The Use of Railroad Economic Theory in the Design of a Highway: The Pulaski Skyway in the State of New Jersey

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In memory of Emory L. Kemp.

Abstract

The Pulaski Skyway in northern New Jersey is a striking and attractive example of the early modern “superhighway” in the United States. Its construction was critical to the reinforcement of regional industrial growth and to the flow of persons and goods into the City of New York. The design of the route followed over three decades of growth in the development of state and national motor vehicle road systems, experimentation in new roadway planning methods, and expansion of highway engineering capabilities. The viaduct is an important structural engineering accomplishment. However, it is even more significant as a pioneer example of railway economic analysis transformed for use by highway planners. This work was undertaken to determine the extent to which railway economic practice was utilized in the Pulaski Skyway design, and whether or not the project was the first in the nation based on such theory. To place the Skyway in its historic context, research was undertaken on the development of roads, road agencies and organizations, and the road design progress beginning in the late 1800s. Documentation was compiled regarding the regional and national significance of northern New Jersey industry and transportation, and state records were analyzed for information on the establishment and work of the New Jersey State Highway Department, which planned the Skyway project. Key to the compilation of information on the method of economic analysis and the definition of the Skyway's role in United States highway economic planning was the thorough review of both the railway theory, as defined in 1887 by Arthur Wellington, and the highway theory as defined by project engineers Frederick Lavis and Sigvald Johannesson. In addition, extensive review of the engineering documentation of the 1920s and early 1930s was utilized as a means of placing the project in perspective through the analysis of the writings of highway engineers of the period. The analysis and research undertaken in the preparation of this work unquestionably indicates that the Pulaski Skyway was designed using railroad economic methodology as applied to highway design. Period engineering literature indicates that the project was the first in the nation to use such theory, and that the Skyway design utilized the most extensive economic analysis in practice at the time. The Pulaski Skyway was also the largest highway project ever undertaken in the United States at the time of its planning, and served to educate and motivate members of the highway engineering profession in the use of economic analysis and the design of the modern "superhighway."

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Railroads in America

The Early Years

The United States was primarily agricultural in nature at the start of the 19th century; farms could not be located at any great distance from the markets they served because travel required the use of roadways developed from earlier Indian trails, which were often little more than dirt pathways. But change would come within a matter of a few short decades as a new mode of transport - railroads - drew the country into the Industrial Revolution. Entrepreneur and inventor "John Fitch invented the steam railroad locomotive during the 1780s and demonstrated his little working model of it before President George Washington and his cabinet in Philadelphia.... Fitch also invented a steam pump … and a steamboat that he demonstrated on the Schuylkill River."[3] In 1804 Richard Trevithich built the first steam locomotive that ran on rails in South Wales spurring a flurry of activity in England that ultimately resulted in the opening of the world's first public railway line in 1823. The first American railroad charter (issued to John Stevens in New Jersey in 1815) went nowhere due to lack of funds. Yet over the next decade, the nation's first three railroads - the Baltimore and

[3] "American Steam Locomotives," last updated February 14, 2002, accessed March 6, 2019, www.nps.gov/parkhistory/online_books/steamtown/shs2.htm.

Ohio and the South Carolina Canal and Railroad Company in 1830, and New Jersey's Camden and Amboy in 1832 - had begun operations.

During this period of early construction England and the United States were also busy working on the development of locomotives to pull their new trains. Young English mechanic, George Stephenson, built his first locomotive – called Blucher[4] – in 1814 to pull coal-laden wagons. In the years that followed, he continued to improve his steam system and railway track, in addition to constructing locomotives for various English collieries. Robert Stephenson and Company became the world's first locomotive company, first constructing the Locomotion in 1825, and later entering the Rocket in England's Rainhill Trials in 1829.

> "The Trials were held by the Liverpool and Manchester Railway Company, to find the best locomotive engine for a railway line that was being built to serve these two English cities. [The Rocket] was the first locomotive to have a multi-tube boiler – with 25 copper tubes rather than a single flue or twin flue. During the race, the Rocket reached speeds of 24 mph during the 20 laps of the course."[5]

The first locomotives used in the United States (such as the Delaware and Hudson's Stourbridge Lion – the first steam locomotive to run on commercial tracks in the US – and the Camden and Amboy's John Bull) came from England. But the Americans were not far behind the English and they quickly realized that larger, more powerful locomotives would be needed. To help spur efforts toward the development of

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[4] "George Stephenson's First Locomotive," copyright 2016, accessed March 6, 2019, www.historytoday.com/richard-cavendish/george-stephensons-first-steam-locomotive.

[5] "Stephenson's Rocket Animation," archived page copyright 2014, accessed March 6, 2019, www.bbc.co.uk/history/british/victorians/launch_ani_rocket.shtml.

domestic manufacturing, railroads developed contests for locomotive designs.[6] The first U.S.-built model to run in the country was the Tom Thumb designed by Peter Cooper, which ran on the Baltimore and Ohio in 1828. In 1830, the South Carolina's Best Friend of Charleston was the first US-built locomotive specifically built for revenue service (pulling train cars). The Americans also quickly made design improvements such as the pilot – or "cow catcher" - developed by Isaac Dripps for use on the John Bull to help deflect obstacles on the tracks they might derail trains. Construction continued as more new railroad companies joined in the effort to link American towns and markets; after only twelve years of construction – by 1840 – the United States had 3,000 miles of railroad track in place.[7]

The early decades of railroading saw not only continued improvement in steam locomotive technology but also advancements in the design of the rails and ties that supported the trains.

> "Early tracks were constructed of wood, which was not strong enough to support ever-heavier locomotives. Iron rails were developed that could carry the weight of large, steam-powered locomotives. These rails were originally laid on crossties made of blocks of stone, which were not only expensive, but also could not support the weight of locomotives. They were replaced by wooden crossties similar to those used today. Several other innovations helped foster the growth of railroads between 1840 and 1860. These included T-shaped rails that distributed the weight of trains evenly and hook-headed spikes that grabbed the rail, thus attaching it securely to the crossties. Swiveling trucks [sets of wheels] under railroad cars created greater stability, allowing trains to travel over rough roadbed

6 "Railroads," accessed October 28, 2016, www.encyclopedia.com/topic/Railroads.aspx.

7 "The Transportation Revolution," accessed March 6, 2019, https://www.apstudynotes.org/us-history/topics/the-transportation-revolution/.

> and high terrain. The development of truss and cantilever bridges provided a way to get railroads over waterways and other obstructions."[8]

By the 1860s, track was easily laid over virtually any terrain, and railroads had replaced canals as the primary mode of American transportation. Thanks to developments in locomotive design, improvements in track technology, and the desire to reach markets and key waterways across the country, the 1850s saw New York City connected to the Great Lakes, Baltimore connected to the Ohio River, the eastern seaboard connected to the Mississippi River, and more – all via railroad.

Thus, the railroad boom emerged in America with the Northern states constructing networks linking every major city and the Southern states creating lines that connected the cotton regions to key ocean and river ports. In the Midwestern Corn Belt, rail expansion and the development of farmland went hand-in-hand. By 1860 eighty percent of farms in the Midwest were within five miles of a railroad line.[9] Although construction began in the eastern portion of the country, it quickly spread west resulting in the rapid population of previously uninhabited regions.

> "Wherever railroads went, people followed and towns grew. Previously uninhabited or sparsely inhabited areas of the country became towns almost overnight when the railroad came through.... Railroads required land on which to lay tracks, build yard tracks, and construct depots. Beginning in the 1850s, speculators bought land in the hopes that a railroad would come through an area and they could then resell the land at a much higher price. Also in the 1850s, the United States government realized the value of the railroads and the land associated with them.... The government granted land to [rail companies] in a patchwork pattern of

8 "Railroads," www.encyclopedia.com.

9 Deborah E. Popper. "The Middle West: Corn Belt and Industrial Belt United," *Journal of Cultural Geography*. 30:1, (2013), 32-54.

> alternating one-mile-square sections, with the government retaining ownership of the intervening lands.... The government further encouraged settlement in the wake of the railroads through the Homestead Act of 1862."[10]

In addition to offering land grants – which essentially resulted in the transfer of huge sections of previously public land into the hands of private entities – the government also issued bonds to the railroad companies to fund construction. Although the government was the primary driving force in the settlement of the west, these "large land grants ... went much further than was necessary simply for tracks and other railroad requirements. They were intended for disposal to settlers, to provide a source of income for the railroads and involve them more deeply in the process of colonization."[11] Through this combination of speculator-driven and railroad-driven homesteading, and government-assisted construction, the nation's railroad network continued to grow. As the population spread west, both agricultural and industrial products had to be moved greater distances to reach their destinations. Railroads were crucial partly to the movement of people but even more so to the transport of freight.

The Transcontinental Railroad

"A large part of the effort to bring the railroad to the freight instead of the freight to the railroad culminated in the building of the first transcontinental railroad."[12] By as early as the late 1840s there had been talk of the need to build a railroad corridor linking

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[10] "Railroads," www.encyclopedia.com.

[11] Stephen V. Ward. *Selling Places: The Marketing and Promotion of Towns and Cities 1850-2000*, (London: Taylor & Francis, 1998), 11.

[12] *Ibid.*

the Atlantic and Pacific Oceans. As settlers continued to seek new lands, and particularly after the 1849 California gold rush spurred ever greater westward expansion, travel from the Atlantic to the Pacific was costly, hazardous and time-consuming.

> "Before the transcontinental railroad was completed, travel overland by stagecoach cost $1,000, took five or six months, and involved crossing rugged mountains and arid desert. The alternatives were to travel by sea around the tip of South America, a distance of 18,000 miles; or to cross the Isthmus of Panama, then travel north by ship to California. Each route took months and was dangerous and expensive."[13]

"In 1845, the New York entrepreneur Asa Whitney presented a resolution in Congress proposing the federal funding of a railroad that would stretch to the Pacific. Lobbying efforts over the next several years failed due to growing sectionalism in Congress, but the idea remained a potent one."[14] In 1854, Secretary of War Jefferson Davis initiated work to survey westward railroad routes looking at northern, central and southern options; however, the lingering slavery issue prevented an alternative from being selected. By the 1850s some east-west routes had been mapped and various railroad companies had already built track along sections of these corridors, but there was still no unified system due to rivalry between the railroads.

Finally in 1861, engineer Theodore Judah enlisted a group of businessmen – Collis Huntington, Mark Hopkins, Leland Stanford, and Charles Crocker – to form a

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[13] "Building the Transcontinental Railroad," Digital History, copyright 2016, accessed March 6, 2019, www.digitalhistory.uh.edu/disp_textbook.cfm?smtID=2&psid=3147.

[14] "Transcontinental Railroad," History Channel, accessed March 6, 2019, www.history.com/topics/inventions/transcontinental-railroad.

company to construct a line that they named the Central Pacific Railroad. The next year, President Abraham Lincoln signed the Pacific Railroad Act authorizing construction of a line to extend from the Missouri River to California in what would eventually lead to the formation of the Union Pacific Railroad that would be controlled by Thomas Durant and Sidney Dillon. "By the terms of the bill, the Central Pacific Railroad Company would start building in Sacramento and continue east across the Sierra Nevada, while a second company, the Union Pacific Railroad, would build westward from the Missouri River, near the Iowa-Nebraska border. The two lines of track would meet in the middle (the bill did not designate an exact location)."[15]

Even before the Revolutionary War, the country that would become the United States had seen settlers moving west and the purchase of new territories to ensure expansion. Then, "in 1845, a journalist named John O'Sullivan coined the term 'Manifest Destiny,' a belief that Americans and American institutions [were] morally superior and therefore Americans [were] morally obligated to spread those institutions in order to free people in the Western Hemisphere from European monarchies and to uplift 'less civilized' societies."[16] America had "embraced railroads [from the start] as an avenue to fulfillment of Manifest Destiny – the idea that American settlers were pre-destined to expand across the North American continent, regardless of what obstacles they may encounter – or something like it."[17] The construction of a

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[15] *Ibid.*

[16] "Westward Expansion," HistoryNet.com, accessed March 6, 2019, http://www.historynet.com/westward-expansion.

[17] Greg Balliet, "Railroads and their Effect on American Society, 1840-1890," *Saber and Scroll Journal*, Volume 2, Issue 4, Fall 2013, 8.

coast-to-coast railroad would ensure that the lands all the way to California would become an integral part of the nation. At the same time, the Ameican South desired to further expand slavery through the formation of a slaveholding colony in California. The battle over a southern versus northern route for the transcontinental railroad came out of the fight for and against slavery. The outbreak of the Civil War further spurred the need for a cross-country rail route, and "the passage of the Pacific Railway Act … was 'justified on the grounds of military necessity … [and] designed to preserve California and the West for the Union'."[18] On the other hand, "Southerners argued that there was no constitutional clause giving Congress the power to build a transcontinental railroad. Jefferson Davis, Secretary of War, got around this by saying that the Constitution gave the federal government responsibility for national defense."[19]

Both of these concerns – Manifest Destiny to expand into California, and military advantage - drove Congress to work to ensure that the transcontinental railroad line was built as rapidly as possible. Thanks to generous land grants from not only the federal government but also the states across which the railroads would run, the two lines worked feverishly toward the goal of finally connecting the two oceans. By tying the acreage of land grants and the amount of the financial loans to the number of miles of track completed, Congress essentially ensured that the Union Pacific and Central Pacific would be competing with each other for both land and money. In addition, the

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[18] *Ibid*., 16.

[19] Gayle Olson-Raymer. "Entrepreneurial Politics and Economics: The Transcontinental Railroad and its Consequences for California", Humboldt State University, accessed March 6, 2019, http://users.humboldt.edu/ogayle/hist383/CentralPacific.html

men controlling the companies were far from honest in their approach to the business of building the railroads. The Central Pacific's investors – commonly referred to as the "Big Four" were ambitious but had no experience in railroads, engineering or construction.

> "They borrowed heavily to finance the project, and exploited legal loopholes to get the most possible funds from the government for their planned track construction. Disillusioned with his partners, Judah planned to recruit new investors to buy them out, but he caught yellow fever while crossing the Isthmus of Panama on his way east and died in November 1863, soon after the Central Pacific had spiked its first rails to ties in Sacramento. Meanwhile, in Omaha, Dr. Thomas Durant had illegally achieved a controlling interest in the Union Pacific Railroad Company, giving him complete authority over the project. Durant would also illegally set up a company called Credit Mobilier, which guaranteed him and other investors risk-free profits from the railroad's construction."[20]

The work of building the railroads was undertaken by thousands of immigrant workers, most of them Chinese, and each laborer risked his life every day in that effort.

> "Along with the development of the atomic bomb, the digging of the Panama Canal, and landing the first men on the moon, the construction of a transcontinental railroad was one of the United States' greatest technological achievements. Railroad track had to be laid over 2,000 miles of rugged terrain, including mountains of solid granite.... The transcontinental railroad was built in six years almost entirely by hand. Workers drove spikes into mountains, filled the holes with black powder, and blasted through the rock inch by inch."[21]

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[20] "Transcontinental Railroad," History Channel.
[21] "Building the Transcontinental Railroad," www.digitalhistory.uh.edu/.

Hundreds of workers were killed by explosions and avalanches, and those who survived had to endure extreme temperatures, inadequate food, risk of Indian attack and poor treatment by the foremen and company owners.

Furthermore, since the federal government's loans provided more money for construction over mountains than through flat lands, and the railroads financed their work by selling government-granted land, the construction typically utilized inexpensive and inadequate materials to save on expenses, and the builders located sections in the manner that would ensure the greatest inflow of government funds. "Consequentially, since building fast brought in more cash than building efficiently, the two lines spent little time choosing routes; they just laid track and cashed in."[22] Although the means and methods of construction meant that many problems were simply deferred to future operators, the Congressional incentives did ensure that the new railroad was completed a full seven years ahead of schedule. Originally intended to be ready by the time of the 1876 centennial celebration, the two lines formed the nation's first transcontinental link when they met in 1869 at Promontory Point in Utah. "The completion of the transcontinental railroad changed the nation. Western agricultural products, coal, and minerals could move freely to the east coast.... Passengers and freight could reach the west coast in a matter of days instead of months at one-tenth the cost.... Equally important, the success of the transcontinental railroad

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[22] "The Central Pacific and Union Pacific Railroads," accessed March 6, 2019, www.let.rug.nl/usa/essays/1801-1900/the-iron-horse/the-central-pacific-and-union-pacific-railroads/php.

encouraged an American faith that with money, determination, and organization anything can be accomplished."[23]

Outside the United States

The 19th century was a period of railroad building in many other countries as well. For example, "in the 1830s, many German authorities and economists … believed that railways were necessary in the unification of the German states."[24] As was true, in part, in the construction of America's transcontinental railroad, Germany saw early-on that railroads could also be more than a means of uniting its territories but also one with military potential. In the event of aggressors approaching from a neighboring country, and the need to respond with the appropriate level of manpower, trains could outpace and "outcarry" men, horses and materiel. "Prominent industrialist Friedrich Harkort was one of the first to call for Prussia to invest in building a defensive railroad in 1833…. Trains could transport personnel and supplies 24 hours a day at six times the speed of a traditional horse-drawn convoy. They could even carry *horses* forward to the lines to hasten existing logistical capabilities."[25] Rail construction began in Bavaria in 1835, and Germany's network expanded rapidly through the 1860s. "In 1871, German unification was finally achieved, with 25 states each having state railways called *Länderbahnen*."[26] All of Europe was essentially involved in a railway arms race in response to concerns

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[23] "Building the Transcontinental Railroad," www.digitalhistory.uh.edu/.
[24] "Railroads in 19th Century Europe: Great Britain, France, Germany, and Russia," accessed March 6, 2019, https://www.zum.de/whkmla/sp/0910/csj/csj1.html#iv.
[25] "Steam Trains Were 19th-Century Super-Weapons," accessed March 6, 2019, https://warisboring.com/steam-trains-were-19th-century-super-weapons-f4899564ee6d#.8e6l7dmty.
[26] "Railroads in 19th Century Europe," https://www.zum.de/whkmla/sp/0910/csj/csj1.html#iv.

with their own safety and sovereignty, but Germany was one of the most determined European countries, investing in extensive railway construction and using that rail network by as early as 1871 when Prussia invaded France just as America's North had defeated the South in large part due to the advantages of its railroads.

The United States was also not the only country that viewed its future as being inextricably linked to its ability to expand into all of its potentially available land. Following the combining of the Province of Canada, Nova Scotia and New Brunswick in 1867 to form the new Canadian Confederation, major national leaders began to push for the addition of British Columbia to help alleviate the financial hardships being faced by the nation due to booming population growth, the end of the gold rush, and the corresponding economic depression.[27]

Bringing the western colony into the union was also seen as critical due to the very real fear that the region might instead be annexed by the United States. As a condition of joining the Confederation, British Columbia insisted that some form of transportation route – originally envisioned to be a roadway – be constructed. Instead Prime Minister Sir John A. MacDonald saw the building of a cross-country railway as a critical component in uniting a continent-wide Canadian nation. Sir MacDonald's vision was realized, the Canadian government agreed to extend the CPR to British Columbia,

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[27] Ged Martin. *Britain and the Origins of Canadian Confederation, 1837-67.* (Vancouver: UBC Press, 1995).

and (importantly) to assume the colony's debt. With that, British Columbia became the sixth province to join the Confederation on July 20, 1871.[28]

The original agreement called for the completion of a transcontinental railroad within ten years, but difficulties arose quickly. The mountainous Canadian terrain was not conducive to easy routing and construction and, as the United States Congress had done, the Canadian government offered massive land incentives in the West.[29] During the early 1870s a number of alternative routes were surveyed and the first segment was laid beginning in 1875. "By … 1878, the massive project was seriously behind schedule and in danger of stalling completely. On October 21, 1880 a group of Scottish Canadian businessmen finally formed a viable syndicate to build a transcontinental railway."[30] At that time trains were running on only about 300 miles of track despite more than twice that amount of the corridor having been completed.[31] The "new syndicate …

> agreed to build the railway in exchange for $25 million … in credit from the Canadian government and a grant of 25 million acres (100,000 km^2). The government transferred to the new company those sections of the railway it had constructed under government ownership, on which it had already spent at least $25m."[32]

[28] A. J. Johnson. *The Canadian Pacific railway and British Columbia, 1871-1886*. Thesis. (1936). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/831/items/1.0098645 August 31, 2021.
[29] *Ibid.*
[30] "Our History," Canadian Pacific, accessed March 6, 2019, https://cpconnectingcanada.ca/our-history/.
[31] *Ibid.*
[32] *Ibid.*

The westward expansion began in Bonfield, Ontario.[33] The originally proposed route across the Rocky Mountains was ultimately discarded in favor of one that followed the border with the United States more closely to prevent encroachment by American railroads. Construction proceeded despite difficulties in locating passable locations, steep grades, difficult topography, and floods, and often dangerous working conditions also meant that progress was oppressively slow. By 1881 – when the original deadline for completion of the corridor was nearing - MacDonald extended the target year to 1891. As had occurred during the construction of the American transcontinental railroad, Chinese laborers worked for little compensation and many lost their lives in the effort.

Amazingly, in spite of incredibly difficult conditions the railroad, having been "founded to link Canada's populated centres with the vast potential of its relatively unpopulated West, this incredible engineering feat was completed on Nov. 7, 1885 – six years ahead of schedule – when the last spike was driven at Craigellachie, B.C. [British Columbia].[34] Its achievement facilitated the expansion of not only transportation but communication, playing a critical role in the development of the nation. The Canadian Pacific Railway made further industrial growth possible, improved the economy, and ensured that even more railway construction would ensue in the decades that followed – as was also the case in the United States.

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[33] Harold Adams Innis. *A History of the Canadian Pacific Railway*. (London: P.S. King & Son, Ltd.; Toronto: McClelland and Stewart, Ltd., 1923).

[34] "Our History," Canadian Pacific, http://www.cpr.ca/en/about-cp/our-history.

The Post-Civil-War Expansion

The belief in the ability to do anything, combined with the conviction in the country's inherent greatness, ensured that the American nation, following the completion of the transcontinental railroad, would work with even greater purpose toward the swift expansion of its rail network. Construction continued rapidly through the 1870s and 1880s as railroading in the United States truly became an enormous enterprise. In 1880 the railroads were the second largest U.S. employment sector, behind only agriculture, and the Pennsylvania Railroad was the largest corporation (with 30,000 employees) in the entire world. In 1881 national railroad mileage first exceeded 100,000 route miles. Following half a century of railroad construction, much of the work of the late 19th century focused on the development of short lines. However, with the Wall Street market focused in large part on railway bonds, most of these short lines were ultimately consolidated into approximately twenty trunk lines by 1890. The United States' railway system was largely complete by 1910 and trackage reached the highest level in history in 1916 at over ¼ Million miles. Although the following two decades saw significant declines in railroad usage due to the Great Depression and the increased use of automobiles and airplanes, American railroad ridership reached an all-time high during World War II.

Not only did the railroads change the way people traveled and transported their goods to market. They also "changed ... even America's concept of time."[35]

> "American railroads maintained many different time zones during the late 1800s. Each train station set its own clock making it difficult to coordinate train schedules and confusing passengers. Time calculation became a serious problem for people traveling by trains.... Every city in the United States used a different time standard so there were more than 300 local sun times to choose from. Railroad managers tried to address the problem by establishing 100 railroad time zones, but this was only a partial solution to the problem. Operators of the new railroad lines needed a new time plan that would offer a uniform train schedule for departures and arrivals. Four standard time zones for the continental United States were introduced [at noon] on November 18, 1883."[36]

The establishment of time zones was not only important as a means of enabling the railroads to maintain logical schedules. The fact that this action was taken by the railroad companies rather than by the federal government demonstrated just how powerful these organizations had become in national affairs.

The railroad boom of the late 19th and early 20th centuries also quickly brought about the development of new inventions that improved rail safety, and increased not only speed but efficiency. Samuel Morse's telegraph – critical to the timely scheduling of trains - was first used for railroad dispatching in 1851. The Pennsylvania Railroad perfected the first system of manual block train controls in New Jersey in 1865, and first

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[35] Henry J. Sage, "American Economic Growth 1820-1860", accessed March 6, 2019, www.sageamericanhistory.net/expansion_manifestdestiny/economicgrowth1800_1860/EconomicIssues1.htm.

[36] "Why do we have time zones?," accessed October 28, 2016, www.timeanddate.com/time/time-zones-history.html.

tested George Westinghouse's patented straight air brake in Pennsylvania in 1869. As the new century approached, the railroads adopted a standard gauge (space between rails) of 4 feet 8-1/2 inches as the national norm (1886), and the Baltimore and Ohio Railroad initiated the nation's first electrified railroad service (1895). In the decade that followed, the Pennsylvania Railroad built what was then the world's longest stone arch bridge over the Susquehanna River near Harrisburg in 1902, and introduced the country's first all-steel passenger coach in 1906. In 1927 a Pennsylvania Railroad locomotive raced and beat an airplane carrying film of Charles Lindbergh, and the first air-conditioned passenger cars became available in 1930.[37] In over a century of railroad construction and innovation, the design and analysis of railroad equipment and infrastructure grew from what began as largely a process of guesswork to what would become a rational system of planning and building requiring ever greater study, oversight and control.

Early Railway Economic Studies

The First Studies

While designers and builders working in the earliest years of the railroad industry were not technically educated engineers as we know them today, through a combination of trial and error and natural intelligence they quickly ascertained what "worked best" to achieve their goals given their constraints and available resources. While the English

[37] "Railroad History Timeline," www.rrmuseumpa.org.

railroad network grew rapidly and standardized design practices were in place within a short space of time, United States railroaders soon realized that much of what was done in England simply did not apply to the conditions and needs in America and that greater variation and experimentation were required. As economist and future Yale president, Arthur Twining Hadley noted, the greatest difference between the approaches to railroading in the two countries was the result of resources and conditions in the countries themselves.

> "The English railroads were mainly built to accommodate and extend existing business.... On the other hand, the American railroads have been mainly built with a view to the development of new lines of traffic, new establishments, or even new cities. The Englishman built for the present and future both; the American, chiefly, and sometimes entirely, for the future.... The English railroads were originally built to meet the demands of a community which already enjoyed good roads and canals, and insisted on having good and secure railroad service. Capital was abundant; it was spent freely and sometimes lavishly. Double track was habitually laid, grade crossings were avoided, and every effort was made to construct the road under a high standard of engineering art.... American railroads, on the other hand, were frequently built where existing business and existing means of communication amounted to little or nothing; where capital was scarce, and where speedy and economical construction was more desired than solidity or safety.... To avoid the expense of cuttings and embankments the line was adapted as far as possible to the natural inequalities of the ground. There were heavy grades and sharp curves."[38]

With readily available funds, an English system designed and built to accommodate the limited power of the early locomotives was soon in place. However, the Americans, struggling with inadequate funds, inexperienced workers, and long

[38] Arthur T. Hadley, *Railroad Transportation Its History and Its Laws*, (New York: G. P. Putnam's Sons, the Knickerbocker Press, 1885), 147-8.

distances to cover in their marginally developed country, typically avoided massive earth-moving work and incorporated lightweight wooden bridges. Having built their infrastructure to accommodate their constraints, they then worked to develop ever larger and more powerful locomotives that were capable of negotiating the difficult rights-of-way and specialized equipment to avoid derailing and assist in braking.[39]

It was not long before engineers started taking a closer look at the physical activities and the economics associated with designing and building railroads and publishing their findings. Although little was written in the early decades of railroading that specifically addressed the subject of what would become structured economic design theory, one small document stands out for several reasons. "The first field-book ever published was the 'Railroad Manual,' of Col. S. H. Long, USA which was published in 1829 – an extraordinary evidence of how early the railway movement set in in this country, since it was in October of that year that the trial of the *Rocket* took place, in which event the modern railway system really had its birth."[40] Long, a New Hampshire born, Dartmouth College educated, United States Army Corps of Engineers explorer, was briefly a member of the Baltimore and Ohio Railroad's board of engineers, and was later known for his inventions in the area of steam locomotive design.[41] He was one of a number of army engineers involved in early railroad surveying.

