

Organizational and Technical Strategies to Mitigate Indirect Costs in Construction

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Samuel Cave

Spring 2020

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Kathryn A. Neeley, Associate Professor of STS, Department of Engineering and Society

Introduction

The construction industry has been doing things in a similar way for years. This is even more prominent in bridge and highway construction. According to VDC Consultant Viet Pham, “If you go to construction sites today, not a lot has changed in the past 50 years. 2D drawings in paper format are still used.” There are a lot of known direct costs that go into the design and construction phases of the project like materials and cost of labor but there are also a lot of indirect costs that are associated with every single construction project. These indirect costs are usually not taken into account or if they are looked at, doesn’t affect much of the design or implementation of the design. Construction is an endless process that is always going to be a part of our society. These direct and indirect costs could have a negative impact on the surrounding community and businesses. Things such as travel time delay, roadway congestion, and local business impacts such as business loss or decline (Alashari, 2016). In some cases, ecological and environmental issues can be major concerns caused by construction and in some cases are costly to design around (Goldbaum, 2008). Though construction has been done in a similar manner for decades, different methods of delivering projects have evolved over time. The main three modern construction delivery methods are design-bid-build (traditional), design-build, and construction management. Each of these have their own benefits but also have some drawbacks to them when it comes to the organizational setup and also the costs that go along with using one method over another. Currently, most construction companies do not include costs related to motorists and the surrounding community in their decision-making process of selecting a delivery method (Coley, 2013). So, as new technology develops, new delivery methods are introduced and implemented into current construction organizations which can lead to some indirect costs being limited through these technological and organizational advancements and

changes. One of these new delivery methods is accelerated construction. Accelerated construction takes advantage of prefabricated elements to allow for a faster construction period which in turns mitigates a majority of impacts a project will have. In turn, accelerated construction usually lures the construction company into having to look at and recognize the major impact of indirect costs or else they would not have been considering accelerated construction in the first place. This also could work the other way around in which a company who fosters values of prioritizing the indirect costs in the design process would be more likely to consider an accelerated delivery method, or a method to mitigate them. More consideration of these indirect costs from the construction and design firms can also be achieved through public hearings and opinions from a wide range of people in the community and outreach programs offered by the company doing the project. Throughout this paper, I highlight the prioritization of the indirect costs that associate itself with construction, specifically highway construction. I also will show how technological advancements can lead to an organizational change (or vice versa) and by doing so can provide the prioritization of indirect costs in the construction industry.

Indirect Construction Costs and their Impact

The construction industry, while it has evolved and in recent history beginning to incorporate more technology, is still doing things in a similar manner as it was forty plus years ago. Since the first bridge was constructed, the method has stayed consistent; first foundations/soil work, then design of the bridge, and finally construction of bridge components. This method is known as conventional bridge construction, or CBC. Infrastructure is a huge market within the United States. Spending by federal, state, and local governments for transportation and water infrastructure totaled \$441 billion (Congressional Budget Office, 2017). New infrastructure is always being built or old infrastructure is being repaired across the United

States. With this high demand, projects are pushed to be done quicker without reducing the quality. To most construction is just a process or nuisance, and the public in general does not really consider the complex nature of it.

From personal experience before getting into civil engineering I did not fully grasp the fast paced, ever changing nature that is construction. There are a lot of different design methodologies, construction methods, political and social goals or challenges that must be overcome, and all which take time and money. Currently, the three main construction delivery methods are design-bid-build, design-build, and construction management. Design-bid-build is a more traditional method of construction in which the complete design must be done before a bid is put in for a particular project. Once the bid is submitted to the owner of the project, a firm is selected and construction can begin. This process takes the longest of the three delivery methods but is most often the cheapest due to competitive bidding of projects. Design-build is a faster paced delivery method due to being able to start construction before the design is completely finished. Finally, construction management is in between the other two methods and share some benefits from both traditional and design-build. In recent years, a relatively new method called accelerated bridge construction which uses prefabricated elements to construct a bridge has recently become popular and is continuing to grow (Chris, 2016). This method is increasing in popularity over the last twenty years due to its ability to complete construction in a fraction of the time while still maintaining quality and safety. The Federal Highway Administration's main focus with regards to benefits that accelerated construction can provide is time related and they have created tiered metrics from one to six to help companies gauge the time benefit they are receiving from using this method (FHWA, n.d). This efficiency of time using accelerated construction methods is shown below, in Figures 1 and 2.

