Urban Infrastructure:

An Ethical Analytic Comparison Between Restoration and Improvement

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Abstract

As the population of urban city areas continues to grow, the increased stress placed on society's support systems requires the innovation of the way future projects are designed, built and maintained. Infrastructure research is split up into two main sub sectors: restoration and improvement. Restoration focuses on the repair and the maintenance of existing structures. Restoration is typically cheaper, and more accessible to the community. It is a fast temporary fix for trivial obstructions; however, it lacks permanence. Improvement focuses on the research of new age building techniques, in order to prolong the lifespan of buildings and enhance the quality of life. Improvement allows for the betterment of society by implementing new technology. While this increases building lifespans, it is costly and more time consuming. The ethical comparison of the two solutions included the evaluations relating to sustainability, aesthetic appeal and functionality. When compared in the ethical reference frames, it was found that improvement served as a better solution.

Introduction

The world, a euphony of vibrant sounds, is painted with the colors of different cultures. Each individual society is built with its own traditions, social structures, and historical developmental stages. However, almost every nation on earth shares one primary key component to its growth, and that is the simple, but broad topic of infrastructure. But, what exactly is infrastructure? Well, in its semantic form, infrastructure is defined as the combination of fundamental systems that support a community, region, or country. It includes everything from water and sewer systems, to road and railway networks, to the national power and natural gas grids (Brownjohn, 2007). Put simply, infrastructure is literally what holds a community together, it is the building bricks of society.

Over time, it is expected that our society's systems of infrastructure will become more and more susceptible due to continuous use and wear. Urban areas especially face more stress due to the large concentrations of people, threatening the safety and security of support systems. The American population has increased by 16 million in the past 7 years, and the rate of population growth shows no signs of slowing (United States Population, 2018). Society’s infrastructure systems are more susceptible to mass destruction due to the threat of natural disasters, accidents and terrorist attacks. In the timeframe between 1980 and 2017, the United States faced 219 climate disasters, the economic impact exceeding over $1.5 trillion dollars (NOAA, 2018). Natural disasters were wreaking havoc to ancient buildings and structures back in the early years too. In 217 A.D., the upper ring of the Roman Colosseum was destroyed when struck by lightning during a storm. In 1349, the colosseum was again subject to natural disasters when an earthquake caused the foundation of the ground on the south side of the building to become disturbed, causing chunks of the colosseum to fall off, and this damage was irreparable (Gabucci, 2002). Accidents, like vehicle collisions, are the most recurrent events that can cause damage to roads, traffic signals and pedestrian walkways. In addition, urban areas are more susceptible to acts of terrorism due to large concentrations of people, businesses and government buildings.

Engineers must be able to provide ample infrastructure for the continuous growth of urban areas. The challenge today is innovating and updating society's fundamental systems and providing them in a more widespread and economic way. However, looking forward, engineers are prompted with higher standards in their ideas and designs. There is an increasing pressure for designs to be environmentally friendly and consider energy reducing resources. Thus, the expectations of urban infrastructure are changing and is adding weight to the tasks of engineers. In addition to creating a structurally sound support systems, there is an increasing expectation for the visual aesthetic to add to the urban area's cultural and community dynamic (Junker & Buchecker, 2008).

Restoration and improvement are two solutions to the engineering grand challenge of creating sustainable urban environments through infrastructure. Restoration is the process of repairing and maintaining current infrastructure through renovation, conservation and redevelopment, while improvement is replacing current infrastructure with new construction methods, building materials or functionality in order to improve efficiency. The solutions are two different methods that engineers use to improve or maintain the safety and functionality of support systems. Both contain their own separate fields of research and development of emerging technology and methods. Improvement is argued to be a better solution than restoration when compared to the overarching principles of sustainability, environmental conservation, and societal culture, which all serve as the medium of ethical decision making.

Restoration

Restoration is a solution to ensuring the safety, functionality and innovation of existing urban-area infrastructure. The action of restoring is to return something to its former condition through repair or renovation. Road repairs, building renovations and the upkeep of public transportation networks are all considered restoration. Long-term maintenance has been around for centuries, and engineers today are still continuously finding and innovating new ways to restore infrastructure more economically and more effectively. Stress on urban infrastructure is the result of growing urban populations, increasing crowd concentrations. As a result, support systems are facing the problem of increasing numbers in human induced vibrations, threatening the safety and wellbeing of its users. The London Millennium Footbridge was closed within two years of its opening because of unexpected movement in its supports when large crowds of pedestrians crossed (Zheng, Shao, Racic & Brownjohn, 2016). Stadiums, skyscrapers, shopping malls and bridges are structures that are often induced to especially large concentrations of pedestrians during peaks times and events. Restoring infrastructure ensures that our systems are maximizing their lifetimes.