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39 "British Railways Compared to American Railroads – Two Nations Separated by a Common Ocean and a Common Language," The Victorian Web, last modified February 4, 2012, accessed March 6, 2019, www.victorianweb.org/technology/railways/23.html.

40 "The Best Method of Keeping Field Notes of Curves," *Engineering News*, Volume XX, September 29, 1888, 249.

41 Richard G. Wood, *Stephen Harriman Long, 1784-1864*, (Glendale: Arthur H. Clark Company, 1967), 292.

> "The army's long history of involvement in internal improvements, the evolution of West Point into a school specializing in civil engineering, and the extensive arguments relating railroad development to national security culminated during the period from 1827 to 1838, when army officers participated heavily in railroad development. Between 1832 and 1836, army surveyors provided assistance to more than twenty different railroad companies.... The first railroad to receive army engineering aid was the Baltimore and Ohio. In 1827, the War Department assigned three topographical engineering brigades, headed by Lieutenant Stephen H. Long, Captain William G. McNeill, and Dr. William Howard, respectively, to identify potential routes for the railroad."[42]

The Army Corps' involvement in the survey of various proposed railroad lines resulted in a military approach to the surveyors' recommendations regarding layout and design. Regardless, the surveyors did generally view the new lines in terms of their commercial, rather than military, possibilities, and focused a great deal of attention on the costs associated with the evaluated alignments. Long's two-volume work, with the full title "Rail Road Manual, or A Brief Exposition of Principles and Deductions Applicable in Tracing the Route of a Rail Road," was amazing not only for the date of its publication, but also for its incredibly early insights into the importance of economic consideration in railroad corridor layout and construction. While working as a railroad surveyor he expressed concerns relative to the economic impacts of decision making in laying new rail lines.

> "Long argued, 'It is obvious that wherever a hill can be avoided, at the expense of horizontal distances,... this measure is to be preferred.'.... Railroads, argued Long, should facilitate and speed transportation at the

[42] Robert G. Angevine, *The Railroad and the State, War, Politics, and Technology in Nineteenth-Century America*, (Palo Alto, California: Stanford University Press, 2004), 64.

> least expense…. Long frequently recommended routes that cost more to construct in order to lower operating expenses…. in his survey for a rail line between Augusta and Portland, Maine, Long chose a route that required expensive bridging over another than included steeper grades and tighter curves, arguing that lower operating costs would compensate for its greater initial expense. Avoiding a grade of thirty feet per mile justified, in his view, spending twenty-five thousand dollars."[43]

These views predated formal railway economic theory by nearly five decades; however, they did not immediately come to be the common focus of other engineers in the field. After the publication of Long's book, other early works – written primarily by educators - mainly addressed two subjects: general statistical information relating to the world's railroads, their costs, operations, advantages and disadvantages; and technical information to assist engineers in designing these new transportation networks and their associated equipment and infrastructure. In 1850, one early text provided extensive, detailed information on railways already in operation in Belgium, England, the United States, France, Germany, Russia, Italy and Spain. Dionysius Lardner, London University's first professor of natural philosophy and astronomy, and a prolific writer and public lecturer on scientific subjects[44], was particularly interested in steam transportation. His book entitled "Railway Economy; a Treatise on the New Art of Transport, its Management, Prospects, and Relations, Commercial, Financial and Social, with an Exposition of the Practical Results of the Railways in Operation in the United Kingdom, on the Continent, and in America" provided a general history of

[43] Angevine, 69, 70 and 71

[44] "Lardner, Dionysius," Oxford Dictionary of National Biography, accessed March 6, 2019, www.oxforddnb.com/view/article/16068?docPos=1.

railroading, a discussion of the importance and advantages of railway transport, information on general operations, descriptions of various types of equipment and infrastructure and the means of maintaining them, and information on accidents and costs. Although economics was not Lardner's area of focus, this document certainly provided a general basis for understanding the costs associated with the industry of railroading.

The early technical works – particularly those written in the United States - typically made a point of observing the deficiencies in knowledge and education found among American railroad men, offering general design guidance, methods for calculating such elements as curvature and grades, and simple means of comparing the basic costs of different proposed lines. For example, in 1857 George Leonard Vose published his "Handbook of Railroad Construction: for the Use of American Engineers Containing the Necessary Rules, Tables, and Formulae for the Location, Construction, Equipment, and Management of Railroads, as Built in the United States," which resulted in his becoming known as a primary educator in the field of railroading.[45] Vose began his career as a working engineer on several New England railroads, and was later Professor of Civil Engineering at Maine's Bowdoin College and the Massachusetts Institute of Technology. The preface to his book explains Vose's straightforward approach to his subject:

> "The object of this work is to give in the plainest possible manner all instructions, rules, and tables necessary for the location, construction,

45 Frederick Albert Cleveland and Fred Wilbur Powell, *Railroad Promotion and Capitalization in the United States. (New York: Longmans, Green, and Company, 1909), p. 336.*

> equipment, and management of railroads. As a general thing, American engineers are not educated for their business; and when they do possess a knowledge of pure science, they are at a loss how to apply it.... Readers will bear in mind that the work is a 'handbook,' and not a 'treatise.' It is intended more as an office companion than as a text-book for students."[46]

Vose was likely correct in saying that American railroad designers of these early decades were ill-trained for their work and, unfortunately, the major design and construction precedent that would soon follow – the transcontinental railroad – did not provide a sound basis for the efficient and economically viable establishment of railroads. During the decade after the joining at Promontory Point, the focus of most railroad-related publications remained design assistance with some associated information on economics – albeit primarily examples of construction costs and not economic design theory. In 1878, Vose published a follow-up volume to his earlier work entitled a "Manual for Railroad Engineers and Engineering Students" that provided statistical information on the extent and associated construction costs of railroads located throughout the world. Although this material touches upon the differing costs related to differing approaches to design, economics is not the primary focus of the work. In fact, Vose's intention clearly remains to provide design (calculation) assistance, and his preface illustrates that other authors of the period were also similarly focused:

> "Some points in Railway Engineering are but lightly touched upon in the following pages. The methods of layout of railway curves, the numerous problems in track laying, and the important matter of computing the quantities of excavation and embankment, have been so fully and so well

[46] George L. Vose, preface to *Handbook of Railroad Construction; For the Use of American Engineers*, (Boston and Cambridge: James Munroe and Company, 1857).

treated by Henck, Trautwine, and Morris, that there is no reason for doing the same work over again."[47]

Vose was certainly correct in his statement; by the time of the publication of his 1878 "Manual" several engineers had published extensive works offering both detailed information on design and construction and illustrated texts on performing various calculations that could be applied to railroad works. Philadelphia architect and engineer[48] John Cresson Trautwine's 1871 "Civil Engineer's Pocket-Book of Mensuration, Trigonometry, Surveying, Hydraulics, Hydrostatics, Instruments and their Adjustments, Strength of Materials, Masonry, Principle of Wooden and Iron Roof and Bridge Trusses, Stone Bridges and Culverts, Trestles, Pillars, Suspension Bridges, Dams, Railroads, Turnouts, Turning-Platforms, Water Stations, Cost of Earthwork Foundations, Retaining Walls, Etc., Etc., Etc." provided invaluable material in all of the areas noted in his title – and more. As the author stated in his preface, "the book [had] been prepared for young members of the profession; and one of the leading objects [had] been to elucidate, in plain English, a few important elementary principles which the savants [had] enveloped in such a haze of mystery as to render pursuit hopeless to any but a confirmed mathematician."[49] To fill what Trautwine saw as a gap in available – and understandable - knowledge and material, and to ensure that the reader would no

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47 George L. Vose, preface to *Manual for Railroad Engineers and Engineering Students Containing the Rules and Tables Needed for the Location, Construction, and Equipment of Railroads, as Built in the United States*, (Boston: Lee and Shepard, and New York: Charles T. Dillingham, 1883).

48 Trautwine, John Cresson," accessed March 6, 2019, www.philadelphiabuildings.org/pab/app/ar_display.cfm/21603.

49 John C. Trautwine, preface to *The Civil Engineer's Pocket-Book*, (Philadelphia: Claxton, Remsen & Haffelfinger, and London: Trubner & Co., 1907).

longer need to rely on inaccurate or confusing prior work, the book, as is evidenced by the massive table of contents alone, provided over 1000 pages of calculations, tables and figures. He made the particular point that "most of the tables [had] been entirely recalculated expressly for this book; and one of the results [had] been the detection of a great many errors in those in common use…. Tables which are absolutely reliable, possess an intrinsic value that is not to be measured by money alone."[50]

The "Field-Book for Railroad Engineers. Containing Formulae for Laying out Curves, Determining Frog Angles, Levelling, Calculating Earth-Work, Etc., Etc.," published by Massachusetts civil engineer John Benjamin Henck[51] in 1877 offered an extremely detailed "problem and solution" method to show the reader various types of calculations that, along with the appended tables, was of enormous assistance to working engineers of the time. Henck – like Trautwine - saw a need for field-type reference books; however, the area in which he perceived the greatest need was specifically that of the working railroad engineer. He stated that "the object of the present work [was] to supply a want very generally felt by Assistant Engineers on Railroads. Books of convenient form for use in the field, containing the ordinary logarithmic tables, [were] common enough; but a book combining with those tables others peculiar to railroad work…[was] yet a desideratum."[52] He, too, must have found that prior publications lacked accuracy as he made a point of confirming that his tables

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50 *Ibid.*

51 "Henck, John Benjamin" in *Appletons' Cyclopædia of American Biography*, eds. J.G. Wilson and J. Fiske, (New York: Appleton, 1892).

52 John B. Henck, preface to *Field-Book for Railroad Engineers. Containing Formulae for Laying out Curves, Determining Frog Angles, Levelling, Calculating Earthwork, Etc., Etc.*; (New York: D. Appleton & Company, and London: 16 Little Britain, 1877).

could be absolutely trusted. Even more than a decade later, although other field books had been published in the interim, *Engineering News* stated that "Henck's admirable treatise was for its day a great advance; and even to this day, [was] in form and method distinctly superior to any other before the public."[53]

The Start of Economic Analysis

While many authors of the period continued to focus on providing either general knowledge about existing railroads or exacting example calculations, one very early document alluding to the type of economic evaluation that would eventually come to be common in the design of railroads was written in 1847 by William Mitchell Gillespie, Professor of Civil Engineering at Union College in Schenectady, New York. Gillespie, a Columbia University graduate, and Union College's first Lecturer in Civil Engineering,[54] prepared his "A Manual of the Principles and Practice of Road-Making: Comprising the Location, Construction, and Improvement of Roads and Rail-Roads" as an introductory college text in Civil Engineering that began with the premise that "the common roads of the United States [were] inferior to those of any other civilized country."[55] Although his focus was primarily on roadway design, the textbook also offered a fairly extensive section related to railroads. In fact, it not only discussed methods of evaluation relative

53 "The Best Method of Keeping Field Notes of Curves," *Engineering News*, September 29, 1888.
54 "The Jackson Years: 1826-1877," created March 6, 1997, accessed March 6, 2019, www.math.union.edu/about/history/jackson.html.
55 W. M. Gillespie, *A Manual of the Principles and Practice of Road-Making: Comprising the Location, Construction, and Improvement of Roads, (Common, Macadam, Paved, Plank, etc.) and Rail-Roads*, (New York: A. S. Barnes & Co., 1853), 3.

to location, layout, construction and equipment, but also offered early comments on the economic value of how one might approach the design:

> "… it will cost nearly twice as much to carry a load on a railroad with ascending grade of 24 feet to the mile, as to carry it on a level route. This consideration will therefore justify large expenditures upon the excavations, embankments, &c., of a railroad, with a view of reducing its grades. The propriety of such expenditures is to be determined by comparing the annual interest of the amount with the annual saving of power ever after, in drawing the expected loads over the flattened road."[56]

Gillespie called attention to the potential savings associated with wisely planned grades as he noted in the above statement, and he also specifically discussed the economic wisdom of constructing straight corridors:

> "Suppose the total cost of a railroad to be $30,000 per mile, the interest of which is $1800; the annual repairs of the superstructure $1000 per mile; and the expenses of engines also $1000 per mile. The total annual expense will then be $3800, which is the interest of $63,000, which sum might profitably be expended to shorten the road one mile, or $12 to shorten it one foot. If this single foot gained was the only result of a day's labor of a locating party, it would be a satisfactory equivalent for the expenses of such a day's work."[57]

This potential for both short-term and long-term cost efficiencies gradually became the focus of other engineers and authors as the young American railroad network continued to expand across the country.

As the transportation network grew, railroad companies needed to expand their management structure to administer not only initial construction and employment

[56] *Ibid.*, 278
[57] *Ibid.*, 271

related activities but also the complex system of infrastructure maintenance, rate setting, and operations associated with these mammoth new enterprises.

> "No other business enterprise, or for that matter few other nonbusiness institutions, had ever required the coordination and control of so many different types of units carrying out so great a variety of tasks that demanded such close scheduling. None handled so many different types of good or required the recording of so many different financial accounts." [58]

This new system of management opened up a related area of study that was focused specifically on the economics associated with railroad construction, operation and accounting and was trending toward the eventually formalized field of railroad economic theory. Prior to the 1850s, the construction and operation of small railroads – with relatively few employees and limited numbers of trains - offered little in the way of useful guidance in the handling of the new expansive systems. The Baltimore and Ohio, for example, found by the mid-1840s that the extent of its operation required a new organizational structure and published its new organization plan in "a printed manual, *Organization of the Service of the Baltimore & Ohio Railroad*."[59] Even with this new system in place, including the introduction of new staff specifically hired to handle money-related issues, "the reports remained … only records of financial transactions. Though detailed and numerous, they were not yet consolidated and reorganized to permit a realistic analysis of the costs involved in operating the road."[60] The Baltimore

[58] Alfred D. Chandler, *The Visible Hand: The Managerial Revolution in American Business*, (Cambridge, Massachusetts and London, England: Belknap Press of Harvard University Press, 1977), 94.
[59] *Ibid.*, 99
[60] *Ibid.*, 100

and Ohio and other railroads worked hard to improve their approach to economic analysis. Men such as the Erie Railway's Daniel C. McCallum and the Pennsylvania Railroad's J. Edgar Thomson restructured their organizations to ensure an improved focus on costs that "contributed substantially to the emergence of accounting out of bookkeeping.... To meet the needs of managing the first modern business enterprise, managers of large American railroads during the 1850s and 1860s invented nearly all of the basic techniques of modern accounting."[61] These new practices "fell into three categories: financial, capital, and cost accounting.... While the largest of the textile mills [of the recent past] had four or five sets of accounts to process and review, the Pennsylvania Railroad had, by 1857, ... 144 basic sets of accounting records."[62]

The efforts of the engineers working in this area flowed into, and ultimately supported the scientific management theory that Frederick Winslow Taylor developed in the United States in the 1880s and 1890s. The primary objective of "Taylorism" was to improve economic efficiency[63], in large part as it related to the growing manufacturing concerns of the Industrial Revolution. "Two of the first contributions to the literature of scientific management"[64] consisted of mid-1850s Pennsylvania Railroad annual reports prepared by Herman Haupt, then the company's transportation superintendent. Haupt, a West Point trained engineer, railroad locator, and bridge

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61 *Ibid.*, 109

62 *Ibid.*, 109-110

63 Stephen P. Waring. *Taylorism Transformed: Scientific Management Theory since 1945*, (United Kingdom: University of North Carolina Press, 2016.)

64 Raymond H. Merritt, *Engineering in American Society 1850-1875*, (Lexington, Kentucky: University Press of Kentucky, 1969), 66.

designer, "worked out a system of monthly purchases to sustain coal, lumber, and iron shops along the railroad line, and a policy of fixed and variable items of business expense, which enabled the company to analyze carefully its monthly income."[65] During his tenure with the Pennsylvania Railroad, he worked diligently to study and control the costs associated with the railroad's operation.

"The railroad manager who most effectively developed … cost accounting and control was Albert Fink, a civil engineer and bridge builder."[66] The most advanced and influential of the various engineers working in this new area of railroad economic analysis, Fink authored the 1874 "An Investigation into the Cost of Transportation on American Railroads with Deductions for its Cheapening," and the 1875 "Cost of Railroad Transportation, Railroad Accounts, and Governmental Regulation of Railroad Tariffs." Working, early in his career, designing and erecting bridges and structures for the Baltimore and Ohio Railroad under chief engineer, Benjamin Latrobe, he later left for the Louisville and Nashville Railroad, where he "turned his attention to financial management, studying the economic relationships between the volume of business, fuel and interest charges, cost of construction, and passenger and freight rates."[67] Fink, "the founding patriarch of the managerial revolution [and the],,, 'father of railway economics and statistics in the United States',"[68] developed an accounting system that placed him at the front of his field. His 1874 publication has since been regarded as the "foundation

65 *Ibid.*
66 Chandler, *The Visible Hand*, 116
67 Merritt, *Engineering in American Society*, 75
68 *Ibid.*

of economics of the American railway industry. The report was referred to as 'the fullest investigation into the cost of railroad transportation ever published in our country or language.' "[69]

Utilizing extensive statistical information from the Louisville and Nashville and Great Southern Railroads to illustrate the actual costs associated with railroad operation, "the purpose of the system devised by Fink was to measure the profitability and efficiency of the railroad's operations in terms of then-revolutionary concepts of fixed and variable costs and costs allocated to multiple accounting periods. Fink's operating statistics, such as revenue and expenses per ton-mile and passenger-mile, became standards in the industry."[70]

> "His first step in obtaining accurate cost of carrying one ton for one mile in each of his divisions was to reorder the financial and statistical data compiled by his accounting and transportation departments.... Fink reordered his accounts into four fundamental categories. One included those costs which, within limits, did not vary with the volume of traffic.... A second category included nine sets of accounts that varied with the volume of freight but not with the length of road or train-miles run.... A third class... of items, 'movement expenses,' varied with the number of trains run.... Fink had a fourth category, the interest charges that, of course, had no relation to traffic carried or trains run.... Table [1] gives the complex formula Fink used to convert these sixty-eight sets of accounts into costs per ton-mile."[71]

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[69] *Railway Gazette*, May 30, 1874, quoted in Merritt, 66

[70] Jan Richard Heier. "The Foundations of Modern Cost Management: the Life and Work of Albert Fink," *Accounting, Business & Financial History*, Volume 10, Issue 2 (2000). http://www.tandfonline.com/doi/abs/10.1080/095852000411041.

[71] Chandler, 116

Fink revolutionized the way that railroad administrators viewed their operations. "Cost per ton-mile rather than earnings, net income, or the operating ratio thus became the criterion by which the railroad managers controlled and judged the work of their subordinates."[72] He authored numerous articles and frequently weighed in on the nationally important issues of railroad regulation, rates and tariffs. "Fink used his cost management techniques to argue against the regulation of the entire rail industry by impending legislation that would create the Interstate Commerce Commission which would subsequently embrace his costing methodology."[73] His published arguments before various House of Representatives and Senate Committees continued to be "held in high esteem among writers on railroad questions"[74] well into the 20th century.

Table 1 - Albert Fink: Classification of Operating Expenses and Computation of Unit Costs[75]

Headings of Accounts	
MAINTENANCE OF ROADWAY AND GENERAL SUPERINTENDENCE *Road repairs per mile of road -* 1. Adjustment of track 2. Ballast 3. Ditching 4. Culverts and cattle-guards 5. Extraordinary repairs – slides, etc. 6. Repairs of hand and dump-cars	7. Repairs of road tools 8. Road watchmen 9. General expense or road department 10. Total 11. Cross-ties replaced – value 12. Cross-ties, labor replacing 13. Cross-ties, train expenses hauling 14. Total cost of cross-ties per mile of road

72 Chandler, 117
73 Heier, "The Foundations of Cost Management"
74 *A List of Books with References to Periodicals Relating to Railroads in their Relation to the Government and the Public*, Chief Biographer Appleton Prentiss Clark Griffin, (Washington, D.C.: Government Printing Office, 1907), 6.
75 Alfred D. Chandler, 118-9

15. Bridge superstructure repairs 16. Bridge watchmen 17. Shop-building repairs 18. Water-station repairs 19. Section-house repairs 20. Total cost of bridge and building repairs per mile of road 21. General superintendence and general expense of operating department 22. Advertising and soliciting passengers and freight 23. Insurance and taxes 24. Rent account 25. Total per mile of road 26. Salaries of general officers 27. Insurance and taxes and general expense 28. Total per mile of road 29. *Total cost per mile of road for maintenance of roadway and buildings* 29½. Total cost per train mile for maintenance of roadway and buildings STATION EXPENSES PER TRAIN MILE 30. Labor loading and unloading freight 31. Agents and clerks 32. General expense of stations – lights, fuel, etc. 33. Watchmen and switchmen 34. *Expense of switching –* Engine repairs Engineers and firemen's wages Expense in engine-house Supervision and general expense Oil and waste Water supply Fuel 35. Total per train mile 36. Stationery and printing 37. Telegraph expenses 38. Depot repairs 39. Total per train mile	40. *Total station expenses per train mile* MOVEMENT EXPENSES PER TRAIN MILE 41. Adjustment of track 42. Cost of renewal of rails - value 43. Labor replacing rails 44. Train expenses hauling rails 45. Joint fastenings 46. Switches 47. Total cost of adjustment of track and replacing rails per train mile 48. Locomotive repairs 49. Oil and waste used on locomotives 50. Watching and cleaning 51. Fuel used in engine-house 52. Supervision and general expense in engine-house 53. Engineers and firemen's wages 54. Total engine expenses per train mile 55. Conductors and brakemen 56. Passenger-car repairs 57. Sleeping-car repairs 58. Freight-car repairs 59. Oil and waste used by cars 60. Labor oiling and inspecting cars 61. Train expenses 62. Total car expenses per train mile 63. Fuel used by locomotives 64. Water supply 65. Total fuel and water expense per train mile 66. Damage to freight, and lost baggage 67. Damage to stock 68. Wrecking account 69. Damage to persons 70. Gratuity to employees 71. Fencing burned 72. Law expenses 73. Total per train mile 74. *Total movement expenses per train mile* 75. GRAND TOTAL for maintenance and movement per train mile

Formula for Ascertaining the Cost of Railroad Transportation per Ton-Mile

$$\text{Movement expenses per ton-mile} = \frac{\text{Movement expenses per train mile (items 41 to 74)}}{\text{Average number of tons of freight in each train}} = a$$

$$\text{Station expenses per ton-mile} = \frac{\text{Cost of handling freight (items 30 to 40) at forwarding station + at delivery station}}{\text{Length of haul}} = b$$

$$\text{Maintenance of road per ton-mile} = \frac{\text{Cost of maintenance of road per mile per year (items 1 to 29)} \times \dfrac{\text{Total miles run by freight trains per year}}{\text{Total revenue trains, pass. and freight, per year}}}{\text{Average number of tons of freight transported over one mile of road per year}} = c$$

$$\text{Interest per ton-mile} = \frac{\text{Cost of road per mile} \times \dfrac{\text{rate of interest per annum}}{100} \times \dfrac{\text{number of freight train miles per year}}{\text{number of revenue train miles, freight and pass., per year}}}{\text{Average number of tons of freight transported over one mile of road per year}} = d$$

Total cost per ton-mile = $a + b + c + d$

Economic Design Theory Takes Hold

Developments in engineering methodology associated with railroading moved forward rapidly making newer and more advanced publications a necessity. Alongside the advancements made in economic analysis as it related to railway operations and maintenance, such as that pioneered by Albert Fink, a major leap forward in the economic theory behind railroad layout, design and construction took place in the 1870s and 1880s. As William H. Searles noted in the preface to his 1880 "Field Engineering: A Handbook of the Theory and Practice of Railway Surveying, Location and Construction,"

> "although the modern railway system is but about fifty years old, yet its growth has been so rapid, and the progress in the science of railway construction so great, as to render the earlier technical books on this subject inadequate to the needs of the engineer of to-day. In the course of his practical experience as a railway engineer, the author was impressed with the want of a more complete hand-book for field use…."[76]

His popular book was issued in its 18th edition in 1925 and continued to be read in its 26th edition 35 years later. Containing information both to aid the designer in performing calculations and to guide him in evaluating the economics of his design decision-making, this book represented the new norm – a combination of design theory and economic theory. Regarding the latter subject for example, Searles, at the end of a chapter devoted to calculating the maximum economy in grades, stated that

> "The value of saving one mile in distance on any route is found by dividing the sum of the annual operating expense and the interest on the cost of construction by the rate of interest, and the quotient by the length of the line in miles."[77]

[76] William H. Searles, preface to *Field Engineering A Handbook of the Theory and Practice of Railway Surveying, Location, and Construction*, (New York: John Wiley & Sons, 1882).

[77] Searles, *Field Engineering*, 39

The authors of the mid-19th-century frequently alluded to the realization that economics was critical to railroad design theory, but few had yet presented anything approaching a thorough or detailed understanding of what that meant or what was required of the engineering analysis. The man who would ultimately change that approach was Arthur Mellen Wellington and designers, writers – and educators - who followed him owed him a debt of gratitude that became clear in the writings of the late 1800s and early 1900s. For example, an unpublished document on railroad engineering, compiled by Cornell University civil engineering professor Charles Lee Crandall in 1889 for use in one of his classes, contained a chapter on railroad economics that was excerpted directly from Wellington's work.[78] In 1904 a book on the related but separate subject area of railway location as it applied to the physical placement of the railroad was authored by Willard Behan. Then Division Engineer of the Chicago and Northwestern Railway, Behan's book mainly addressed the topics of reconnaissance, surveying, geology and field conditions and was presented primarily for use by locating engineers. However, he did also provide some information on economic location theory while making it clear that:

> "The economic units and the principles established by the late A. M. Wellington in his valuable book, "The Economic Theory of Location of Railways," are here used, and referred to by chapter or section in each case. Had the book just mentioned never been written, this present volume would be of a very different nature and probably much less useful. Mr. Wellington was studious and brave enough to venture first into the

[78] C. L. Crandall, "Notes on Railroad Engineering For Use in the College of Civil Engineering Cornell University," Mimeograph Print 1889-90, accessed at Google books, March 8, 2019.

> untrodden field of the economics of railroad location.... It is still, in this writer's opinion, an authority in railroading."[79]

Engineering books written in the later decades of the 19th century and into the early 20th century, including those not directly related to railway economics but still referring to the subject as part of the overall discussion, typically referred to material drawn from Wellington's work rather than attempting to redefine something that he had so definitively covered decades before. In 1894, Edwin Harrison McHenry published his "Rules for Railway Location and Construction used on the Northern Pacific." First a rodman and ultimately the chief engineer of the Northern Pacific Railroad[80], McHenry noted in his narrative that "the economic values given for 'Distance,' 'Curvature,' and 'Rise and Fall,' were derived from Wellington's 'Economic Theory of Location'."[81] In the same year, G. F. Allen copyrighted a short unpublished paper entitled "Notes on Railroad Engineering and Economics of Location." His premise was that "civil engineering may be defined as the science and art of utilizing the forces and materials of nature in producing fixed structures. Among the most important of these [were] railroads.... Questions of economy appear at nearly every step in most engineering work in its application to railroad building. (Read Introduction to Wellington.)"[82]

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79 Willard Behan, preface to *The Field Practice of Railway Location*, (New York: The Engineering News Publishing Company, 1904).

80 "Edwin Harrison McHenry," accessed March 6, 2019, https://en.wikipedia.org/wiki/Edwin_Harrison_McHenry.

81 E. H. McHenry, *Rules for Railway Location and Construction Used on the Northern Pacific Railway*, (New York: The Engineering News Publishing Co., 1903), 19 (footnote).

82 G. F. Allen, "Notes on Railroad Engineering and Economics of Location," copyright 1894, 1.

"Railway Maintenance Engineering with Notes on Construction," published in 1915 by William H. Sellew of the University of Michigan, as another example, contained frequent footnotes indicating that sections of his text were taken directly from Wellington's work. Furthermore, the following statement was made in the preface of Lehigh University president[83], Clement C. Williams' 1917 publication "The Design of Railway Location – A Study of the Physical and Economic Conditions that Control the Location of Railways in Order that their Operation may be at Maximum Safety and Efficiency":

> "An attempt has been made to give credit in the body of the text and in foot-notes to the source of subject matter taken from other writings, but special mention should be made of the monumental work by Mr. A. M. Wellington, "The Economic Theory of Railway Location," which had such a marked influence on railroad building during the latter part of the last century."[84]

Clearly, from its initial publication in 1877 and well into the early 1900s, Wellington's work was the authoritative document on railroad economic theory.