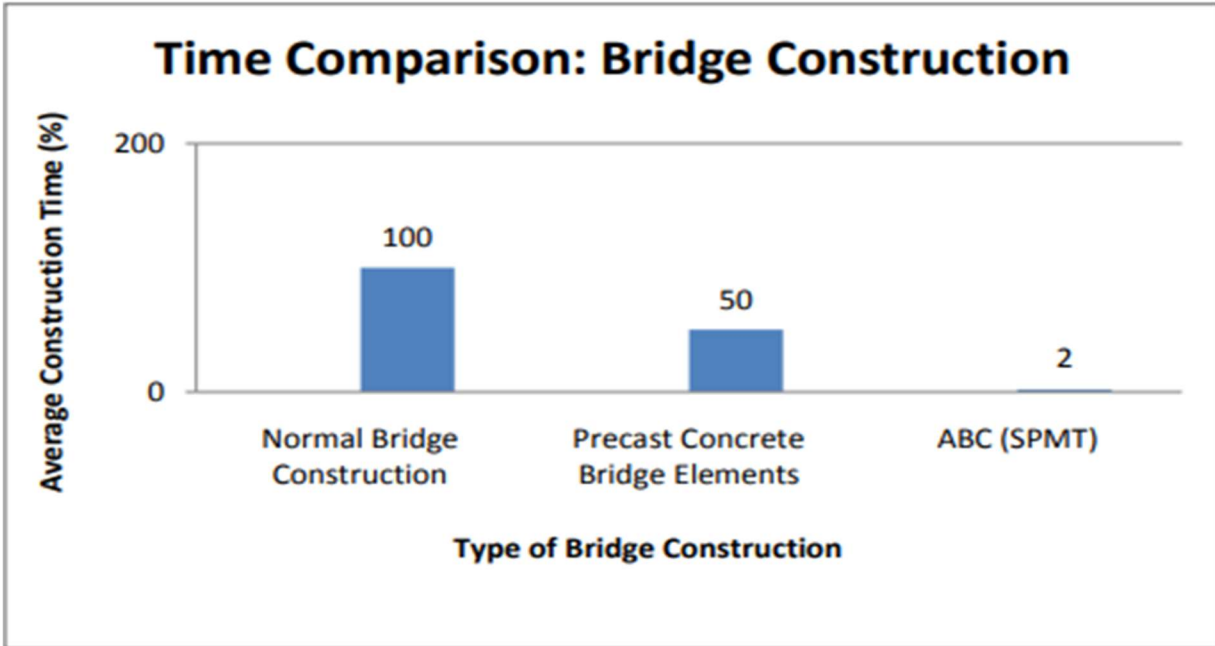


Figure 1: Time comparison of the different bridge construction approaches. With normal construction being the most common in practice, it is also substantially longer than newer methods. ABC and similar methods offer a significant decline in the overall construction time. (Lee, J. H., & McCullouch, B. G, 2009, August, p 65).

