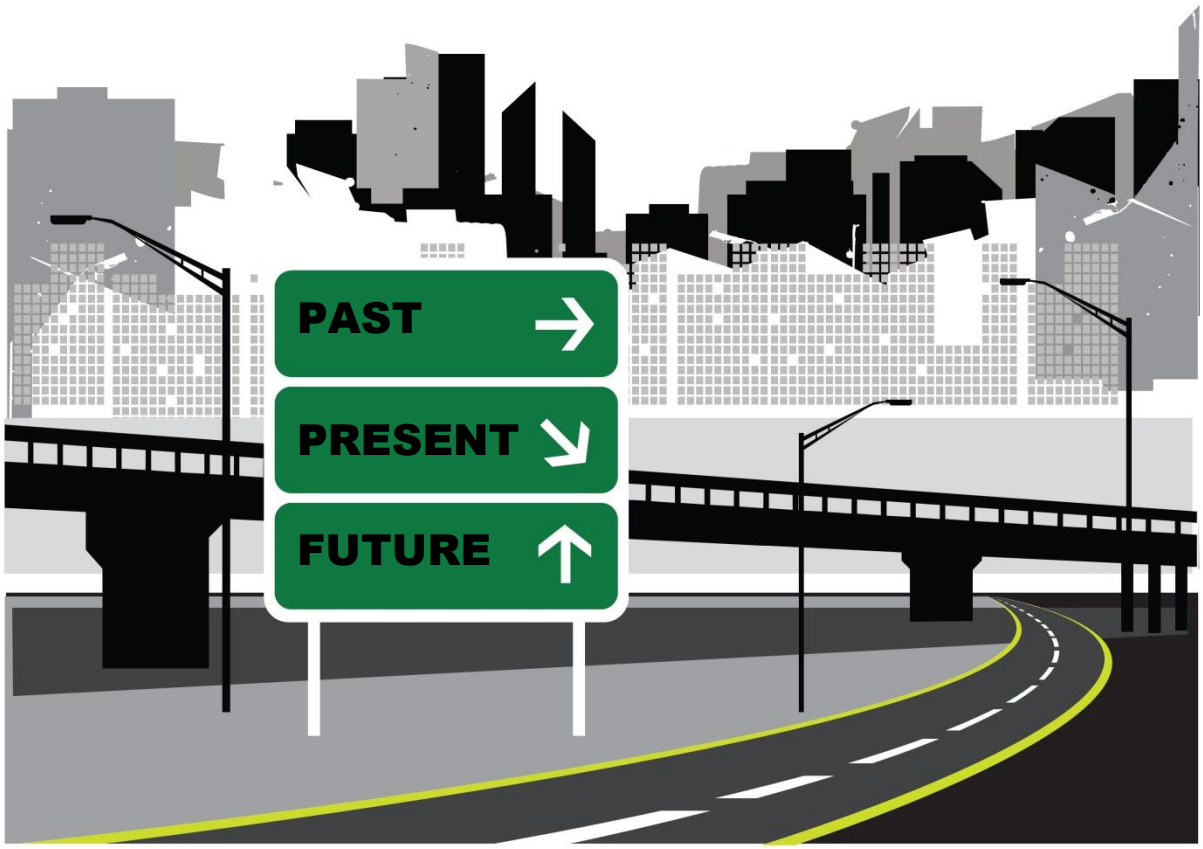
AMERICAN PUBLIC WORKS ASSOCIATION

SUSTAINABILITY IN FUTURE ROADWAYS



EMERGING LEADERS ACADEMY VIII AUGUST 2015

Acknowledgments

The Emerging Leaders Academy Class VIII would like to thank the many people within APWA who have made this class possible. We would also like to thank our respective employers, who have seen the benefit that the program brings to them as well as those of us who have participated.

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ELA Experience

Imagine throwing 16 motivated professionals into a room, each with different ideas and backgrounds from all different regions of the United States. Not sure what to expect from this year long ELA program, or just how much of an opportunity it was, our group met when we spent 2 days together in Kansas getting to know each other and taking part in many different self and group assessments. APWA provided professionals to help us with our public speaking, management styles, to even personality assessments. All this was leading up to the biggest challenge of the 2 day retreat, choosing a topic that we would spend the next nine months researching.

This proved to be a dynamic lesson in and of its self. How else can we become leaders if we cannot learn to lead ourselves and work together for a common goal? A real positive for the group is that we were able to make decisions purposefully and quickly. Choosing the group project leader was our first step. It was that small step that made all the difference, not because of the leader, but because now the group had made that little step towards being more than a group of individuals and becoming a team. Our random thoughts and ideas were quickly narrowed down to a single topic that would later be refined. Members in the group began volunteering for different responsibilities to undertake and our roles were defined, not by delegation, but out of compulsion for the group to succeed.

The ELA experience is one that you will get out of it more than you put in, if you allow it. In the short time that we have been a part of the program we have seen members grow both professionally and personally. We have gained friendships that will last a lifetime. Most importantly we were given an opportunity to become leaders. For this we greatly appreciate all the efforts of those within APWA who have made this possible.

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Table of Contents

EXECUTIVE SUMMARY

Establishing a network of infrastructure was once an important task for the United States that opened endless doors of opportunity for its citizens and economy, but now maintaining that infrastructure with limited resources is a major concern for citizens and government alike. While futuristic roadway ideas are enticing and exciting, governments face many obstacles in implementing these ideas. These obstacles include funding, safety, legislation, durability, operating, and maintenance. As well as identifying some intimidating obstacles and barriers, this report serves to explore feasible options for innovation that are currently available as well as ideas for the future that should be considered and sought after to accomplish sustainability in future roadway infrastructure. Investment and innovation in roadway infrastructure is a long term objective that cannot be delayed. It is the current generation of public works professionals' responsibility to take action now in building the foundation and plan to make the nation's roadways function for future generations. This change in culture must be an ongoing progression of continuous improvement, unlike a one-time project that has a definite beginning and end. As part of this progression, future technologies should always be welcomed and considered. It is not just the technologies of the future that bear relevance. There are technologies currently available that can be used now to meet the increasing demand of the nation's failing infrastructure to help begin the nation's journey to sustainable roadways.

INTRODUCTION

As the United States' infrastructure ages, public works management faces the challenge of maintaining, replacing, and managing its timeworn roadways. This can be addressed through the use of new technologies to maintain and improve existing infrastructure with diminishing resources. It is through these innovations that public works can strive for sustainable roadway infrastructure development. Sustainability is defined by Webster's Dictionary both as (1) utilizing resources in a manner that does not destroy them as it relates to environmental awareness, and (2) the ability to continue on for a long period of time. It is these two definitions of sustainability that the technologies and programs described are attempting to meet.

This paper will focus on emerging technologies that meet the definition of sustainability. These technologies include roller compacted concrete and permeable pavement, and future technologies (such as solar roadways). These technologies have the potential to enhance public works programs to achieve longevity, while minimizing environmental impacts and improving the day-to-day operations of roadway systems.

With all emerging technologies there are barriers that each must surmount when it comes to implementation and funding. Public works organizations must carefully evaluate the advantages and disadvantages of implementing these technologies with the goal of sustainability in mind to ensure that they are used appropriately and economically. These technologies will be described in detail to assist public works professionals in evaluating these options. Additionally, information to assist in overcoming common obstacles to implementation with recommendations for aggressive education and outreach will also be provided. It is expected that this information will assist all public works organizations in providing the next generation a more sustainable future.

1.1 Background

Largely due to the invention and popularity of the automobile, the "Greatest Public Works Project in History" began in 1956 - the US Interstate Highway System. Having such a vast interstate system has impacted Americans' dependency on vehicles. Prior to the interstate system, transportation by road was slow and dangerous. The improved infrastructure network added 41,000 miles to the existing infrastructure allowing travelers to go farther, faster. Once the interstate system was constructed, other forms of transportation rapidly declined and by the mid 1960's passenger travel between cities fell to less than two percent. In addition to the increase in leisure traveling, the new interstate system improved the trucking industry resulting in economic growth for North America.

Once the pride and joy in comparison to the international community, the United States transportation infrastructure has seen a dramatic decline in condition and functionality in the last fifty years. United States leaders have voted on bills and cut funding to the effect that the United States is now currently spending less on infrastructure replacement and maintenance than at any time in the last twenty years. Americans are dependent on this underfunded transportation system to get to and from work to keep the United States' economy above water.

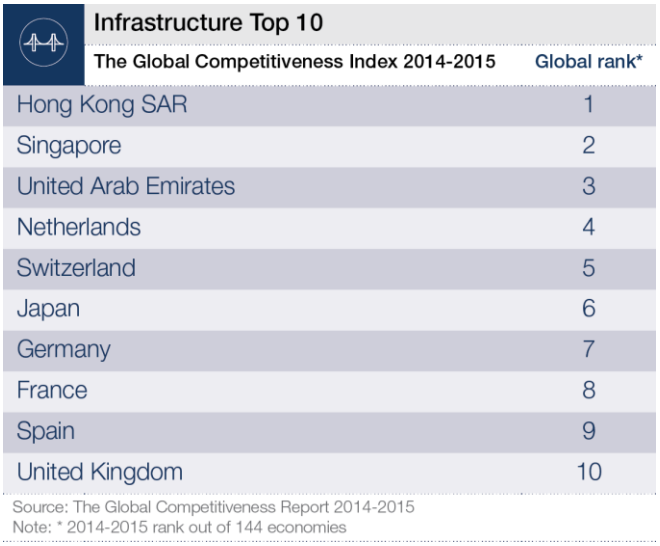
So how did one of the most “progressive” thinking countries in the world allow such a vital component to its own economic health fall by the way side?

The current state of the nation’s infrastructure continues to crumble literally and figuratively. Unfortunately, the past has shown that it takes a major disaster for people to start to take notice of critical and possibly catastrophic epidemics that any American may face on any given day. The current status of the United States infrastructure may currently be “under the rug” but the numbers don’t lie, and public works officials need to advocate for proactive instead of reactive solutions to repairing America’s bloodlines.

