no previous studies to learn from. The author wants to try something different to see if a solution can be found or not. Albert Einstein once said, “The significant problems we face cannot be solved at the same level of thinking we were at when we created them.” Therefore, to solve the current problems in the construction industry, a new level of thinking could be a possible solution. However, what is this new level of thinking? How can we find it? How could it help to solve the problem brought by the uniqueness of construction projects? The author is going to try to answer these questions in this paper.

2 THE CONCEPT OF FOUNDATIONAL ATTRIBUTES

The concept of Foundational Attributes of construction projects was initially brought up in the keynote presentation given by Dr. John A. Gambatese during the CIB W099 Conference 2011 in Washington, D. C. The presentation was titled “A Look at Prevention through Design Based on Foundational Attributes of Construction Projects”. In the presentation, Dr. Gambatese introduced the concept of foundational attributes of construction projects. The Foundational Attributes of construction projects are defined as “the fundamental elements of all projects that establish a project’s nature and shape a project’s outcomes, and the disposition of a project’s foundational attributes must be known in order to understand and characterize a project, to compare one project to another, and to determine how to effectively impact a project’s outcomes” (Gambatese 2011). Dr. Gambatese proposed five foundational attributes and described the scope and meanings of them as shown in Table 1.

Table 1: Foundational attributes proposed by Dr. Gambatese

Attributes	Descriptions and scopes
Physical Form and Function	The physical properties of a project's design and the construction features and processes; Shape, size, weight, texture, materials, stress, strain; The nature and arrangement of construction activities undertaken to construct a project.
Organizational and Project Structure	The formal relationships established between the project team members that define the interconnectivity and interactions between the parties; The formal relationships within an organization which establish the roles and responsibilities of the employees, and the relationships between the employees on a project.
Resources, Tools and Processes	The devices and resources utilized to design and construct a project and the means and timing in which they are implemented; The materials, equipment, labor, money, and time needed and available to construct a project.
Culture	The patterns of interacting elements and the accumulated learning of a group; The ways of thinking, feeling and perceiving the world that has made the group successful and shape its interpretations and actions; The shared beliefs in the minds of all employees.
Risk	The potential that an action, activity, or condition will lead to a loss; Probability, severity, exposure; Risk tolerance/threshold.

Figure 1 is an illustration of the five foundational attributes and how they may work together to define a project. In the figure, the area enclosed by the solid lines represents one project and the area enclosed by the dash lines represents another project. The overlapping area represents the similarity between the two projects.

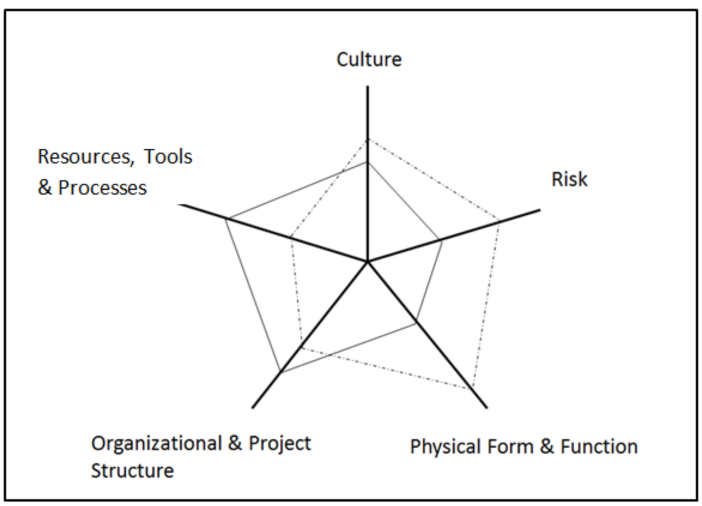

Figure 1: An illustration of the five foundational attributes in a spider diagram

The illustration in Figure 1 is just one possible framework, and there has been no effort to quantify the five attributes. It is to be determined whether or not the overlapping area could represent the similarity between projects, and if so, what is the threshold used to conclude that two projects are similar enough to be considered comparable.