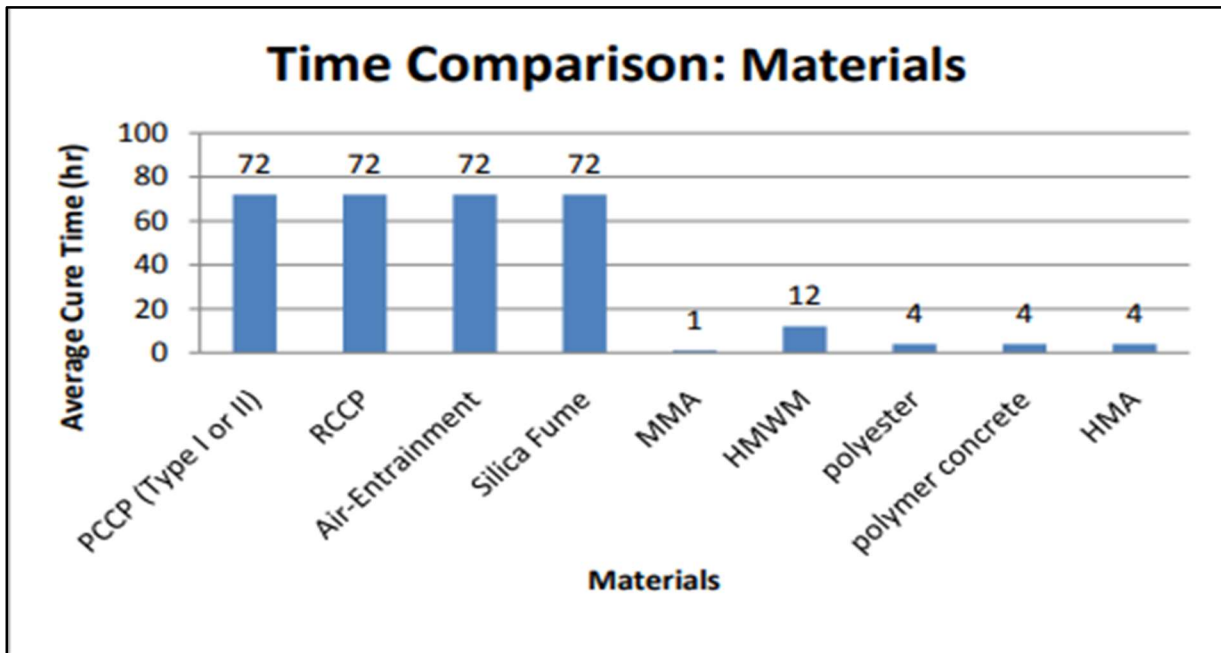


Figure 2: Time comparison of curing bridge components. On-site construction of bridge components like air-entrained concrete takes much longer than prefabricated elements like polymer concrete to install due to prefabricated elements already being constructed and just having to be connected in place. (Lee, J. H., & McCullouch, B. G, 2009, August, p 57).

Even with me being in civil engineering, the first time I heard about this was my fourth year in college. There are a lot of factors that affect why construction and design firms do what they do for a given bridge or road project, many of which are cost and time related.

In general, the public wants quality infrastructure that they know is safe for them to use and for the construction of said infrastructure to come as less of an inconvenience to them as possible. So, a less time consuming, more efficient construction method should be widely welcomed and accepted since it would cause less inconvenience for the users. It may not be accepted, however, that this time saving construction method would cost more money which could be coming directly from their tax dollars (Dutzik, 2015). Another issue is getting construction and design firms to coordinate and start implementing new construction methods into projects. The dilemma of having to choose between longer construction at a cheaper price or shorter construction at higher price will come into play as to which method is preferred and ultimately chosen for a given project. According to Bala Sivakumar, a professional engineer and ABC expert, “Projects typically cost 20% to 30% more than traditional bridge construction jobs.”

My research plans to help show the complexities that go into the construction projects and the benefit of considering and acting on the negative indirect costs that come with construction. Through this, it will help bridge the gap between the public's knowledge of infrastructure construction and the construction companies' knowledge of indirect costs of their actions. Technological advancements and organizational means can begin the process of mitigating the negative impact of these indirect costs. Other ways, like public hearings and small business outreach can be implemented also to get the public more involved and considered during every phase of a construction project to try and get the best solution as possible.

Organizational Structure Impact on the Construction industry

Conventional construction methods tend to take months to even years until completion of the project and to the owner of the project the two most important factors are cost and time. These two direct costs are usually what dictate most, if not all, decisions during the lifespan of that project. However, there are indirect costs that go with construction that can have wide ranging effects that are not related to construction or the project at all. This is why it is crucial to implement a technological or organizational change in the construction industry to help quantify or consider these indirect costs to mitigate them. In this particular case, I will apply Mesthene's ideas of economic and political organization to help analyze the ways of limiting indirect costs associated with construction through organizational and technological means.