In its 2013 study, “Report Card for America’s Infrastructure,” the American Society of Civil Engineers (ASCE) estimated that roughly $3.6 trillion in total investment is needed by 2020 to return the nation’s facilities to good repair, which ASCE defines as safe and reliable with minimal capacity issues and minimal risk. The same report labeled America’s current infrastructure as a D+ from a grade school scoring mechanism. Americans rely on these same “D+” transportation systems to commute to and from work on a daily basis. Americans come in as the third longest in the world’s average daily commuting time when compared to the rest of the world.

Figure 1

The poor quality in infrastructure undoubtedly contributes to a higher than average motor vehicle death rate amongst citizens with 15 deaths for every 100,000 people. In 2012, the United States global ranking in quality of overall infrastructure ranked 14th in the world according to the Global Competitiveness report. In 2014, it continued the downward trend coming in at 16th behind countries such as; Luxembourg and Portugal. Below shows a chart of the top ten ranked countries in infrastructure per the “2014 Global Competitiveness Report”. The US continues to fall farther from this top 10 rating. [1]



Infrastructure Top 10

The Global Competitiveness Index 2014-2015	Global rank*
Hong Kong SAR	1
Singapore	2
United Arab Emirates	3
Netherlands	4
Switzerland	5
Japan	6
Germany	7
France	8
Spain	9
United Kingdom	10

Source: The Global Competitiveness Report 2014-2015
Note: * 2014-2015 rank out of 144 economies

Figure 2

The current state of the country's infrastructure is at an unacceptable level. Anybody who drives a vehicle can surely name a couple of bad roads or scary bridges when called upon at any moment. Systems continue to fail and will continue to fail at a higher rate if the public works organizations within the United States do not start to address these issues. Technologies need to be looked at to develop and implement a progressive plan to fix the nation's roads. The nation's failing infrastructure may provide an opportunity to look at new technologies for implementation while repairing and replacing the infrastructure that currently exists.

1.2 Future Concepts

In many ways, the past can serve as a good indicator of what the future holds in store. Unfortunately, this does not necessarily hold true regarding technologies that do not yet exist. Today, many of the technologies that are used in daily life were viewed as science fiction only decades ago. It is possible to look at visionary ideas that are currently being conceptualized, but seem outrageous to people now, and see how they could be implemented in the future. There are some ideas on the horizon which may very well serve as the needed catalyst for change.

1.2.1 Rail Transportation

Of the various ways to transport people, goods, or services, one of the least innovative in the United States is the rail system. Unless you live in a dense urban area, most people's experience with trains is limited to what they see as they wait for a long, clunky, diesel driven behemoth to pass by at a railroad crossing. All of this may be about to change. The use of Maglev or "magnetic levitation" trains and low pressure tube trains is quickly moving from concept to potential reality. These trains, which require altogether different infrastructure than traditional rail, could provide the nexus for a more sustainable future transportation system. In August of 2014, Elon Musk—innovator, entrepreneur, and co-founder of Tesla motors—

announced a design scheme for the “Hyperloop.” This transportation concept uses nearly airless tubes to transport “trains” at speeds in excess of 800mph. This technology could provide the needed sustainable solution to replace long haul air transportation of people, goods, and services.

1.2.2 Automobile

Consumers are accustomed to new technologies in the automotive industry. However, very few, if any innovations provide for reduced wear and tear on the aging infrastructure. What if the car you drove down the road didn’t actually touch the road? Many people have dreamed of owning a hover board like the one used by Marty McFly in Back to the Future II. Could this technology become a reality, even for automobiles? Back in 2012 there was a rumor floating around the internet that Volkswagen had a concept hover car. This was based on Volkswagen’s “People’s Car Project” in China in 2011, where they solicited over 119,000 concept ideas and selected a hover car as one of three design worthy ideas. A YouTube video that showed what appeared to be a concept hover car that travels along a magnetic roadway further perpetuated the rumors of this cars existence. Unfortunately, it appears the video was “enhanced” and as of this writing, no known hover concept cars are in existence.

1.2.3 Re-Urbanization

Today, as more and more people demand sustainable, environmentally friendly transportation solutions the idea of the post-World War II American Dream of owning a home in the suburbs is slipping. This idea, sometimes termed re-urbanization, is growing in popularity as more and more people are choosing to live and work in or near the downtown core of medium to large sized cities. This trend has the potential to provide the most sustainable transportation solution currently on the horizon: less of dependence on automobiles. This concept is scale dependent and requires the availability of goods and services that are multi-modal accessible. The idea that a person does not need a car to get around is not new for those living in very large cities. However, for the car-centric culture of those living in large to medium sized cities, it can be difficult to let go of the ease and freedom to travel great distances quickly and at will. How this trend will develop is still out there on the horizon. However, reducing the amount of automobiles on the road is the most sustainable near-term solution out there.

1.2.4 Final Thoughts

Across the United States, there is a common understanding that sustainable, more environmentally friendly solutions are needed to improve how people are transported from one place to another. Future technologies will be driven by the private sector, but the infrastructure needs will be mostly installed and maintained by the public sector. What tomorrow holds in store, no one really knows. However, it is clear public works professionals across the country will continue to provide collaborative, innovative, reliable solutions to this nation’s transportation problems for years to come.

2.0 EMERGING TECHNOLOGIES

With the declining infrastructure and changes in the expectations and behavior of American's, there is a need for significant infrastructure investment and the use of new efficient and sustainable methods of infrastructure maintenance. Necessity breeds invention. This statement is particularly true in the world of public works. With the tremendous pressures on public works organizations to provide better, cheaper, and more reliable services to citizens, there is always a need for innovation and change.

There are many emerging technologies that are among the innovations that will be important for infrastructure improvement. These technologies, if embraced, have the potential to not only repair the infrastructure that currently exists, but to drastically improve it. Current technologies, such as permeable pavement and roller compacted concrete, and emerging technologies, such as solar roadways, may offer solutions to some of the many challenges that those in the public works profession face.

No technology is perfect and each possible solution has its own set of challenges to implementation and barriers to progress. As stewards of infrastructure, it is the responsibility of public works professionals to diligently investigate these technologies and weigh their value. For your consideration, below is an investigation into just a few of the emerging technologies for infrastructure solutions.

2.1 Roller Compacted Concrete

Roller Compacted Concrete (RCC) is a high strength, zero-slump concrete that has the performance of conventional concrete. It receives its strength from compaction rather than steel reinforcement like traditional concrete. Yet it also has the economy and simplicity of installing asphalt. It is placed with an asphalt paving machine to form a non- reinforced concrete pavement, providing a superior product at an economical price. Currently, more than two million square yards of RCC is being placed annually. It continues to grow and expand in utilization and application as the technology in mix design, production, and surface smoothness is enhanced. [2]

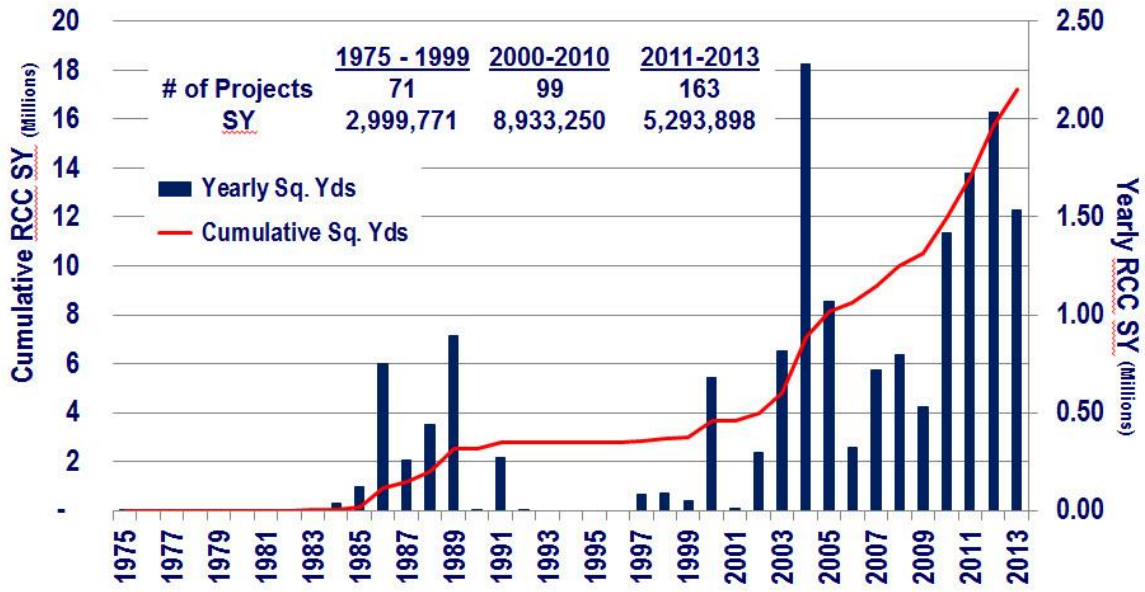


Figure 3: RCC Installations per U.S. Army Corps of Engineers

2.1.1 Design and Installation Procedure

Sub-grade preparation is the same as a conventional concrete and asphalt. By installing the curb and gutter first, it provides the elevation and line controls for RCC paving but is not required. A nuclear gauge is used during the laying of the RCC to monitor the density and moisture insuring proper compaction. RCC can be placed in a single lift up to 9", unlike asphalt. No forms or reinforcing steel are necessary, therefore reducing labor and material costs while increasing construction speed. The required equipment to lay RCC includes an asphalt paver, dump trucks, and a roller. Compaction is achieved using a roller and is the most critical step. Compaction provides density, strength, smoothness, and surface texture.

2.1.2 Benefits

- Useful street life is 50 years compared to asphalt at just 25 years.
- Can reach compression strengths of up to 10,000 psi.
- High density and low absorption is less vulnerable to freeze/thaw cycles.
- Higher shear strength than concrete (eliminates rutting and subsequent repairs).
- High durability, low initial cost.
- Light colored surface reduces lighting requirements and higher solar reflectivity mitigates urban heat island effect compared to asphalt.
- Can be open to local traffic within four hours and to heavy traffic within 48 hrs.
- Aggregate interlock provides high shear resistance. Reducing uncontrolled cracking and pavement faulting.