3 FRAMEWORK DEVELOPMENT

To develop the framework of Foundational Attributes, a literature review is conducted. Various sources are used to populate each attribute, and potential methods to quantify each attribute are discussed at the end.

3.1 Physical Form and Function

The attribute of Physical Form and Function of a construction project refers to the physical properties and the function of the final product. In the construction industry, it is a common practice to put projects into two major categories: building construction and heavy civil construction. Building construction is also referred to as “vertical” construction, and heavy civil construction, also called “horizontal” construction, usually includes projects involving highways, airports, bridges, canals, harbors, dams, and other major public works (Nunnally 2001). Another popular way to categorize construction projects is based on the owner’s status. If the owner is a public entity, then the project is a public project, and if the owner is a private company or individual person, then it is a private project. The Value of Construction Put in Place is the monthly estimates of the total dollar value of construction work done in the U.S. and includes new structures and improvements to existing structures for private and public sectors. This survey has been conducted monthly since 1964 by US Census Bureau. The author used its structure as the basis for developing the first three levels of categories for the attribute of Physical Form and Function. Details of the first three levels of categories for the attribute of Physical Form and Function can be found in the author’s PhD dissertation (Zhang 2016).

The first three levels only explain the basic types of projects. Usually, projects can be further distinguished by the major structural materials and the project size. For example, the pavement projects under the highway and street category of heavy civil construction can be further divided into new construction and preservation projects, as shown in Figure 2. According to the Federal Highway Administration, pavement preservation projects can be divided into minor rehabilitation, routine maintenance, and preventative maintenance, which consist of level 5 of the Physical Form and Function. Figure 2 describes an example of the level 4, 5 and 6 of Physical Form and Function. For each level 3 type of project a different sub-level can be developed.

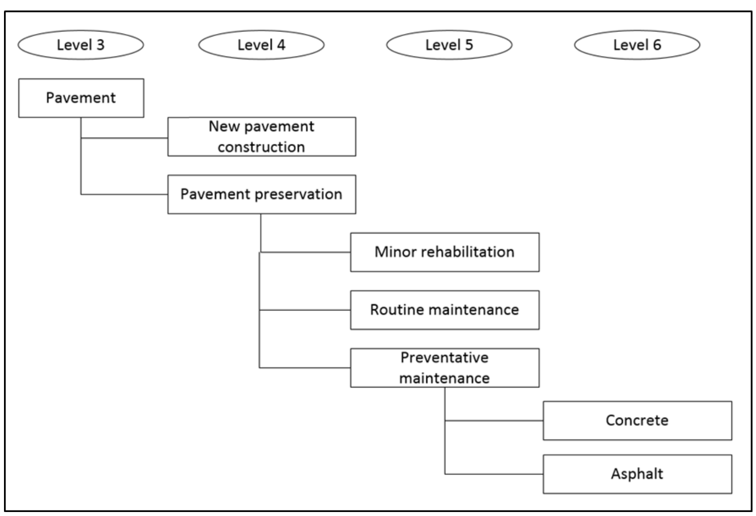

Figure 2: An example of level 4, 5 and 6 of Physical Form and Function

The attribute of Physical Form and Function is a categorical factor, and it is unlikely to be quantified. Comparison between projects which are not in the same category may not be wise, but this may become possible when comparing projects in certain aspects.

3.2 Organizational and Project Structure

The attribute of Organizational and Project Structure refers to both the formal relationships established between the project team members and the formal relationships within an organization. There are two folds here, and they need to be dealt with separately.Project Structure is often determined by the project delivery method or contracting method that is used to bond different organizations together in a project. Three major participants in most construction projects are the owner who wants the project, the designer who provides the service of designing the structure, and the contractor who is in charge of building the structure. The contracting method used in a project has a great impact on the relationships between different parties and many other aspects of the project (Tran et al. 2015, Korkmaz et al. 2010, Gaba 2013). It likely also plays a very important role when doing project comparisons. Project Structure is also a categorical factor, similar to the attribute of Physical Form and Function. However, when comparing projects regarding some specific outcomes, the Project Structure can be quantified by how well the selected project structure facilitates the desired outcome.