Technological advancement often requires a large amount of people participating to be effective, as shown in the growth of cities, corporations, and universities (Mesthene, 1970, p. 65). In the face of a new technology, social change can affect both personal values but also bring about political problems (Mesthene, 1970, p. 63). These two ideas from Mesthene could be applied to the adoption of new technology that is happening recently within the construction industry. With this, new delivery methods have evolved and brought about a change within construction corporations. This has brought an organizational shift to how business is done between owners and the builders by placing different priorities on different aspects of construction depending on the method chosen but for any one of them to be effective, a large number of people had to implement them first. The construction industry has developed three main delivery methods that are used in modern construction with each method having different benefits that associate with it. The three delivery methods are design-bid-build (traditional methods), design-build, and construction management (Ellingson, 2004). Each method has its

own hierarchy and benefits associated with it whether it be cost or time related. With the creation and implementation of a new delivery method, a struggle of adopting the new method as a standard has followed. Each one had a personal, political, and social factors that contributed to it being successful or not. The breakdown of each method is shown below in Figure 3.

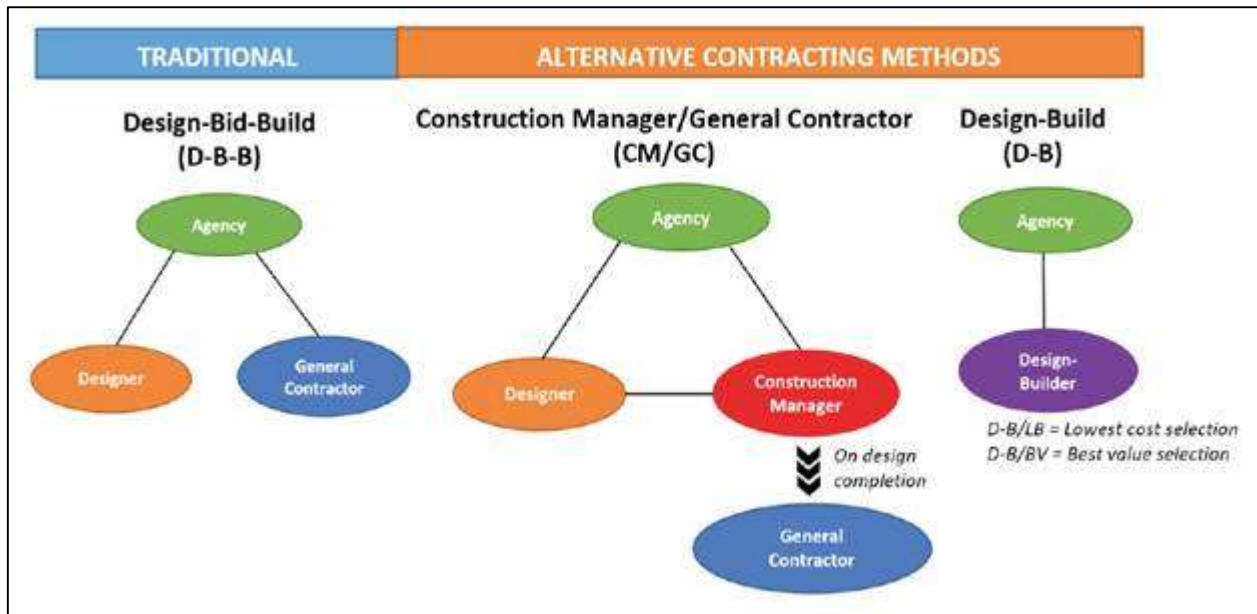


Figure 3: The breakdown of the three main construction delivery methods with the benefits of each method. The graph also shows the organizational relationships between the different parties during a construction project, like owner-designer and designer-general contractor. (FHWA, 2018, p 2).