[83] "Clement C. Williams," Lehigh University, copyright 2016, accessed March 6, 2019, www1.lehigh.edu/about/history/Williams.

[84] Clement C. Williams, preface to *The Design of Railway Location A Study of the Physical and Economic Conditions That Control the Location of Railways in Order That Their Operation May be at Maximum Safety and Efficiency*, (New York: John Wiley & Sons, Inc. and London: Chapman & Hall, 1917).

Chapter Two – Railway Economics Transformed Into Highway Economics

The Theory of Railway Economics

Arthur Mellen Wellington

Arthur Mellen Wellington stated that "railways are not undertaken unless they are to be profitable, not to the general public, nor to other parties in the near or distant future, not to those who lend money on them, but to those who at first control the enterprise."[85] From the early days of railroading attempts were made to determine the controlling factors that would enable railway owners to profit through the establishment of these transportation corridors. By the 1870s, engineers such as Albert Fink had developed methods for the systematic management of railways through the new methods of cost accounting that were utilized by nearly all railroad companies for decades to follow. Although many railroad planners worked toward the standardization of cost efficient design systems, it was Wellington who

> "is regarded as the father of the subject of engineering economy, which is the analysis of the economic consequences of engineering decisions. The importance of this study is evidenced by its inclusion in the Fundamentals of Engineering examination on the path to the certification of an engineer. It rests mainly on the reduction of the consequences to monetary amounts and the comparison of amounts at different times on the basis of

85 A. M. Wellington, *Economic Theory of the Location of Railways*, (New York: John Wiley and Sons and the Engineering News, 1902), 15.

> compound interest.... Wellington defined engineering as the science 'of doing for a dollar what any fool can do with two, in a fashion'."[86]

Wellington was born in Massachusetts in 1847, and became an articled pupil and apprentice to practicing engineer, John Benjamin Henck of Boston, at the age of sixteen. After leaving Henck's office, he worked briefly under Frederick Law Olmstead in the engineering corps of the Brooklyn Park Department.[87] Beginning in the late 1860s, he worked for a number of railroads, serving primarily on locating parties. During the period of limited railroad construction that came with the Depression of 1873 Wellington turned much of his attention to research and writing. In 1874 he published *The Computation of Earthwork from Diagrams*, which "was very favorably received, ... and that by which his fame as an engineer was firmly established, 'The Economic Theory of the Location of Railways,' was begun in 1875."[88]

Critical to Wellington's theory was the idea that a railroad was a form of industry which he defined as the manufacture of transportation. "Transportation, indeed, existed before its invention,... but it was ... mainly provided on a small scale by each consumer for his own use and his immediate neighbors. With the invention of the railway first began the manufacture of transportation for sale on a large scale and by modern processes."[89] Wellington stated that even the strongest of railroad corporations existed within very narrow financial margins for error. Even relatively small variations

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86 "Arthur Mellen Wellington's Railway Location," copyright by J. B. Calvert, last revised January 29, 2005, accessed March 6, 2019, Mysite.du.edu/~jcalvert/railway/wellingt.htm.

87 "Arthur Mellen Wellington," *Grace's Guide to British Industrial History*, accessed March 6, 2019, www.gracesguide.co.uk/Arthur Mellen Wellington

88 Arthur M. Wellington Obituary. *The New York Times*. May 18, 1895.

89 Wellington, *Economic Theory of the Location of Railways*, 48

in initial costs, operating expenses, or revenues could mean the difference between success and failure for many proposed or operating lines. Every recommended increase in expense at any point of construction or operation had to be thoroughly verified and justified in terms of its future impact.

He first presented the economic theory that was then under development in a series of articles published in the September 1 through December 29, 1876 editions of the *Railroad Gazette* entitled the "Justifiable Expenditure for Improvement in the Alignment of Railways." This series immediately introduced the alignment details that he had determined to be critical to his evaluation – distance, curvature, rise and fall, and ruling grade – and heralded the soon-to-be publication of the book on economic theory with the statement that "to compare properly these different characteristics of alignment with each other, it is essential that the value or cost of each should be referred to some common standard. The TRAIN MILE is at once the most convenient and the most exact for this purpose."[90] The cost per train-mile was defined as the expense incurred in operating a given train over a length of track of a single mile.

In a method similar to that used by Fink in his Louisville and Nashville and Great Southern Railroads studies of the prior year, Wellington established three major categories of operating expenses – maintenance of way and works; train expenses; and station, terminal and general expenses and taxes. Wellington's evaluation was more elaborate than Fink's because he provided, noting that "the writer is not aware of such

[90] A. M. Wellington, "The Justifiable Expenditure for Improvement in the Alignment of Railways, *Railroad Gazette*, Sept 1, 1876, 377.

having been previously compiled, owing probably to the great labor involved,"[91] a substantiating statistical analysis of the expenses of thirteen representative railroads from across the country. As if this great volume of data might prove insufficient, and despite calling particular attention to the obvious consistency in expenses from across the country that the information already indicated, Wellington then stated that "in order to determine, however, if the same law of uniformity will hold universally true, we will make some comparisons with a few English railways,"[92] and proceeded to make this part of his analysis. Determining thereafter that the apparent discrepancies between American and English statistics were due to differing methods of accounting typical to the different countries, he concluded that there was sufficient "reason to believe that the various percentages of cost on English railways, and even the aggregate cost of a train mile, are closely approximate to those ruling in the United States."[93]

The articles that followed the first in the series evaluated, again based on extensive statistical data, the economic advantages and disadvantages associated with variations in distance, curvature, rise and fall, and gradient, making use of illustrative calculations, and offering information generated by the work and experience of others in the field. The research that went into the preparation of his text was clearly extensive; he frequently referred to situations where the assumptions or beliefs of others were proven to be incorrect, and where actual railway construction could have been

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[91] Wellington, "The Justifiable Expenditure," 377.
[92] Ibid, 378
[93] Ibid, 379

greatly improved by following his economic theory of location. For example, in discussing the construction of the Erie Railway, "although the writer would not be understood as questioning the consummate engineering skill with which that road was carried through the mountains and the wilderness,… the Erie Railway and its branches have lamentably ill-adjusted grades at various points, apparently owing to the mistaken idea that if a lower grade can be secured at any point by a moderate expenditure it is always advisable."[94] In closing the group of articles, Wellington clearly reiterated his certainty regarding the approach that he had presented, referring to the rail line considered in his analysis and stating that

> "the engineer who made the survey started out with the definite purpose of finding a line with 20 feet maximum grades. In order to do it he made a detour at the very beginning which sacrificed eight miles of distance, in order to reach the point marked A on the map…; and yet even this process, continued throughout the survey, could not produce a line with 20 feet maximum grades, although it *did* show a very absurd and worthless line. Consequently this territory stands reported as wholly worthless for railway purposes, with maps and profiles to prove it abundantly, and yet a better line than if he had actually obtained his 20 feet maximum without sacrifice of distance was there before him, if he had but looked for it. In making these remarks the writer would be very unwilling to wound the feelings of any one, and still more to appear to set himself up as a master of the art of location; but he has used this line because an actual distance is so much more convincing and effective than an imaginary case, and if the facts be questioned, he can only add that he is at all times ready to substantiate them by running the line without money or price, solely for the

[94] Wellington, "The Justifiable Expenditure", 490-491.

satisfaction of testing the correctness of his own judgment and seeing exactly what may be done."[95]

The Book that Defined Railway Economic Theory

The first edition of the book that expanded upon the *Railroad Gazette* articles and was "his most enduring contribution to engineering economy"[96] was published in 1877. "The Economic Theory of the Location of Railways" expanded upon the earlier articles utilizing the following elements, and their comparative costs, in its presentation: fuel, water, oil and waste, engine repairs, switching engines, train wages, train supplies, car repairs, car mileage, rail renewals, adjusting track, tie (aka sleeper) renewals, earthwork and ballast, yards and structures, and station, terminal, general and tax costs (see Table 2). The principles of Wellington's economic theory were based on the determination that three minor and two major details of alignment were of significance in financial considerations. The minor details, defined as such due to their lesser influence on the future of railroad property, were the elements of distance, curvature, and rise and fall. The more critical elements for consideration were the amount of traffic on a given line and what Wellington termed the "ruling gradients," so called because these grades were the worst encountered on the entire line. The cost typically utilized for purposes of comparison was one cent per "train-mile." Despite this deceptively low cost, Wellington

[95] Wellington, "The Justifiable Expenditure", 566.

[96] Gerald J. Thuesen and William G. Sullivan, "Engineering Economy – A Historical Perspective," (paper presented at Session 1639 of American Society for Engineering Education Annual Conference, 1999).

observed that revenue and expenses could be significantly influenced by even relatively slight variations in design.

The effect of distance, or length of line, according to Wellington, varied in a fashion dependent upon the factor under comparison. Some elements were fixed and varied only slightly, if at all, with changes in length, while others were considerably impacted by each increase in mileage. The general statement could be made that for short increases in length little change was observed in expense; however, as distance increases became greater the expenses connected with the increases varied more directly with the distances covered (refer to Table 3). Curvature impacted railroad operating costs by causing possible losses of power, limiting train lengths and increasing the need for periodic confirmation of safe track conditions. In addition, sharper curves increased the dangers of derailment or collision, slowed travel speeds, and reduced the feasibility of using longer or heavier cars. Wellington noted that the most important and expensive location detail relative to construction costs was sharp curvature. Therefore, he saw reason for the establishment of maximum curvatures and determining the costs inherent in exceeding such curves.

Two causes of increased expenses were related to rise and fall, or the "elevations overcome by [an] engine on gradients not exceeding in resistance the maximum of the road, and hence not limiting the length of the train."[97] The first was the direct cost in terms of the fuel used in overcoming the rising and falling, and in terms of the wear and tear on equipment ascending and descending a given grade. "The second objection to

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[97] Wellington, *Economic Theory of the Location of Railways*, 185

gradients [was] … the effect which the maximum or rather ruling grade … [had] to increase the cost of operating the entire line, …. not by increasing the direct expense per train-mile but by limiting the number of cars to a train."[98] Wellington observed that the general cost of rise and fall was in direct proportion to the elevation climbed, and that the ruling grade cost was directly affected by the rate of the grade (refer to Table 4). The ruling grade was that which most adversely impacted a railway's performance and future development. Although the effect of grades could be overcome via economies of power expenditure or choice of train length or weight, careful incorporation of grades was preferable to dealing with the limitations and potential dangers inherent in the utilization of steep grades. Wellington's general rule regarding gradients was stated as follows: "Follow that route which affords the easiest possible grades for the longest possible distances, using to that end such amounts of distance, curvature, and rise and fall as may be necessary, and then pass over the intervening distances on such grades as are then found necessary."[99]

The amount of traffic a line could be anticipated to see was the result of the combination of the same factors previously discussed. Important to increasing traffic was the use of the least number of trains per mile, and the careful choice of the line location and the number of "traffic points" on that line. Each traffic point was a tributary source of additional traffic that would directly impact the general railway earnings. "The equation giving the general law of increase in earnings due to an

[98] *Ibid.*, 327
[99] *Ibid.*, 713

increase of tributary points on the same length of line … [showed that] the productive traffic [varied] as the square of the number of tributary sources of traffic."[100] This law of increment in traffic was Wellington's means of indicating a basis for the assumption of increased financial productivity and acceptability of expenditure (refer to Table 5).

[100] Wellington, *Economic Theory of the Location of Railways*, 660

Table 2 – Approximate Estimate of the Details of Operating Expenses for an Average American Road[101]

Train Expenses 47.0 percent	Engines 18.0 percent	Road Engines 14.4 percent	Fuel	7.6 percent
			Water	0.4 percent
			Oil and Waste	0.8 percent
			Repairs – Engines	5.6 percent
		Switching Engines		3.6 percent
	Train Wages and Supplies 17.0 percent	Switching Engine Wages		1.6 percent
		Train Wages and Supplies 15.4 percent	Engine Wages	6.4 percent
			Car Wages	8.5 percent
			Car Supplies	0.5 percent
	Cars 12.0 percent	Repairs and Renewals		10.0 percent
		Mileage (a practical equivalent to repairs)		2.0 percent
Maintenance Of Way 23.0 percent	Track Between Stations 8.0 percent	Renewals of Rails		2.0 percent
		Adjusting Track		6.0 percent
	Road Bed 7.0 percent	Renewing Ties		3.0 percent
		Earthwork, Ballasting, etc.		4.0 percent
	Yards and Structures 8.0 percent	Switches, Frogs, Sidings		2.5 percent
		Bridges, Masonry		3.5 percent
		Stations, Other Buildings		2.0 percent

Total Line or Transportation Expenses	70.0 percent
Station, Terminal, and General Expenses and Taxes	30.0 percent
Total Operating Expenses	100.0 percent

[101] *Ibid.*, 179

Table 3 – Estimated Approximate Effect of Great and Small Differences of Distance[102]

Item	Total Cost in Per Cent	Increase for Greater Differences of Distance of Per Cent Varying with Distance	Total Amount Per Train-Mile
Fuel	7.6	from 67 percent to 85 percent	6.5
Water	0.4	from 0 percent to 50 percent	0.2
Oil and Waste	0.8	from 50 percent to 50 percent	0.4
Engine Repairs	5.6	from 40 percent to 57 percent	3.2
Switching Engines	5.2	from 0 percent to 0 percent	0.0
Train Wages	14.9	from 0 percent to 100 percent	14.9
Train Supplies	0.5	from 0 percent to 40 percent	0.2
Car Repairs	10.0	from 35 percent to 50 percent	5.0
Car Mileage	2.0	from 100 percent to 100 percent	2.0
Rail Renewals	2.0	from 80 percent to 100 percent	2.0
Adjusting Track	6.0	from 50 percent to 100 percent	6.0
Tie Renewals	3.0	from 100 percent to 100 percent	3.0
Earthwork and Ballast	4.0	from 100 percent to 100 percent	4.0
Yards and Structures	8.0	from 0 percent to 50 percent	4.0
Station and General	30.0	from 0 percent to 0 percent	0.0
Total	100.0	from 24.8 percent to 51.4 percent	51.4

Table 4 – Estimated Cost Per Train-Mile and Per Daily Train of 26.4 Feet of Rise and Fall[103]

Item	Total Cost of Item	Percentage of Same Increasing with 26.4 Feet of Rise and Fall for Class C	Cost Per Train Mile of 26.4 Feet of Rise and Fall
Fuel	7.6	100.0 percent	7.6 percent
Water, Oil and Waste	1.2	50.0 percent	0.6 percent
Repairs of Engines	5.6	4.0 percent	0.22 percent
Switching-Engine Service	5.2	Unaffected	0.0 percent
Train Wages & Supplies	15.4	Unaffected	0.0 percent
Repairs of Cars	10.0	4.0 percent	0.4 percent

[102] *Ibid.*
[103] *Ibid.*

Car Mileage	2.0	Unaffected	0.0 percent
Renewals of Rails	2.0	10.0 percent	0.2 percent
Adjusting Track	6.0	5.0 percent	0.3 percent
Renewing Ties	3.0	5.0 percent	0.15 percent
Earthwork, Ballast, etc.	4.0	5.0 percent	0.2 percent
Yards and Structures	8.0	Unaffected	0.0 percent
Station and General	30.0	Unaffected	0.0 percent
Total	100.0	9.7 percent	9.67 percent
Per Foot of Rise and Fall			0.366
Per Foot of Rise and Fall per Daily Train – Class C (round trip)			$2.67

Table 5 – Illustrating the Law of Increment in Traffic Resulting From the Interpolation of the Additional Traffic Points[104]

Number of Traffic Points	Names of Traffic Points	Increment Due to Each Addition	Total Traffic	
1	A	0	0	
2	B	1	1	A B
3	C	2	3	A C, B C
4	D	3	6	A D, B D, C D
5	E	4	10	A E, B E, C E, D E
6	F	5	15	A F, B F, C F, D F, E F
7	G	6	21	A G, B G, C G, D G, E G, F G
8	H	7	28	A H, B H, C H, D H, E H, F H, G H

Note: The comparative aggregate traffic for any number of traffic points n is given by the sum of the natural numbers to n-1 inclusive.

104 *Ibid.*

Beginning in 1881, several years after the release of his groundbreaking book, Wellington held positions on the various lines of the Mexican National Railway.

> "In 1884 he returned to the United States and entered the field of technical journalism, becoming a member of the editorial staff of the 'Railroad Gazette.' His leisure, outside of office hours, he devoted to preparing for the press the second edition of his work on 'Railway Location,' which was finally published in the spring of 1887. On this treatise, more than on any other part of his life's labors, Mr. Wellington's fame as an engineer [would] doubtless rest. It must be borne in mind that in 1877, when the first edition was published, there was practically nothing in print of recognized value as a guide to scientific railway location. Mr. Wellington aimed to show in his work that to make a good railway location it was not safe to depend upon blind instinct or rule of thumb, but that all the elements entering into the problems must be taken into consideration and each much be given its proper weight."[105]

In 1887 Wellington became part owner and one of the editors of the "Engineering News," and continued to work as a practicing consulting engineer. In ill health beginning in mid-1894, he died on May 16, 1895.[106]

The publication of "The Economic Theory of the Location of Railways" changed the way in which engineers approached railway layout and design thereafter and proved that Wellington was correct in stating so emphatically that his method of analysis was both thorough and reliable. Wellington's 1877 book continued to be reprinted, widely read and widely referenced well into the early 20th century. His theory was used as the standard of practice throughout the railroad industry and was taught in railway

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105 "Arthur M. Wellington," Obituary
106 *Ibid.*

engineering college courses across the country. By the time of the release of the 1936 edition of the manual of the American Railway Engineering Association's Committee on the Economics of Railway Location, a formula had been established for determining the economic value of a given line location. This formula was based upon the ratio between the original invested capital and the annual operating revenues less operating expenses. Train-mile costs remained in use by the railroad engineering industry throughout the decades preceding and during the Second World War, and were presented for general use not only by the American Railway Engineering Association but also within standard engineering texts. By that time, roadway engineers were also looking at Wellington's evaluation process as a starting point in the development of a theory of highway economics.

Railway Economics After Wellington

In the years following Wellington's work, and as track mileage approached its peak, railroad economics – primarily as it related to transport rates, but also as it related to layout and construction - became a major focus across the country. The Interstate Commerce Commission had been created by the Interstate Commerce Act of 1887 "largely to protect the public from the monopolistic abuses of the railroads."[107]

> "Rate wars in competitive markets drove down profits, leading carriers to raise prices to shippers without alternative means of transport. Often, a farmer located along an intermediate point served by only one railroad

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[107] Paul Stephen Dempsey, "The Rise and Fall of the Interstate Commerce Commission: The Tortuous Path From Regulation to Deregulation of America's Infrastructure," *Marquette Law Review*, Volume 95, Issue 4, Summer 2012, accessed March 6, 2019, 1152 http://scholarship.law.marquette.edu/cgi/viewcontent.cgi?article=5129&context=mulr.

> would find that the price he was charged to ship his grain to market was higher than that charged to another shipper, even though that other farmer's grain would be moved a longer distance over the same line. Hence, pricing in this era was highly discriminatory. Prices were generally low, but unstable, between points served by competing railroads or having access to navigable waterways, and relatively high (and even extortionate) at points between which shippers had no alternative means of transport. Pricing began to reflect the level of competition in any market, rather than the cost of providing service. Moreover, preferred shippers enjoyed special rates, under-billing, and rebates."[108]

In response to spreading concerns with the growing economic power of the railroad companies, the goal of the Interstate Commerce Commission was to regulate the industry and ensure the establishment of fair rates by requiring that railroads both publish their rates and adhere to them. "The Interstate Commerce Act was the first comprehensive regulation of any industry in the United States…. Perhaps it was inevitable that government would come to play a role in protecting the public and industry from the ravages of economic instability and exploitation. As one commentator remarked, 'the railroad dominated the US economy and society in the 19th century. The domination existed from every standpoint…. There was no force, industrial or religious, which matched the societal impact of the railroad after the first third of the 19th century."[109]

As part of this process of regulating rates, the Interstate Commerce Commission established standardized classifications for expenses and kept detailed records for railroads across the country. With that framework of newly available statistics, civil

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108 *Ibid.*, 1155
109 *Ibid.*, 1162

engineer and former Pennsylvania University professor, Walter Loring Webb, whose earlier (1900) text had been the design-focused "Railroad Construction Theory and Practice," published a book in 1906 entitled "The Economics of Railroad Construction." By the time of the 1912 release of the second edition Webb noted, in his chapter on operating expenses, that

> "the system developed by the United States Interstate Commission [had] been followed, so that the invaluable statistics published by them may be quoted and freely applied to illustrate general principles. Until 1908 the various items were grouped into four general classes. In that year the system was expanded by dividing the expenses of 'conducting transportation' into 'traffic expenses' and 'transportation expenses' and also by increasing the number of sub-items from 53 to 123. Since that time changes in classification have altered the number to 116."[110]

Interestingly, Webb's assessment of the available data confirmed what Wellington had reported in his earliest documentation on railroad economics. "The reports published by the Interstate Commerce Commission [gave] the operating expenses per train-mile for nearly all of the railroads in the country.... The very surprising feature of these figures [was] that the operating expenses per train-mile [were] so nearly uniform, for the various roads of the country for any one year."[111]

Webb's book discussed the means of calculating the cost of every item of expense – operating, motive power, car construction and track – often referring to and retaining assumptions from the past evaluations of others including Wellington, and typically

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[110] Walter Loring Webb, *The Economics of Railroad Construction*, (New York: John Wiley & Sons, New York, 1912), 89.
[111] *Ibid*., 91

updating earlier information to take into consideration modern equipment and conditions. His document also thoroughly discussed the topics of distance, curvature and grades with the primary economic focus of explaining how these characteristics were typically not given appropriate weight in setting rail transport rates. For example, Webb believed that the influence of grades and curvature should not be ignored in determining rates, and distance traveled should not be the sole basis of such rate setting. As "the general object to be attained in either passenger or freight traffic is the transportation from A to B, however it is attained…. from the standpoint of service rendered, the railroad which adopts a more costly construction, and thereby saves a mile or more in the route between two places, is thereby fairly entitled to additional compensation rather than have it cut down, as it would be by a strict mileage-rate."[112]

Even as designers of the early decades of the 20th century began to shift their focus to the newly developing system of roadways in the United States, railroad design and construction continued to be a primary field of attention, and authors often provided guidance that was useful to both roadway and railway engineers. John Alexander Low Waddell, a Canadian-born civil engineer and prolific bridge designer published several books specifically associated with economics and design – the 1917 "Engineering Economics" and the 1921 "Economics of Bridgework – a Sequel to Bridge Engineering." The first book, subtitled as "a series of lectures delivered before the students of the University of Kansas, School of Engineering," offered several short

[112] *Ibid.*, 233

papers related to economics in various areas of engineering endeavor, including railroads. In a brief section specifically dedicated to railroading, Waddell noted that

> "the subject of the economics of modern railroading is a broad and intricate one, and deserves a full and elaborate treatment by a master hand; but, unfortunately, none of the authorities seem inclined to write an exhaustive treatise on the subject. Wellington's great work, "The Economic Theory of Railway Location," is now out of date, and should be replaced by a modern book covering the entire ground. The best that the speaker has been able to do with this subject for these lectures was to obtain a few notes on railroad economics from two of the highest American authorities; and these are presented herewith."[113]

The referenced "authorities" were "Elliot Holbrook, Esq., CE, valuation expert to the Union Pacific Railway System, and Fred Lavis, Esq., CE, consulting engineer to the American International Corporation."[114] Clearly Waddell acknowledged that railroad construction was still taking place across the country and felt that it was important to state that modern conditions called for a new generation of engineers willing to offer their expertise in the still-expanding area of economic theory.

By the time of the writing of Waddell's 1917 text, Fred Lavis had become perhaps the most prominent engineer in the field of railroad economics since Wellington's time. In 1908 he published "Railroad Location Surveys and Estimates," and in 1917 he released an abridged version of the same document entitled "Instructions for Locating Engineers and Field Parties." Although quantity and cost determination aids had been an element

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[113] J. A. L. Waddell, *Engineering Economics*, (Lawrence, Kansas: Engineering Alumni Association, School of Engineering, University of Kansas, 1917), 51.

[114] *Ibid.*

of these two books, the 1917 "Railway Estimates – Design, Quantities and Costs" was Lavis' first publication that chiefly addressed economics. "Railway Estimates" begins with the statement that "the object of [the] book is to present in convenient form data for the use of engineers, called upon to: (1) report on the value of, or estimate the probable cost of, proposed railways, either before or after surveys have been made; (2) estimate the value of existing lines; (3) design the general features of a proposed railway or modify the design of an existing line; (4) determine the value or utility of such features of the general design of railways as affect their cost or value as transportation machines."[115] This reference to "transportation machines" was a key to understanding Lavis' view of the railroad and his approach to its associated economics. In an approach very similar to Wellington's view of a railroad as the "manufacture of transportation," Lavis wrote that "a railroad is a machine, the product of which is transportation. The type of machine which produces the finished article at lowest cost is the most economical."[116]

"Born in Torquay, Devon, England"[117] in 1871 Lavis immigrated to America at the age of sixteen "after attending St. Luke's College."[118] He was soon hired to work as a railroad survey team rod-man in Massachusetts, and by the time he was nineteen he had joined a survey crew in Cuba and learned the duties of transit-man. "After the Cuban

115 F. Lavis, preface to *Railway Estimates Design, Quantities and Costs*, (New York: McGraw-Hill Book Company, Inc. and London: Hill Publishing Co., Ltd., 1917).
116 Waddell, *Engineering Economics*, 52
117 "Fred Lavis is Dead; Rail Authority, 79," *The New York Times*, November 26, 1950.
118 *Ibid*.

venture evaporated in 1892, Lavis sailed to Colombia for the first of many railway jobs that would bring him back again and again to South and Central America."[119]

> "In 1901 Mr. Lavis was engaged … to take charge of the location of various [railway] lines in Oklahoma, Indian Territory and Texas…. From 1905 to 1909 he was resident engineer on the Pennsylvania Railroad's North River tunnels into New York. After 1909 he was in private engineering practice, specializing in South and Central American railroads. He also … was a consulting engineer on construction of the Panama Canal."[120]

By 1914 Lavis had settled in Scarsdale, New York, where he soon became supervisor for the Village Committee on Highways.[121] The American International Corporation, for which Lavis was a consulting engineer during the 1910s, was organized in New York in 1915.

> "The company's charter authorized it to engage in any kind of business, except banking and public utilities, in any country in the world. The stated purpose of the corporation was to develop domestic and foreign enterprises, to extend American activities abroad, and to promote the interests of American and foreign bankers, business and engineering…. The original idea was generated by … international railroad contractors who 'were convinced there was not much more railroad building to be done in the United States'."[122]

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[119] Steven Hart, *The Last Three Miles*, (New York: The New Press, 2007), 59.

[120] Lavis obituary

[121] "South Scarsdale Civic Ass'n Hears Village Officials," *Scarsdale Inquirer*, Number 43, October 25, 1916, accessed March 6, 2019 at https://news.hrvh.org.

[122] Anthony C. Stutton. "Wall Street and the Bolshevik Revolution", 2001 from Solar General website; Chapter VIII – 120 Broadway, New York City, accessed March 6, 2019. (http://www.bibliotecapleyades.net/sociopolitica/bolshevik_revolution/chapter_08.htm).

Lavis' work with this organization saw him building railroads in such far-away places as Spain, Italy and China in addition to his extensive ongoing activity in Central and South America.