2.1.3 Disadvantages

- The surface is not smooth or aesthetically as appealing as traditional concrete. It looks more like asphalt. This can be corrected in several ways. Over the past several years there has been an increase in admixtures to allow better finishing with a power trowel. The second way that is gaining popularity is to diamond grind the surface to improve the ride and stopping resistance. The last way is to overlay the surface with a 1½ - 2" lift of asphalt.
- Many concrete suppliers and contractors lack the experience and expertise to produce the proper RCC mix and properly install it. The Portland Cement Association (PCA) and State Concrete Pavement Associations will have more information on local contacts, education and past projects within your area.
- High temperatures especially above 90°F will affect the workability and hydration. Stabilizing admixtures may need to be added.

2.1.4 Asset Maintenance and Assessment Needs

Higher compressive and flexural strengths reduces potholes and spalling (flaking, pitting or cracking), resulting in lower maintenance cost than concrete and asphalt. There is no seal coating or resurfacing required.

2.1.5 Maximizing Lifespan

RCC's lifespan can be maximized by the use of concrete sealers and crack sealers. Sealers will help the concrete resist penetration of water and chlorides into its surface. Whereas crack sealers will prevent the infiltration of water and chlorides into the joints, cracks and base. Therefore both surface sealers and crack sealers reduce the harmful effects of water infiltration, freeze thaw cycles, corrosion and deterioration.

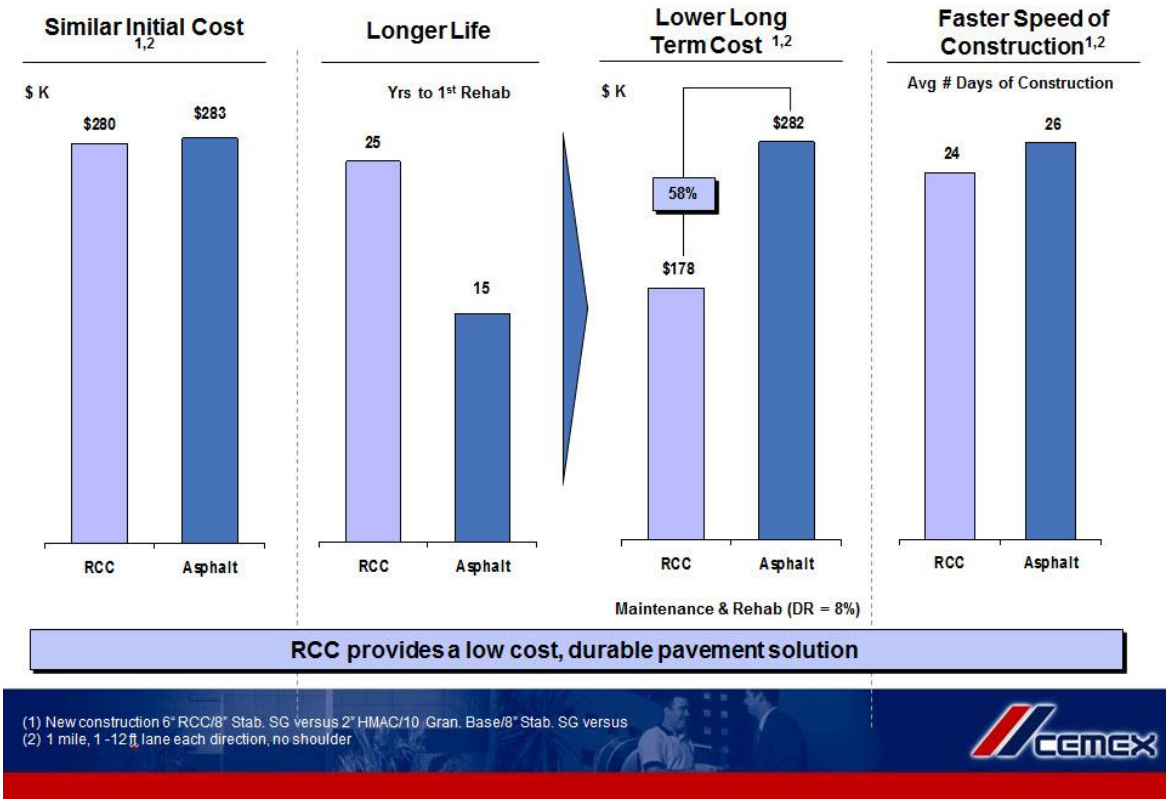


Figure 4: Cost benefit Analysis (RCC vs Typical Asphalt Pavement)

2.1.6 Who's Using It?

Roller compacted concrete has become increasingly popular in the Midwestern states. This can be attributed to the resistance to weather related fatigue and damage which are caused during multiple freeze thaw cycles. As this method of roadway replacement becomes more prevalent in the rest of the United States, the cost to install should also decline. See Figure 5 below for a graphical representation of RCC projects and their locations. [2]

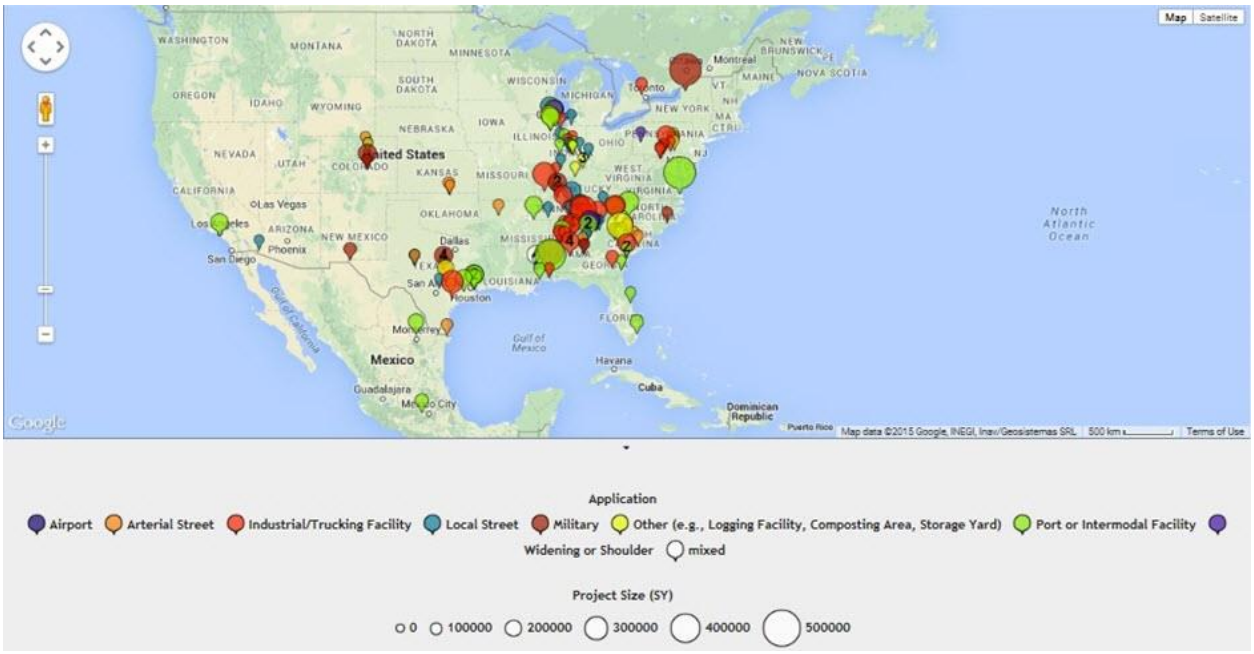


Figure 5: Roller Compacted Concrete Projects in the U.S. (Projects submitted to the American Concrete Pavement Association)

2.1.7 Conclusion

The benefits of RCC are the low cost of ownership over time due to the low maintenance, high durability, and low installation costs. With limited funds set aside for road construction, it is imperative to take a good look at RCC and what it can provide to communities. Even with the additional installation work, it is still more cost effective in the long run than conventional concrete and asphalt.

2.2 Permeable Pavement

Today, as a result of increased environmental regulations directed toward improving water quality, most transportation improvement projects trigger the need for installation or retrofit of stormwater controls. Traditionally, this has necessitated land acquisition in order to have adequate space to provide the appropriate sized detention/retention or infiltration facility needed to provide those controls. Frequently land acquisition costs exceed the costs of the rest of the project, especially with sidewalk projects. In some cases, such as retrofits in highly urbanized areas, land acquisition is simply not an option. This development has led design professionals to think of infrastructure design from a more sustainable point of view, both financially as well as environmentally. Infrastructure technology continues to develop and will always continue to evolve as long as the demand for transportation resources continues to remain high. One of the more popular emerging technologies that have arisen over the past decade in sustainable

transportation is the use of permeable pavements for projects involving roads, sidewalks, and bike paths.

The term “permeable pavements” can refer to many different types of in-filterable transportation ground material including interlocking concrete and brick pavers, plastic grids, and porous turf. This summary report will focus on porous concrete and porous asphalt used for projects more applicable to municipal public works departments.

2.2.1 Design and Installation Procedure

Permeable pavements can reduce the percent imperviousness for project areas, which allows for greater infiltration rates and reduced storm water runoff volumes. [4] In addition, these alternate pavement types function as storm water pollutant removal mechanisms. The infiltration rate and structural capacity of the native soils found on the development site directly influence the size of the stone reservoir that is needed to provide structural support for permeable pavement systems. If design parameters cannot accommodate the storm water runoff volume generated by the target runoff reduction rainfall event, site planners should consider additional low impact development (LID) practices in addition to permeable pavements. Below are three different design types and short descriptions of each configuration: [5]

- **Standard designs** – standard underdrain and no infiltration sump or water quality filter.
- **Infiltration designs** – no underdrains that can infiltrate the design storm volume in 48 hours.
- **Hybrid designs** – underdrains that contain a water quality filter layer and an infiltration sump beneath the underdrain sized to drain a portion of the design storm in 48 hours.