Organizational structure refers to the hierarchical arrangement of lines of authority, communications, rights and duties of an organization. It is widely agreed that the organizational structure of a company can have a large impact on the ability to manage a project (Oberlender 2000, Elkassas et al. 2013). Construction companies usually have their own organizational structure which fits their needs. Small construction firms usually do not have many departments, and project managers play a key role in the management of the company as well as their projects. Project engineers for a small firm sometimes are entrusted to manage a whole project and act as the project manager for small and medium size projects. Therefore, the organizational structure of a company will impact the authority of project managers and the information flow and communication, the paperwork processing time, and many other factors. The organizational structure is also a categorical factor, and it may be quantified by how well the selected organizational structure facilitates the desired outcome.

3.3 Resources, Tools and Processes

The attribute of Resources, Tools and Processes refers to the devices and resources utilized to design and construct a project, and the means and timing in which they are implemented. The resources here include the materials, equipment, labor, money and time needed to construct a project. Therefore, the resources needed for one project are more than likely different from the resources needed for another project. However, the specific resources needed for a project may not be a big factor as long as there are adequate resources to conduct the work. There are many other ways to quantify resources depending on the research interest.

The design of a project used to be recorded and communicated in hand-draw drawings. After computer aided design systems were developed in the 1970s, more and more companies started to use some kind of software to help with the design. It starts with providing 2D drawings and gradually moves to 3D design. As construction management software was developed, contractors become more and more dependent on technology as well. A variety of software can be used to help with document management, cost estimating, scheduling, risk analysis, and almost every aspect of a construction project management. It does not matter what specific software is used in a project, but using new technology can make the project management more effective. So the tools part of this attribute is also quantifiable by the level of utilization of new technologies. It is noted that the tools part of this attribute is not only about software, but also about other tools. It can be quantified by not only the level of utilization of new technologies but also in many other ways.

The processes used to construct a project are choices made by the general contractor. The timing and sequence of the work is an important factor which affects project outcome. Similar to resources and tools, the processes may be an enabler or inhibitor for the project outcome of interest, depending on what kind of project outcome is being compared. So the processes can be quantified according to the level of fitness of the specific process to the project outcome of interest.

3.4 Culture

Research on culture started in the field of anthropology and sociology, which gives a perspective on how groups of people develop a common sense of history, values, beliefs, and purpose through collective interpretations, and then act to produce the social institutions of their existence (Schein 2004, Fellows and Liu 2013). In the construction industry, organizational culture can be defined as the shared beliefs in the minds of all employees. Many people believe that organizational culture conveys a sense of identity for organization members, facilitates the generation of commitment, and enhances the stability of the organization (Peters and Waterman 2006, Cheung et al. 2011). The attribute of Culture here refers to the companies' cultures, not the project climate. The project team is a short-term temporary-formed group with team members holding different objectives, so it is not appropriate to use the word 'culture' to describe the shared beliefs of project participants. The attribute of Culture can be quantified by the degree to which major project participants' organizational cultures are aligned. There are many other ways to quantify the attribute of Culture. For example, it can be quantified by the degree to which each organizational culture facilitates the project outcome of interest. It could be more important than whether or not the participants' organizational cultures are aligned.