Latin America began a shift toward significant growth in the second half of the 19th century as many countries began to both export and import more goods to and from the United States and Europe. "In many Latin American economies the construction of railway networks was one of the most important bases of the economic expansion of 1870-1913…. The first railway line in the region was open in Cuba in 1837…. [Cuba] would not be joined by any other Latin American economy until the 1850s, when railway construction started in Argentina, Brazil, Mexico, Peru, Colombia and Chile. By 1900, the railways were already present in all countries of the region"[123] and overall mileage in the region nearly tripled between 1880 and 1912. Lavis was one of the engineers who played a key role not only in the construction of these railroads but also in encouraging increased American investment in these lines. He became a consultant to the International Railways of Central America in 1911 and was later (beginning in 1928) the president and director of that organization.[124] During his first three decades in the United States Lavis had become extremely knowledgeable in the layout and design of railroads, a vocal advocate for railroad construction, and a major proponent of economic railroad analysis. By 1917 he was, as the cover page of his "Railway Estimates"

[123] Alfonso Herranz-Loncan, "The Contribution of Railways to Economic Growth in Latin America before 1914: a Growth Accounting Approach," Universitat de Barcelona, no date, accessed March 6, 2019 at http://www.ub.edu/histeco/pdf/herranz-DT01.pdf.

[124] "Mr. Lavis, President of Central American Railways," *Scarsdale Inquirer*, Number 51, November 9, 1928. Accessed March 6, 2019 at https://news.hrvh.org/.

illustrates, a member of both the American Society of Civil Engineers and the American Railway Engineering Association, and a Special Lecturer in Railway Engineering at Yale University. His work with the American International Corporation saw him "specializing in transportation practice and economics."[125]

One man whose work would later merge with that of Lavis was fellow railroad engineer, Sigvald Johannesson, who was

> "born in Copenhagen, Denmark [in 1877 and] graduated from the University of Copenhagen with a degree of civil engineer. For three years he was an engineer for the London Underground before going to New York, where he became a member of the engineering staff of the Pennsylvania Railroad during the building of the Hudson River tubes. An assistant also in construction of the tunnels for the Hudson and Manhattan Railroad, Mr. Johannesson was a member of the technical staff of the Interborough Rapid Transit Company."[126]

The Pennsylvania Railroad constructed its tunnels under the Hudson River between 1904 and 1908 to permit trains to reach Manhattan from New Jersey for the first time. The engineering organization required for the design and construction of this massive undertaking was understandably large. "Mr. Rea, Vice-President, [had] general charge of all matters involved in the designing and execution of the project…. Before the beginning of the work, the Management appointed a Board of Engineers … to pass upon the practicality of the undertaking; to determine upon the best plans for carrying it out; to make a careful estimate of its cost; and, if the work was undertaken, to exercise

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125 *Ibid*.

126 "S. Johannesson, 75, a Civil Engineer," *New York Times*, February 23, 1953.

general supervision over its construction."[127] Several professionals were designated to assist the Board in key areas of expertise. For example, "Mr. William R. Mead, of the firm of McKim, Mead, and White, Architects for the Terminal Station, was associated with the Board for the consideration of architectural subjects. S. Johannesson, Assoc. M. Am. Soc. C. E., was Engineer Assistant to the Chairman from December 1st, 1905, to April 30th, 1909."[128] The construction project "was divided into three parts, each managed by a resident engineer: the 'Terminal Station' in Manhattan, the 'River Tunnels' east from the Weehawken Shaft and under the Hudson River, and the Bergen Hill tunnels."[129] "The Bergen Hill Tunnels [was] under the charge of F. Lavis, M. Am. Soc. C. E., Resident Engineer, including the rock tunnels from the Weehawken Shaft to the Hackensack Portal on the west side of the Palisades, all in New Jersey."[130]

The Hudson and Manhattan Railroad had originally planned to tunnel under the Hudson River as early as 1874 but technology had to "catch up" before those plans could be realized. Construction began in 1890, soon stopped due to lack of adequate funding, and began again in 1900. Due to several deadly accidents and difficulties with tunneling methodology the work was undertaken in installments over the coming years with the uptown and downtown tunnels finally completed in 1906 and 1909, respectively. The most significant engineering accomplishment associated with the construction of the Hudson and Manhattan (now Port Authority Trans Hudson, or PATH) Tunnels was the

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127 "Transactions of the American Society of Civil Engineers," Volume LXVIII, September 1910, New York: Published by the Society, 16.

128 *Ibid.*, 17

129 "North River Tunnels," accessed March 6, 2019, https://en.wikipedia.org/wiki/North_River_Tunnels.

130 "Transactions of the American Society of Civil Engineers," 44.

use of the "tubular cast iron method" of tunneling that utilized a shield to push through the silty river bottom and a chamber to hold mud for transport to the surface.[131] In 1922, Johannesson co-wrote a book entitled "Shield and Compressed Air Tunneling" that provided data from the Hudson and Manhattan project as well as extensive information from the experience obtained during the Pennsylvania Railroad tunnel construction. Acknowledging that shielded tunneling had been in use for several decades by the time of the writing, the authors noted that "the Pennsylvania Railroad Company, through Samuel Rea, President, [had] authorized the publication of the important facts in connection with its Hudson River tunnels,"[132] and the preface of the book indicated that its intent was to establish standards for future construction based primarily on the two New York projects.

By the 1920s, Lavis' vast experience around the globe would ensure that his was truly the "voice of experience" in matters pertaining to railway design and construction, and that other engineers would listen to him in matters applying to the soon-to-be established field of roadway economics. Although Johannesson was not yet the notable figure in the engineering community, or the established author, that Lavis had already become, he certainly also had valuable proficiency in railroad design that would mesh well with Lavis' work "in the field" when their paths crossed again in New Jersey.

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131 "PATH (rail system)," accessed March 6, 2019, https://en.wikipedia.org/wiki/PATH_(rail_system).

132 B. H. M. Hewett and S. Johannesson, preface to *Shield and Compressed Air Tunneling*, (New York and London: McGraw-Hill Book Company, Inc. in New York and London, 1922).

Seeking Roadway Economics

Early Roadway Development

The earliest roads in America were simple trails used by people and animals, and routes were formed primarily as a means of connecting or establishing new areas of settlement, and to facilitate the transport of goods, passengers and the mail. Some of the early settlement roads, such as the Albany and Boston Post Roads, were formed in the late 1600s and early 1700s, and a number of major mail routes, such as the Pony Express Route, were established in the mid-1800s. Despite improvements brought about by the Industrial Revolution, during the closing decades of the 19th century, roads throughout the nation, particularly those within rural areas, were crude and generally made of dirt or gravel. They became dusty in dry weather and muddy in wet weather making them barely passable at many times of the year for even the limited traffic that utilized them. The introduction of bicycles to the public led to the establishment of the Good Roads Movement in the 1890s and, as the nation's population grew and urban areas expanded, Americans began to see the need for better roads – even if initially only for use by cyclists. The earliest Good Roads efforts were focused on education to aid in road building, primarily in rural areas of the country, but this work gradually led to progress in other fields as well. The work of these advocates prompted the 1893 creation of the Federal Office of Road Inquiry; the Office's road construction programs formed the basis of its emphasis on the education of both the public and the government.

As public officials and American citizens began to pay greater attention to road conditions, it was the State of New Jersey that led the nation in the establishment of funding for road construction and the development of a state highway planning agency. The first State Aid Road Act in the nation was enacted by New Jersey in 1891, and by the early 1900s New Jersey provided more money for the improvement of highways than all other existing state highway departments combined. During World War I the damaging impact of defense traffic on domestic highways, the inability of railroads to meet the nation's transport requirements, and the growing importance of the trucking industry led to a turning point in the American peoples' perceptions about roads. Inadequate road conditions and insufficient funding and planning mechanisms became obvious; not only did existing roads desperately need improvement, but the continually expanding population needed more and more roads. It also quickly became clear that governmental involvement was needed to deal with the issue of United States roadways. "In 1909 … the Michigan highway department laid the first mile of concrete pavement on a road in Wayne county. This proved that highway paving was possible, but the expense was more than many states could handle alone."[133] Over the next few years, Good Roads organizations sprang up across the country and "business owners and civic organizations banded together to improve their existing roads and promote local road travel between their towns. Eventually there were about 250 of these Good Roads highways, though most remained dirt, or at best dirt-and-gravel…. Over time, the crush

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[133] "Good Roads Movement," *Encyclopaedia Britannica*, accessed March 6, 2019, http://www.britannica.com/topic/Good-Roads-movement.

of traffic and deepening mud turned public reluctance to be taxed for road paving into an overwhelming push for better roads."[134] When the first Federal Aid Road Act was passed in 1916 it put the mechanism in place for the funding of road construction at the federal level. This act clearly reflected the thinking behind and wording of its predecessor, the New Jersey Road Bill of 1891.

By the early 1920s engineers had begun seriously considering the need for highway design utilizing economic theory. Most American roads had originally been based on pioneer trails, the locations of which had changed little over time. Roadway routes were firmly set, as were the social concepts of how road design and funding should take place. "Critical roads were solely the responsibility of the most local of jurisdictions. They were typically created … and maintained, if at all, by 'statutory labor' under haphazard supervision. Neither state nor national governments took part in road affairs beyond chartering, and occasionally helping to finance, a few favored private turnpikes."[135] Some of the primary factors that had originally influenced roadway location had been cost, existing laws, the placement of existing centers of population, and the transportation needs of the public, and there had been a relative lack of improvement in highway location practice over time. "Roads [had] grown up from the pioneer trails with but small regard to the possibilities of location to accommodate more than the traffic of the day…. Small use of the science of highway location ha[d]

[134] *Ibid.*

[135] "Pioneers of Transportation," *Institute of Transportation Engineers*, Publication No. LP-673, February 2011.

been made;… it [had] been found well nigh impossible to abandon the old road[s] and the projection of new roads… [had] been retarded by laws protecting the established order."[136]

United States road building throughout history had been based primarily on cost, and work had generally been funded through some form of taxation. It had long been fundamental to roadway development that any new or improved construction being proposed did not cost more than the benefits that could be realized upon completion of a given project. In the 1920s the American Association of State Highway Officials had stated that "no road should be improved by expenditure of funds in excess of its earning capacity. The return to the public in the form of economic transportation is the sole measure of this justification for the degree of improvement."[137] Founded in 1914 as an organization for setting standards for national highway design and construction, the Association was the primary link between the federal government and the state transportation departments. Originally established as a cross-organizational dispenser of information for the use of state and local highway engineers, the Association became the national policy maker when the passage of the 1916 aid act required adherence to Association standards as a prerequisite for receiving funds. As the agency to which all of the country's highway officials turned for guidance, its statement about roadway improvement was generally understood to be valid; however, some writers of the decade

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[136] C. R. Thomas, "Notes on Economic Highway Location," *Highway Engineer and Contractor*, Volume 35, (1929), 44.

[137] *Ibid.*, 42

also recognized that the time had come for a different way in which to measure the described – and perceived - benefits. The economic gains to be considered included tangible ones, such as savings in construction and operation costs, and gains in time and convenience. There were also intangible benefits to weigh, such as "appreciation on real estate value,… reduced cost of merchandise and produce due to lowered transportation costs, [and extended] range and ease of travel."[138] All of these items were worthy of analysis in design and planning; however, many planners were uncertain as to how to affect changes in engineering practice.

The Need for Roadway Economic Theory

Prior to the start of the 20th century engineers coming from the railroad community had provided the only source of economic analysis. Since the publication of Arthur Mellen Wellington's "Economic Theory of the Location of Railways" and even, to a certain extent, prior to that time, railroad engineers had been aware of the value of economic analyses in the establishment of rail routes and the design of rail infrastructure. Although his efforts were primarily in the area of bridges and other structures, following in Wellington's footsteps, John Alexander Low Waddell was an advocate of an economic design theory, defining economics as the means of obtaining one's goals while absolutely limiting one's expenses. He advised young engineers that "the determination of the best possible layout for any proposed structure [was] … truly an economic

[138] *Ibid.*

problem.... The general idea that the best possible layout [was] one which makes the first cost of a structure a minimum [was] a fallacy."[139] However, even Waddell and his fellow early-20th century engineers did not actually provide a means of performing the thorough economic analysis necessary to the design and construction of the emerging modern highway bridge or roadway. Even by the 1920s the forward thinking highway engineer still needed to turn to the extensive economic research and writings of his railway engineering predecessors, and to develop some procedures of his own.

The definition of an economic theory for roads took time to develop. Despite the fact that designers were beginning to interpret highway location in terms of economic feasibility, most continued to speak and write in only very general terms. Consideration was given to the comparison of possible variations in alignment and their feasibility over different types of terrain and for various types of vehicles. However, no publication yet provided financially based methods indicating how designers should perform their analyses. Even as motor vehicle volume rapidly increased many American engineers continued to believe that vehicular traffic was not and never would be the primary means of transport in the country. For that reason, some writers of the time did not believe that exhaustive economic design was always justifiable. While some authors recognized the need for a more systematic and scientific approach to highway engineering, others believed that designers should temper economic study and comparison with the likelihood that automobile and truck traffic would not prove to be

139 Wellington, *Economic Theory of the Location of Railways*, 116.

critical to the nation or ever offer serious competition to long distance railroad transport.

Despite concern by some in the United States over the hesitancy to utilize modern roadway planning methods and commit to the widespread use of economic theory, other planners wrote strongly in its defense. In 1923, Construction Engineer Orin L. Kipp of the Minnesota State Highway Department presented a paper, published in the *Engineering News Record,* entitled "Economic Study of Highway Design and Location." Kipp recommended the careful accounting of operational vehicle costs using an estimated ten cent per vehicle-mile savings for every section of route length reduced. Kipp also proposed the use of an average two-hundred-fifty day per year operating period and an estimated five percent capitalization rate with which to compute estimated savings. While much of Kipp's analysis was devoted to the cost effects of various pavement types, backed by data obtained from Iowa State Highway Commission Experiment Station studies, the article remains one of the earliest American publications that provided details and actual figures for an economic roadway analysis. Although some other engineering professionals and academics wrote, during the late 1920s, about the need for economic highway design, their published articles of the period remained very general in scope and content. Their discussions focused primarily on cost savings which the use of different types of structural materials, particularly those utilized for roadway surfacing, yielded. Those articles that did focus on the economic aspects of planning and location did not provide sample figures for use in an actual analysis.

The lack of a thorough and scientifically based process continued to be felt and, as no one had yet stepped forward to take Wellington's place on the highway side, the call for such a person became louder. In the February 20, 1920 edition of *Engineering and Contracting* an unsigned article called attention to what the author perceived as a major difficulty in the establishment of a theory of roadway location:

> "If one company owned and maintained the railway tracks and if another company owned and operated the rolling stock, it is evident that the track would not be maintained by the first company in a manner satisfactory to the second company. In general, when two or more organizations co-act in effecting a result, without a common directive head having power to co-ordinate their actions, there is invariably failure to secure the maximum of economy. A striking instance that falls within this generalization is transportation over roads and streets."[140]

This arrangement, combined with the facts that the public did not always pay for roadway improvements readily and that engineers did not always have sufficient power to assure that the most economic designs were utilized, made for an extremely difficult situation. Regardless, the author made it very clear that some means of addressing the need must be found. In the interim, and until an equivalent roadway theory was forthcoming, he advised all engineers to familiarize themselves with Wellington's work, saying: "Saturate your mind with Wellington's data and you will realize not only what a dearth of corresponding information exists in the highway field, but what a great handicap this lack of information places upon highway engineers."[141]

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[140] "Motor Vehicle Operating Cost Essential in Designing Economic Highways," *Engineering and Contracting*, Vol. LIII, No. 5, February 20, 1920, 113.

[141] *Ibid.*, 114

In the edition of *Engineering News-Record* published only the previous day, Supervising Engineer of the North Carolina State Highway Commission, George F. Syme offered an article entitled "Need for Economic Location of Highways – Let Highway Locators Follow Railroad Principle – 'Make Cost Per Ton-Mile a Minimum,' Is Engineer's Appeal." A brief editorial in the same publication stated emphatically that

> "all engineers interested in highway work will, we are sure, be fully in accord with Mr. Syme … in his plea for some competent authority to give us a practical treatise on "The Theory and Practice of Highway Location." What is needed is another Wellington to do for the rising field of highway transportation what that great authority did for railway location in the seventies. Possibly it is too much to hope for a work of authority at this comparatively early date in motor-truck transportation…. Possibly we are too hopeful in wishing for a Wellington at this date, but eventually some one with his masterful mind must do for the highways what he did for the railways."[142]

Syme's comments hailed the continuing increase in rail traffic in the country that he saw as being due, in large part, to the highly efficient design of railroads by highly talented engineers. He stated that "the development of the highway and of the railway are absolutely synonymous, both being based upon the same underlying principles – to move maximum tonnage at minimum expense, with a minimum initial construction cost."[143] While Syme expressed concerns, he also stated that the possibility of developing a workable economic theory was doable. He recommended cooperation between the Bureau of Public Roads and the state highway departments as the

142 "Economics of Highway Location," *Engineering News-Record*, Volume 84, Number 8, 354.
143 "Need for Economic Location of Highways," 383.

appropriate starting point for the required research, data compilation and presentation of such material.

Syme's article prompted the publication, only a month thereafter, of a responding article by Economics Engineer, Robert C. Barnett of Kansas City, Missouri, urging that "the present day need for an economic theory of highway transportation is so urgent that construction work might better be held in abeyance than that time be lost in developing and perfecting such a theory." While Barnett was clearly concerned that money was being spent for infrastructure improvements that might well prove to be far from cost efficient, his article indicated that the development of a necessary theory might not be as far away as some might think. He stated that defining the need and the associated factors for study could be readily completed at the present time and that the establishment of relationships between factors and objectives would require additional data, but that pulling all of the pieces together into an economic analysis was not beyond the capabilities of many working engineers. He concurred with Syme's call for a joint committee to undertake the necessary research but added that the data thus obtained should "primarily be for the use … in furthering the development of an economic theory, yet the data should be made available as rapidly as possible to the engineering profession, in order to stimulate interest in the goal to be attained and to induce others also to undertake the work of analysis and deduction."[144]

In spite of the earlier calls for work on the part of the Bureau of Public Roads (formerly the Office of Road Inquiry) to take the lead in doing the research necessary to

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[144] "Economics of Highway Transport," *Engineering News-Record*, Volume 84, Number 13, 641.

develop a highway location theory, it was clear by 1922 that significant work had not yet been undertaken. An article entitled "Some Unsolved Problems in Highway Economics" by H. S. Fairbanks, Senior Highway Engineer with the Bureau, appeared in *Good Roads* magazine explaining that extensive progress had been made in studying roadway design and the physical properties of pavements, "but [that] even more important than some of the physical problems are those of an economic nature which condition the character of the physical construction. Before any highway at all can be built these problems must be faced, and by far the majority of considerations influencing the location and type of road are economic and not physical considerations." [145] However, despite the apparently slow start it was finally true that more focused research efforts were beginning. "Research in transportation was initiated in the [National Research Council] Division of Engineering's Committee on Highway Research in 1919 to assist in coordinating a program of research begun for the new US Bureau of Public Roads. A year later new committees on the economic theory of highway improvement and on the character and use of road materials led to the organization of the Research Council's Highway Advisory Board."[146]

The Council, in July of 1921, formally announced that the newly formed board for highway research would be directed by Purdue Professor William Kendrick Hatt[147] and included numerous cooperating organizations, state highway departments and

145 "Some Unsolved Problems in Highway Economics," *Good Roads*, January 4, 1922, 8.
146 Rexmond C. Cochrane, The National Academy of Sciences – The First Hundred Years 1863-1963, (Washington, D. C.: National Academy of Sciences, 1978), 259.
147 "Road Research," *Engineering News-Record*, Volume 87, Number 4, July 28, 1921, 132.

universities. As of the date of the announcement it was stated that "three technical committees [had] been at work for a number of months on economic theory of highway improvement [under] Prof. T. R. Agg, Iowa State College, chairman."[148] Professor Hatt authored a follow-up article that appeared the following September outlining the planned approach of the research program, noting in his tentative outline that the area of economics would cover the topics of traffic studies, community needs, cost of transport, financing, highway valuation – and economics of location – the latter category to address the cost of distance, rise and fall, curvature, ruling grade and ruling curve. Hatt stated that

> "[t]here is apparently a widespread activity in highway research throughout the United States on the part of the US Bureau of Public Roads, the US Army, the state highway commissions, the universities and industrial organizations and an earnest desire to put highway construction on a scientific basis. The economic features are under critical examination by such organizations as the National Chamber of Commerce. We should be able to express qualitatively the results of a standardized economic survey of a road project, just as in the case of a water-power project, for instance, except for those imponderables, which, like social betterment and public policy, influence the conclusions so profoundly. It is not too much to say that the situation is critical, and that the sooner those interested come to a basis of fact, the more assurance we will have that the public will not interrupt progress in providing for highway transport because of a general feeling of insecurity."[149]

[148] "To Co-ordinate Highway Research Work," *Engineering News-Record*, Volume 87, Number 4, July 28, 1921, 164.

[149] "Outline of Highway Research Program," *Engineering News-Record*, Volume 87, Number 11, September 15, 1921, 451.

Hatt's new group was officially named the National Advisory Board on Highway Research and reorganized as the Highway Research Board in 1925. While it was originally established primarily for compiling and sharing information, by the mid-20th century it became involved in actually commissioning research, and is now known as the Transportation Research Board. Although the establishment of the board was encouraging, as an entity that, in its original form, did not actually perform research activities, the best that it could do in the 1920s was to urge others to develop an actual workable theory of roadway economics.

As was discussed at the second annual meeting of the Advisory Board (held on November 23, 1922), the purpose of the committee on economic theory was the "determination of all elements of cost of highway transportation (both motor vehicle and animal drawn), and the effect upon each cost element of each feature of highway improvement (improved surface, grade reduction, elimination of rise and fall, etc.) to enable reliable and scientific determination of the sums which could be economically expended for scientific highway improvement."[150] In this effort, the committee, noted that

> "The following will suggest the type of research involved:
> A. Effect of grades, alignment, rise and fall, weather and speed and methods of operation on cost of transport.
> B. Determination of all of the elements entering into the resistance to translation of vehicles (tractive resistance) and magnitude of each element.

[150] "Bulletin of the National Research Council Proceedings of the Second Annual Meeting of the Advisory Board on Highway Research, Division of Engineering, National Research Council," Volume 6, Part 1, Number 32, May, 1923, 4.

C. Determination of the elements of cost of vehicle transportation classes as capital costs, and operating costs exclusive of those included in A and B.
D. To determine the relation between traffic and capital and maintenance costs of roads."[151]

Professor Agg's committee report for the year described the varying degrees of progress made in the prior year in each of the research areas, with the most significant efforts having been made in the study of grades and resistance thanks to work performed at Iowa State College. In 1904 the college had established both the Iowa State Highway Commission and the "nation's premier Engineering Experiment Station – the first research agency organized in an engineering school. The purpose of the experiment station was to support faculty research in the emerging areas of science and technology, and then transfer the results to the state's industries."[152] Over the decades that followed, the Experiment Station played a large and critical role in work that aided not only the college's faculty and the state's industries but also the nation as a whole.

Despite the efforts undertaken in some areas of the planned research, Agg's 1922 remarks also indicated that "no progress [had] been made on the project for the establishment of capital and operating costs for vehicles and for highways. The data relative thereto [were] so widely scattered and so fragmentary that it [would] require another year to secure enough information to justify a progress report."[153] Furthermore,

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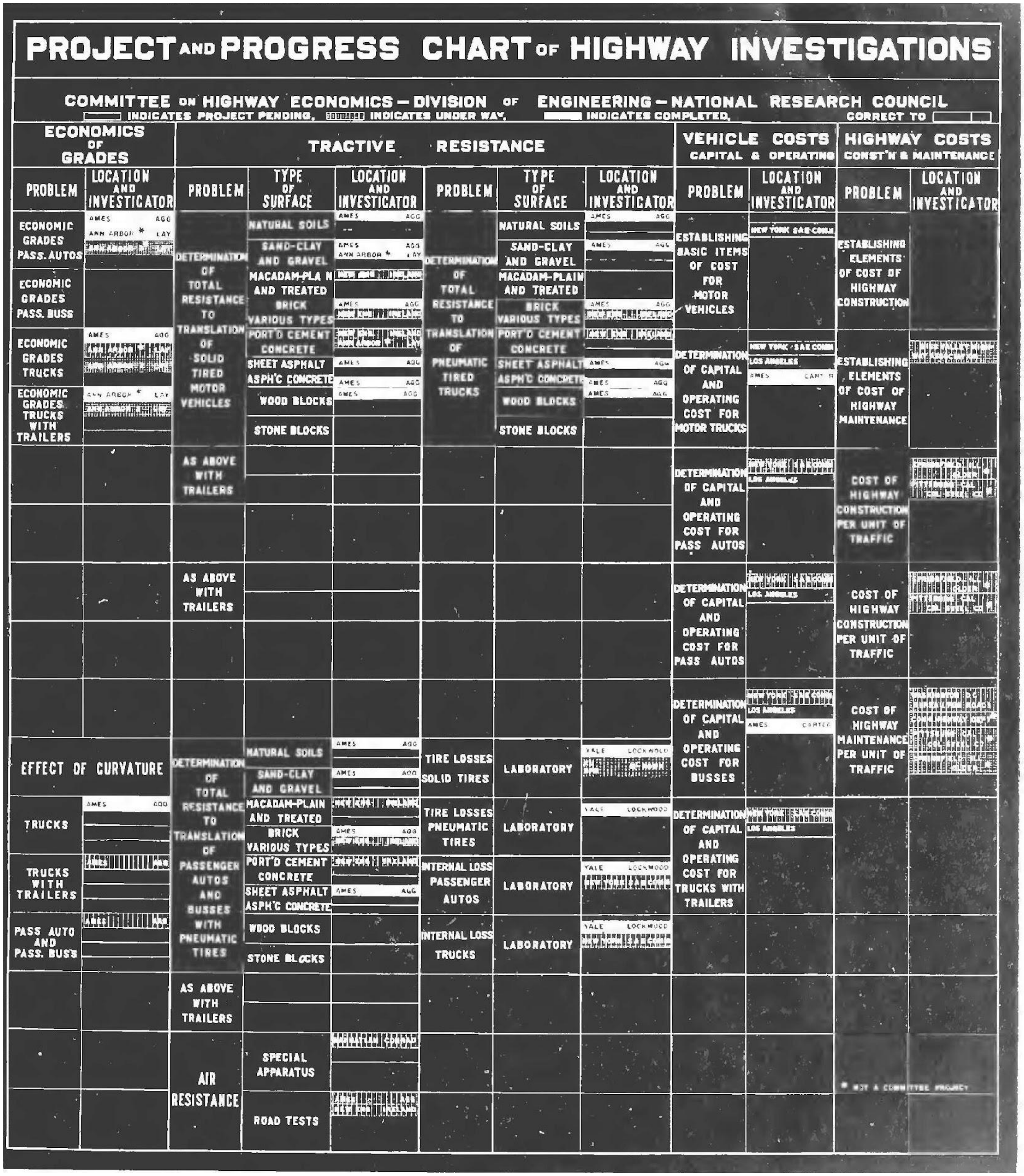
[151] *Ibid.*, 11

[152] CIRAS History, Iowa State University, accessed March 6, 2019, http://www.ciras.iastate.edu/history.asp.

[153] "Bulletin of the National Research Council Proceedings of the Second Annual Meeting of the Advisory Board on Highway Research, Division of Engineering, National Research Council," Volume 6, Part 1, Number 32, May, 1923, 31.

he called particular attention to the fact that recognizing the need for research was simpler than actually performing research and that, while many men working in the highway field had volunteered their efforts on behalf of the committee, it remained critical that a central organization both call attention to – and fund – the needed investigations if real progress were to be made. During the following year, progress was made as evidenced by the chart that Agg presented at the Advisory Board's third annual meeting. Although the material that had been published and was being prepared for publication was greatly appreciated by the highway engineering community, it was clear that the effort involved in the development of a cohesive roadway economic theory was enormous and would not be completed in the immediate future.



Project and Progress Chart of Highway Investigations[154]

[154] "Proceedings of the Third Annual Meeting of the Advisory Board on Highway Research, Division of Engineering, National Research Council," Volume 8, Part 1, Number 43, March 1924, 32A.