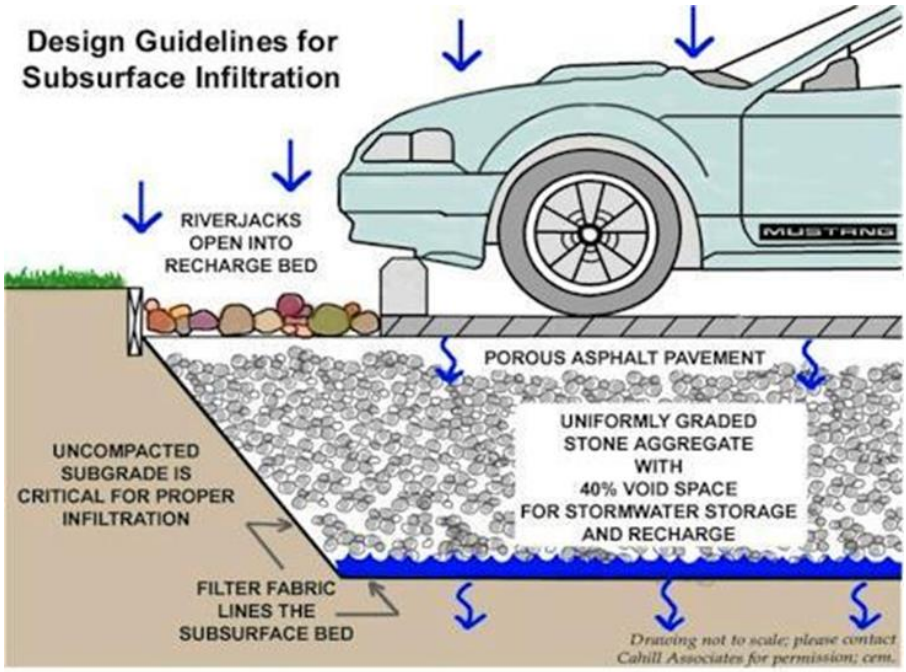


Figure 6 Representative Permeable Pavement Section [3]

The development site should have preexisting conditions to include a soil percolation rate at or above ½" per hour minimum. The distance from bottom of the practice to the top of the seasonal high water table should not be less than ½ feet. The site should be removed at least 100' from water wells intended for drinking water. For porous pavement sites there should be low to medium traffic volume accompanied on the road.

Installation costs in the Pacific Northwest are estimated to be between $80-120 per square yard depending on site conditions and underdrain design. Regular porous concrete is a mixture of coarse aggregate, cement and water, (no sand). Because aggregate contains a significant amount of voids, the addition of the cement does not close off all the voids. Void content can range from 15-30% and is designed to allow storm water drainage to sub-grade for filtration. Water flow rates (through porous concrete material) are in the order of several hundred of inches per hour. The sub-base should be designed as a retention layer.

The final mixture is a very stiff, zero slump concrete. The material must be raked into the forms, as it does not tend to flow well. The mixture is leveled to half an inch higher than final grades. A weighed roller is used to compress the excess material to the final grade. Expansion joints are placed every fifteen feet while crack control scores are placed every five feet before the concrete sets. The finished surface is immediately covered with plastic and left to cure for up to seven days. Monitoring wells should be included in site design to monitor drawdown in reservoir.

2.2.2 Benefits

- Better infiltration, groundwater recharge, reduction in runoff volume, and treatment of stormwater pollutants.
- Applicable to sustainable design and building certification programs including the Institute for Sustainable Infrastructure's (ISI) Envision program.
- 100% credit for storage volume of practice in coastal zone.
- 100% credit for storage volume of infiltration design and 50% credit for storage volume of standard design.
- Expected annual pollutant removal 80% total suspended solids, 60-80% total phosphorous, 60-85% total nitrogen, high removal rates for zinc and lead, 45-75% pathogens removal. [5]
- Additional costs associated with installation maybe offset by the reduction of traditional curb and gutter systems used to conveyance of storm water.
- Reduces noise pollution per study in Europe. [6]

2.2.3 Disadvantages

- More expensive to construct than traditional asphalt systems.
- Development “rules” may restrict design of innovative practices i.e. zoning codes, subdivision regulations, etc.
- Life span for material area dependent on climate and other factors.
- Increased annual maintenance costs.
- Specialized installation may limit fewer experienced contractor options with specialty knowledge.
- Patching becomes more difficult.
- Cleaning more difficult and use of specialized equipment is needed.
- Restricted Average Daily Travel (ADT) specifications rates.
- Geotextiles fabrics used for prohibiting intrusion into bottom reservoir may become future plane for clogging.

2.2.4 Case Study: RW Johnson 21st Avenue Project-Olympia, WA

After nearly a decade of success installing pervious concrete surfaces, in 2006 the City of Olympia chose to push the innovation barrier during the reconstruction of RW Johnson Boulevard, a major industry collector, by incorporating two pervious concrete bicycle lanes adjacent to two asphalt vehicle lanes. The bicycle lanes treat and infiltrate the stormwater runoff generated by the vehicle travel lanes. The roadway project also included pervious concrete sidewalks along the length of the roadway.

At the time the pervious concrete used for this project was a new material with a surface texture more similar to traditional concrete than the large aggregate products previously used. The concrete has a high fines content (75%) resulting in a smooth finish for the bicycle lanes and sidewalks. At that time, the City of Olympia had installed over 7,500 square yards or about two miles of porous concrete sidewalk. Up to that point, they had experimented with three different types of porous concrete materials ranging from the regular “no-fines” porous concrete to a new form of 100 percent sand “all-fines” concrete. [7]

The RW Johnson 21st Avenue Project was a good place to try pervious concrete sidewalk and bicycle lanes for a variety of reasons [7]:

- Olympia City Council has long supported staff’s use of permeable pavement in sidewalk applications and encouraged the use of permeable pavement in low risk roadway projects,
- RW Johnson Boulevard is adjacent to an extensive City-owned stormwater facility. Underperformance of the permeable pavement system could be mitigated in the existing stormwater facility.
- The project site has a lack of readily available land for construction of traditional stormwater management resulting in potential high costs.

- RW Johnson is an industrial major collector with considerable truck traffic. High loading from traffic challenges the potential use of permeable asphalt or other completely permeable roadway section. Durability and life cycle cost concerns are significant in high truck traffic areas. Concrete was chosen for the permeable surface rather than asphalt.
- The underlying soils provide a reasonably high expected infiltration rate. This enables the area under the 5-foot bicycle lanes to effectively manage the site's stormwater.
- Olympia has past experience and success constructing pervious concrete sidewalks on the following page is a detailed photographic illustration of the construction sequence that was used for this project.

Figure 7: Sidewalk First & Outside Curb

Figure 8: Excavate & Check Dams

Figure 9: Line with Geotextile

Figure 10: Pour Inside Curb

Figure 11: Backfill Drain Rock and Compact

Figure 12: Place First Lift of Pervious Concrete

Figure 13: Place Second Lift of Pervious Concrete

Figure 14: Screed, Roll, Compact, and Cover

Figure 15: Stripe Bike Lane

Figure 16: Bike Lane Adjacent to Sidewalk

Current Project Status

At the time, this project was hailed as a huge success. Today, it still is a huge success. It was a success in innovative uses of new technologies, and pushing the barrier by taking calculated risks. These risks are needed to find new solutions to very complicated problems. Today, less than a decade after construction, the project's pervious concrete components have experienced a failure rate of 42% on the pervious concrete sidewalk, and 67% on the pervious concrete bike lanes. At a cost of $50-80 per square yard for replacement, the risk has proven costly. However, the environmental risks are non-existent due to good project design contingencies. As pervious concrete sections or panels experience failure, they are replaced with the newest pervious concrete mix designs which so far have experienced a lower failure rate. Though costly, those innovative risks have provided good information regarding product limitations and challenges.

2.2.5 Asset Maintenance and Assessment Needs

Annual Inspections, as well as well monitor inspections after major storms, should be regularly scheduled. Routine inspections are encouraged to monitor debris build up on surface. There have been varying opinions on how best to maintain porous concrete and pavement, but most maintenance applications involve at least one of the following or combination of the following activities: mechanical sweeping with street sweeper, pressure washing, or vacuuming. Vacuum and sweep surface at least three to four times a year, depending on application, and location are important to maintaining functionality in most cases.

2.2.6 Maximizing Lifespan

Typical life span estimating for porous concrete is twenty to thirty years, while estimating for porous asphalt is 15 to 20 years, but these estimates vary significantly when factoring ADT and environmental contributors. The most sited maintenance problem is surface clogging caused by organic material, and failure caused by more frequent maintenance. By maintaining a proactive schedule for inspections and maintenance activity, as well as training maintenance staff on proper maintenance techniques, owners can increase the lifespan of the material in place. Street sweeping and regular vacuum activities seem to be the standards of practice, but an important factor as well maybe educating citizens on the systems applicability's and limitations.

2.2.7 Conclusion

As previously described the design of the permeable application is very dependent on existing conditions more specifically in the sub surface material of the design site. When application design standards require more attention to the piping or conveyance of water runoff in the sub grade due to poor infiltration material, the costs of construction may outweigh the benefits of the sustainable design. Also, design professionals need to be cognizant of their climate and the reaction of the permeable pavements has to external elements in extreme environmental conditions. Overall, permeable pavements are a viable option in selecting sustainable

technology for use in multiple transportation applications. From the public works perspective, departments need to make sure that staff and maintenance personnel are well educated in the uses, applicability and maintenance needs to each individual application.

2.3 Solar Roadways/Pathways

The concept of solar roads is a relatively new concept and research and data is limited. There are a few pilot projects, which have provided some data for analysis. Some of these projects have been created to understand the capabilities of solar panels in the roadways and the possibilities these panels could provide. These panels could have multiple types of sensors, heating elements, or light emitting diodes (LED) lights for various applications once installed.

There is concern with the strength of the panels and whether they provide a safe surface for the transportation of vehicles, motorcycles, bicycles, and pedestrians. These panels, which are still experimental, seem capable of providing these services. Most panels are made of tempered glass that can handle all traffic loads, and the surface incorporates features that provide sufficient traction. Cost has been prohibitive for conducting more test projects.

2.3.1 Current Projects

The most famous project in the United States is the Solar FREAKIN' Roadways project featured on YouTube and Indiegogo. [8] This project was a prototype solar parking lot made of 108 panels in Sagle Idaho, built in 2014. Over $2 million was raised to build this test project. The goal was to include as many elements in the panel as possible. These panels are hexagon shaped and attached to a concrete foundation. The information gathered from this test project presents a case that if all roadways were converted to system to collect solar energy; the roads would produce over three times the energy that the US consumes per year. These estimates were very conservative and as solar technology improves, so would the energy produced. Solar roadways would help the environment by reducing greenhouse gases from coal burning power plants and vehicle emissions. Solar roadways could reduce emissions by up to 75% according to the research from the project.