Each method also has its own risk associated with it, whether it is on the owner or the general contractor side but regardless there is risk involved with each one. In the use of a traditional design-bid-build delivery method, the risk is shifted more towards the general contractor due to the projects being a competitively bid contract so the general contractor is then obligated to deliver the project for the price the company guaranteed the project at. In the use of design-build, there is no competitive bid so a lump sum price for the project is still negotiated but the risk shifts slightly away from the general contractor because the owner may not be getting the absolute best price due to no competitive bidding. Finally, for the use of construction management delivery method, the risk can vary from almost all the risk falling on the general

contractor to the owner taking on most of the risk depending on the contract details that are agreed upon between the parties. This risk allocation is shown below in Figure 4.

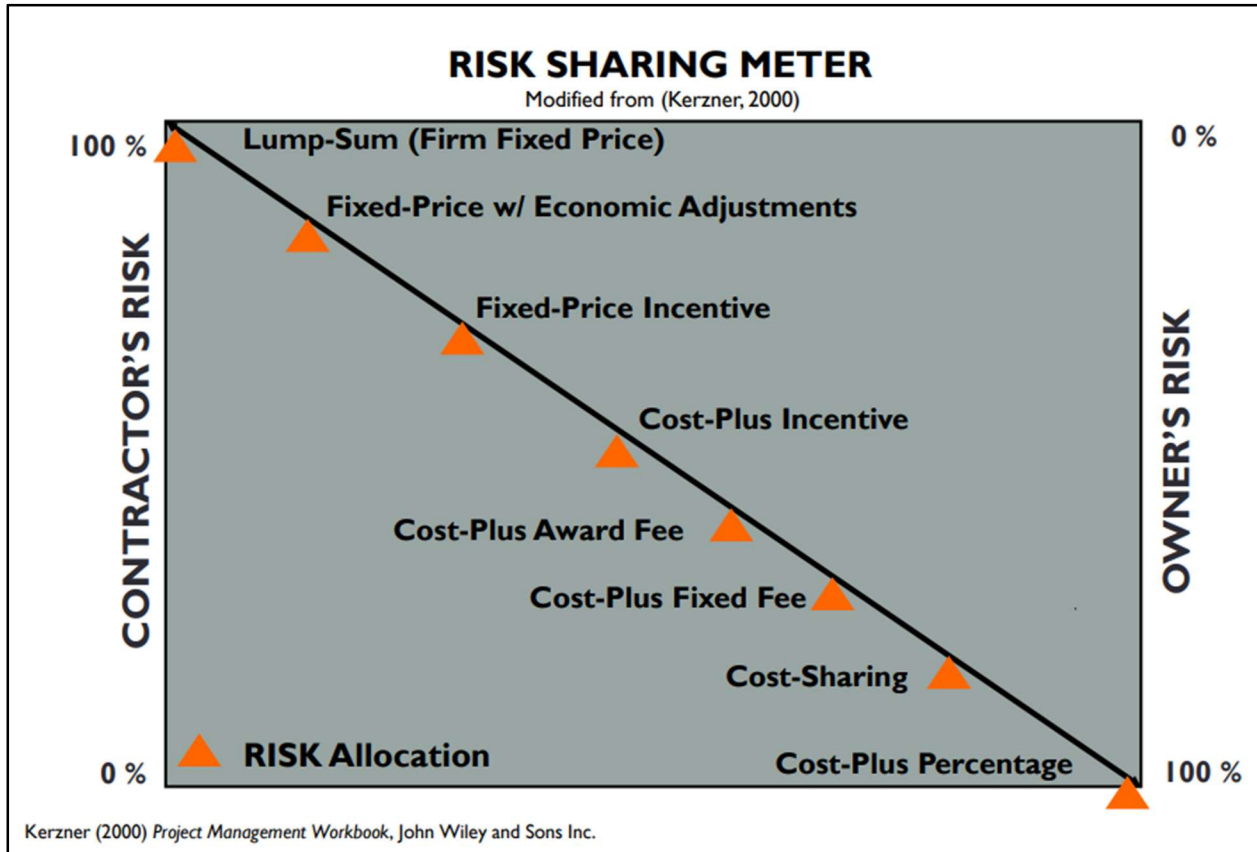


Figure 4: The graph shows the relationship between how much risk each party takes depending on the type of contract that is agreed upon for a given construction project. In most cases, each type of contract usually goes with a certain delivery method. (Kerzner, 2000).