Roadway Economics Goes to College

In addition to efforts on the part of professionals to develop a workable theory of roadway economics along the lines of Wellington's railway economic theory, there was an emerging interest, in the early 1900s, in providing adequate education in the area of economics within standard engineering curricula. In actuality, the focus was not just on adequate economic education, but on adequate engineering education in general. Before the Civil War, "engineering" education mainly meant young men learning the practices of the field through apprenticeship with working engineers. Little technical knowledge was imparted in that process as the main goal was to train men to be able to deal with the practical needs of the world in which they worked. Then in 1862 Congress passed the Morrill Land-Grant Act to provide states with money for the establishment of institutions of higher education.

> "Officially titled 'An Act Donating Public Lands to the Several States and Territories which may provide Colleges for the Benefit of Agriculture and the Mechanic Arts,' the Morrill Act provided each state with 30,000 acres of Federal land for each member in their Congressional delegation. The land was then sold by the states and the proceeds used to fund public colleges that focused in agriculture and the mechanical arts."[155]

Three purposes "were embodied in the legislation: (1) a protest against the dominance of the classics in higher education; (2) a desire to develop at the college level instruction relating to the practical realities of an agricultural and industrial society; and (3) an

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[155] "Primary Documents in American History – Morrill Act," accessed March 6, 2019, https://www.loc.gov/rr/program/bib/ourdocs/Morrill.html.

attempt to offer to those belonging to the industrial classes preparation for the 'professions of life.'"[156] While the early emphasis was mainly on agricultural training and home economics, as the need for greater access to scientific fields increased, these institutions also became major centers of engineering education. In fact,

> "engineering became a key component of land-grant universities. As this occurred, … drawing and shop classes were reduced as the 'mechanic arts' of the Morrill Act were redefined to more closely resemble modern-day engineering. Economics replaced history and political science as the preferred social science of engineers foreshadowing the synergy between engineering and industry that became manifest in the following century." [157]

The land grant legislation was named after its primary sponsor, Justin Smith Morrill, Congressman from Vermont. Despite no consistent precedent at the time for the federal funding of higher education, and opposition from the Southern states due to concerns with increased federal control over the states, after half a dozen years of working toward the passage of such an act, Morrill and his compatriots finally succeeded when Lincoln signed their bill in 1862. "The bulk of Justin Morrill's defense of his act revolved around the issues of fair democratic access to higher education and the benefit the Union would receive from such support of agriculture … [at a time when] classical colleges were educating only a small percentage of the nation's youth and still were providing far more graduates than the nation could use."[158]

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[156] *The Land-Grant Tradition*, copyright Association of Public and Land-Grant Universities, Washington, DC, 2012, 4.

[157] Daniel E. Williams, "Morrill Act's Contribution to Engineering's Foundation," *The Bent of Tau Beta Pi*, Spring 2009, 19-20.

[158] Williams, "Morrill Act's Contribution", 18

Unfortunately, "in most of the fields in which these [land-grant] colleges [gave] training … there was not in 1862 an organized body of scientific knowledge sufficient to furnish working material for courses such as higher institutions are expected to give."[159] Even as engineering programs – often only teaching at the equivalent of a current high school level - began to arise, they were far from standardized, concentrated heavily on mathematics, and essentially consisted of vocational (or practical) work preparation.

> "Graduates were expected to join the work force immediately, and professors were expected to have industrial experience…. Starting in the 1880s and moving forward there was a shift away from shops and hands on careers and a move toward higher education. This meant the inclusion of more science and math into engineering curriculum…. Some universities such as Columbia and Harvard changed slowly, while keeping a balance between theory and practice. Engineering faculty believed that students needed to know *why* things worked as much as *how* they worked…. [However], industrial employers were seeking graduates who could start working on projects right away after being hired. Therefore, practical knowledge continued to matter as much, if not more than science…. It was not until the turn of the century that the emphasis on practice over theory started to shift."[160]

As the need for well-trained engineers continued to be felt an organization called the Society for the Promotion of Engineering Education was founded approximately thirty years after the passage of the Morrill Act (in 1893). Despite the best intentions of the land-grant colleges and other institutions of higher learning prior to the start of the 20th century, graduates still "often lacked grounding in … science and engineering principles

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[159] Benj. F. Andrews, "The Land Grant of 1862 and the Land-Grant Colleges," *Department of the Interior Bureau of Education Bulletin 1918, No. 13*, (Washington, D. C.: Government Printing Office, 1918), 5.

[160] Marjaneh Issapour and Keith Sheppard, "Evolution of American Engineering Education," paper for the Conference for Industry and Education Collaboration, *American Society for Engineering Education*, Session ETD-315, 2015.

… [and] professors of engineering began to question whether they should adopt a more rigorous approach to teaching the fundamentals of their field. Ultimately, they concluded that engineering curricula should stress fundamental scientific and mathematical principles, not hands-on apprenticeship experiences."[161] The establishment of the federal aid highway program in 1916 finally focused the profession and the educational establishment on the "urgent need to apply scientific principles to the building of roads suitable for automobile travel…. With the exception of traditional civil engineering surveying and earthwork practices, there was little reference or education material available on the engineering principles involved in building highways,"[162] and the need for such material – and for engineers trained on such material - was now keenly felt.

Former Columbia University Professor William H. Burr authored a lengthy article in the July 14, 1921 *Engineering News-Record* entitled "Engineering Courses Should be of Professional Grade." Despite the shift, during the previous two decades, toward a more science-based engineering educational system, and in spite of the efforts of the Society for the Promotion of Engineering Education, Burr was emphatic in stating that professional engineers of the time felt a general lack of public appreciation

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[161] "ASEE at 120," American Society for Engineering Education, accessed March 6, 2019, https://www.asee.org/about-us/the-organization/our-history.

[162] Kumares C. Sinha, Darcy Bullock, Chris T. Hendrickson, Herbert S. Levinson, Richard W. Lyles, A. Essam Radwan, and Zongzhi Li, "Development of Transportation Engineering Research, Education, and Practice in a Changing Civil Engineering World, an American Society of Civil Engineers 150th Anniversary Paper," *Journal of Transportation Engineering*, July/August 2002, 308.

of their status as professionals due, in his mind, to the inadequate and inconsistent level of training available across the country. He noted that

> "doubtless much [could] be done to relieve this situation among experienced practitioners, but the greatest influence [was] that which [could] be exerted through suitable and effective professional educational training. If the Society for the Promotion of Engineering Education had had as a body a true vision as to what it could and should have done in developing wholesome and effective ideas of engineering education, it is not unreasonable to suppose that the present unsatisfactory and disappointing condition of the profession could have been prevented. This was the proper mission of this society and it [had] failed fundamentally in it."[163]

Apparently, Burr was not the only educator who believed that the Society had failed. In a 1922 edition of the *Engineering Education* bulletin, Society president Professor Charles F. Scott quoted a letter that had been submitted in response to a request for input on the organization taking "an active leadership in the larger development of engineering education. [The writer said that] I believe the Society for the Promotion of Engineering Education is incapable of assuming an active leadership. It seems to me that we must look to the engineers in practice and not to the teachers for any very far-reaching work on this problem."[164]

Visibly the problem was not only with the lack of a theory and education related to engineering economics, but a more deeply rooted one of how the young engineers who would have to design and build the nation's ever expanding system of roadways

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163 Wm. H. Burr, "Engineering Courses Should be of Professional Grade," *Engineering News-Record*, Volume 87, Number 2, July 14, 1921, 65.

164 "Engineering Education," *Bulletin of the Society for the Promotion of Engineering Education,* Volume XII, Number 8, April 1922, 330.

were learning even the basics of their profession. The public discussion relating to the improvement of the type and quality of engineering education in the United States followed a path alongside that related specifically to the need for improved highway engineering education – including highway economics training. It remained to be seen whether educators – or organizations – or working engineers would solve these problems associated with training and theory. Many American engineering schools continued, well into the 1920s, to focus their transportation-related courses on railroads rather than highways. However, some schools began to step forward as "during the first part of the [20th] century, state highway departments [began] to team up with local universities."[165]

Not surprisingly, Iowa State College was again at the forefront in this effort when it introduced economics into its engineering program in 1913. Not only did the college's four-year course in civil engineering include a class in railway economics but the five-year program added a course entitled engineering economics.[166] A few years later, the University of Michigan followed suit when it first announced the addition of "Civil Engineering 41: Highway Engineering Economics and Theory" in the 1919 to 1920 class year.[167] As a means of ensuring that a wide audience was made aware of the new short course offering, the university's class information was even published in the

165 Kumares C. Sinha, et al., "Development", 309

166 "Official Publication of Iowa State College of Agriculture and Mechanic Arts, Admission and Courses of Instruction," Volume XII, Number 19, November 20, 1913.

167 "Special Announcement of Courses in Highway Engineering and Highway Transport 1919-1920," University of Michigan Colleges of Engineering and Architecture, Department of Civil Engineering; Vol. XXI, No. 18, December 20, 1919.

August 12, 1920 *Engineering News-Record*.[168] The new class offerings were further "advertised" when they formed the primary emphasis of an article in the November 1919 *Highway Engineer and Contractor* entitled "Highway Engineering and Transport Education."[169] While the course listing itself said extremely little about the actual economic content of the course, the very existence of the class illustrated the school's understanding that economics was an important element of highway engineering design. By the 1925 to 1926 class year the university was offering advanced courses entitled "Civil Engineering 67: Highway Transport Economics and Surveys," "Civil Engineering 77: Highway Engineering Financing, Management and Organization," and "Civil Engineering 82: Highway Transport Costs and Record Systems."[170] These three classes taught students methods for estimating traffic volumes, capacities and time losses; means for locating highways and designing curves and grades; and ways to handle financial matters from the perspective of both contractors and highway departments.

Despite the introduction of not only highway engineering classes but even some very basic courses related to economics into engineering curricula, some schools were still "on the fence." For example, in the class year 1920-1921, the University of Maryland's civil engineering program offered a class in Highway Engineering – but still

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168 "Michigan to Give Graduate Short Courses in Highway Subjects," *Engineering News-Record*, Volume 85, Number 7, August 12, 1920, 333.

169 "Highway Engineering and Transport Instruction," *Highway Engineer and Contractor*, November 1919, 31.

170 "Professional Short Period Advanced Courses in Highway Engineering and Highway Transport 1925-1926," University of Michigan College of Engineering, Department of Civil Engineering; Volume XXVII, Number 8, August 22, 1925.

only a class in Railway Economics – both in the senior year.[171] Other schools offered classes in economics but separated them from the strict engineering curriculum. Yale University's Sheffield Scientific School included classes in Railway Engineering and Highway Engineering in its 1921 to 1922 Civil Engineering program but offered its class entitled Engineering Economics in the Administrative Engineering program.[172] Even as the study of "economics" entered mainstream engineering educational programs, the definition of economics varied widely and very often – or perhaps typically - meant only the study of how to obtain construction funding and what entity was responsible for that money. The chapter of a 1915 text source book written by Columbia University's Professor Arthur H. Blanchard that discussed economics spoke only to the general benefit of improved highways and the various means of financing highway construction and maintenance. This limited approach to economics was felt to be sufficient coverage of the subject matter despite the fact that Blanchard's preface indicated that the book was intended as suitable for courses in civil engineering that addressed both fundamentals and modern practice including that in the "rapidly developing" area of economics.[173] Colleges and universities continued to be widely inconsistent in their approach to the need for highway versus railway engineering programs in general and engineering economics classes in particular. Interestingly, as the highway system continued to grow by the 1930s some colleges chose to combine transportation modes in

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171 "Catalog 1920-1921," University of Maryland, Volume 17, Number 1, July 1920, 91.

172 "Catalog of Yale University 1921-1922," 260-261.

173 Arthur H. Blanchard, preface to *Elements of Highway Engineering*, (New York: John Wiley & Sons, Inc., 1915).

offering classes such as the University of Washington's "Highway and Railway Economics."[174] On the other hand, in the same decade, as is illustrated by the University of Missouri's 1935-1936 course catalog, some schools still continued to not only offer separate highway and railway design courses but also failed to incorporate economics into engineering classes at all.[175] In response to this great degree of uncertainty, the call for additional young highway engineers and for greater access to economics education in engineering schools continued to be voiced.

In 1920 the Department of the Interior's Bureau of Education issued a report on "Education for Highway Engineering and Highway Transport" in which the conference committee noted that "whereas the phenomenal development of highway transportation in the United States [had] created a demand for men having knowledge of and training in a new technical field, which may be designated highway transport engineering, [the committee] strongly recommend[ed] that universities and colleges offer courses in highway transport as their facilities [would] permit."[176] The following year the Highway and Highway Transport Education Committee held a conference on the "Economics of Highway Transport." Chairman and Johns Hopkins University Professor, Charles Joseph Tilden called the conference to order by stating that the purpose of the gathering was to obtain assistance from the attendees. He said that

> "the rapid development of motor transport, with increased production of motor vehicles and consequent stimulation of public interest in highways,

[174] Bulletin, University of Washington, College of Engineering, 1934-1935 (p. 24) and 1935-1936 (p. 21).

[175] "Catalog, Announcements, 1935-1936" The University of Missouri Bulletin, Volume 36, Number 7, 299-300.

[176] "Education for Highway Engineering and Highway Transport," Bulletin Number 42, (Washington, D. C.: Department of the Interior, Bureau of Education, 1920), 95.

> [had] raised economic questions difficult to answer. Many of these [had] not as yet been clearly formulated. Technical schools [had] surprisingly few courses bearing on the subject, although it [was] of vital concern to every citizen. We … [ask] you, therefore, to come together … to exchange views and, through discussion, indicate the direction in which educational activity may be started."[177]

Much of the discussion that followed confirmed that conference attendees from the many different represented fields agreed with the need for improved education in the area of both highway design and highway economics but that "much remained unknown." One speaker was Professor of Civil Engineering at the University of Tennessee, Nathan Washington Dougherty, a strong supporter of the Good Roads Movement and later an advocate of the establishment of engineering experiment stations at his school.[178] Dougherty explained that

> "for a number of years [the university had] been giving a short course in Highway Engineering…. About two years ago we decided to undertake an enlargement of our field of instruction by giving some instruction in Highway Economics…. Last year we enlarged the scope of the work and gave a six-week course on what we called Highway Economics and Highway Organizations…. In our study we found a great dearth of reliable cost data. It is doubtful whether anyone knows the exact cost of rise and fall or curvature, or, indeed, many other items which enter into the location and construction of a highway … and … in giving this work we tried to stress the need of accurate data and the further need of a careful study of the whole problem before expending large sums of money."[179]

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177 "Proceedings of a Conference on the Economics of Highway Transport," *Highway and Highway Transport Education Committee*, July 27, 1931, 5.

178 "Nathan Washington Dougherty," The Tennessee Encyclopedia of History and Culture, text copyright 1998, accessed March 6, 2019, http://tennesseeencyclopedia.net/entry.php?rec=394.

179 "Proceedings of a Conference on the Economics of Highway Transport," 19-20.

Plainly both additional data and better knowledge were required to not only advance the field of roadway engineering in general but also to improve engineering education as a whole.

Efforts in the advancement of engineering economics education continued during the following years in parallel with the work being performed specifically toward the advancement of a formalized highway economic theory for practical use. In 1922, Lewis W. McIntyre of the University of Pittsburgh authored a "Preliminary Outline of the Economics of Highway Transport" that was, he said, issued by the Education Committee "as part of their work in furthering Highway Transport Education ... to assist [students] in forming a more definite idea of the field of highway transport [and to] assist teachers of this subject in the formulation of adequate courses."[180] In his tentative course outline, McIntyre included a category on the "economics of location" that included the following topics: "general considerations; minor details of alignment (distance, curvature, rise and fall and their effect on the cost of transportation); ruling gradient and curvature; typical calculations of the effect of these items on operating expenses; justifiable expenditure for their reduction; virtual profile."[181] The primary references he attached to his explanatory remarks on the economics of location were Chapters III, VI, VII, VIII, IX, XVIII and XIX of Wellington's "Economics of Railway Location," indicating that Wellington's basic theory continued to be seen as the example to be followed and that no viable similar roadway theory had yet been established.

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[180] Lewis W. McIntyre, "Preliminary Topical Outline of the Economics of Highway Transport," prepared for the *Highway and Highway Transport Education Committee*, 1922, 3.

[181] McIntyre, "Preliminary Topical Outline", 6

On the Verge of a Roadway Economic Theory

The early decades of the 20th century were a busy time for highway research in the United States. During the First World War the country had overworked its railroads and then increased the production of trucks to help ship materiel. "Hauling record per-vehicle loads of up to 12 tons gross at speeds up to 20 miles an hour, wartime truck traffic reached its peak during the spring thaw of 1918. The nation's primitive but fairly adequate system of roads of gravel, brick, wood, macadam or concrete literally fell apart under the burden."[182] By this time, the country's roads were shared by all sorts of vehicles – automobiles and trucks, bicycles and motorcycles, and – still - horse-drawn carriages and wagons. They were not only in terrible condition; they were also too narrow with sharp curves, and little or no lighting and signage. "Recognizing a national crisis concerning roads, the federal government apportioned $200 million in 1919 to state highways, adding this amount to unspent funds from the first Federal Aid Road Act of 1916. Adequate funds were now available, but highway needs were new, uncharted and immediate."[183] National organizations, state highway organizations, and universities quickly realized that extensive research was needed to address these needs. The 1916 aid act had mandated that "in order to qualify to receive federal funds, states were required to create highway departments run by engineers…. By 1917, all forty-eight

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182 *Transportation Research Board 1920-1995 – 75 Years of Excellence… and IOWA was There From the Beginning*, Iowa Publications Online, 2, accessed March 6, 2019 at: http://publications.iowa.gov/18912/.

183 *Ibid.*

states had a state highway department,"[184] and these entities played a key role in the highway research effort that was underway by the 1920s. The majority of work being performed by the various state highway organizations was related to the subject of greatest concern to the physical construction and maintenance of roadways - materials testing.

The Michigan State Highway Department was the first in the nation to establish a testing laboratory (in 1912).[185] Until 1919, its "studies for the most part included experimental road sections constructed primarily for the purpose of acquiring information to be used in the preparation of specifications and for improving construction methods."[186] Michigan expanded its research capabilities significantly through the 1920s and by 1927 its new "Division of Research and Statistics [was] responsible for the collection and preparation of all data having a bearing on highway problems."[187] The Wisconsin State Highway Commission established its Wisconsin Road School in 1912 to bring "together county highway commissioners, municipal officials, road contractors, machinery manufacturers and others, with the goal of identifying highway construction and maintenance best practices."[188] The Illinois Department of Transportation "pioneer[ed] the scientific study of road design at the

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184 Jeremy F. Plant, editor, *Handbook of Transportation Policy and Administration*, (Boca Raton, London and New York: CRC Press, Taylor & Francis Group, 2007), 123.

185 "Transportation Timeline," Michigan Department of Transportation, accessed March 6, 2019, http://www.michigan.gov/mdot/0,4616,7-151-9623_11154_39107---,00.html.

186 "The Michigan State Highway Research Laboratory – its Facilities, Functions and Activities," Michigan State Highway Department Report No. 132, June 1, 1949, 4.

187 *Ibid.*

188 "History of WisDOT," State of Wisconsin Department of Transportation, accessed March 6, 2019, http://wisconsindot.gov/Pages/about-wisdot/who-we-are/dept-overview/history.aspx.

Bates Experimental Road Project near Springfield in the early 1920s."[189] The "Bates Road" was constructed in a series of sections with the research work consisting of "carefully controlled special investigations bearing on the most important factors involved in the rational design of pavement surfaces … [and] traffic tests for a variety of pavement sections."[190] In 1921, the Washington State Department of Highways created a materials testing laboratory that "conducted physical tests on cement, sand, gravel, and crushed rock, and on paint and steel reinforcing bars…. The physical testing allowed highway engineers to determine in advance what sand and gravel deposits would provide the best road materials … [as well as] which of many patented forms of concrete achieved the best results."[191]

Perhaps not surprisingly, many of the states involved in highway research were also homes to land grant colleges. As was noted in a 1923 Advisory Board on Highway Research report, land grant colleges were "officially established and supported by the government[s] of the state[s] in which [they were] situated … [making it] especially fitting that the land grant college … should cooperate officially and systematically with the State Highway Commission in the same state…. [At the time of the reporting], in 29 of the 48 states highway research [had] been undertaken at the land-grant colleges. In some states … a large number of highway research projects [were] in active progress at

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189 "Transportation Research," Illinois Department of Transportation, accessed March 6, 2019, http://www.idot.illinois.gov/transportation-system/research/index.

190 "Bates Experimental Road or Highway Research in Illinois," Bulletin No. 21, State of Illinois Department of Public Works and Buildings, Division of Highways, January 1924, 4.

191 Kit Oldham, "Division of Highways First Testing Laboratory Opens in the Former Boiler and Coal Rooms of Olympia's Temple of Justice in July 1921," History Link Essay 7236, Free Online Encyclopedia of Washington State History), posted January 28, 2005, accessed March 6, 2019, http://www.historylink.org/index.cfm?DisplayPage=output.cfm&file_id=7236.

each institution."[192] The 1887 federal Hatch Act had mandated and funded the creation of agricultural experiment stations at land grant colleges[193] and, as scientific research needs shifted in the early 20th century, these institutions had established numerous engineering experiment stations as well. Although proponents of strict agricultural and mechanic arts programs prevented the establishment of any federal funding apparatus for the establishment of engineering stations, the stations were ultimately created and funded by the states and colleges, and by 1928 there were thirty-five land grant college engineering experiment stations in existence.[194]

The Association of Land-Grant Colleges stated, during its October 1920 convention, that "the land-grant colleges of many States [were] cooperating actively in [highway] research, in many cases by entering into cooperative research contracts with the United States Bureau of Public Roads. In numerous other cases the land-grant colleges [were] cooperating directly with the State highway commissions."[195] To reinforce this information, a paper written by Iowa State College's Dean of Engineering, Anston Marston, was read at the 1923 meeting by Advisory Board Director Dr. Hatt, stating that the land grant colleges "constitute[d] the greatest single organized agency

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192 "Proceedings of the Third Annual Meeting of the Advisory Board on Highway Research, Division of Engineering, National Research Council," Bulletin of the National Research Council, Vol. 8, Part 1, Number 43, March 1924, 109-110.

193 "History of APLU," Association of Public and Land-Grant Universities, accessed March 6, 2019, http://www.aplu.org/about-us/history-of-aplu/index.html.

194 *Reawakening the Public Research University*, copyright by Renee Beville Flower and Brent M. Haddad, 2014, 224.

195 Proceedings of the Thirty-Fourth Annual Convention of the Association of Land-Grant Colleges, Free Press Printing Company, Burlington, VT, 1921, 273.

for engineering research in the country."[196] Marston offered some remarks about what he believed to be the appropriate mission of the experiment stations.

> "No line of research … could be more fittingly developed at each land-grant college than highway research. The planning, the construction and the maintenance of good roads, their use and economics of highway transportation have the most vital relation to agriculture and to every branch of mechanic arts; in fact, to every line of work for which the land-grant colleges were established…. Upon the initiation of [the] Engineering Experiment Station Committee, the Association of Land-Grant Colleges is now a constituent organization of the Advisory Board on Highway Research, with a personal representative on the Board…. I should say that in my judgment the character of highway research which should be undertaken by the land-grant colleges should be fundamental and theoretical, rather than purely practical in character. For example, I believe that the testing of road materials, to determine their acceptance of rejection, in general should fall to the state highway commissions."[197]

Marston's college and state – Iowa – were probably the busiest in the nation when it came to highway research.

> "When Iowa had fewer than 25 miles of concrete highway … Anson Marston was the mainstay of a movement for a national, coordinated program of highway research…. Due largely to Marston's progressive vision and tireless efforts, the National Advisory Board on Highway Research (later the Highway Research Board) was established in November 1920…. The first dean of engineering at Iowa State College, Marston led the drive to establish the Iowa State Highway Commission in 1904 – the

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196 *Ibid.*, 109

197 "Proceedings of the Third Annual Meeting of the Advisory Board on Highway Research, Division of Engineering, National Research Council," Bulletin of the National Research Council, Vol. 8, Part 1, Number 43, March 1924, 110-111.

> mechanism that … went on to build one of the finest and best maintained state road systems in the nation."[198]

Iowa was the home to several other professors who played key roles in highway research not only within the state itself but in the nation as a whole. Iowa State Professor Roy Crum "became engineer of materials and tests" for the highway commission in 1919 and by 1928 was the director of the Highway Research Board.[199] Chief engineer of the state highway commission and former Marston student, Thomas MacDonald, became the chief of the Bureau of Public Roads in 1919 where he "crusaded for a national program of highway research [and helped the Bureau enter] … into joint research programs with state highway departments and universities."[200] Professor and testing engineer, Thomas R. Agg worked as chair of the American Association of State Highway Officials' Committee on Tests and Investigations. Agg was also instrumental in efforts undertaken by the Highway Research Board, and he "chaired its committee on economic theory of highway improvements from 1919 to 1929."[201] While the various states were hard at work studying their local conditions and needs, national organizations such as those directed by Crum, MacDonald and Agg were key to the coordination of highway research efforts and the dissemination of newly available information. However, obviously national entities could not do all of the required work alone.

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198 *Transportation Research Board 1920-1995*, 4
199 *Ibid.*, 7
200 *Ibid.*, 5
201 *Ibid.*, 6

Many engineers had looked, early on, for guidance from – for example - the Bureau of Public Roads, but the demand was so great that even the Bureau itself viewed solving the deficiencies in the engineering field as beyond its abilities alone. Bureau Chief MacDonald addressed the third annual meeting of the Advisory Board on Highway Research, in November 1923, to stress both the importance of ongoing research and the urgency with which it must be approached. He stated that "the United States [was] carrying on a highway improvement program which, measured in terms of expenditures, approximate[d] a billion dollars annually, [and that] very recently a well-known manufacturer stated that four million new vehicles would be placed on the highways in 1924."[202] He expressed some concern with the ability to handle the highway development and construction problems of the country, emphasizing the immense importance of highway research to achieve that goal and stating that

> "all this [had] occurred without warning and without precedent. The whole development of highway transport [was] in the making, bringing with it hundreds of problems – social, economic and engineering.... In no other development, ancient or modern, affecting in so major a degree the whole structure of our social and economic life has the engineer been given so commanding an opportunity for leadership and for carrying into effect policies formulated by his profession.... Beyond all doubt the ability of the engineer to … lead in a new and major translation in our national life, it will be through research.... The real objective of highway research is the most economical, in every sense of the word, and the most efficient highway transport service possible for the use of the public as a whole.

[202] "Proceedings of the Third Annual Meeting of the Advisory Board on Highway Research, Division of Engineering, National Research Council," Bulletin of the National Research Council, Vol. 8, Part 1, Number 43, March 1924, 105-106.