Another test project is the SolaRoad [9] which is a bike path in Krommenie, Netherland and was built in 2014. It cost around $1.9 million for 230 feet of panels. The cost figure included monies for research as well, and no cost break down was provided. Their project's concept was a panel and foundation incorporated into one unit, which could be dropped into the ground. By their calculations, if all roof tops were used for solar collection in the Netherlands, the panels would only provide the country with 25% of its energy needs. This in turn led them to utilize pavements as an alternate location to gather solar energy.

Solar Panels bring an element of technology to the driving surface for vehicles. This presents the opportunity to have the panels send real time data to control or manipulate given situations such as traffic jams, pedestrians or animals in the roadway, or alternate routes around problem areas.

2.3.2 Concerns

Solar roads do face some opposition. The 2009 Federal Highway Administration's report "Innovations for Tomorrow's Transportation" [10] does not speak to solar roadways. The word solar is not even in the report once. Others criticize the potential cost to convert the existing roadways to solar producing surfaces. Some critics fear the electronics would be too easy to be hacked. The longest prototype is about 36 feet in length, which is too short to test road noise. Yet some believe these panels would create a constant whine, and how about those cloudy days? What about the night time and winter sunshine, with little UV light? Would the panels draw energy from the grid when they cannot produce electricity in these instances? Maintenance is also a huge concern. Some feel that current roads are not maintained, so why would a solar roadway be maintained?

Overall, the largest hurdle is the cost analysis. Most of the research and testing that has been done on very small scale prototypes. Without mass producing the panels, it is hard to nail down what a cost would be. Existing roads would need to be modified for the utilities. Some of the existing roads could be reused as a foundation, given their condition, but the conduit costs would vary. Additionally, the solar roads would produce revenue, which would vary over time, further increasing the complexity in the cost analysis.

3.0 BARRIERS

Despite the fact that the American Society of Civil Engineers in 2013 graded the American roadway and transit systems with a D+ there still has not been directed and widespread investment and adoption of innovative technologies through the country. Unfortunately, the path to a sustainable solution has been riddled with potholes. Serious reconsideration of current infrastructure practices that go beyond the traditional methods of asset management and innovation in the automotive industry will be necessary in order to raise the roadway and transit standards, but there are significant barriers that inhibit development on these fronts. A thorough evaluation of how and why people, goods, and services are moved at a local, regional, and global scale is necessary in order to remove the cultural and economic barriers which prevent the sustainable transportation solutions needed.

3.1 Cultural, Societal, & Behavioral Barriers

Public services employees and organizations are not viewed as dynamic institutions but as static bureaucratic organizations that are resistant to change. While many in the industry try hard to defy those stereotypes, there is some truth to the highly regulated and institutionalized environments that public works organizations operate within that makes change, especially change that needs to be made within a short period of time and with processes that are not thoroughly vetted, very difficult to implement.

3.2 Economic & Market Barriers

Newer technologies are often more expensive to adopt, more risky to implement, may not be widely available, and have more unproven long term maintenance costs versus traditional methods. The environments in which public works organizations operate under require standardization and predictability. Testing out new technologies becomes tricky in these environments because a new technology may not continue to be utilized or supported and that may leave infrastructure where new technologies have been utilized difficult to maintain, in need replacement and/or in investment. Public works organizations are tasked to spend funds in a manner that is deemed by the voting public as responsible. Investing in innovative and untested technologies may be viewed as irresponsible and unsupported. Without testing and wide implementation, these technologies are unable to be fully vetted, and therefore cannot get the market penetration necessary to reduce costs and make them more widely available.

3.3 Regulatory & Political Barriers

The highly regulated environment in which public works organizations operate prevents the utilization of new technologies that do not meet existing regulations. Current planning regulations and engineering standards have been created to address current and emerging technologies. These standards would need to be updated for some of these newer technologies to be adopted.

3.4 Financial Barriers

Funding for public infrastructure is a struggle. With the current infrastructure on the verge of failing, significant financial investment is required. Many technologies that do have cost savings over time have an upfront cost that during a time of such degradation of public infrastructure may not be feasible or fiscally responsible to utilize.

3.5 Survey Results

In order to better understand what was preventing public works organizations from utilizing new technologies the Emerging Leaders Academy conducted a survey of all American Public Works Association (APWA) members and received 238 responses. These respondents were from at least 40 different states, the majority of which (78.5% were from cities, counties, and townships) with a wide variety of populations being served by each organization.

3.5.1 There is a will, but limited way

The survey results indicate that while interested and even ready to move forward with more innovation, public works agencies are restricted by finances. When respondents were asked about the flexibility and adaptability within their organizations and the support they receive from their elected officials most respondents indicated positively, but when asked about their current financial requirements and how well they were funded 62% of respondents indicated that they agreed with the statement that they were "...underfunded and barely able to meet current mandated services (they) are required to provide". This gap between the abilities and political interests of most communities and their inability to adequately fund services presents a significant barrier to innovation.

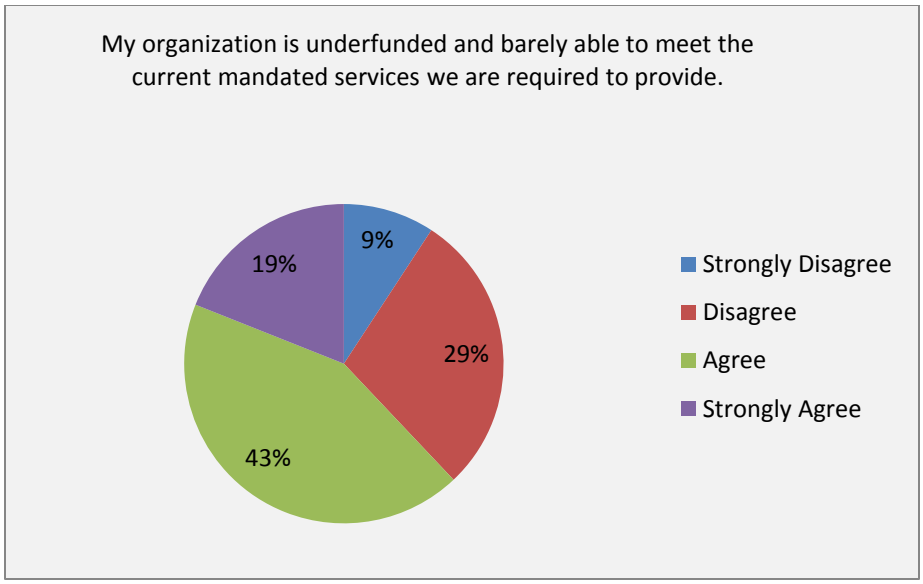


Figure 17

Some of the technologies presented provide some overall short term and/or long term cost savings. Those with short term cost savings are a simple solution to implement. Those with long term cost savings that require up front investments are a harder financial sell due to their higher upfront costs and require the political will and financial resource in order implement. Based on the results of the survey it is unlikely that many communities will be able to afford technologies that have long term savings potential and technologies that may become best practices due to durability or environmental impact that have an increased cost. Financial barriers are certainly significant in making innovation to public infrastructure possible, but communities with sufficient resources and strong long term planning will hopefully be able to lead the way in utilizing these technologies so they will hopefully be able to lower the barrier to entry to these technologies for all communities in the long run.

3.5.2 Barriers

Respondents provided insight into barriers to their own implementation of innovative practices. The most significant being budgetary constraints. This is followed by the concerns of long term maintenance in new innovative technologies, and followed by the complexity of the innovative solutions. All of the potential barriers that were presented in the survey were given a fairly high ranking by the respondents, illustrating that all of the barriers envisioned are having an impact on the implementation of innovative technologies.

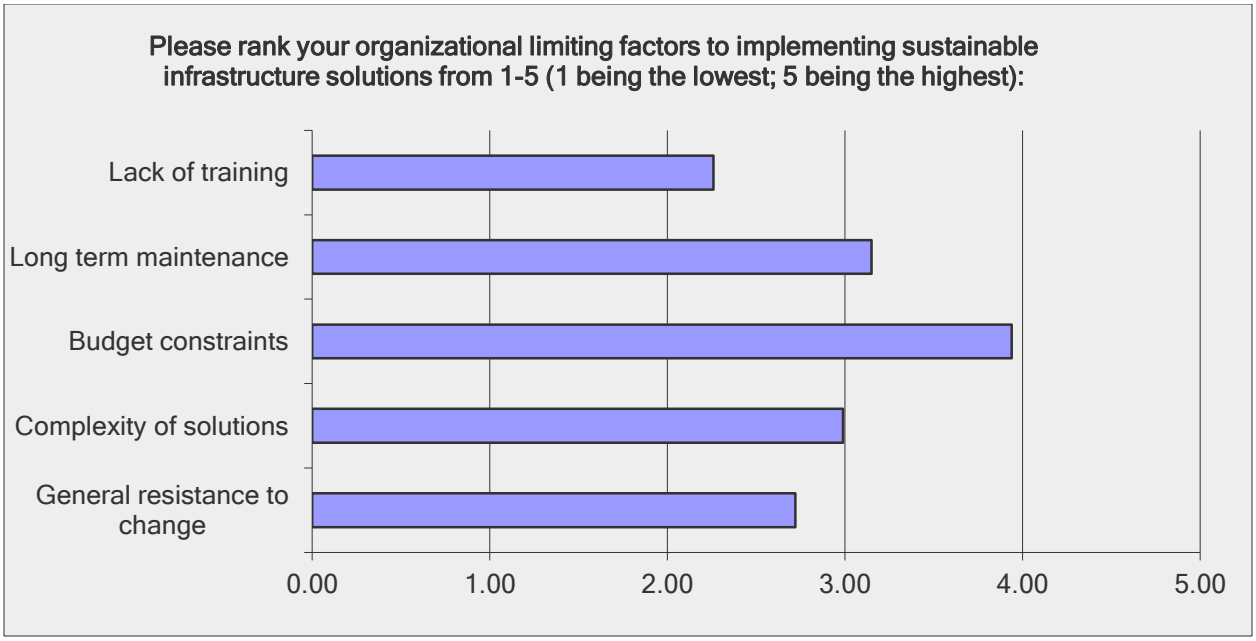


Figure 18

3.5.3 Current Utilization Impacts Future Choices

Respondents were asked how they assessed the expenditure of funds presently, and the results were quite split. Most of the comments that were received that explained why the respondent indicated whether or not they thought that current funding was being utilized efficiently was on the negative, and pointed to reasons like political decision making, government waste, poor life cycle maintenance, and struggles with bureaucratic process as making efficient use of current resources difficult. It is these impediments for long term decision making that could also have a negative impact on adoption of new technologies.