According to the New Hampshire Department of Education, “In any construction contract, the cost of the project consists of the costs for labor and materials and the builder's profit and overhead... There is risk involved for both the owner and the builder concerning the builder's ability to perform the work for a given actual cost. The differences between types of contracts primarily lie in who takes the risk, who has to pay for cost overruns, and who keeps the savings if the project costs less than the estimate. In a major construction project, some or all of the different types of contracts may be used. There may be one type of contract between the owner and the primary contractor and different types of contracts between the primary contractor

and the sub-contractors.” From this quote, most of the department’s concern is with direct costs such as cost and labor, who takes on more of the risk, and the builder’s ability to perform the work at a given price. Nowhere in this decision-making process is the impact of indirect costs being heavily evaluated and, in most cases, this happens in any construction project.

Often times there are push back and issues with any process, especially new or innovative ones. A new model or process is never polished from the beginning but if the benefits outweigh the risks it is worth pursuing. Similar to how Mesthene showed that newer technology has a wider impact through a horse-powered transportation technology versus a supersonic transport airplane example. In this example, the horse-powered transportation is limited in its speed but its impact was very local. As for the supersonic airplane, the vibration and noise impact were inflicted upon whoever was within a certain radius of the hundreds of miles long trip of the aircraft. This simple example shows the wide ranging impacts that can associate itself with newer technology but I believe in the case of adopting newer technology in the construction industry, the negative impacts will fall upon the corporations and businesses in the form of losing a money for the benefit of the public by limiting various indirect costs. Another example is the Belmont Learning Center in Los Angeles, California. The Belmont Learning Center was a secondary school that was being built in the early 2000s using a design-build method. This project received significant criticism for exceeding costs expectations by a wide margin but also a variety of environmental issues like contaminated soil. The Los Angeles District Attorney, Steve Cooley investigated the project and in a final report concluded that the design-build process was the main cause for the variety of issues. As seen in this example, there are drawbacks to different delivery methods that lead to widespread effects in the community. The issues caused by using this delivery method could have been due to miscommunication within

the organization of how to implement this design using this delivery method or a conscious decision by the builder to let some unethical things pass by, like the contaminated soil, to save some money and time since the project was already over budget. This ties in to Mesthene's ideas of individuals (or companies) balancing their commitment to public goals and their private desires (making money). The idea of the balance between public goals and individual or company values happens all the time on construction projects and when possible, usually leans towards the side that will save or make more money. Either way there is a host of organizational and political factors that come into play when trying to use other delivery methods instead of traditional means for the sake of saving time and money on a project.

Organizational and Technical Aspects Can Spark a Social Change within an Industry

As stated earlier, the construction industry is slow in adopting new technology and even slower in actually implementing this new technology in a way that provides benefits. As the construction industry expanded and grew over the years, three major delivery methods have developed into a household name among all construction. These three methods are design-bid-build, design-build, and construction management. While each provides their own benefits, there are indirect costs that are common across projects regardless of which method is chosen. Some indirect costs are limited by which method but in general none of the three methods mitigates these issues in significant manner. Travel time delay, roadway congestion, local business impacts like business loss or decline, and environmental issues are all concerns caused by construction but with current technology these indirect costs can be both prioritized and reduced significantly by construction companies.