> The opportunities are unlimited. There is not a single phase in which there is not the necessity for major research."[203]

MacDonald was certainly not alone in his concern. By the 1920s, engineers and educators continued to stress the need for the development of a "Wellington-style" theory for the design of roadways and indeed for detailed research in the fields of highway design and construction in general. Although the establishment of a cohesive economic theory was still in the future, the critical ongoing research associated with the design, construction and maintenance of roadways did include some studies related to the elements that would ultimately comprise roadway economic theory. An article arguing for adequate funding to ensure road longevity based on the type and volume of anticipated traffic was authored by Texas State Highway Engineer, George A. Duran and entitled "The Cost of a Mile of Road." This work appeared in the May 1919 edition of *Highway Engineer and Contractor* magazine and offered extensive documentation on the costs of road construction and maintenance taken from research undertaken by the Texas State Highway Department.[204]

In a report given before the 1921 Conference on Highway Economics and Highway Transport, University of Tennessee Professor N. W. Dougherty offered remarks about a survey undertaken by the University in cooperation with the Tennessee Highway Department and the Bureau of Public Roads. He stated that this group had developed a general outline of highway economics and transport for use in organizing

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203 *Ibid.*, 106 and 109

204 George A. Duren, "The Cost of a Mile of Road," *Highway Engineer and Contractor*, May 1919.

future data collection. While he acknowledged that "from the very beginning of the survey it was apparent that information could not be obtained on all phases of the outline, … enough work … was accomplished to demonstrate the feasibility of the method and to point the way to a more complete survey in the future."[205] His outline included the following headings and general areas of subject matter[206]:

- Highway Evaluation - Existing System (types of surfaces and soils, types of topographical features)
- Maintenance (systems used, costs of roads, financing methods, system and traffic success)
- Service Road is Giving or May Give (traffic counts, vehicle classification, character of traffic, estimate of future traffic, property values)
- Study of Finances (county income, indebtedness and available monies)
- Study of Local Materials (classification of materials, quality and quantity)
- Selection of Economic System for County (classification of road systems and types of surfaces)

As was evidenced by the Tennessee survey, although "economics" was generally recognized to be a subject of concern, it was typically defined as the compilation of data on road construction costs, funding, material longevity and the appropriate types of roads for given locations. While all of this cost and census data would ultimately be important to the specialized economic theory that was yet to come, it still fell far short

[205] N.W. Dougherty, "Highway Economics and Highway Transport in Typical Counties of Tennessee," Proceedings of the Conference on Highway Economics and Highway Transport, National Capital Press, Washington, DC, 1921, 9.

[206] *Ibid*., 9-10

of the type of evaluation that Wellington had provided for decision-making regarding location and types of infrastructure.

Despite the strong focus on pavements, and the limited approach to economics, there were also states that were evaluating roadway design given the changing nature of the types, volumes and weights of traffic – a field of study that would also provide valuable support for the future economic design of highways. For example, in 1925 the Michigan State Highway Department issued a publication entitled "Special Instructions to Engineers – the Superelevation and Widening of Curves." This document confirmed that "the methods used by [the] Department previous to January 1, 1923, in the superelevation and widening of curves [had] been found to be inadequate"[207] because motorists altered their driving habits to avoid perceived dangers even when existing roadway geometrics were not actually unsafe. Geometry-related subjects – curvature and grades in particular – gradually came under study as part of the broader field of highway economics. The National Research Council, which reported regularly on the status of research in the United States, noted at the 1923 meeting that the following projects, among others, specifically associated with highway economics were then ongoing or had recently been completed[208]:

- Economic problems in highway transport: University of Michigan
- Traffic studies and/or census: Minnesota State Highway Department; Colorado State Highway Department; Connecticut State Highway Commission; US Bureau of Public Roads, District of Columbia; University of

[207] Harry L. Brightman, *Special Instructions to Engineers – Superelevation and Widening of Curves*, (Lansing, Michigan: Robert Smith Co., State Printers, 1925).
[208] Dougherty, "Highway Economics", 24-31

Maryland; Michigan State Highway Commission; Missouri State Highway Department; King County, Washington; Massachusetts Department of Public Works; San Francisco, California Department of Highways and Streets; Pittsburgh, Pennsylvania Citizens Committee on City Plan
- Highway economics and highway transport survey: University of Tennessee
- Traffic counts: Jefferson County, Alabama; and states of Colorado, Delaware, Idaho, Illinois, Iowa, Maine, Maryland, Massachusetts, Nevada, New Hampshire, New York, Rhode Island and Wisconsin
- Operating expenses: Connecticut State Highway Commission; Purdue University, Indiana
- Economic life of road: Pennsylvania State Highway Department
- Curvature: North Carolina State College of Agriculture; Virginia Polytechnic Institute
- Tractive resistance: US Bureau of Public Roads; Connecticut, Yale University Sheffield Scientific School; Illinois, Portland Cement Association; Iowa State College; Kansas State Agricultural College; Massachusetts, Quartermaster Corps, US Army; University of Michigan
- Economic grades: Iowa State College, University of Michigan

Although not identified as an area of research associated with economics, other studies were also being undertaken at the same time that would ultimately have a significant bearing on highway design from not only a structural standpoint but also a financial one. "The thirteen-year period 1922 to 1935 saw the formal recognition of highway capacity as an engineering problem, and the beginnings of scientific research in the area."[209] The Highway Research Board established a Committee on Highway Traffic Analysis, "concentrat[ing] its activities on developing methodologies for predicting current and future traffic demand."[210]

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209 John R. McLean, *Two-Lane Highway Traffic Operations, Theory and Practice*, (New York: Gordon and Breach Science Publishers, 1989), 9.
210 *Ibid.*

> "The early Committee reports [showed] some confusion with the concept of 'traffic capacity.' In some instances it appear[ed] to refer to the maximum traffic throughput that a particular roadway can accommodate. At other times it refer[red] to the traffic volume (often referred to as 'traffic density' during this period) at which 'congestion' becomes apparent, with the specification of congestion remaining vague. Despite these limitations, the reports contain[ed] a number of judgements and observations which are still pertinent … today. The 1923 Committee report … recognized the deleterious effect of slow-moving vehicles…. The 1924 report … discussed the effect of 'bottleneck points.' Such points effectively determine the 'maximum road capacity' and they cause congestion to spread into adjacent sections of road with otherwise adequate capacity."[211]

The primary focus of this early research was the determination of the capacity of a single lane, and the Committee ultimately recommended (by the time of its 1928 annual report) that this capacity be assessed primarily on the basis of traffic speed. "In retrospect, the most significant contributions of the early deliberations … came in its first few years; namely the effects of slow-moving vehicles and of bottleneck points…. Research might have followed a much different course if attempts had been made to fully investigate and quantify these effects … [rather than concentrating] on the concept of the maximum theoretical capacity of a single lane and on measurements of traffic speed."[212] Regardless, these research efforts led to information that was valuable in the design of new and improved roadways, and traffic demand and capacity would be important variables in future design efforts – both structural and economic.

211 *Ibid.*, 10
212 *Ibid.*, 10-11

Although all of the research in highway economics and associated traffic analysis did not yet represent an organized effort and increased coordination was required to ensure greater focus, advancements were certainly being made. Materials testing laboratories had made significant strides in defining the costs, applicability and durability of specific roadway materials when applied at different locations and under given conditions of use – all of which data was already of great value to local and state roadway owners and maintainers and would ultimately be a significant element in the larger analysis of the expense of locating and building new highways. Many states had or would soon be engaging in traffic census studies that would be important in the greater evaluation of roadway structural needs and in projecting future traffic demands. Separate research on roadway capacity would tie directly to the data being compiled through these traffic counts. Studies on the economic effects of grades, curvature, vehicular type and use, and tractive resistance were also well underway thanks to leadership from the National Advisory Board on Highway Research. In addition, a number of states were developing plans for highway systems anticipated to be capable of accommodating their statewide and regional needs. These new networks of roads would have to be economically designed and built if they were to truly meet the needs of trucks and automobiles for decades to come.

New Jersey, in particular, had made significant strides by the mid-1920s in defining its roadway needs as they related to the movement of both local and through traffic. Studies had clearly identified the suitability – at least in concept - of limited access highways to reduce the “bottleneck points” noted to be of concern to the

Committee on Highway Traffic Analysis and thereby address the demands of traffic passing through one of the most densely populated and developed areas of the country. However, New Jersey – like the majority of the other states – was only beginning to actually plan and construct these new modern networks of roadways. The economic input utilized in design was mainly associated with improved materials – which was, at the time, the most advanced area of nationwide research. The roadway equivalent of 19th century railway economic theory still merely consisted, as was noted above, of materials statistics, some census data, a list of generally agreed-upon categories to comprise an economic analysis, some of which had been investigated and many of which had not, and early theoretical efforts in determining the capacity of roadways. When Fred Lavis and Sigvald Johannesson came together in New Jersey in 1924, the elements of roadway design theory had been defined, but there was not yet a cohesive theory of economic analysis, and it remained to be seen how they, or others, would take the available information and applicable engineering considerations and merge them into a model for an actual highway design. Fortunately, these two men brought with them strong backgrounds in railroad design and construction, and knowledge of the railroad economic studies of Wellington and others. Of equal importance, they felt strongly that the establishment of a strong economic basis for the layout and design of the highway that would connect northern New Jersey with the soon-to-be Holland Tunnel was crucial to their work.

Chapter Three – Early Highway Economic Theory and the Pulaski Skyway

Serious Highway Planning Gets Underway

Early Efforts at Traffic Control

With hindsight, it seems that it should have been clear even by the earliest years of the twentieth century that roadways – and roadway vehicles - were here to stay, and that those who were adamant that vehicular traffic was not and never would be the primary means of transport in the country would be proven wrong, it took time for this reality to "sink in." This was due, in part, to the fact that even as motor traffic increased the railroads still represented a major force in the movement of both people and freight. In addition, in fairness to the engineers and planners of over one-hundred years ago, those multiplying cars and trucks were still sharing the roads with carriages and horses. In spite of dramatic pronouncements to the contrary by organizations such as the Bureau of Public Roads and the National Research Council, some engineers felt that exhaustive roadway analysis - economic or otherwise - was not always justifiable and that its use should be weighed alongside the likelihood that automobile and truck traffic would *not* ultimately prove to be critical to the nation.

When the attendees at the First National Conference on City Planning met in 1909, their "proceedings … reveal[ed] how much early planners underestimated and misunderstood the future impacts of the automobile. The minutes contain surprisingly few specific references to the auto as a distinct mode; if participants realized they were standing on a fault line between two eras of urban transportation, they did not betray any sign of it. The automobile came up as a trivial aside."[213] The conference participants viewed their responsibility to be enabling people to move out of crowded cities and into healthier suburbs rather than trying to find ways in which the cities themselves could be revitalized. At this time when automobiles were still primarily used for recreational purposes, planners also still believed that it was not only appropriate, but possible, to mix motor vehicles, trolleys and people together. They "retained their principles even as they confronted an increasingly difficult urban problem – the spiraling automobile congestion that resulted from the auto's transition to [a] mass market good. Not only was the number of autos inexorably rising, but automobile congestion was qualitatively different than what came before."[214]

During this period, highway engineers and traffic planners were not the only professionals involved in efforts to address the realities of the motor age. Due substantially to the dramatic urban population growth that was being driven to a great degree by the increase in automobile transport, this was also a time of broader visioning efforts that touched upon all aspects of life in and around major cities. "The 1920 census revealed that, for the first time, more than half of the American people lived in

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213 Jeffrey Brown, *Planning for Cars in Cities: Planners, Engineers, and Freeways in the 20th Century*, (Tallahassee, Florida: Faculty Publications, Florida State University, Department of Urban and Regional Planning, 2008), 6.

214 *Ibid.*, 8

urban areas.... The automobile was a particularly powerful agent of urban change, pushing out the boundaries of metropolitan regions and permitting suburban commuters to live in distant fringe areas."[215] While engineers evaluated roadway needs from a strictly technical standpoint in terms of materials, capacity and geometry, planners began to study streets and highways as they related to the larger issues of land use and the overall public good. "Transportation facilities were viewed not as ends in themselves but as tools for providing access between cities and suburbs, work and home, ... [and planners] valued these non-transportation effects of transportation investments as much as, if not more than, the traffic."[216]

As traffic levels increased, rural and suburban area engineers attempted to keep pace with the growing demand for new and better roads, and city planners began to look closely at their current and future needs. Unlike traffic and highway engineers who were attempting, in large part, to design new roads and maintain or upgrade existing ones, transportation planners focused much of their early attention on fixing the problems seen in downtown areas where drivers had to contend with "narrow streets, ... the 'promiscuous' mixing of local and through traffic, ... and 'irrational' street plans which featured jogs, dead-ends, uncontrolled intersections, and abrupt changes in width and paving."[217] Early efforts included the development of traffic codes; the "world's first traffic code (for New York City) ... [introduced] the stop sign, the pedestrian island, the

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[215] Arnold R. Hirsch and Raymond A. Mohl, editors, *Urban Policy in Twentieth-Century America*, (New Brunswick, New Jersey: Rutgers University Press, 1993), 4-5.

[216] Brown, *Planning for Cars in Cities,* 7

[217] *Ibid.*, 8-9

traffic circle, and the taxi stand."[218] Planners were later responsible for the introduction of traffic signaling systems and motor vehicle registration. But these early focused attempts at imposing order on existing city streets continued to be a battle as more and more cars besieged urban areas.

> "Confronted by an ever-rising sea of automobiles that swamped their best regulatory efforts, planners began to collect traffic data to better understand the underlying causes of congestion. Their data analyses led them to propose an array of strategies that came together in documents entitled 'major traffic street plans.' Planners … pioneered the development of major traffic street plans during the late 1910s and 1920s. Los Angeles, Portland, Sacramento, Saint Louis, San Diego and scores of other cities hired … consultants to prepare them…. Major street traffic plans typically advocated the creation of 'rational' street systems through infrastructure improvements that would connect and widen streets while eliminating jogs and dead ends."[219]

The improvements that were actually implemented in response to the preparation of these plans varied from location to location as the execution of such work depended in large part on the willingness of the local public to fund construction. However, street plan recommendations "designed largely to accommodate automobiles were implemented, at least partially, in many cities around the country between the late 1910s and the 1930s."[220]

Planners of the time focused not only on isolated downtown street problems; in response to ever-expanding urban growth and the social problems that went along with it, regionwide planning efforts took hold as a means of evaluating

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[218] *Ibid.*, 9
[219] *Ibid.*, 10
[220] *Ibid.*, 12

> "geographic area[s] that [transcended] the boundaries of individual governmental units but that [shared] common social, economic, political, cultural, and natural resources, and transportation characteristics…. The first regional planning agency with planning powers was the Boston Metropolitan Improvement Commission created by the Massachusetts legislature in 1902."[221]

Incorporating recommendations for dock, highway, civic center, canal and waterfront enhancements in its 1909 planning document,[222] Boston recognized early "the need for a system of radial and circumferential highways in an American metropolis."[223] Other urban regions quickly followed suit in the regional planning effort.

> "From 1913 to 1915, when the state legislature repealed the statute creating it, Pennsylvania authorized the establishment of a Suburban Metropolitan Planning Commission. Within a 25-mile radius of Philadelphia, the commission could levy assessments and prepare comprehensive plans for highways, parks and parkways, sewerage and sewage disposal, housing, sanitation and health, civic centers, and other functional areas…. In 1922, the first metropolitan area planning commission was established in Los Angeles … [and] in 1923, the Ohio General Assembly enacted the first enabling legislation for regional planning commissions."[224]

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[221] "Growing Smart Legislative Guidebook, Chapter 6: Regional Planning," American Planning Association, accessed March 6, 2019, https://www.planning.org/growingsmart/guidebook/six01.htm.

[222] *Report of the Commission on Metropolitan Improvements*, (Boston: Wright & Potter Printing Co., State Printers, 1909).

[223] "Shurliff, Map of the Existing and Proposed Circumferential Thoroughfares (Boston, 1909)," accessed March 6, 2019, http://publications.newberry.org/makebigplans/plan_images/shurcliff-map-existing-and-proposed-circumferential-thoroughfares-boston-1909.

[224] "Growing Smart Legislative Guidebook"

Progressivism, the City Beautiful, and Roadway Planning

All of these activities occurred in the midst of widespread social, economic and political changes in the United States that occurred in response to the enormous transformation that had come with the Industrial Revolution. While the rapid expansion of business and manufacturing that occurred during the last quarter of the 19th century brought many previously unknown advantages to the American people, "not all citizens shared in the new wealth, prestige, and optimism…. Progressivism was rooted in the belief, certainly not shared by all, that man was capable of improving the lot of all within society."[225] The Progressive movement of the 1890s through 1920 was led in large part by well-educated middle-class Americans, and advanced significantly by publicity about the dangerous conditions in cities and factories generated by muckraking journalists. Adherents worked to end human ignorance and political corruption, and purify society. They "believed that the problems society faced (poverty, violence, greed, racism, class warfare) would best be addressed by providing good education, a safe environment, and an efficient workplace…. [They also] believed that government could be a tool for change."[226] A major element of this movement focused specifically on curing the ills of the nation's ever-expanding cities.

> "Common to almost all the reformers … was the conviction – explicit or implicit – that the city, although obviously different from the village … should nevertheless replicate the moral order of the village. City dwellers,

225 "The Progressive Movement," accessed March 6, 2019, http://www.u-s-history.com/pages/h1061.html.

226 "The Progressive Era (1890-1920)," The Eleanor Roosevelt Papers Project, Teaching Eleanor Roosevelt Glossary, accessed March 6, 2019, https://www2.gwu.edu/~erpapers/teachinger/glossary/progressive-era.cfm.

> they believed, must somehow be brought to perceive themselves as members of cohesive communities knit together by shared moral and social values. The most visible expression of this belief in the creation of moral and civic virtue in the urban population was created by the reformers of the City Beautiful movement. The movement was conceived as explicitly reform-minded; Daniel Burnham, a leading proponent of the movement, linked their efforts with Progressivism. A reform 'of the landscape, he suggested, [would] complement the burgeoning reforms in other areas of society.'"[227]

"Broadly defined, the City Beautiful Movement was a Progressive reform agenda that united architecture and urban planning … with the intent of using beautification and monumental statuary to counteract the perceived moral decay of poverty-stricken urban environments. The movement … did not seek beauty for its own sake, but rather as a social control device to promote moral and civic virtue among [the] urban population."

A defining goal of all of these reformers was "efficiency," or "the use of science, engineering, technology and the new social sciences to identify the nation's problems, and identify ways to eliminate waste and inefficiency and to promote modernization."[228] It was, therefore, not surprising that the objectives of Progressivism meshed so well with those of the City Beautiful movement, or that the efforts of the City Beautiful Movement carried over so logically into seeking means of addressing the infrastructure needs of urban areas. It is interesting to note that "a key part of the [Progressive] Efficiency movement was scientific management, or 'Taylorism.'"[229] The practice of

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[227] "The City Beautiful Movement," accessed March 6, 2019, http://xroads.virgina.edu/~cap/citybeautiful/city.html.

[228] "Progressive Era," accessed March 6, 2019, http://www.conservapedia.com/Progressive_Era.

[229] "The Progressive Era," Boundless US History, accessed March 6, 2019, https://courses.lumenlearning.com/boundless-ushistory/chapter/the-progressive-era.

scientific management that had been linked to Albert Fink's and Arthur Mellen Wellington's approach to railway economics in the late 1800s was still active in the early 1900s and helped push forward the engineering solutions viewed as the means of addressing highway and other city-related problems. "By 1906, civic beautification in the US had matured as activists from diverse backgrounds were united in a comprehensive city plan movement."[230] In the nation's largest cities, in particular, "business leaders, social reformers, architects, and city planners devoted tremendous energy and imagination to improving the American metropolis. At the heart of this movement was the visionary Plan of Chicago, published in 1909 by Daniel H. Burnham and Edward H. Bennett."[231] Considering Chicago as the center of a region extending outward for 75 miles, the "Plan of Chicago" proposed the expansion and enhancement not only of the surrounding highway system but also of infrastructure related to railroads, parks, bridges and streets, civic centers, and harbors.

Not everyone agreed with the plan's intentions, fearing that their implementation would only result in exorbitant tax increases. However, Burnham, in true Progressive style, believed that the use of a holistic plan, taking advantage of new technologies, would enable the City to better control and manage planned development making it more cost effective than many thought. While certainly rich in illustrations of its proposals, "the document itself was neither vague encouragement to lofty goals nor

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[230] Julian C. Chambliss, "Beautification and Regional Identity: Conflict and Compromise in the United States During the City Beautiful Era," accessed March 6, 2019, http://fch.fiu.edu/FCH-2006/Chambliss-Beautification%20and%20Regional%20Identity.htm.

[231] "Make Big Plans," accessed March 6, 2019, http://publications.newberry.org/makebigplans/.

mere technical diagrams. Instead, it was a list of specific public improvements that should be made and the reasons why."[232]

> "Increasing automobile travel in the 1910s and 1920s gave new urgency to the arterial improvements recommended in the 1909 Plan of Chicago. In 1927, the Chicago Plan Commission laid out a system of limited-access highways.... Although the Great Depression slowed urban growth and limited civic spending, auto use continued to grow and in 1940 the city council approved a system of superhighways radiating from downtown Chicago that is nearly identical to what was eventually built."[233]

Many important elements of Burnham's plan were realized during the years following its publication and, although others were either not completed or not even considered for implementation, the later development of the City's superhighway network was clear evidence that the 1909 plan continued to be used as a guiding document for decades.

Regional Planning and New York Area Roadways

While cities worked towards means of addressing traffic problems through locally focused street planning and larger regional analyses,

> "in the United States, the most prescient thoroughfare plan of the 1920s was the *Regional Plan of New York and Its Environs* (RPNYE), which portrayed a complete transportation network for the New York region.... The RPNYE was the most technically sophisticated plan of its time, drawing upon reams of detailed urban research and a stellar array of

[232] "The Plan of Chicago, A Regional Legacy," (Chicago, Illinois: Burnham Plan Centennial Committee, May 2008), accessed March 6, 2019 online at: http://burnhamplan100.lib.uchicago.edu/files/content/documents/Plan_of_Chicago_booklet.pdf.

[233] "Expressways," Encyclopedia of Chicago, accessed March 6, 2019, http://www.encyclopedia.chicagohistory.org/pages/440.html.

> leading professionals from planning, architecture, transportation, and urban economics. The highway component of the RPNYE was not a pure radial-concentric pattern, but a hybrid between the grid and a radial-concentric plan."[234]

"Even by today's standards, [this] Regional Plan is an impressive work."[235] New York in the 1920s was thriving economically, its population had doubled since 1890, many residents still lived in tenements, and construction was occurring seemingly everywhere. "Yet by and large, the explosive growth of the city and the region in the 1920s was unplanned – the result of little but market forces at work."[236] Seeing that the expansion of the New York City area was not only uncontrolled but also unplanned, city business and professional leaders formed the Committee on a Regional Plan of New York and Its Environs in 1922 to survey and analyze the region and make recommendations for future managed and rational growth. Studying an area comprised of 22 counties in the states of New York, New Jersey and Connecticut with funding from the Russell Sage Foundation, "the results of this effort were the publication of the landmark 1929 *Regional Plan of New York and Its Environs*, the first long-range, region-wide master plan for the New York metropolitan region, and the incorporation of the Regional Plan Association, an organization whose purpose was to see that the regional plan was implemented."[237]

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234 Joseph F. C. DiMento and Cliff Ellis, *Changing Lanes – Visions and Histories of Urban Freeways*, (Cambridge, Massachusetts and London, England: MIT Press, 2013), 20.
235 "Growing Smart Legislative Guidebook"
236 "Shaping the Region," Regional Plan Association, accessed March 6, 2019 online at: http://library.rpa.org/pdf/RPA-Shaping-the-Region.pdf.
237 *Ibid.*

The plan was officially made public at a dinner held at the Engineer's Club in New York City on the evening of May 27, 1929. As was widely reported the following day,

> "some of the facts about the project are: it makes provision for the 20,000,000 who are expected to live in the region in 1965. The population is now about 10,000,000. The plan includes complete systems of highways, railways, commuters (sic) rapid transit lines, parks and parkways.... The highway system is made up of circumferential or 'belt' routes, and radial roads, together with the necessary connecting links. It connects New Jersey directly with Brooklyn, Queens and the Bronx. Through traffic could avoid Manhattan's congested streets almost entirely."[238]

Although the Regional Plan was extremely specific in its recommendations, "its proposals, tho carefully and comprehensively worked out, [were] intended to be tentative, and to serve, flexibly, as a guide"[239] for use by regional railroad and utility companies, and federal, county and municipal authorities because "the value of any plan [was] of course in proportion as it [was] carried out."[240] Of the first regional plan's complete proposal calling for 91 major regional highways, 107 minor regional highways, and 33 parkways and boulevards[241] significant elements were realized in the 1930s and 1940s. For example, the uptown Manhattan location of the George Washington Bridge was based largely on the plan's recommendation, and the Whitestone Bridge, Henry Hudson Parkway, Palisades Interstate Parkway and Brooklyn Battery Tunnel were all constructed prior to 1940. In addition, as was "recommended in the … First Regional

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238 "Regional Plan for Tri-State Area Revealed," *Democrat and Chronicle of Rochester*, New York, May 28, 1929, 5.
239 "Principal Proposals of Regional Scheme as Outlined by McAneny," *Asbury Park Press*, May 28, 1929, 3.
240 *Ibid.*
241 *Ibid.*

Plan, the New Jersey skyway from Elizabeth to the Holland Tunnel was completed in 1932."[242] The first plan was surprisingly accurate in its prediction of regional population growth; by 1967, when the Second Regional Plan presented a report entitled "The Region's Growth," the population of the study area had reached 19 Million. The first and second regional plans of the 1920s and 1960s were followed by a third plan published in 1996. The Regional Plan Association continues its efforts even today as it "conducts research and advances policies that improve the region's shared economic prosperity, environmental sustainability and quality of life,"[243] having begun work in 2013 on a Fourth Regional Plan that is expected to be published in 2017.

Highway Planning in New Jersey

Pioneering Roadway Work

During and after the First World War, the improvement and construction of roads became such an obvious need that the states began to look more seriously at their approach to road building and design. The 1916 passage of the Federal Aid Road Act marked

> "the first time that the federal government provided assistance for state highway costs…. [It] provided funding for the improvement of any rural road over which the U.S. mail was carried. A key feature of the legislation was the requirement that the states must have a highway department

242 "History," Regional Plan Association, accessed March 6, 2019, http://www.rpa.org/about/history.
243 "Shaping the Region"

> capable of designing, constructing and maintaining designated roads in order to share in the appropriation."[244]

For twenty-five years prior to the passage of the first federal funding law, New Jersey had already been providing government aid for the construction of roadways. The original 1891 legislation had "established a $75,000 fund in the state Department of Agriculture to help the counties in the construction of highways to the extent of one-third of their cost.... The [State] Legislature followed through and allowed the appointment of a Commissioner of Public Roads in 1894 … [who was] responsible for the State Road Aid Law."[245] The State Highway Commission (later the Highway Department and now the Department of Transportation) was established in 1909. Through laws enacted in 1916 and 1917, New Jersey established one of the nation's first systems of numbered highways – beginning with the following fifteen routes that were believed, at the time, to be sufficient major roadway coverage for the state[246]:

- Route 1 – Elizabeth to Trenton
- Route 2 – Trenton to Camden
- Route 3 – Camden to Absecon
- Route 4 – Route No. 1 in or near Rahway to Absecon
- Route 5 – Newark to the bridge crossing the Delaware River above Delaware
- Route 6 – Camden to Bridgeton and Salem
- Route 7 – Hightstown to Asbury Park
- Route 8 – Montclair to New York state line at Unionville

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244 "History of the Federal-Aid Highway Program," National Stone, Sand and Gravel Association, accessed March 6, 2019, http://www.nssga.org/advocacy/grass-roots/reauthorization-roadmap/history-federal-aid-highway-program/.

245 *PEOPLE The Transportation Connection – A Brief History of the NJDOT*, (Trenton, New Jersey: New Jersey Department of Transportation, October 2001), 9.

246 Ibid, 10

- Route 9 – Elizabeth to Phillipsburg
- Route 10 – Paterson to Fort Lee Ferry
- Route 11 – Newark to Paterson
- Route 12 – Paterson to Phillipsburg
- Route 13 – New Brunswick to Trenton
- Route 14 – Egg Harbor City to Cape May City
- Route 15 – Bridgeton to Cape May Court House

Changing the old system of road maintenance that consisted primarily of only repaving, and the old system of road layout, the designated highway system was intended to respond more fully to the state's needs, and existing and anticipated future conditions.