3.5 Risk

Risk can be defined as a positive or negative deviation of a variable from its expected value (Schieg 2006). In practice, when people talk about risk, it usually refers to negative deviation and the potential for a loss. The construction industry is usually considered to be a high-risk industry, and the risk associated with a project is an important factor to the project outcome. Karim et al. (2012) put major risk factors related to a construction project into five categories from a contractor's viewpoint, and they are construction, politics and contract provision, finance, design, and environmental risks (Karim et al. 2012). The attribute of Risk is not the same as construction project risks mentioned above, and it has two folds. One of them is the risk associated with the project in different project participants' perspective, and the other one is the risk tolerance/threshold of major project participants. For each organization, the attribute of Risk can be quantified by the overall level of project risk, and the tolerance level of the organization.

3.6 An Updated Spider Chart

A spider chart is initially chosen to host the concept of Foundational Attributes of construction projects because a spider chart can represent multiple quantitative variables and give a vivid view of the difference and similarity between two entities. As mentioned in this paper, not all attributes are quantifiable. The attribute of Physical Form and Function is mainly a categorical variable, so it is not appropriate to put this attribute in a spider chart. The attribute of Physical Form and Function can be considered as a super-attribute or a prerequisite before using a spider chart with the other four attributes to assess project similarity. If two projects have similar Physical Form and Function, for example, then they meet the prerequisite and can be compared further using the spider chart shown in Figure 3.

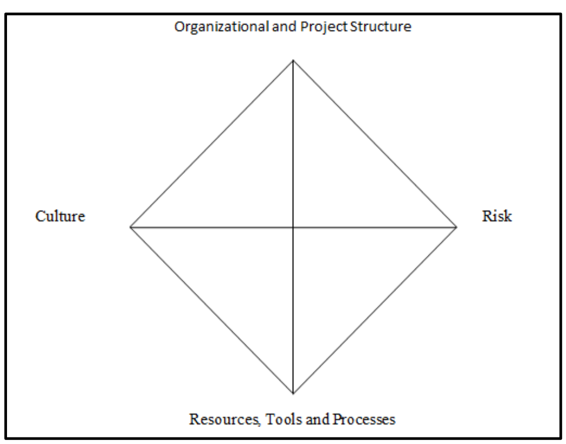

Figure 3: An updated spider chart for Foundational Attributes

4 PROJECT COMPARISON

The five Foundational Attributes were developed and discussed in the previous section, and they will be used in this section to determine how they could help with project comparison.

4.1 Case Study Projects

Two case study projects were selected and will be used to demonstrate the comparison. The two case study projects were selected from five similar construction projects in which the author was previous involved. All five projects are highway preservation projects that took place in Oregon during the past few years. The projects are very similar in a common sense, and one of them is more complicated than the other four, so it becomes the author's first choice. For the second project, the author chose the most recent one.

The first case study project was located on Interstate 5 in Douglas County approximately 50 miles south of Roseburg and 20 miles north of Grants Pass, so it was located in a rural area. The limits of the project were between milepost 66.7 and milepost 81.4, including both southbound and northbound lanes. The overall scope of the project contained many pieces of work, including pavement resurfacing for both lanes in both directions within the project boundary and the construction of a new lane in the northbound direction for trucks to climb the steep grade without significantly slowing down normal traffic. The project consisted of both base course and wearing course paving and included not only paving in the fast and slow lanes but also shoulder paving. A large part of this project was located in a mountain area, with sharp curves and elevation changes.

The second case study project is also a highway preservation project and located in a rural area on Interstate 84 along the Columbia River in Oregon. At this location, the roadway is mostly flat and straight, unlike case study #1. The project extended for about 21 miles from milepost 138 to milepost 159, and the paving scope of work consisted of grinding 2 inches of existing highway surface and placing a new layer of asphalt in both the slow lane and fast lane.

4.2 Application of the Framework to Case Study Projects

To apply case study projects to figure out how to use the Foundational Attributes to compare projects, the subject of interest, which is the project outcome being compared, needs to be determined. Usually, the overall project cost, schedule, quality, and safety are subjects of interest. For example, if we want to implement a new safety procedure and to assess the effectiveness of this new procedure, two projects are chosen: one with the new procedure, the other one without. To confidently conclude that the new safety procedure makes a difference in safety performance, we need to eliminate confounding factors brought by the uniqueness of a construction project.