The problem with the current construction industry decision making and the delivery methods themselves are they still focus on labor, material, and time related costs. For example,

design-bid-build is usually selected when the owner of the project wants the lowest price that can be achieved but this comes with a longer completion time. Design-build on the other hand provides a much faster project completion time than traditional methods but could come at a higher cost or less security for the owner due to no competitive bidding. So, each method prioritizes one major direct cost over another and it is usually a tradeoff between cost and time which rightfully so is the two most important aspects of a project, especially to an owner. Furthermore, no construction company is going to begin to consider, let alone implement, new technology or organizational values that will help limit the indirect costs of construction because by doing so would increase the cost at which they can perform the work which in turn will cost the company jobs since most owners care about the ability to deliver a project within a certain cost. Trying to get all owners of every construction project to have a cultural shift in which they are willing to spend a little extra money to help mitigate the impacts the construction will have on the surrounding community is farfetched, especially in a capitalist country. That is not to say that all owners only care about the money and time of the project. There are plenty of owners who attempt to get LEED certified (Environmental certification) and achieve other social goods during and after the project completion but there are also plenty of owners who just want the project done as cheap and quick as they can get it. This is why the focus of how to mitigate these impacts needs to shift to the construction industry and the people who implement and build these projects.

While it might be possible to change how the current delivery methods are implemented and used, it may be more beneficial in the long run to develop a cultural and/or organizational shift within the industry. These organizational values of prioritizing community impacts have to start from the top of the hierarchy and funnel its way down to the rest of the company. This is not

to say that every employee must share the exact same values as the company they are working for. Antonio Argandoña addresses this in “Fostering Values in Organizations”:

Thus, an organization is a group of people whose actions are coordinated in order to achieve certain results in which they all have an interest, although not necessarily for the same reasons. This justifies the existence of a management – structure, rules, culture, . . . –, which explains why the values implemented within the organization may not concur with those of its members. For example, an “I’m the boss” culture which gives priority to control may quash the creativity of the organization’s members, their desire to be involved and their sense of responsibility, even though these values are present in the people who work in the organization. Likewise, a group of honest people may end up losing this value if the culture and operating rules of the company in which they work encourages dishonest conducts. ¹⁶ Consequently, we can distinguish between the values of the organization’s members as such, and the values that the organization holds or needs in order to achieve its purpose¹⁷ (2003, p. 19).

Thus, it is possible to have companies foster certain values that will direct the business in a direction that will consider and implement ways to mitigate community impacts while still achieving any companies goal of making money. Though the cost may be higher on projects from the owner side, if this increase in cost is concurrent with other companies then a move towards it being a standard can be achieved.

Finally, technological innovation could possibly accelerate this organization and cultural change within the industry and help neutralize these indirect costs. A relatively new design methodology known as accelerated construction could be implemented on a wider scale to help

reach this goal. By using prefabricated elements for construction, accelerated construction can shorten the construction time from months to a matter of weeks. It seems that a shorter construction time is the answer to most of the side effects that construction causes. With a shorter construction time, travel delays, congestion, and business loss or decline are all limited to a matter of weeks. The downside is the premium cost of prefabricated elements which are essential for an accelerated construction technique. Both in the public and private sector, cost drives everything. In order to accommodate the negative impact of construction indirect costs, the combination of organizational and technological change must occur within the industry to ensure that these impacts are mitigated as much as possible on a wide scale.

Conclusion

The construction industry is often times slow to adopt new technology and change with the current times. Though this is reasonable in the physical aspect of how to construct a building or bridge, it is not acceptable in the approach and implementation of a design for a project. In the present day, there are numerous resources to not only assist in quantifying indirect costs but many methods and means to limit the impact of them during a construction project. Either technological or organizational advancement can begin the transition to improving the industry. On the technology side, as an industry, we need to do a better job of becoming more adaptive when it comes to terms of adopting and implementing this technology into a way that can be beneficial. While this will come at a cost, the benefits are beyond just money. These technological innovations can provide social and environmental benefits for the whole community. This willingness to adopt and adapt can be taught through what values our educational system teaches as well what the construction and engineering companies' value beyond making money. This can also go the other way by which technological change could

force companies to consider the social and environmental impacts more prominently than just organizations taking the initiative to prioritize the indirect costs. For example, one of these ways is the idea of using accelerated construction. Accelerated construction can lure the construction company into having to look at the major impact of indirect costs. Regardless, indirect costs are a major issue when it comes to construction and whether it is through technological or organizational change, it needs to be more highly considered. This will only lead to a better, well thought out solution while also limiting the impacts.