In terms of increasing existing revenues most respondents, who work in the public works field and know the infrastructure deficits that exist, either supported no increase or a very marginal increase. If those who are fully aware of the cost of maintaining and improving existing infrastructure are resistant to increasing the funding sources for maintaining that infrastructure, it is unlikely that the general public, who is likely less educated about the costs of maintaining the highway infrastructure, would support such a change.

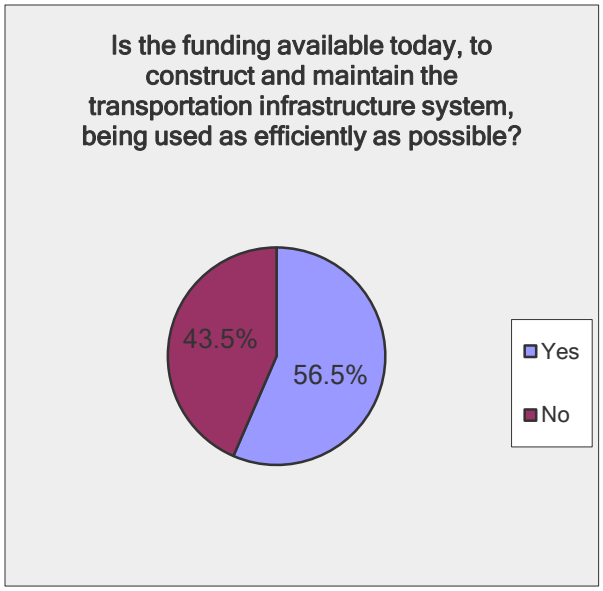


Figure 19

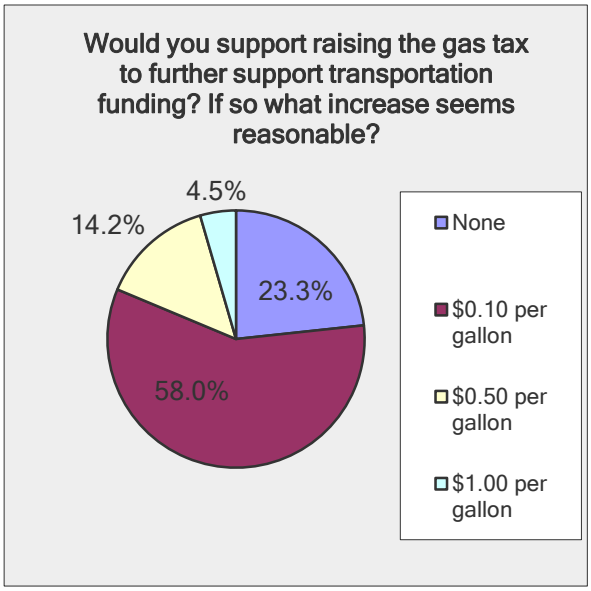


Figure 20

3.5.4 On the Positive Side

Despite there being many barriers to innovation for public works agencies, there are some positives indications that were clearly visible through the survey results. The majority of respondents to the survey indicated that they both supported investigating innovative ways of delivering services and that their organizations were well suited to adapt new technologies.

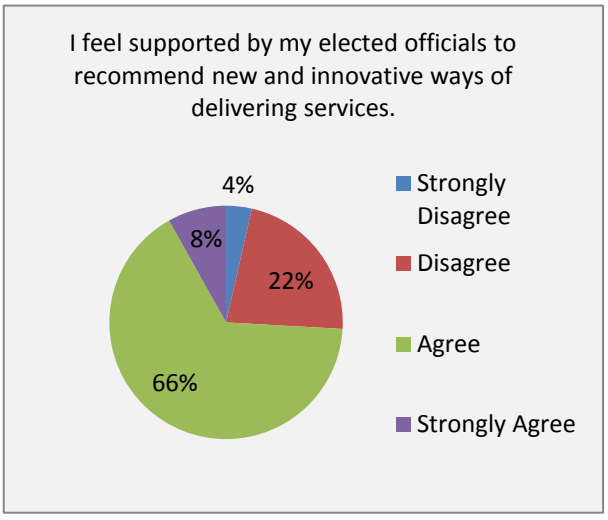


Figure 21

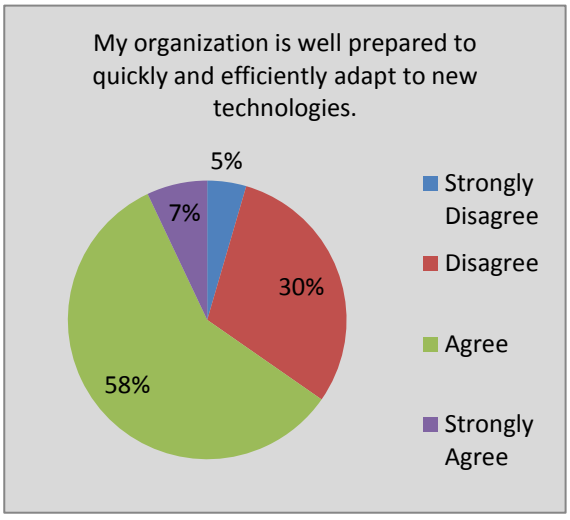


Figure 22

4.0 EDUCATION AND OUTREACH

Creating sustainable roadways requires investment of time, money, outreach and education. Education and outreach to the general public may not been seen a key element as part of sustainability and emerging technologies in relation to roadway infrastructure, but it is just as crucial as any other physical structure. Funding and supporting outreach, education, and research is fundamental to creating sustainable roadways. Without this investment, the natural tendency to slip back into practices that provide short term gain at the expense of the future will undo efforts to modernize public roadways.

At each educational level (Elementary School, Middle/High School, College and then into adulthood) public works institutions need to be broadcasting the idea of sustainable roadway infrastructure to the public in order to create an environment where previous practices are so backwards that they seem as farfetched to future generations as emerging technologies seem today. Public works organizations need to reach out to coworkers, family members, and communities to reinforce the ideas and values of sustainable new technology.

There are four distinct opportunities to provide classical education about emerging technologies outlined below. Within these opportunities there are a myriad of venues for promoting, testing, and embracing emerging technologies.

4.1 Elementary School Program

Education needs to begin with students from kindergarten to fifth grade. Public works has floundered in selling its story. In fact, public works organizations may have acted in the past in ways that have led to excluding itself from the common dialogue about how government plays a role in the life of everyday people. Few say, “When I grow up I want to patch potholes, dig ditches, build bridges, or join the fight to control mosquitoes”. Even though it is universally understood that these services are necessary, they rarely reach into the conscious thoughts of most individuals. Public works organizations must deliver a message of engagement and inclusion.

From September to June students ride past public works projects in their school busses on their way to school. They watch public works employees swinging loads of material into dump trucks or placing concrete or patching a pothole. Public works employees and functions are characters in their lives acting out scenes from their very first books. Young kids want to know what those people on the sides of the street are doing and it is the job of public works institutions to teach them.

Inclusion can begin with inviting kids into work areas so they can see for themselves what work is being done and the role that the public works organizations play in their daily lives. A safe introduction to trucks for example could consist of letting boys and girls climb into the cab, honk the horn, tilt the bed and raise or lower the bucket. Exposure to equipment and staff will plant

the seed in kids about caring for the future of public works. It is up to public works professionals to encourage these young kids to want to join their ranks and it is essential to have them understand the role that public works plays in their daily lives, so they can support public works projects as adults and lead us into the future. These educational programs will hopefully inspire the innovators of the future, who will be tasked with finding new ways and methods of construction and funding infrastructure. New millennium children already understand technology and embrace its ability to transform their lives, so extending this opportunity to public works is a nature extension of their innate proclivities.

The APWA's K-12 education initiative has a curriculum focused towards introducing children in four key areas of public works; construction, traffic and transportation, solid waste, and water/wastewater. Elementary school is a great time to begin the discussion with future public works professionals that, as much as the country needs to continue to fill the engineering fields with qualified civil engineers, it is also noble to entertain the idea of working in a dump truck, trash truck, or the water treatment/distribution plant.

It is possible that elementary school is the best launch pad for the ideas of innovation. In his essay titled, "Yes, I Can!" Robert Fulghum discusses the reality that, almost to a person, if a group of kindergarteners is asked if they can draw, sing, dance, act in a play, play musical instruments, write poetry, read, write and count they will shout a resounding "Yes!" If the same question is asked of a group of college students, the number of positive responses drops off precipitously. If the lights were dimmed at the APWA Emerging Leaders Presentation, and the "The Electric Slide" started playing and those in attendance were encouraged to come up on stage to dance, it might show either who's crazy or who has already been drinking by who comes on stage. Many grown-ups have long abandoned the optimism needed to drive innovation. There should be outreach to elementary school students for some of their ideas.

Public works organizations should ask the elementary school students to start thinking about innovative technologies. It is important for communities to raise a generation of young people who believe they can do something different, so when they take the helm at some point in the future they are already of a mindset to ask "What other methods are available?" Some young people who have been reached out to may not grow up to be public works employees; in fact, most of them will not. Some of them though might grow up to be City Planners, City Managers, local, state or federal politicians. Certainly they'll grow up to be taxpayers who need to be educated about how their tax dollars are used. There needs to be advocates for public works in the future.

4.2 Middle/Junior High School Program

Once public works organizations plant the first crop of seeds, they need to continue over-seeding the other fields that compete for future leaders by advocating for public works and encouraging young people to gravitate towards during the tumultuous years of Middle or Junior High School. This is when schools are beginning to channelize students. This is the time to

reiterate and articulate how important public works is to the community and reinforce the idea that a career in public works is an honest, respectable path. Again, the APWA's education initiative has a program tailored specifically to students in Middle/Junior High School. This straightforward curriculum integrates school subjects like social studies, language arts, science, math, and art into the study of important public works topics - construction, parks and recreation, traffic and transportation, water and wastewater, solid waste, and careers in public works.