Case study #1 and #2 are both heavy civil construction projects. The second level of Physical Form and Function is Highway and street, and the third level of this attribute is pavement. Therefore, the first three levels of the Physical Form and Function are the same for both case study projects, as shown in Table 2.4. Starting with the fourth level, they become different because case study #1 includes not only the pavement preservation work, but also the new construction of a climbing lane for trucks, while case study #2 only involves pavement preservation work. With the same first three levels, they pass the prerequisite and can be compared further for the other four attributes. Assuming the project outcome of interest is the effectiveness of a new safety procedure, the attribute of Organizational and Project Structure can be quantified by the degree to which the project structure and organizational structures of major participants help to facilitate the implementation of a new safety procedure. For this evaluation, a scale from 1-5 can be used, with 5 equal the best. The ratings for the attribute of Organizational and Project Structure for both case study projects are listed in Table 2.

Table 2: Organizational and Project Structure for both case study projects

Organizational and Project Structure (OPS)	Case study #1	Case study #2
Owner's organizational structure	2	2
Contractor's organizational structure	4	3
Project delivery method	2	2
Average rating (AR- OPS)	2.67	2.33

Table 3: Resources, Tools and Processes for both case study projects

Resources, Tools and Processes (RTP)	Case study #1	Case study #2
Resources	4	4
Tools	5	4
Processes	4	4
Average rating (AR-RTP)	4.33	4

Table 4: Culture for both case study projects

Culture (Cu)	Case study #1	Case study #2
Owner's company culture	4	4
Contractor's company culture	5	4
Average rating (AR-Cu)	4.5	4

Table 5: Risk for both case study projects

Risk (Ri)	Case study #1	Case study #2
Overall project risk to the owner	2	2
Overall project risk to the contractor	4	2
Owner's risk tolerance	2	2
Contractor's risk tolerance	4	3
Average rating (AR-Ri)	3	2.25

The ratings for both case studies in terms of the owner's organizational structure, the contractor's organizational structure, and the project delivery method are assigned based on the information from the case studies and the author's judgment. The owners for both case study projects are the same, the State Department of Transportation (DOT). The subject of the safety procedure mainly impacts the construction phase, so the role of the designer/engineer can be omitted. The general contractor for case study #1 is a large nation-wide heavy civil construction company with about 4,800 employees. The general contractor for case study #2 is a local heavy civil construction company with about 240 employees. The project delivery methods are the same for both case study projects, and because it is a government funded project, the project delivery method is the Design-Bid-Build method. The attribute of Resources, Tools and Processes can be quantified by the degree to which the resources, tools and processes of construction projects help to facilitate the implementation of a new safety procedure, and the rating for this attribute is shown in Table 3. The attribute of Culture can be quantified by the degree to which the major project participants' company cultures facilitate the implementation of a new safety procedure. The rating for this attribute is shown in Table 4. The attribute of Risk can be quantified by the overall project risk level and the tolerance level of the major project participants. This attribute is not affected by the subject of interested being compared. The rating for this attribute is shown in Table 5. All of the ratings are assigned based on the information from the case studies and the author's judgment. The average ratings of each project of each category are calculated.

Figure 4 shows the spider chart which describes both case study projects using the average ratings for the four attributes listed above. The solid green line represents case study #1, and the dashed orange line represents case study #2.