References

- Alashari, M. (2016). Accelerated Bridge Construction (ABC), A Better Approach to Bridge Construction? Retrieved from <https://ijier.net/index.php/ijier/article/view/577/490>.
- Argandoña, Antonio. (2002). Fostering Values in Organizations. IESE Business School, IESE Research Papers. 45. 10.1023/A:1024164210743. Retrieved from https://www.researchgate.net/publication/4884372_Fostering_Values_in_Organizations
- Chris. (2016, May 11). 7 Benefits of Prefabricated Construction. Retrieved from <http://www.constructionworld.org/7-benefits-prefabricated-construction/>.
- Coley, N. (2013, January 10). Work-Zone Road User Costs – Comparison between ABC and Conventional Construction. Retrieved from https://abc-utc.fiu.edu/mc-events/work-zone-road-user-costs-comparison-between-abc-and-conventional-construction/?mc_id=43.
- Federal Highway Administration (FHWA). (2018, April). Alternative Contracting Method Performance in U.S. Highway Construction. Retrieved from <https://www.fhwa.dot.gov/publications/research/infrastructure/17100/index.cfm>.
- Federal Highway Administration (FHWA). (n.d.). Retrieved from <https://www.fhwa.dot.gov/bridge/abc/>.
- Dutzik, T., & Weissman, G. (2015, May 5). Who Pays for Roads? Retrieved from <https://frontiergroup.org/reports/fg/who-pays-roads>.
- Goldbaum, E. (2008, May 5). Professors Say Ecological Impact of Bridge Design Is Not Trivial . Retrieved from <http://www.buffalo.edu/news/releases/2008/05/9362.html>.
- Lee, J. H., & McCullouch, B. G. (2009, August). Purdue e-Pubs. Retrieved from <https://docs.lib.purdue.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=2647&context=jtrp>.
- Lou Ralls, M. (2014, December). Home - Accelerated Bridge Construction. Retrieved from https://abc-utc.fiu.edu/wp-content/uploads/sites/52/2015/11/Ralls_2014_Natl_ABC_Conf_Paper_History_of_ABC_Impl_in_US_updated_10-03-2015.pdf.
- Mesthene, E.G. (1970). Economic and Political Organization. In *Technological Change: Its Impact on Man and Society* (pp. 63-89). Cambridge, MA: Harvard University Press.
- Mitigation of Transportation Construction Impacts. (2009, February 27). Retrieved from <http://www.dot.state.mn.us/businessimpacts/pdfs/businessimpacts-report-feb2009.pdf>.
- Mullix, A. (2018, August 31). What Is Accelerated Bridge Construction? - U.S Bridge. Retrieved from <https://usbridge.com/what-is-accelerated-bridge-construction/>.

- New Hampshire Department of Education. (2020, February 28). Construction Documents and Delivery Methods. Retrieved from https://www.education.nh.gov/program/school_approval/ccdm.htm
- Pix4D. (2017, Mar 30). The Construction Industry - Ready to Embrace New Technologies? Retrieved from medium.com/@Pix4D/the-construction-industry-ready-to-embrace-new-technologies-546e38492bfa.
- Rodriguez, Juan. 2019, Nov 30. Techniques to Speed the Process for Accelerated Construction Schedule. Retrieved from www.thebalancesmb.com/techniques-used-to-accelerate-a-construction-project-844487
- Russell. (n.d.). Delivery Methods. Retrieved from <https://www.russellco.com/construction/construction-services/preconstruction/>
- Slowey, K. (2018, July 18). Safety in bridge construction: some say it's as simple as ABC. Retrieved from <https://www.constructiondive.com/news/safety-in-bridge-construction-some-say-its-as-simple-as-abc/526267/>.