Gentrification, an emerging new topic in community restoration, is the process of redevelopment and revivalment of urban city areas to make them more attractive to a wealthier class. As seen in Austin, populations have continued to grow rapidly due to the city's growing job opportunity field, its affordable cost of living and its unique culture (Stimpson, 2016). The effect of Austin's booming population is the city and multiple private companies looking to redevelop and rehabilitate city areas to make them more appealing, particularly in East Austin. The area's centralized location is in close proximity to the city center, allowing residents to be close to their jobs and students to be close to schools like The University of Texas at Austin and St. Edward's University. The area's location also has easy access Interstate 35, the Austin-Bergstorm International Airport and public transportation, which are all systems of the city's infrastructure. The City of Austin and private companies have redirected their attention to creating new projects that will rehabilitate the area by adding in new park, entertainment and retail spaces.

A method that has developed over the past decade is embedded continuous monitoring systems. This has aided restoration as a solution by providing data for maintenance planning and structural monitoring. The Duomo di Milano is a gothic cathedral whose main spire, installed in the 18th century, towers 108.5 meters tall and is topped with the Maddonia, a gold statue of Virgin Mary. Through anticipated effects of weather and pollution, over time the marble spire began to deteriorate. When the Cathedral's main spire went under restoration in 2010, the installment of a 90 tons of scaffolding raised concerns about potential wind and bearing loads. Thus the installment of a fiber optic continuous monitoring systems was embedded to keep the spire and the scaffolding under observation (Christian, 2013). Due to its historical and cultural impact on the community, the option to tear down and rebuild is unlikely, so the Cathedral undergoes continuous conservation. Embedded monitoring systems is a way for engineers to track the structural health of infrastructure systems and provide a timeline for future maintenance.

One of the largest emerging problems, that continuous monitoring systems contributes in, is restoring infrastructure that is buried underneath the ground. This includes systems for water and wastewater, pipelines for chemicals and gas, networks for electrical and communication needs, access ways and other tunnels used for various tasks. Trenchless Technology (TT) systems are methods that nations, like the United States and Canada, have moved towards and innovated in order to preserve and repair underground infrastructure. Engineers hope to improve TT systems to be more accurate methods of assessing underground conditions and increasing restoration productivity while minimizing disruptions on the surface level. On average, Canadian municipalities spend $12-15 billions of dollar a year maintaining buried systems, most of which deteriorate faster than they are repaired (Ali, Zayed & Hegab, 2007). TT heavily relies on productivity, therefore engineers collect data on managerial, environmental and physical conditions to estimate a productivity index (PI) model. The PI represents of the efficiency of TT methods, and is based on subjective and quantitative factors of restoration. Quantitative data is collected through continuous monitoring systems and subjective data is surrounding factors that affect the project, like safety regulations and environmental conditions. Further research in TT methods and PI models will contribute to estimates restoration cost and timelines by optimizing budgets and increasing productivity.

Continuous monitoring systems is an emerging tool for maintaining existing infrastructure, the collected data has potential to contribute to future engineering designs. The development of stimulating realistic conditioning is evolving. However, models still lack adequate information to accurately describe the dynamic loading on structures, specifically in human movement. The implementation of cameras that monitor human movement and inertial forces will allow engineering to improvement their tracking on the movements of individuals in a crowd (Zheng, Shao, Racic & Brownjohn, 2016). The diffusion of the technology will allow engineers to collect and assess larger contents of statistics, increasing the accuracy of modeling realist conditions. Building conditions and environments vary with every project, so the widespread use of continuous monitoring will lead to data that can specified by region. It will also highlight the discrepancies due to the difference in surrounding environments and given locations. More accurate simulations allow engineers to assess the efficiency and effectiveness of their designs in the changing socio-economics settings and deviations in urban population growth (Charalampos, Rembrandt, Xiaonan, Van Dam & Shah, 2018).

Improvement

Often engineers are commissioned for improvement in the real world: most research actively done at universities and government departments is done for the sake of improvement. A good working example of improvement in terms of aerospace engineering is NASA and SpaceX: while one is public and the other is private, both organizations are actively trying to create new and improved technology for the space industry. Improvement can be described as the design and implementation of state-of-the-art technology on infrastructure.

An example of improvement's application to real world problems is hurricane modeling. Now, in order to understand the purpose of this sub sector of research, some background knowledge is required. When water based natural disasters occur, in this case hurricanes, they impact coasts by causing a storm surge. A storm surge is defined as a large change in water levels due to various reasons, such as pressure changes during these black swan events. Storm surges can be catastrophic in terms of human life, as well as in property damages, therefore it is important to be able to predict how a storm surge acts before it happens in order to put precautions into place. Currently, the National Weather Service has been using 2D model to predict storm surges. While 2D models are computationally fast and are good approximations of water when it comes to shore, 2D models cannot accurately depict the water before it comes to shore, which can lead to discrepancy. 2D-3D model has thus been proposed: this type of simulation will not only have the speed of the 2D model, something an entirely 3D model lacks, but it will also be able to predict how water behaves in the bay before it comes to shore, hopefully decreasing error caused by 2D model (Choudhary, 2017). The 2D and 3D models are held together strong-type differential equations, in order to decrease error.