Middle and Junior High School students are also a potential gold mine for future technology and innovations. These are the people who are gladly grabbing onto all things technical, working those technologies to the breaking point, finding innovative solutions to the failures of new technology. They are growing up into the change innovators that public works needs. These kids are still sure that nothing is impossible. They have yet to be burdened with the cynicism associated with budgeting funds, time, and manpower. They exist in the gray area between recess and having to mow lawns to pay to go to a movie. It is the young people with this kind of unrestricted thinking that can help bring sustainable roadway innovation into a reality.

4.3 High School Program

High school, like Middle and Junior High School is a time when young people are making decisions about their future employment opportunities. It is crucial that public works advocates for itself and emphasizes the value and pride of working in public works at all levels. Science, Technology, Engineering and Math (STEM) students are a great place for focus in order to drive some of the future innovators towards the public works sector. It is important to target the students who are interested in micro-technology, robotics, geography, engineering, or modeling as much the students in the career and technical centers. These are the students who are going to see the "cool factor" of new technologies. Students can envision something that is missed by professionals who may be stuck in a paradigm of insufficient funding, interest, skills or desire to install and maintain what is not currently available. Pragmatism is winning out over optimism while Americans continue to drive around on bituminous roads that have only changed by matters of degree since the mid-1800's.

The U.S. Department of Transportation/Federal Highway Administration (FHWA) had a program called FHWA "Recruiting the Next Generation". As the FHWA's website describes, [11]

> "The specific objectives of the 1-day program were to acquaint students with the challenges involved in providing a safe, effective, and efficient transportation system and to describe the policies and programs to address those challenges. Other objectives were to familiarize them with the programs, expectations, and cultures of university engineering programs and to inform them about the missions and activities of national professional engineering organizations, including programs for students and support for engineering career professionals.

> More than 350 students from 15 high schools in the District of Columbia, Maryland, and Virginia participated in the program. Recognizing the potential of women in the engineering field, the program welcomed 12 female students from the all-girls Holton-Arms School in nearby Bethesda, MD. The Holton-Arms participants excel in what is generally referred to as the STEM disciplines of science, technology, engineering, and mathematics. Altogether, more than 100 girls attended."

In an article published in 2014, USA Today highlighted a manufacturing skills program developed by *Project Lead The Way* that is helping to generate not only interest, but trained future employees in a variety of STEM related fields. Pinellas County Florida has a Public Works Academy for high school graduates and adults interested in joining public works. The Hampton Roads region of Virginia has a Public Works Academy that serves seven member cities along with the regional wastewater treatment organization by exposing local public school students to 32 public works related fields. These programs are integral to ensuring that high school students know what public works has to offer and starts them along the path to easy incorporation into the field.

Once students leave High School, they should know that public works is a place that will provide a career path and an opportunity to give back to their own community. They should believe that public works is not only excellent career choice, but that public works is looking for innovators and forward thinkers. Public works employees should be their own best advocates to students at home, work and social settings. Today's high school students are both comfortable with emerging technologies, and young and energetic enough to provide the labor necessary to build the infrastructure of the future.

4.4 Undergraduate and Graduate School Program

There is an immediate need to focus efforts on college students. Any cross section of current public works employees is bound to include college students who are pursuing degrees ranging from Associate to Doctorate. At the collegiate level, public works organizations should find ways to lobby innovation along with studying existing materials and accepted practices. Future sustainable roadway development is going to be in the hands of some of these current students either as managers, engineers, engineering technicians or leaders and they will need to approach new road designs with an open mind to alternatives.

Colleges and universities are on the leading edge of robotics, micro-engineering technology, alternative energy sources, alternative construction materials and techniques. College students need to be on the leading edge of how we're going to use these technologies in roads. Before the limits of materials testing, engineering reviews and budget constraints are applied; the world of ideas surrounding sustainable roadways and their technology is as broad and expansive as the minds of these students.

4.5 Community Programs

Public works officials and employees need to talk to their adult co-workers, neighbors, family and anyone else who will listen to discuss the endless opportunities for advancement of technologies that affect public works practices in the future. There is no need to be timid about these ideas. In fact, there is a common benefit from prideful exhortation of contributions and the potential of outside the box thinking. APWA President, Larry Stevens, would be proud to hear a public works professional having a well thought out discussion about alternative funding sources for some new idea to be implemented. Public works organizations cannot continue to return to the same well with more and more needs and expect the well to never run dry. It is the responsibility of the entire community to ask if there are the current funding sources for its own ambitions, and how is that working out for all of us across the United States and Canada?

4.6 Private Innovation

Public works is tasked with managing a public trust of infrastructure. Its responsibility for its stewardship includes its advocacy and forethought of its future needs. Private industry and research institutions will play an increasing role in emerging technologies and sustainable roadways. As there is more public education and a new generation of employees, there must also be advocacy for research at private institutions.

Historically, organizations like Defense Advanced Research Projects Agency (DARPA) have funded far thinking military technologies. Recently, XPRIZE [12] has helped push innovation through competition. These prizes have helped to develop space flight, super-efficient cars, and oil-spill cleanup. Not only do these prizes drive innovation they shed light on problems or technical challenges the public may not be aware of. Public works organizations should be lobbying for sustainability through the transformation of technologies and practices. Government funded public agencies may not be able to provide the seed money for these type of competitions, but a compelling need for a sustainable future will assist in finding sponsors. The XPRIZE mission statement is:

> "XPRIZE is an innovation engine. A facilitator of exponential change. A catalyst for the benefit of humanity.
>
> We believe in the power of competition. That it's part of our DNA. Of humanity itself. That tapping into that indomitable spirit of competition brings about breakthroughs and solutions that once seemed unimaginable. Impossible.
>
> We believe that you get what you incentivize. And that without a target, you will miss it every time. Rather than throw money at a problem, we incentivize the solution and challenge the world to solve it.

We believe that challenges must be audacious, but achievable, tied to objective, measurable goals. And understandable by all.

We believe that solutions can come from anyone, anywhere and that some of the greatest minds of our time remain untapped, ready to be engaged by a world that is in desperate need of help. Solutions. Change. And radical breakthroughs for the benefit of humanity.

Call us crazy, but we believe." [12]

4.7 Conclusion

What if a road system is developed that functions as sustainable, helpful, changeable, and affordable, and also promotes local economies? What if people talk to each other about trying something different, first on a small pilot scale, then on to a larger scale until the only thing left that's different is the old way of doing things? Co-workers, neighbors, family, and friends need to know that public works employees do care about the work that they do and the service that they provide. Public works organizations need to bring them into the fold to accept the cost and the benefit of new road technologies if they ever want to see a change in the nation's existing infrastructure. Resources need to be shared between maintenance, new roads, road widening, and alternative road designs in order to evaluate the opportunities available. Unless public works organizations pursue emerging technologies, at least at the experimental level, these emerging technologies will always be relegated to some odd ball idea that "Insert your most commonly heard reason for not pursuing change here." Change starts with this generation and works backwards through college, high school, middle school and elementary school. Change can be an amazing thing once it begins.

5.0 FUNDING

The model for infrastructure funding based on a fuel tax alone has run its course. Americans are starting to hang up the car keys and choose alternative forms of transportation such as biking, riding the bus, or just plain walking. Automobile owners are choosing more fuel efficient cars and choosing to not drive as far. With the main source of revenue declining, the gap between what is spent on infrastructure and what should be spent continues to increase. New technologies will increase the sustainability of the nation's roadway system and lower maintenance costs. Some options might even help the United States' infrastructure to pay for itself. With these new technologies, new models like pay per use and public-private partnerships will help bridge the gap. New choices such as better pedestrian and bicycle access might provide options that users will want to pay a premium for, further providing funding to maintain and upgrade infrastructure for the foreseeable future.

Infrastructure funding is, and will, continue to be a controversial topic for municipalities, states and the federal government. Without good infrastructure the nation's economy will suffer due to lost efficiencies and wasted time in traffic, and if bad enough loss of lives. The current and most widely used source of transportation infrastructure funding is the motor fuel tax. The money generated by the motor fuel tax is not keeping up with current needs. To remedy this shortfall new options should be explored. These options include new and different types of taxes, better utilization of the infrastructure already built, and new means of transportation that will ease the demand for the conventional roadway system.

5.1 Motor Fuel Taxes

The motor fuel taxes currently provide close to 40% of state revenue for highways, and 92% of gross federal Highway Trust Fund Receipts. These revenues have not kept pace with needs, partly due to changing travel patterns and fewer miles driven nationwide. Improvements in vehicle fuel efficiency and growing use of alternative fuels also present serious challenges for transportation funding. While the potential for funding from the motor fuel tax is declining the need is increasing due to inflation, rising construction costs, and expanding infrastructure inventory. Studies have estimated the gap between total federal, state, and local revenues and the cost to maintain the nation's highway transit system at $57 to $118 billion per year; and to both maintain and improve the highway transit system the gap is $113 to $185 billion. [13]

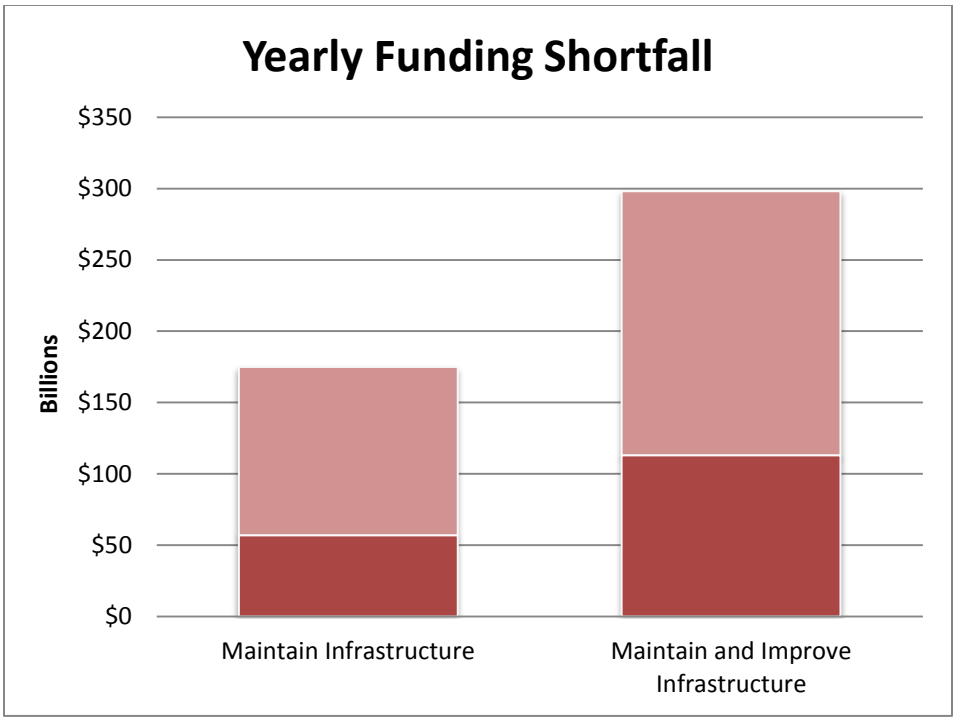


Figure 23 Funding Shortfall

The fixed-rate federal gas tax has lost 33% of its purchasing power since it was raised in 1993. While the purchasing power of the revenue decreases, the quality of the infrastructure decreases as well. According to the American Society of Civil Engineers, deteriorating surface transportation infrastructure cost U.S. households and businesses nearly $130 billion in various costs and time delays in 2010 alone. To deal with these issues and help fund infrastructure needs and new technologies, new taxes, fees for vehicle miles traveled (VMT's), public-private partnerships, and life cycle cost analysis should be explored. [13]

According to the survey that was conducted by the Emerging Leaders Academy 58% of those polled would support increasing the motor fuel taxes by $0.10 per gallon. This small increase could help the shortfall that is being experienced.