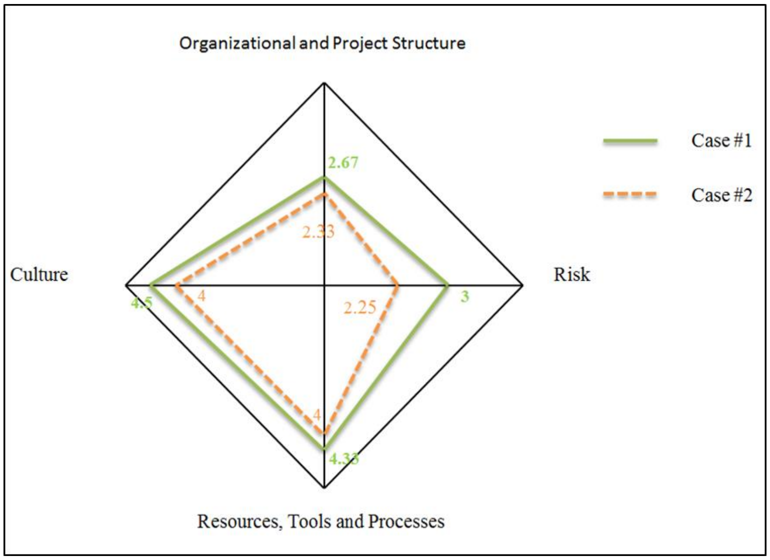

Figure 4: Spider chart for both case study projects

The original idea of quantifying similarity is to use the common area enclosed by both projects to represent the similarity between them. Apparently, this idea is not applicable to the situation shown in Figure 4. The area enclosed by case study #2 is completely within the area enclosed by case study #1. A different method to quantify the similarity between projects is needed. The author proposes using the ratio of the overlapping area to the area covered by either case study #1 or case study #2. The overlapping area between two case study projects is 19.8 and the area covered by either case study #1 or case study #2 is 26.2. The similarity between the two case study project is calculated to be 75.6%. However, while calculating the areas for case study projects, the author noticed that the area enclosed by a project depends not only on the value of each attribute but also on how the attributes are arranged in a spider chart. For example, if we exchange the location of Risk with Resources, Tools and Processes, the similarity between the two case study projects will become 73.2 %. Therefore, the order and arrangement of attributes in different spokes affect the final results. An alternative solution is needed.

5 CONCLUSIONS AND RECOMMENDATIONS

This paper describes the development of a framework for the concept of Foundational Attributes of construction projects. A literature review is conducted in order to explain and to find elements for each attribute. It is concluded that the attribute of Physical Form and Function is a categorical factor, and cannot be quantified. This attribute has many levels and serves as a prerequisite for project comparison. If projects have similar first three levels of Physical Form and Function, they can be compared further using the spider chart developed to host the other four attributes. To compare different outcomes of projects, different methods need to be used to quantify the attributes. The similarity between projects can be calculated by using the overlapping area divided by the entire area covered by all projects. However, alternative solutions are needed for a more reasonable comparison.

This research is based on many assumptions and many simplifications have been made in order to proceed. Each assumption and simplification can be a future research direction, and a few of them are listed below.

- A thorough development of each attribute can become an independent research study. More papers need to be read and more scientific methods need to be applied to fully develop each attribute.
- Rethinking the allocation of attributes. For example, organizational structure and project structure can be two attributes, or organizational structure can be relocated to the attribute of Culture.
- Resources, Tools and Processes needs to be separated into three attributes because they are very different components.

- The current method to quantify each attribute is to have a project outcome in mind and to give a rating to each project based on project information and the researcher's judgment. It may have a broader application if all attributes can be quantified according to a reference point so that the rating for each attribute does not change for different project outcomes of interest.
- To reduce the bias from the researcher, a rubric or a standard procedure to evaluate each attribute is needed.
- Instead of using average rating for each attribute, using other methods to calculate the rating that represent each attribute to address the differences between each component within an attribute.
- Since the spider chart has limitations in hosting the concept of Foundational Attributes, consider other graphical/non-graphical methods to describe the concept and compare projects.
- Concept validation is needed before further application.

In summary, this manuscript describes an initial effort on developing a framework for the concept of Foundational Attributes. It is an attempt, not a proof or validation. This is an interesting topic which needs further development and validation, and this manuscript serves as a basis for future work.

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