Another example of improvement research is the study of eigenvalue dynamic analysis. Eigenvalue dynamic analysis is computational the root finding method used to calculate the natural frequency and modes of stress bearing structure such as towers and bridges, in an effort to improve material stability. Theory states that all fluctuating buildings have a natural frequency: a natural frequency is the frequency at which a structure will fluctuate or vibrate when introduced to stress (Chapra, 2017). The natural frequency of a building is unique, and is directly based on the component materials it is based off of. When a building deforms at its natural frequency, it will produce a characteristic shape: this is called the mode of the structure (Chapra, 2017). The natural frequency produces a separate mode; this behavior is depicted in Figure 1 of the appendix, for varying angular velocities. As mentioned before, eigenvalue dynamic analysis is used to find the roots, or eigenvalues, of the function. Placed in context, when using this computational method, the roots of the system correspond to the natural frequencies of the structures, with the smallest eigenvalue representing the first mode of vibration. By performing these calculations, determining the best materials for a certain structure is possible. The only drawback to this method is that, as a system of linear equations which must be successively reduced, it can take a significant amount of time and computational power for such problems to be solved (Chapra, 2017). That is why research must be performed, for speed and efficiency. An example of this is producing a sparse diagonal matrix, instead of a full matrix: this significantly cuts down on computational power, as it reduces the number of calculations that need to be computed (Chapra 2017).

Green infrastructure refers to the balance between maintaining the human needs and preserving the environment around us. Its goal is to allows us to perform the duties to help our everyday lives, while also benefiting the pre-existing environment. There are 3 main types of education relating to green infrastructure: *about*, *in*, and *for* (Cole, 2017). Environmental education *about* green infrastructure is about finding learning opportunities in the real world that demonstrate how the green infrastructure is effective. This allows people who are uninformed to become informed and want to contribute. Environmental education *in* green infrastructure is concerned with the specific information about the entire process. This includes learning about the different areas where green infrastructure is applicable and what goes on during this cycle. Environmental education *for* green infrastructure is the “why is this important.” This area focuses on explaining the importance of green infrastructure and the consequences of ignoring it. A good example of green infrastructure is the implementation of solar panels. Currently, solar panels are used to power structures in parts of the world where there is much sunlight. However, due to the design of solar panels at this moment, solar energy is not transferable over long distances. Solar panels can also only store between 2% and 3% of energy collected. A proposed solution for this problem has been to create between silicon substances to trap sunlight, as well as shaping the materials such that the light is refracted within the panels, rather than reflected.

Improvement’s purpose in infrastructure design is to enhance the technology that is the basis of building. That being said, improvement does have its downfalls. It is often significantly more expensive than restoration, therefore it can be alienating to lower income societies.

Ethics

Ethics form the cornerstone of any good, large scale decision. In this way, it only makes sense that ethics be used to compare improvement and restoration solutions. The first point that should be considered is economic impact. Initially, it is less economically sound to focus on improving because time and money is spent doing research, while there are no immediate results. However, once the research is done and the final product is completed and testing finished, it will likely be more efficient and, more economical. A new road design will be able to outlast an old one, and it will not have the annual cost of maintenance. If a structure was to just be repaired endlessly, eventually the cost of repairs would be more than the cost of designing and implementing a better structure.

When looking at restoration from a societal viewpoint, support systems can often only be fixated up to their original condition. There is virtually no movement forwards, the quality of the infrastructure is at a stalemate and cannot be revolutionized without improvement. Improvement allows progression as a whole, which positively affects the society's common good and its virtues. Due to a city-wide earthquake that occured in 1949, the historical, Seattle Hotel’s decorative cornice was removed for safety and economic concerns. In 1961, the hotel, located in the Pioneer Square Historic District, was destroyed and replaced with a four story parking garage that is said to look like a sinking ship (Dorpat, 2015). The citizen response was negative and resulted in many failed attempts at saving the hotel. While the Seattle Hotel was significant to the city's culture, the building's structural health was in poor condition, compromising the well-being of its users. The limitations of a restoration project for the hotel would only allow engineers to work with the current state of the building. Any additions or fixations could only be applied around the existing structural framework. In order to adhere to the major concern, an improvement project was the ethical solution to the situation. While it did disrupt the city's historical district, engineers made the ethical decision for the common good of the citizen's safety.