> "The 15 routes were each (presumably) selected because they were vital to the state's various interests, whether agricultural, commercial, industrial, recreational, or the larger national interest in defense.... The 1917 system [also] included standards for state highways for characteristics such as cross sections and vertical and horizontal alignment.... Roads were now more highly engineered … [and they] were also now designed for economy of construction and operation."[247]

The state's earliest comprehensive highway system was a milestone in not only regional, but national, highway planning. Combining the use of existing routes with the establishment of new corridors and alignments, it represented pioneering national work in the use of future projections of road needs. However, the initial state routes were soon recognized to be totally inadequate. "Statistics indicate[d] that New Jersey residents eagerly adopted the automobile as a mode of transportation. A 1913 survey revealed that New Jersey had a higher number of vehicles per mile of road than most

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[247] *New Jersey Historic Roadway Study*, KSK Architects Planners Historians, Inc. with Armand Corporation, Inc., Michael Baker, Inc., January, 2011, 81.

other states in the region, including New York, Massachusetts, Maryland, and Connecticut."[248] New Jersey, geographically positioned between Philadelphia and New York City in one of the most congested areas of the nation, and with its own popular shore resorts and thriving commercial centers, saw the volume of motor vehicle traffic increase rapidly in the early decades of the 20th century. "As the volume of traffic increased, and the types of automobile came to include ever heavier and more numerous trucks, the state assumed more and more responsibility for road construction."[249] However, money for the construction of additional roadway mileage was spent more quickly than it could be made available. Plus, it soon became clear that a highway system with a different focus was necessary. When state engineers began studying the existing road network toward the goal of accommodating the already taxing number of motor vehicles, they focused primarily on developing a system incorporating the construction of commercial routes with the separation of through and local traffic.

One element of national highway engineering that overlapped that of transportation planning was the study of vehicular separation – seen as an important means of dealing with the delays and other problems that resulted from the mingling of through and local traffic. Variations of the new concept of the limited access highway were gradually developed, and New York State began the country's earliest experimentation in controlled access with the construction of parkways that were the pioneer examples of scenic highways. The first such route, called the Bronx River

[248] *Ibid.*, 82
[249] *Ibid.*, 78-79

Parkway, was completed in 1907 and incorporated the natural beauty of its surroundings in the design and appearance of both the route and its infrastructure. New York State made extensive use of the parkway form, constructing a series of scenic routes between the heart of New York City and its outlying recreational areas. Although these parkways and the others that followed were landmarks in national highway planning, this type of route was essentially intended for slower speed automobile traffic, and "the traffic service capabilities of these roads were secondary to their recreational attributes. But many of the ideas employed by parkway designers … were soon adopted by engineers and planners with a much more utilitarian object in mind."[250]

> "Planners and engineers hit upon a new strategy, which at the time was widely regarded as the permanent 'cure' for metropolitan traffic congestion…. At first called by various names – the 'speedway,' the 'limited way,' the 'superhighway,' and the 'expressway' – this new type of roadway was eventually christened the 'freeway.' The freeway borrowed two important design characteristics from earlier rural and suburban parkways: limited access and grade separation."[251]

Freeways were intended to be more functional in design than their "sister" parkways, but planners still viewed them "not merely as a means of facilitating movement but also as a tool for reshaping urban form,"[252] and consultants developed recommendations for networks of freeways for major cities across the country during the 1920s and 1930s. While the parkway was obviously not appropriate for all situations and conditions, and

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[250] Jeffrey Brown, *A Tale of Two Visions: Harland Bartholomew, Robert Moses and the Development of the American Freeway* (Draft), (Berkeley, California: Institute of Transportation Studies, School of Public Policy and Social Research, University of California, July 24, 2002).

[251] Jeffrey Brown, *Planning for Cars in Cities*, 13.

[252] *Ibid.*, 5

was certainly not seen as the means by which New Jersey could accommodate the enormous volume of industrial and passenger traffic found in the densely populated northeastern region of the state, the freeway or the soon-to-be-coined "superhighway" form might be just what was needed.

Sloan Becomes State Highway Engineer

In April of 1923, New Jersey Governor William Silzer named Major William G. Sloan the new state highway engineer. Sloan brought with him to this position

> "varied experience in the field of engineering. In 1900 he started as assistant engineer of the Illinois Central Railroad Company. [Working with nationwide contractors, he] carried on large contracts in this and foreign countries to the extent of hundreds of millions of dollars. In February, 1918, he was given the rank of major in the construction forces of the United States army. A few months after he was commissioned Major Sloan took the 22nd regiment of engineers to France. This organization took charge of light railway construction there."[253]

At this time, the greatest concern of New Jersey engineers was the improvement of the state's oldest route – United States Route 1. Joint planning by New Jersey and New York to design and construct the future Holland Vehicular Tunnel under the Hudson River did not initiate New Jersey's highway improvement plans but it did serve to focus and solidify them. "Plans for the Hudson River crossing began in 1906…. While initial proposals called for a bridge, … the commissions would later concur that a bridge was not economically feasible due to the long span that would be required to cross the

[253] *Asbury Park Press*, April 11, 1923.

Hudson River, the deep foundations that would be needed to reach bedrock, and the lengthy approaches would necessitate the purchase of large amounts of real estate."[254] Tunnel design work began in 1919 with construction activities starting in 1922. Only a month after his selection as state engineer the following year, Sloan was chosen to chair "a special advisory committee to assist [the State Highway Commission] in solving traffic problems growing out of completion of the Hudson vehicular tunnel."[255]

It was clear that the completion of the tunnel would place numerous vehicles that currently exited Manhattan by ferry onto the already busy local streets of Jersey City and the surrounding municipalities. The first goal of state engineers prior to the planning of the tunnel had been easing traffic in the northeastern portion of the state and the accommodation of vehicles transporting goods and passengers across the region. Traffic studies performed in the 1910s and early 1920s had illustrated the increase in the volume of motorized traffic that was beginning to overwhelm the industrial areas of northern New Jersey, and the state's Engineering Advisory Board clearly indicated the need for significant highway improvement for the region to accommodate both municipal concerns and financial goals. Given the conditions that already existed, state engineers were well aware that current regional roads – including Route 1 - could not possibly accommodate the additional traffic that would be generated by the proposed Hudson River tubes, and so the extension of area routes to address anticipated tunnel traffic became an even more pressing need. The Board developed a proposal for the

[254] "Holland Tunnel," American Society of Civil Engineers Metropolitan Section, accessed March 6, 2019, http://www.ascemetsection.org/committees/history-and-heritage/landmarks/holland-tunnel.
[255] "To Study Traffic From New Tunnel," *Asbury Park Press*, May 12, 1923.

project – named the Route 1 Extension – to accommodate future tunnel traffic, ease congestion between Jersey City and Elizabeth, and address economic concerns as well as the requirements of vehicular traffic and navigable passage on the Passaic and Hackensack Rivers. Following the guidelines set forth in the original state highway system planning reports, the project was intended, from the start, to separate local and through traffic and to result in the construction of a new corridor connected to the existing roadway network.

Having come from a railroad engineering background, Sloan strongly believed that highways could and must utilize the same principles of economic planning that railroad designers had long used in the comparison of line locations and structure types. Clearly, although some characteristics of standard highway planning and railway design were dissimilar, the Route 1 Extension project was one in which Arthur Mellen Wellington's economic theory could be applied to a significant degree. Unlike most roadway projects, that were largely governed by long standing limitations in location methods and means of funding, the Extension route was anticipated to be one built much along the lines of a railroad. Bypassing existing roads and city areas, and laid out within an entirely new right-of-way, the proposed, high-speed, express corridor was intended to provide uninterrupted traffic flow in imitation of a railway line. It was to be constructed along a new alignment, rather than occupying a previously existing route, and in this respect the highway would mirror railroad alignment and location practice of the past.

The Extension project was also seen as an opportunity for incorporating whatever structural options – tunnels, drawbridges or high level spans - were found to be the most appropriate from the standpoint of combined economic feasibility, capacity requirements, and functional needs. Finally, the undertaking was also anticipated to permit only limited access. The controlled access, high-speed highway was just coming into use in the 1920s, and New Jersey engineers saw this embodiment of the "superhighway" as the answer to the state's traffic flow concerns. Although it appears unlikely that state officials and planners viewed the project as a model for future regional or national highway systems, the designers clearly believed that the limited access form was the best solution for New Jersey's future needs. Once completed, however, it would prove to be an illustrative example for the entire nation of the successful design and construction of the newly emerging high speed style of traffic corridor. Understanding the urgency of the Route 1 problem Sloan, and the Advisory Board that he chaired, completed their detailed "Vehicular Tunnel Traffic Study" in less than a year and presented its results and recommendations to the New Jersey State Highway Commission in 1924. This report, which is discussed in more detail in the next section of this document, would support the subsequent project alternatives analysis and design work.

The 1926 Highway System Plan

In 1926, when the Route 1 Extension project was well underway, Sloan completed a major study of existing and anticipated traffic demand throughout the state leading to the proposed designation of a total of 45 state routes focused mainly on separating local and through traffic. This recommendation "also proposed that the state system would be used primarily to connect major population centers; ideally, a separate state highway would serve each destination. These highways could be either newly constructed in their entirety, or a combination of upgraded sections of existing roads connected by new construction."[256] "Sloan's plan called for the creation of a 1,247-mile primary road system that would be maintained by the state and a 647-mile secondary road system that would be maintained by the counties."[257] In a recommendation presented to the State Legislature, Sloan estimated that $80 Million would be required to finance the first four years of an overall twelve year highway construction program anticipated to cost approximately $160 Million. "The state highway engineer's plan would eliminate practically all grade crossings on the state highway routes.... Mr. Sloan's survey estimate[d] that when the 12 year construction work [was] completed it would meet the state's traffic demands for a generation at least."[258]

During the highway commission hearings for the consideration of proposed legislation based upon Sloan's report, Bureau of Public Roads Chief Thomas MacDonald publicly stated that the report was

> "far-sighted, comprehensive and courageous.... I have studied it with care and feel that it comes none too soon and that unless action is taken by the state to place in effect this plan in its definite features, the state will be faced with a breakdown of its highway facilities much greater than any it

[256] "New Jersey Historic Roadway Study," 81
[257] Ibid, 89
[258] *Asbury Park Press*, December 2, 1926.

> has heretofore experienced.... I fully concur in the principles he has expressed and in the definite plan which he proposes.... New Jersey faces a congestion on its highways that will prevent the normal usage by its own citizens of their motor vehicles. It faces the loss of patronage of those from outside who desire to make use of its recreational facilities. Undoubtedly if conditions become sufficiently acute, drastic action will be taken, but too frequently this happens only after everyone has been convinced for years that 'something ought to be done.' ... There is one feature of this report upon which I wish to comment as indicative of the big idea expressed by Major Sloan.... If every mile of highway built is built as part of a far-sighted, comprehensive plan, the affect is accumulative, and within a relatively short time more adequate facilities have been provided than are expected or will be possible unless every mile is directed toward a definite end."[259]

MacDonald was not alone in his praise for Sloan's proposal as requests for information and complimentary letters arrived at the highway commission offices in late 1926. J. G. McKay, chief of the Division of Highway Economics and Transport of the United States Department of Agriculture wrote to Sloan, saying "I wish to take this opportunity to tell you what a splendid report you have made. Reports of this character are the type of a report that the several state highway departments need so badly to issue to their public and I am confident that your work and suggested plan ... will have a far reaching effect upon the future development of the New Jersey highways."[260] Although elements of the proposal were ultimately completed, and despite the strong support of national leaders in the highway engineering field "unfortunately, Sloan's plan, as devised, was never

[259] *Asbury Park Press*, December 11, 1926.
[260] *Asbury Park Press*, December 18, 1926.

carried out. Both the State Highway Commission and the state legislature altered the plan based on political agendas rather than sound planning."[261]

The Route 1 Extension Project

Sloan and the Extension Project Study

Colonel William Sloan left the position of state highway engineer prior to the completion of the Route 1 Extension project, handing over his job and responsibilities in 1929 to Colonel Jacob L. Bauer, a former long-term Union County engineer. However, in 1924, while he was still with the state, Sloan made a decision that was crucial to the direction of the project when he selected Fred Lavis and Sigvald Johannesson to join his project team. He was also instrumental in determining the approach to the project design via the study work performed by his Advisory Board. Both Lavis and Johannesson – like Sloan - came from the railroad engineering community and, with his extensive railroad construction background and previous publications, Lavis in particular evidenced a thorough familiarity with and skill in the use of economic and alignment analyses such as had been utilized by railway engineers for decades and had first been defined in published form in Wellington's 1877 book "The Economic Theory of the Location of Railways." As engineers and educators across the country continued the exhaustive research effort required to obtain the data and determine the methodology required for a substantive economic theory for roadway

[261] "New Jersey Historic Roadway Study," 90.

location and design, and as cities and states studied and planned for the means of addressing their local and regional highway needs, Sloan, Lavis and Johannesson began the monumental effort of moving forward on the basis of the Advisory Board's recommendations in the design of a corridor that would enable northeastern New Jersey to handle the traffic that was anticipated to emerge from the mouth of the soon-to-be Holland Tunnel and in the development of a design method that would become the long-sought highway economic theory.

Sloan and his fellow Advisory Board members had performed exhaustive analyses to help guide the project design in the course of a few short months. Formally published in 1924, but presented to the State Highway Commission on August 8, 1923, Sloan prefaced his report as follows:

> "Gentlemen – In accordance with the action of your Board at its meeting on May 11th, 1923, I have to advise that the Advisory Board has carefully considered the problems submitted to them by you, concerning the proper handling of the volume of traffic in the vicinity of Jersey City, and taking into consideration the increase in such traffic which will be occasioned by the construction of the Vehicular Tunnel between New York City and Jersey City. The Board has embodied the result of these studies in a written report and the conclusions and recommendations embraced therein cover, in the opinion of the Board, the best method of handling this most unusual situation."[262]

The study document explained that area surveys had been undertaken, existing traffic counts obtained, and records for ten years'-worth of traffic conditions compiled. The recommendations derived during the analysis were based on three major assumptions

[262] *Report of the Advisory Board to the New Jersey State Highway Commission; Vehicular Tunnel Traffic Study*, 3.

taken from the language contained in the Highway Commission's resolution for the formation of the Advisory Board:

- The limits to be evaluated were to extend outward from Jersey City based on "the probability of present or future traffic developing to a point where congestion may be reached at such time as the traffic through the tunnel shall have reached the capacity of the tunnel."[263]
- The location and construction type were to be based on a combination of traffic needs, economical grades, and elimination of draw bridges and at-grade crossings.
- The overall recommendations should consider overall improvement as well as the wants and needs of local municipalities as deemed appropriate.

The report continued by discussing the geographical limits of the investigation and the roadways impacting that area, as well as where traffic counts were obtained. The results of these traffic counts for highways entering Jersey City were provided as follows:[264]

263 *Ibid.*, 7
264 *Ibid.*, 13

Table 6 - Summary of Traffic Counts for 1923
on Main Roads Out of Jersey City

	Yearly	*Daily*	*Max. Hour*
Lincoln Highway	5,756,200	16,930	1387.7
Anderson Avenue	1,995,460	5,869	464.6
Palisade Avenue	1,799,280	5,292	434.5
Fairview	2,807,380	8,257	676.8
Paterson Plank Road	2,382,720	7,008	574.4
Newark Turnpike	3,607,740	10,611	861.5
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	18,348,780	53,967	4,399.5

Counts were also taken for streets within the City of Newark and on major thoroughfares within Bergen County, as well as for traffic generated by area ferries, with the latter counts separated into the categories of motor trucks, pleasure cars and – believe it or not - horse drawn vehicles. The Board also noted that

> "the situation created by the two drawbridges over the Hackensack and Passaic Rivers, respectively, is one which has received … careful consideration…. The opening of these bridges to accommodate the requirements of navigation creates a serious delay to the traffic over the highway. From records which have been kept by the counties of Essex and Hudson there is shown that, due to the opening of the bridges, traffic was blocked for an average of 10.4% of the time."[265]

The data obtained indicated that during the calendar year 1923 a total of 3,528.6 minutes and 1,176.5 minutes were lost per day due to openings at the Passaic and Hackensack

[265] *Ibid.*, 22

River bridges, respectively which, if capitalized at 5 cents per minute could justify a total possible investment of over $1.7 Million.[266]

To evaluate potential future traffic, it was assumed that the recently seen growth in automobile use would continue into the coming years. The Board compiled data on

> "the number of motor vehicle licenses issued from 1914 to 1922, inclusive, in twelve States, those being selected which, in 1922, had the greatest number of motor vehicles licensed per capita.... Examinations ... indicate[d] that the States selected, at least, [were] fast approaching a saturation point in automobile ownership. This saturation figure [might] be assumed ... at four persons per licensed vehicle. In 1922 the ratio of motor vehicles to population gave New Jersey 9.2 persons per motor vehicle.... [and] this was projected into the future along a curve which seem[ed] logical in the light of past experience."[267]

Anticipated population growth curves were prepared for the study, upon which the Board indicated that "by 1950 ... it [was] to be expected that the number of licensed vehicles [would] be 2.7 times that of the present year.... Experience in the State of New Jersey as a whole [did] not indicate any such probable increase of 2.7 times. However, the situation ... [was] not representative of the State of New Jersey as a whole, and it [was] believed that the extreme assumption, that traffic in this particular district [would] increase as the number of licenses, should be used."[268] As additional support for the report's recommendations, it was noted that "the Chief Engineer of the New Jersey Interstate Tunnel Commission estimate[d] that traffic through the tunnel [would] more than double within eight years after the tunnel open[ed].... It [was] further expected that

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[266] *Ibid.*, 22-23
[267] *Ibid.*, 26
[268] *Ibid.*, 32-33

the ferries [would] continue to operate with at least their present volume of traffic, a considerable part of which [would] pass through Jersey City."[269] Assuming that half of that traffic would utilize Route 1, and based upon previous estimates of future demand, the Board members were able to determine a "safe estimate" for maximum hourly traffic equal to 5,444 vehicles.

The next section of the report noted that "in the study of the economics of grades and rise and fall on highways used by motor vehicles, the Advisory Board was confronted with a problem on which very little work [had] yet been done."[270] Given existing topographical conditions the Board did recommend the general use of a maximum 3.2 percent grade extending outward from the tunnel into Jersey City with some locations where this slope would have to be exceeded. However, it was also noted that it was "questionable whether this grade of 3.2 per cent [would] permit all loaded commercial tucks to negotiate it on high gear,"[271] and that studies performed in Trenton and Jersey City indicated the need for truck drivers to shift gears to climb hills of similar grade. Therefore, although it was unlikely that trucks that would ultimately be using the new route would be able to make the necessary climb without downshifting, "physical conditions determine[d] these grades and they could not be reduced without an unwarranted expenditure of money."[272]

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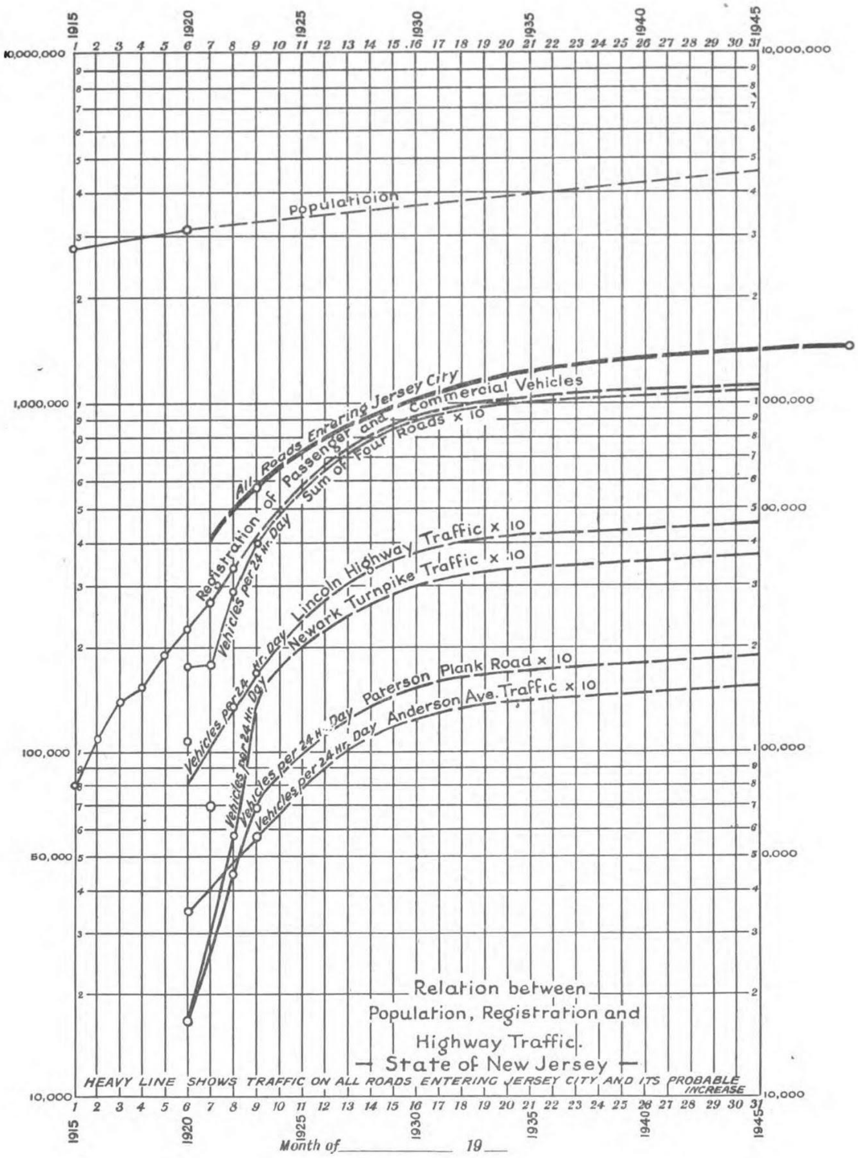
[269] *Ibid.*, 36-37
[270] *Ibid.*, 39
[271] *Ibid.*
[272] *Ibid.*, 40



Relation Between Population, Registration and Highway Traffic[273]

The Board proceeded to recommend a route-long minimum curvature with a 150 foot radius, as well as the elimination of all at-grade highway and railroad crossings with the exception of the one at Tonnelle Avenue in Jersey City. The Board stated that “we

273 *Ibid.*, 38

believe the capitalized value of elimination of a grade crossing on this highway to be approximately $1,700,000.00."[274] Geometry was also evaluated resulting in a recommendation that the designers use a 50 foot wide highway where parking was not required along the sides, a 100 foot wide right-of-way, and granite block pavement on a concrete base to ensure longevity. The study also provided a brief assessment of the advantages and disadvantages of using low-level moveable bridges, high-level fixed bridges, or tunnels to cross the Hackensack and Passaic Rivers, and concluded with an extensive financial evaluation of the best routes for each section of the overall alignment.

"The selection of the route between the entrance to the tunnel and the westerly outskirts of Elizabeth, on Route 1, was given very careful study and consideration, … [and was] believed to represent the best route which [could] be selected, giving due weight to the economics involved."[275] The Board separated the overall route into six separate recommended sections and provided information regarding property acquisition issues, property damage potential, possible types of construction, topography, railroad and trolley intersections, and municipal concerns associated with each. It was on the basis of this documentation that the section definitions and costs noted below were derived. The study was completed with the presentation of the recommendations shown below, in Table 7.

[274] *Ibid.*, 41
[275] *Ibid.*, 45

Table 7 – Proposed Route Sections and Cost Estimates

"As regards Route No. 1 extension, the Advisory Board respectfully recommends the selection of the following sections as representing the route and type of construction best fulfilling the requirements laid down in the resolution of the State Highway Commission, namely:

	Estimate
Section No. 1. Jersey Avenue to Palisade Avenue, Viaduct via Twelfth Street,	$1,121,250.00
Section No. 2A. Palisade Avenue to Broadway and Halleck Street, in open cut from Palisade Avenue to P.R.R., with approach ramps at Baldwin Avenue and Hudson Boulevard,	4,813,325.00
Section No. 3. Jersey City to Newark over the Meadow location, using tunnels under the Hackensack and Passaic Rivers,	16,186,825.00
Section No. 4. Newark Plank Road to Weston Avenue,	3,134,325.00
Section No. 5. Carnegie Avenue, McClellan Street, King Street to North Avenue, Elizabeth. Undercrossing at Frelinghuysen Avenue,	2,377,395.00
Section No. 6. North and Irvington Avenue, to Elmora Avenue, to Rahway Avenue,	561,832,50
Total Route No. 1,	$28,194,952.50
Bergen County Connecting Links,	1,347,312.50
Grand Total,	$29,542,265.00

It is to be noted from the estimate sheets included in this report that if the bridges using an underclearance of 40 feet are used, instead of tunnels, the above estimated amount would be reduced by $8,334,337.50."[276]

Major Sloan and his fellow board members had clearly performed a great deal of work in a matter of months. Interestingly, they recommended the use of tunnels at the two rivers along the planned route but still acknowledged that, despite their thoughts

[276] *Ibid.*, 55

on the advantages of tunnels, the use of high-level bridges would actually be more financially advantageous. It would be the work of the design team, under the leadership of Fred Lavis and Sigvald Johannesson, to make the final decisions regarding the best approach to the location and design of the Route 1 Extension from the standpoints of structural capacity, geometric needs, constructability in the context of a dense urban setting, and – in large part if not primarily – economic feasibility. That design process would be a long and complicated one, but one that was necessary due to both the criticality of the project goals and the enormous anticipated financial investment. Writing about the design process when looking back in 1930, Fred Lavis praised Sloan's support of his engineering team, saying

> "it has been the writer's experience, and that of many engineers, that all this work of preparing sketches, plans, detailed studies, innumerable estimates of costs, etc., for various schemes eventually to be discarded, is apt to be entirely forgotten after the structure is completed; or, it is assumed that the engineers should have brought forth, full fledged, the final design at the beginning.... [It is] important, therefore, to … give due recognition to the fact that the State Highway Commission of New Jersey and the State Highway Engineer never failed to give those in charge of the project complete support and full recognition of the work required, and which was accomplished, in working out the problems of this important enterprise."[277]

Lavis and Johannesson were indeed fortunate to have Major Sloan's complete cooperation as it related to the design effort as a whole and also his validation that the design process would emulate past railroad economic analysis.

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277 Sigvald Johannesson, "Lincoln Highway from Jersey City to Elizabeth, New Jersey," *Transactions of the American Society of Civil Engineers*, 100, 1 (1935).

Lavis Begins the Project Design

Following the passage of the 1916 federal Road Act, when railroad construction was waning and states were desperately in need of well-educated and trained engineers to staff their new highway departments, many former railway designers moved into the field of highway work. These engineers brought with them a wealth of knowledge and experience in the area of economic design theory – albeit for railroad construction. But, as had been stated by so many in prior years, a Wellington style theory for highways was not only appropriate but also achievable if only the "right" man or right team were to come forward with such a process. Fred Lavis strongly believed that highways could and must utilize the same principles of economic planning that railroad designers had long used for the comparison of line locations and structure types. He felt that, although some characteristics of standard highway planning and railway design were dissimilar, the Route 1 Extension project was one in which Wellington's theory could be applied to a significant degree. The 1923 state study clearly illustrated that Sloan's approach to the design of the project was compatible with that of Lavis. Unlike most roadway projects, which were largely governed by long-standing limitations in location methods and means of funding, the Extension route was anticipated to be one built much along the lines of a mainline railroad. Bypassing existing roads and city areas, and laid out within a new right-of-way, the proposed, high-speed, express corridor was intended to provide uninterrupted traffic flow in imitation of a rail line. It was to be constructed along an entirely new alignment, rather than occupying a previously existing route, and in this respect the highway would mirror railroad alignment and location practice of the past. The Extension project was also anticipated to permit only limited access.

When Lavis took charge of the project design in 1924 he began to develop a complete documented theory of roadway location, based on the preliminary data and assessments contained in the recently completed "Vehicular Tunnel Traffic Study," and as derived and revised from Wellington's railway economic theory. The process first involved the determination of those elements comprising the operating costs of the vehicles that he anticipated would use the completed route. Using a procedure much like that of Wellington, Lavis stated that "the costs of operation of a commercial motor vehicle may be defined into these items:

1. Interest on capital invested
2. Depreciation
3. Insurance
4. Drivers' wages
5. License fee
6. Gasoline
7. Oil
8. Tires
9. Repairs
10. Washing and cleaning
11. Battery
12. Overhead

It will readily be seen that Items 6, 7, 8, 9 and 11 are directly affected by and generally proportionate to the distance traveled by the vehicle, while the others are not."[278] Available studies of vehicular costs for the region were based on an existing observed vehicular makeup for the area roads, comprising fifty percent heavy trucks, twenty-five percent medium weight trucks and buses, and twenty-five percent passenger cars. Using this information, Lavis estimated that, for the metropolitan New York City area, the combined cost of the five indicated items equaled approximately twelve cents per mile.