5.2 New Taxes

New types of taxes could include "Variable Rate" and "Indexed Fuel Taxes". A variable rate design can allow fuel taxes to automatically adjust for changes in purchasing power over time. Tax rates can be tied to the Consumer Price Index, average wholesale price of fuel, and percentage-based sales tax on fuel distributors or suppliers based on the price of fuel. These types of taxes are easy to implement and track and would not seem much different than the system that is already in place. This type of tax would also continue to generate revenues from those that use the system the most by driving the most miles and using the most fuel. This system does not address the concerns of the loss due to more fuel efficient vehicles, or

alternative fuel vehicles. Another concern with this system is that fuel prices are volatile so budgets would continue to be tied to this very volatile commodity. Other critics believe that this system unfairly tax the lower income or rural living citizens who tend to drive less fuel efficient cars.

5.3 Taxes on Alternative Fuel Vehicles

Alternative fuel vehicles are good options for the environment by cutting down on emissions or reusing materials that are byproducts of another process for fuel, however they do not provide revenues from the motor fuel tax. To deal with this lost revenue some states assess taxes on alternative fuel types or assess fees when licensing alternative fuel vehicles. “At least 27 states now impose a tax on some form of alternative fuel, such as ethanol, natural gas, propane, hydrogen, electricity or biodiesel.” [13]

5.4 Vehicle Miles Traveled (VMT) Fees

A very progressive type of generating revenue from the traveling public is VMT fees. The premise of this type of fee is that a user of the transportation system would pay a certain fee for the number of miles traveled on the infrastructure. The more a person drives the more they pay regardless of the type of vehicle they drive and what type of fuel it requires. The advantages of the system are that it generates revenue that is more predictable and more sustainable than the gas tax because it doesn’t have to be tied to fuel. Additionally larger, heavier vehicles that put more of a strain on the system would pay higher fees per mile. Current estimates state that the driver would be charged around $0.01 per mile as a fee. The National Surface Transportation Infrastructure Financing Commission called “VMT fees the consensus choice of the future and urged transition to this model by 2020.” [12] To further utilize the system the amount of fee could change based on what time of day the driver was on what type of road. Drivers that chose to be on the interstate during the peak of the rush hour could be charged more than the driver on the same road at the middle of the day. To encourage drivers to continue to pursue alternative fuel types, reduced fees could be setup for more fuel efficient vehicles, if so desired. There are barriers to this system as well. The system is not inflation proof and could require legislative action to be increased. Dependent on the type of system, the cost of implementing this fee structure could be quite expensive. If mileage was recorded for fee purposes based on an odometer, inspection staff and facilities would be required. GPS units could be utilized to track miles driven, but this could seem to be an invasion of privacy by citizens. The government could potentially know where people and their cars are at all times of the day. The GPS method of tracking could cost a lot to implement and maintain for the government and the driver. The system could be hard to implement not only for privacy concerns, but also because it would be seen as just another fee on top of what the government already gets, which would not be popular.

According to the survey that was conducted by the Emerging Leaders Academy, this topic is as volatile as the results for those that favor taxing based on miles traveled. Those surveyed were more in favor of commercial vehicles paying for miles travelled. 63% agreed with commercial vehicles paying on a per use basis.

5.5 Other Funding Mechanisms

Other types of funding mechanisms could include public-private partnerships through tolls and expedited construction methods. Toll roads allow for private investment to provide the needs that are usually public funded. Toll roads allow users to choose to pay for the convenience of a certain roadway and take the burden of this infrastructure off of the government. Investors are sometimes drawn to toll roads because they can be sound investments for a long period of time. 56% of those surveyed by the Emerging Leaders Academy considered toll roads a viable option to fund new infrastructure projects.

Another way to save the overall cost of a project could be through innovative contract methods. Design build contracts are becoming increasingly popular because they expedite construction and sometimes save the public entity money. If meaningful costs savings or design alternatives are chosen through the design build process, these innovative designs can save the owner money in the long run.

Additionally, life cycle costs for each project should be further analyzed. This would ensure that new projects and their required maintenance would both be considered when deciding whether to move ahead with a project or not. If maintaining the new infrastructure would put an undue burden on the controlling agency then other alternatives could be explored. Additionally, funding resources could be allocated based on the strength of the life cycle cost analysis when compared to other projects with the same price tag.

Raising taxes and fees is not always popular and should be avoided when possible. For this reason public entities should look at the infrastructure in place and should work to make sure it is getting proper maintenance and should look at ways to make the current infrastructure work better. Although roadway expansions are popular and generally warranted they become additional infrastructure that must be maintained and could take away from maintaining what is already built. Roadways require maintenance just like a car, and just like a car routine maintenance when appropriate can prevent bigger repair costs down the road. For this reason public entities should strive to keep their existing roads in good to fair condition. Estimates have been given that demonstrate $1 spent on repairs while a road is still in “fair” condition can prevent costs of $6 to $14 to later rebuild the same road once it has deteriorated. A Federal Highway Administration study found that allowing a road to deteriorate before repairing it can double the cost for each lane mile. To ensure that existing streets receive priority some states are starting a “fix-it first” mentality. This policy orientation requires that a state have adequate performance measures in place to accurately assess and catalog the condition of their roads. [13]

Maintaining the existing infrastructure is important. However, making the existing road function better than it is currently will help with congestion and lost work hours. Several options are available to get better use from existing lanes no matter what time of day. Demand management includes efforts to reduce total travel demand or shift trips to off-peak hours. High-Occupancy Vehicle (HOV) lanes are part of a plan to better utilize the existing roadways. HOV lanes or new faster ways of tolling cars would create large improvements to the roadway commute and cut significantly on congestion. Active traffic management could be another easy way to make a difference without costing a lot of money. Active traffic management includes ramp metering, variable speed limits, reversible lanes, and use of shoulders during peak periods. The purpose of active traffic management is to utilize the existing roadway effectively during peak times without the cost of expansion that would not be used during most times of the day. A key component of active traffic management is through traffic signal improvements. Traffic signal adjustments can significantly increase the utilization of a roadway. Retiming or synchronizing traffic signals based on optimized traffic signal timing plans has been shown to decrease delays by 13 percent to 94 percent. Traffic adaptive signal control systems can reduce delay by an additional 18 percent to 20 percent compared to fixed time signal control. Overall, $1 invested in traffic signal improvements can return $40 or more to the public in time and fuel savings while cutting emissions by up to 22 percent. [13]

Although new methods of funding and better utilization of the systems already in place will help fund new methods of roadway construction like roller compacted concrete and intelligent traffic systems, further thought should be given on how to reduce the need for the conventional roadway system. The wants and needs of the travelling citizen are changing. Commuting while exercising, and using public transit, is becoming increasingly popular. Providing options for commuters will help to cut down the need for expansion and thus allow more and more funding to be spent maintaining what is already in place.

A major component of the means of travel for the modern commuter is by bicycle. Bicycling provides a healthy way of getting to work that is faster than just walking. To encourage bicycling, public entities must be willing to make a commitment to build safe and convenient ways to travel by bike. Besides bicycling, pedestrian facilities are also becoming more and more important more people want to walk to work and to the store and don't want to have to get into the car. Washington D.C. is making strides to provide safe pedestrian and bike facilities. The concept of including pedestrian and biking facilities in the design of a roadway is generally called "complete streets". Minnesota state law defines complete streets as: the planning, scoping, design, implementation, operation, and maintenance of roads in order to reasonably address the safety and accessibility needs of users of all ages and abilities. A complete street considers the needs of motorists, pedestrians, transit users and vehicles, bicyclists, and commercial and emergency vehicles. If motorized vehicles are needed to travel larger distances, transit will continue to be a popular choice. Public entities can help increase ridership through promotions and rewards for the public transit user. These types of transportation are better for the environment and reduce the strain on roadway system. Functional transit systems will encourage redevelopment in urban areas and cut down on the

vehicle miles travelled per year. Providing more options for commuters will help society emotionally and physically. Stress levels will decrease when congestion clears and those that choose to bike or walk to work will become healthier overall. [13]

New technologies will aid in cutting costs for public entities charged with maintaining the country's infrastructure however new funding methods or utilization of infrastructure is also required to ensure a sustainable transportation system. New types of taxes, project deliveries, utilization of existing roads, and options for commuters will help public entities provide the needed transportation Americans rely on while ensuring that the gap between what is available for funding and what should be spent decreases.

6.0 Conclusion

Creating sustainability in the nation's future roadways will not be an easy feat, but it is the responsibility of public works organizations to take action now to ensure the nation's roadways do become sustainable. Establishing partnerships to implement new and emerging technologies, along with addressing and overcoming funding barriers, will allow future roadways to meet sustainable expectations. Incorporating education and outreach of new and emerging technologies now will prepare the future generations to exceed sustainability expectations.

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