From a humanitarian outlook, our cities and infrastructures are built to last generations. They will provide for our great grandchildren before finally needing to be replaced. Improving the design of our infrastructure allows us to push back the expiration date of our current infrastructure further and further. This allows more and more people to benefit from our expense with almost no repercussions. Focusing mainly on restoration is ignoring the inevitable that our infrastructure will fail, and it also keeps the standard for our infrastructure at a standstill. Sustainability is also an important factor when considering infrastructural ethics, especially environmental effects. The structural quality of infrastructure systems being at a standstill, but there is also no progression in decreasing its ecological footprint. While changing light fixtures and implementing energy saving protocols, the overall impact on a structures energy use is minimal. Improvement allows engineers to reassess the ecological footprint that these systems of infrastructure are leaving. In addition, a recent nationwide survey done in Switzerland showed that the public eye preferred the aesthetic appearance of infrastructure systems that appeared naturalistic or environmentally innovative (Junker & Berit, 2008). When compared to economic means, sustainability can be said to be the predominant factor that determines ethical decision making in reference to financial needs and public acceptance.

Sustainability is an important factor in engineering design, especially when it comes to improvement because a design should not only last a long period of time, but it should also be relevant for a long period of time. That being said, the costs of a building should not exceed the benefits gained by the creation of said building. When applied to the ethical dilemma of infrastructure, it is easily seen that improvement supersedes restoration on principle alone. Restoration, at most, can only bring a building back to its original condition, whilst shortening a building's lifespan. Improvement, on the other hand, enhances both a building technologically, and delays building expiration significantly (Wee & Handy, 2014). Therefore, the benefits associated with restoration are superficial at best. Improvement not only benefits the welfare and maintenance of a city through creating more technologically developed structures, but it also utilizes funds in a progressive manner.

Conclusion

Improvement can be seen to be a good ethical choice, in regards to engineering solutions, because it supersedes restoration when compared to sustainability, environmental conservation, and societal culture. Restoration is a good choice when considering temporary cases. That being said, it falls short to improvement in a pragmatic manner. Improvement is a better engineering solution for infrastructure because it allows for a change in the manner of cultural creativity, as well as technological development. Restoration is used practically today to protect the integrity of historical monuments. However, it leads to the drastic accumulation of economic burden over time. Improvement, while costlier, allows for the creation of more sustainable infrastructure. Improvement creates a better society by creating an environment of positive growth and development. Whatever their technical goals may be, all engineers should strive to create ethical solutions for humanity.

Appendix

Gentrification

The process of redevelopment and revivalment of urban city areas to make them more attractive to a wealthier class.

Improvement

Improvement is replacing what we have with a new design in order to improve efficiency.

Restoration

Restoration is the process of repairing and maintaining the current infrastructure that we already have. Fixing potholes in roads, keeping water clean, and renovation of homes and buildings fall into this definition

Figure 1: Building Modes

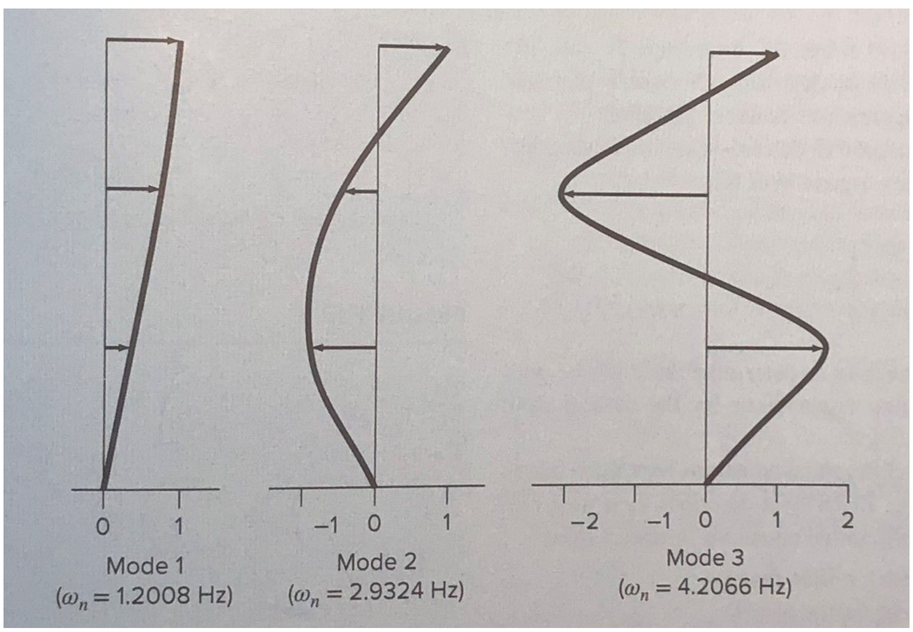

Figure 1 shows the primary frequencies of a three story building. When an earthquake's frequency resonates with the building's frequency, more stress is caused in the beams and more damage can be potentially caused. (Chapra, 2017)

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