Other assumptions were made in order that the project might be planned on a realistic cost basis. A speed of fifteen to twenty miles per hour was used for traffic in a total of four proposed traveled lanes (two in each direction), yielding a 5,455 vehicle per hour capacity – a figure essentially equal to that derived by the Advisory Board in 1923. In addition, "at times of peak traffic in one direction it was assumed that the traffic on the other two lanes would be at one half capacity."[279] When combined, these determinations yielded a maximum estimated traffic count of 3,600 vehicles per hour, or a total estimated annual traffic count of approximately 18, 360,000 vehicles. With this yearly estimate in hand Lavis had the starting point on which to base his alignment option analyses. "The economic problem [was] … the determination of the effect of the physical characteristics of the route and the cost of modifying or changing them."[280]

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278 Fred Lavis, "Grade Crossings: The Money Value of a Car Minute," *The Annals of the American Academy*, Volume 133, (1927), 173.

279 Fred Lavis, "Highways as Elements of Transportation," T*ransactions of the American Society of Civil Engineers*, Vol. 95, Iss. 1 (1931).

280 Lavis, "Grade Crossings," 174.

Heavy trucks were determined to be those with a weight capacity of at least two to two and one-half tons, and this category of vehicle also included heavy buses. Light trucks included all other smaller commercial vehicles, and automobiles were intended to be primarily those used for recreational travel. The daily cost of operating a given truck was a combination of some items that were associated with trucks that were actually in use and others that were spent regardless of usage. For example, research of area costs indicated that a three ton truck cost its owner $3,336 per year in payment for interest, depreciation, insurance, drivers' wages, licensing fees and overhead. Divided over an average three-hundred working days per year this sum yielded an operating cost of 2.30 cents per mile. For smaller commercial and business vehicles these costs added up to $3,120 per year or an equivalent 2.20 cents per mile.

Lavis also noted that some vehicles would be utilizing the highway for purposes of pleasure and, therefore, had no true commercial value. However, he also stated that, in his opinion, even those persons who drove pleasure vehicles would be upset by delays and would probably be willing to pay for the capability of avoiding such delays if they could be given the opportunity to do so. Therefore, although payment for the option of moving ahead of others or of avoiding slowdowns altogether was not an actual possibility, Lavis believed that it was "proper to assign money value for delays at not less than 1 cent per minute."[281] By combining the average costs of all anticipated vehicles for his proposed route, Lavis could now determine what he termed the "Money Value of One Car-Minute." Assuming that the primary usage on the proposed Route 1 Extension

281 *Ibid.*, 177

would consist of seventy-five percent heavy trucks, twenty percent light trucks and passenger vehicles, and five percent pleasure cars, Lavis' preliminary analyses yielded an average calculated equivalent operating cost per car-minute of 2.20 cents. Interestingly, Sloan's 1923 report had stated that "economists figure the value of the time of a motor vehicle at 5 cents a minute and upward,"[282] so Lavis was certainly taking a conservative approach in his design of the new highway to ensure that it met current and future needs.

With this computation completed the various factors to be considered for the planning of the highway location and alignment could be calculated in terms of their comparative expenditures. The goal of the analysis was to determine the amount of money that could be spent, at a profit, in the shortening of the proposed alignment. Some diversions from a straight-line highway that were required to address conditions or constraints – such as municipal and railroad issues – and that were beyond the control of the design team Lavis termed "governing points." Regardless, the primary focus of the entire design process remained economics. Distance was the first element for which operating costs were computed. Studies were performed using combined time costs and operating costs. Lavis began with available area-wide information indicating costs for a vehicular makeup of fifty percent heavy trucks at a cost of 15 cents per mile, twenty-five percent light trucks and buses at 10 cents per mile, and twenty-five percent non-commercial vehicles at 6 cents per mile. From this information he computed an average 11.5 cent cost per mile, or 2.18 cent cost per one-thousand feet of

[282] *Report of the Advisory Board*, 23.

distance traveled. Assuming 18,360,000 vehicles per year, a distance shortening of one-hundred feet was equivalent to a savings of just over $400,000 which, when capitalized at 6 percent, was equal to $6.67 Million in savings. Therefore, using an estimated $2.4 Million per year that would be gained by reducing the highway length by a single mile, Lavis stated that it was justifiable to spend $48 Million for each mile reduction of his route. The same ratio of cost to length could also be applied to other distance variations, and therefore, it was determined to be reasonable to spend $9,000 for the saving of every single foot of length on the highway.

The Extension was designed using only curves with large radii in accordance with the recommendations contained in the planning study, and so it was assumed to be reasonable that the effects of curvature would be insignificant in comparison with the other items under evaluation. Therefore, the effect of curvature was believed to have no significant impact on operational costs, and was not considered by Lavis and his design team. Rise and fall were "considered [in terms of] how much power/fuel it took to move a vehicle up a grade and at what point it was more efficient to keep a road at a higher grade for a consistent length when a higher grade was needed at a specific point, than build a road with a series of grades."[283] Earlier experiments performed at Iowa State College had indicated that the work done to raise a weight to a height of one foot was approximately equal to the force required to propel the same weight over a level distance of fifty feet on good pavement. On this basis, the cost of producing power

[283] *Routes 1 & 9 Corridor Historic Engineering Survey: Historical Narrative and Assessment of Significance and Integrity*, TAMS Consultants for New Jersey Department of Transportation Bureau of Bridge Inspection, (1991), 19.

alone could be approximated by the combined cost of fuel and oil, which was determined to be 3.22 cents per mile or 0.03 cents per fifty feet. Thus a cost equivalent to the value of raising the average automobile to a height of one foot could be determined. On this basis, Lavis attempted to reduce significant variations in grade for the sake of cost efficiency. Grades of between two and three and one-half percent were utilized with gradients varying for long distances of continuous rise. Lavis computed that for rises of less than fifteen feet in elevation there was no cost effect. However, rises of between eighteen and twenty feet, between twenty and twenty-five feet, and over twenty-five feet saw the profitable expenditures of $30,600, $61,200, and $91,800, respectively, for each reduction of a single foot of rise.

Another major factor to be considered, that significantly impacted mainline highway traffic, was the presence of crossings of other highways at grade. Wellington had not considered the cost of such delays because railroads were generally constructed with few occurrences of local crossings. However, in an area as congested with motor vehicles and motor vehicle routes as Northern New Jersey the time delay cost of highway crossings was critical. For computational purposes "it was assumed that the traffic conditions at the crossing were such that traffic on the main highway could proceed for three minutes and then be interrupted for one minute."[284] The delays caused by at-grade crossings were assumed to occur randomly throughout any given day, and the predetermined average operational cost of 2.20 cents per minute was used for mainline highway traffic. The daily loss on the main route was estimated at 14,532

[284] Lavis, "Grade Crossings." 173.

car-minutes (or single minutes of vehicle travel time) per day, and the loss on the cross street at 9,000 car-minutes, providing a combined 23,532 car-minutes lost per day at one crossing. Using a conservative assumption of 7 Million lost car-minutes per day at a conservative 2.0 cent cost per car-minute it was determined that every crossing would result in a loss of more than $140,000 per year. Therefore, the capitalized equivalent that could reasonably be spent to eliminate a single at-grade highway crossing was found to be $2.33 Million. Even using what Lavis believed to be a conservative approach to his computations, with then-current information in hand his $2.33 Million value exceeded the preliminary figure of $1.7 Million that Sloan and the Advisory Board had published in their study report.

Lavis explained that delay costs included not only actual loss of vehicular time but also reductions in highway capacity. Therefore, capacity calculations had to be factored into the previously derived crossing delay costs. Assuming that delays occurred only at times of maximum volume demand, Lavis estimated a 12.2 percent reduction in movement on the main highway. Assuming a construction cost of $22 Million for the Route 1 highway the twelve percent total loss of efficiency was valued at $2.66 Million. By adding the two elements of crossing delay cost together one might profitably spend $5 Million in order to avoid each crossing. "Of course, if there were a series of such crossings, this sum would not be multiplied by the number of crossings…. It was further calculated that, if there were several of such crossings, spaced at approximately equal distances apart and controlled by synchronously operated signals, the amounts which might be spent to avoid them might be assumed"[285] to approximately equal $5 Million for a single crossing, $5.3 Million for two crossings, $5.6 Million for three crossings, $5.84 Million for four crossings, and $6.08 Million for a total of six at-grade crossings.

In consideration of the type of structure for use on the Passaic and Hackensack River spans, drawbridges similar to those existing at the adjacent Lincoln Highway route were considered versus high-level fixed structures in terms of vehicular operating costs. Sloan's 1923 study had ascertained that traffic on the existing Lincoln Highway was delayed approximately 10.4 percent of the time due to river openings, and the Board's preliminary calculations had confirmed that "the establishment of movable bridge floors at higher clearances than 40 feet [did] not seem economically sound, but the additional cost of constructing the bridges with 40-foot under-clearance over that of bridges at approximately the present level [was] amply justified."[286]

Moving forward, Lavis evaluated the use of thirty-five foot high, movable bridges as opposed to drawbridges for what was then called Section 3 of the newly named, proposed Route 25. Two factors were considered in this analysis that mirrored the evaluation of at-grade crossings. The actual cost of delays was combined with the cost of decreased overall highway capacity. The delay cost was found to equal the average number of openings per hour multiplied by the number of vehicles using the highway per hour, providing the resultant estimated loss in car-minutes. Delays were estimated

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285 Lavis, "Grade Crossings," 174.

286 *Report of the Advisory Board*, 44.

at 32,470,000 car-minutes per year. Using a conservative 2.0 cent value of a car-minute and a six percent capitalization rate, $10,823,000 could be saved through the elimination of one drawbridge. Efficiency was estimated to be reduced by 6.33 percent for the highway, based on the previously assumed construction cost of $22 Million. Therefore, an additional $1,392,600 could be saved through the gain in capacity, resulting in a total savings of $12,215,600 for the elimination of a single waterway crossing. Rather than use fixed or movable bridges, the Sloan report had indicated a preference for the use of tunnels at the two waterways, thereby avoiding any delays associated with bridge openings. However, it was now the responsibility of the design team to perform the thorough analysis of river span alternatives that would be required to justify the final design.

Johannesson Completes the Design

After Fred Lavis departed the New Jersey Highway Department in 1928 to return to railroad construction as president of International Railways of Central America Sigvald Johannesson, who, prior to that time, had "not only worked out the mathematical solutions of [the various design] problems, but who also [had been] …in entire charge, under the direction of … [Lavis], of the design of the structure,"[287] took over the primary work. He continued performing alternative studies, assessing the economic effects of length, rise and fall, curvature, and construction costs for the four options under consideration for what was known as the Route 25 Connecting Link. What had

[287] Lavis, "Highways as Elements," 1040.

historically been US Route 1 largely became the newly designated NJ Route 25 under the 1927 state highway renumbering plan. Therefore, what had been the Route 1 Extension became the part of Route 25 that would connect the Holland Tunnel to nearby New Jersey routes (also referred to as the Diagonal Highway), and the portion that would ultimately become the Pulaski Skyway was called Section 3 (as defined in the Sloan report) of Route 25 – or the Route 25 Connecting Link. Although construction on the end segments of the overall highway began in 1925, controversy surrounding the types of structures to be utilized for the two river crossings led to several iterations of the Connecting Link evaluation. As had been the case in the 1923 study, the waterway span options consisted of either tunnels or the combined possibilities of two different bridge types – high and low level. The original Advisory Board recommendation had called for consideration of up to 40-foot high movable bridge spans and the state ultimately applied to the US War Department in 1925 for permission to construct 35-foot high structures.

At the time of Lavis' departure, the design had been based on the assumption that this type of bridge would be utilized at both river spans. However, when concerns that navigational demands would increase in future years resulted in opposition to this plan, the War Department denied the requested construction permits.

> "Various options were subsequently studied, including shifting the Passaic River crossing (a lift bridge) to a location adjacent to the existing Lincoln Highway Lift Bridge so that both could be operated synchronously. This proposal was rejected by the State Highway Commission because the

> revised alignment would add approximately 3,000 feet to the highway and would compromise the traffic handling efficiency of the route."[288]

The failure to obtain bridge construction permits prompted the creation of a new committee to study the crossing types as well as the overall configuration of the Route 25 Connecting Link section of the highway. While this effort was underway, construction on the outer segments continued and, in late 1928, two routes for the Connecting Link were proposed for consideration. Designated Lines A and B, these routes measured 12,253 and 13,003 feet, respectively, regardless of the level at which they crossed the Hackensack and Passaic Rivers. Therefore, the analyses indicated that, due to the relationship between the length of line A at either the high or the low level and that of line B (also at either the high or low level), A was preferable to B simply because of the approximate 750 foot savings in overall length and associated savings in cost. Johannesson eliminated Line B from further consideration and utilized only Line A, comparing the differences between the high level and low level crossings. It was obvious that the high level route would require greater rises and falls, while the low level route resulted in additional operational costs due to delays caused by drawbridge openings. Therefore, Johannesson needed to perform calculations through which the results of the two options might be made equivalent for purposes of comparison. To accomplish this, the cost of rises and falls was added to the overall low level construction cost, and the cost of drawbridge delays was added to the overall high level cost. These computations indicated that the high level bridge option was preferable.

[288] *Routes 1 & 9 Corridor Historic Engineering* Survey, 13.

The resultant construction cost combined with the cost of either delays or rise and fall was $21,474,223 for the low level route versus $16,898,410 for the high level route.

As design neared completion, final studies for alternatives for the Connecting Link structure were performed in 1929 on the basis of three slightly different options. Comparison was made between 135 foot high fixed bridges, 35 foot high movable bridges, and tunnels. Estimated delay costs for the drawbridges were derived from careful consideration of traffic density and loss in highway efficiency based upon known figures from the Lincoln Highway spans. New lift bridges to be constructed over both rivers were estimated to cost a total of $19,289,900. An estimated $20,454,000 would be required for an independent route for a new highway utilizing tunnels under both rivers. An independent route with high level fixed bridges at both crossings was estimated at $18,915,000. (Refer to Tables 8, 9 and 10.) All total costs combined the expenses associated with both construction and real estate takings. Annual operating costs were analyzed for all three options, as were the costs of differences in distance, rise and fall in grade, and bridge operation delays. The total combined construction and operational costs for the three alternative schemes were computed to be $49,194,054, $48,512,333 and $42,259,167 for the movable bridges, tunnels and fixed bridges, respectively (refer to Table 11). "The results obtained indicated that the most economical type of structure would be a high-level fixed bridge. This type of construction was then adopted."[289] Although no longer involved in the project, when writing in 1930 about the design

[289] H. W. Hudson, "The New Jersey High-Level Viaduct." *Civil Engineer*, Volume 3, (1933), 149.

efforts Fred Lavis indicated that he was "entirely in accord with this final decision."[290] As the bridge types ultimately selected were of the high-level (135-foot) fixed type that posed no impediment to river traffic, the War Department and the Board of Commerce and Navigation readily issued the necessary permits to allow New Jersey to complete the corridor.

Portions of the highway were gradually opened to traffic with the major sections at each end opened on December 16, 1928 and a subsequent partial opening occurring on September 27, 1930. As was stated in the *New York Times* on the following day, "Route 25, the superhighway providing a through route from the Jersey end of the Holland Tunnel all the way to Philadelphia, as well as Trenton, Camden and other South Jersey points, was opened to traffic yesterday afternoon."[291] Construction of the Route 25 Connecting Link was completed and the entire highway viaduct formally opened on November 23, 1932. The *New York Times* immediately hailed the project as a "time-saver," saying:

> "Motorists who have struggled through the traffic jams and delays common along the Lincoln Highway between Jersey City and Newark will welcome the opening, on Thanksgiving Day, of the magnificent new viaduct across the Newark Meadows … [that will] permit the motorist to cover in about five minutes a distance that formerly required from twenty minutes to two hours…. The structure has a roadway fifty feet wide with five lanes of traffic capable of accommodating 20,000,000 vehicles annually."[292]

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290 Lavis, "Highways as Elements," 1039
291 "New Jersey Opens New Auto Route," *The New York Times*, September 28, 1930.
292 "New Viaduct a Time-Saver," *The New York Times*, November 26, 1932.

Table 8 - Estimate of Cost of Drawbridges[293]

Linear Feet	Item	At	Cost
250	Steel structure, 24,760 square feet	$15	$371,000
500	Surface roadway	60	30,000
520	Embankment between retaining walls	800	416,000
250	Steel structure, 24,760 square feet	15	371,000
240	Steel structure	660	158,000
40	Concrete abutment		43,000
2,490	Concrete arch structure	650	1,618,500
40	Concrete abutment		43,000
255	Steel structure	660	168,000
179	Steel superstructure	600	107,400
739	Lift and tower spans, Hackensack River		997,000
558	Steel superstructure	600	322,800
	Foundation, Hackensack River		612,000
40	Concrete abutment		43,000
2,780	Concrete arch structure	660	1,834,000
40	Concrete abutment		43,000
2,280	Steel structure	660	1,504,800
	Ramp		435,400
	Paving Jacobus Avenue		14,600
534	Lift and tower spans, Passaic River		601,000
	Substructure, Passaic River		340,000
1,500	Steel structure	700	1,050,000
400	Embankment	166	66,400
			$11,389,900
	Lincoln Highway tunnel, Hackensack River		6,000,000
	Lincoln Highway bridge, Passaic River		1,900,000
			$19,289,900

293 Sigvald Johannesson, *Highway Economics*, (New York and London: McGraw Hill Book Company, 1931), 131.

Table 9 - Estimate of Cost of Tunnels[294]

Linear Feet	Item	At	Cost
400	Steel structure	$660	$265,000
450	Embankment, retaining walls	600	270,000
3,000	Ramps	60	180,000
250	Embankment	200	50,000
2,000	Depressed roadway	1,000	2,000,000
3,600	Tunnel, Hackensack River	1,800	6,480,000
2,900	Depressed roadway	1,000	2,900,000
	Bridges over roadway		120,000
	Ramps		1,000,000
3,200	Tunnel Passaic River	1,800	5,760,000
350	Depressed roadway	1,000	350,000
	Bridge over Lincoln Highway		40,000
500	Embankment	120	60,000
	Ramp to Avenue P		40,000
	Reconstruction, Lincoln Highway ramp		40,000
	Additional for rock excavation for Hackensack River tunnels		900,000
	Total		$20,454,000

Table 10 - Estimate of Cost of High Level Viaducts[295]

Linear Feet	Item	At	Cost
800	Steel structure	$800	$640,000
1,000	Steel structure (with ramp)	2,000	2,000,000
2,000	Steel structure	1,000	2,000,000
1,500	Steel structure (Hackensack River bridge)	2,000	3,000,000
1,200	Steel structure	1,000	1,200,000
1,000	Steel structure (with ramp)	2,000	2,000,000
2,600	Steel structure	1,200	3,120,000
1,500	Steel structure (Passaic River bridge)	2,000	3,000,000
1,400	Steel structure	800	1,120,000
300	Steel structure	1,000	300,000
500	Steel structure	800	400,000
500	Steel structure	270	135,000
	Total		$18,915,000

[294] *Ibid.*, 132
[295] *Ibid.*, 133

Table 11 - New Jersey State Highway, Route 25, Broadway, Jersey City, to a Point West of Lincoln Highway, Newark Comparative Estimate[296]

Item	Scheme 1, lift bridges	Scheme 2, tunnels	Scheme 3, high bridges
Physical Characteristics:			
Length, in feet	15,050	14,800	14,800
Rise and fall, in feel	58	131	114
Annual Costs:			
Highway maintenance	$15,330	$10,240	$52,940
Highway depreciation	265,679	292,180	214,690
Highway operation	136,600	120,900	43,900
Total annual highway costs	$416,609	$423,320	$311,530
Motor vehicles, distance	$100,000	$0	$0
Motor vehicles, rise and fall	532,440	1,202,580	1,046,520
Motor vehicles, delays	798,000	0	0
Total annual motor vehicle costs	$1,430,400	$1,202,580	$1,046,520
Total annual costs	$1,847,049	$1,625,900	$1,358,050
Cost of construction and Capitalized Annual Costs:			
Cost of right-of-way	$1,020,000	$960,000	$710,000
Cost of construction, Route 25	11,389,900	20,454,000	18,915,000
Cost of Lincoln Highway tunnel	6,000,000		
Total right-of-way and Construction	$18,409,900	$21,414,000	$19,625,000
Annual highway cost capitalized, 6 per cent	$6,943,487	$7,055,333	$5,192,167
Annual motor vehicle cost capitalized, 6 per cent	23,840,667	20,043,000	17,442,000
Total annual cost, capitalized	$30,784,154	$27,098,333	$22,634,167
Total comparative costs	$49,194,054	$48,512,333	$42,259,167

In addition to being a time-saver, the bridge was an impressive engineering achievement. A few months short of opening day, a lengthy article about the viaduct was released in *Scientific American* magazine. Author Frank A. Reddan said that "states

296 *Ibid.*, 141

far removed from the metropolitan areas cannot visualize the traffic problems of New Jersey nor can they fully appreciate the pioneering spirit demanded of the Highway Board in setting a precedent for its solution."[297] He further noted that, "representing a courageous conception of road-building, [the] structure and its adjacent links have been described as a marvel of engineering by authorities both here and in Europe, … [and] the most outstanding highway-engineering achievement in history."[298] As further evidence of its stature within the engineering community, the American Institute of Steel Construction gave the bridge portion of the corridor its 1932 annual award of merit as the "Most Beautiful Steel Structure" among long-span bridges.

Even long after the opening day, the Connecting Link segment of the project was still being variously referred to in the press as well as in common usage as the Diagonal Highway, the High-Level Viaduct, or the Newark-Jersey City Viaduct. People across the state made recommendations for a name better suited to the new bridge. "One of the myriad of suggestions for a name [was] 'Molly Pitcher pike,' … [and] Mayor Jerome T. Congleton of Newark, in a letter to the state highway commission … suggested the span be called Alexander Hamilton highway, in honor of the first secretary of the treasury."[299] Finally, in early 1933 the New Jersey State Legislature passed a joint resolution to rename the road, and the new superhighway was rededicated in honor of the Polish

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297 Frank A. Reddan, "A Super-Highway System Being Supplemented by a Super Viaduct – Longest of its Kind in the World," *Scientific American*, August 1932, 83.

298 *Ibid*.

299 "Would Name Road Molly Pitcher Pike," *Asbury Park Press*, December 1, 1932, 2.

Revolutionary War leader on October 11, 1933 as the General Casimir Pulaski Memorial Skyway.

> "A plaque, bearing the name of the highway was unveiled at a point over the Passaic by Mayor Meyer C. Ellenstein, of Newark. A similar marker was unveiled over the Hackensack river by [Jersey City] Mayor Frank Hague. The Mayors, accompanied by Gov. Harry A. Moore and an official party that had started from Newark airport, then motored to Lincoln park [in Jersey City] where the governor unveiled a memorial tablet to Pulaski." [300]

Before the formal renaming had even taken place, Sigvald Johannesson began his new work of educating engineers in the study of highway economics and what the use of the theory had achieved in New Jersey.

[300] "Mayors Dedicate Pulaski Skyway," *Asbury Park Press*, October 12, 1933.

The Theory of Highway Economics

Johannesson Writes the Book

Even before the completion of the Route 1 Extension, the New Jersey superhighway that was then under construction was seen as the leading example of the value and applicability of the new economic design process. In 1930, Fred Lavis wrote an article that was published by the American Society of Civil Engineers entitled "Highways as Elements of Transportation." Focusing primarily on the need for what he called "special highways" that were

> "necessary where the traffic demand [was] large, to provide for the free uninterrupted flow of the through traffic without interference from local uses, [Lavis stated that] the nature of the problem and suggested methods of solution [could] best be indicated perhaps by a description of the design and construction of the arterial highway between the Hudson River and Elizabeth, known as Route 25 of the New Jersey State Highways."[301]

Comments on this paper by W. W. Crosby and W. L. Webb stated that, in the utilization "of the principles suggested by Mr. Lavis … perhaps no single example of remarkable magnitude [could] … be cited … [and] the construction of Route 25 in New Jersey [was] … one of the first of many … projects which [would] … undoubtedly arise in the solution of the fast growing motor-transport industry."[302] The New Jersey project provided, in the words of D. P. Krynine, "an introduction into the transportation system of a new kind of

[301] Lavis, "Highways as Elements," 1022
[302] Lavis, "Highways as Elements," 1041 and 1043

link that is something between ‘highway’ and ‘railway.’”[303] As was clear from these and other responses to Lavis’ article, the work on the Route 25 highway was recognized as pioneering as well as significant to future highway development. Lavis’ participation in the design of the Route 25 project and in the development of economic theory continued to be recognized by his peers long after his departure from New Jersey, and the American Society of Civil Engineers awarded him the Wellington prize in 1932 for his 1930 article. “This prize was instituted in 1921 … in response to a proposal by the Engineering News-Record, which endowed the award in honor of Arthur M. Wellington, … [and continues to be] awarded annually for papers on transportation on land, on the water, in the air, or on foundations and closely related subjects.”[304]

Although Lavis continued his advocacy for economic roadway design, it was Johannesson who took up the effort of providing the full documentation, explanation and justification of the theory that he believed was required. He stated that “since the study of highway economics [was] … quite new, it [was] … natural that there should be a number of questions relating to it that [had] … not been fully answered as yet.”[305] Authoring a paper for the New York publication *Civil Engineer* in 1933 that addressed his primary concern with the cost of building highways, he stated that delays had to be considered in terms of loss of travel time, which was a combination not only of vehicular operating costs per vehicle-minute but also the value of the time being

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303 *Ibid*., 1047
304 “Arthur M. Wellington Prize,” American Society of Civil Engineers, accessed March 6, 2019, http://www.asce.org/templates/award-detail.aspx?id=1605.
305 Sigvald Johannesson, “Cost of Traffic Delays,” *Civil Engineer*, Volume 3, (1933), 149.

expended as it was perceived by the persons occupying the vehicles. Johannesson was well aware that not all highways of the type in question were then being designed to carry primarily large trucks. In addition, it was obvious, by the early 1930s, that the passenger vehicle volume within the northern New Jersey area with which Johannesson was familiar was increasing even more rapidly than had been previously anticipated. Presenting his argument on the basis of passenger vehicle, rather than commercial truck, usage he offered computed cost savings as they applied to more general usage than that which had been assumed in the Route 25 design. He also did this because he believed that if operational highway costs were better understood by the general public people would be more willing to pay for savings that they acknowledged would benefit them directly.

In his 1933 article, Johannesson shifted his focus away from Route 25 project study costs, wherein an approximate 2.0 cent per vehicle-minute had been utilized, in favor of discussing savings based on cars alone, stating that on Route 25 "the proportion of heavy trucks [was] … exceptionally high, and for that reason the estimated money value of a vehicle minute naturally [was] … materially greater than that for the average highway."[306] In approaching the cost of delays due to slowing and stopping, he presented an equation of his own derivation that computed the amount of time lost under known conditions. The formula was stated thus:

$$T = a^2p / 2(d-t)$$

[306] *Ibid.*, 151

where T represented the time lost in vehicle-minutes, p represented the rate of speed, a was the time traffic was stopped, d was the average distance between vehicles, and t equaled the minimum distance between them. Based upon the little available documentation of the time on vehicle spacing at various speeds he "tentatively concluded that the spacing t, expressed in feet [might] … be determined by the equation: t = 0.025q + 25, there q [was] the rate of speed in feet per minute at which the vehicles [were] … moving."[307] Johannesson went on to state that he was aware that some within his profession believed this latter equation to be inaccurate based upon variations in then-current calculated estimates for vehicular capacities at different speeds. For that reason, he noted that sufficient documentation did not yet exist from which to ascertain accurately the relationship between speed and vehicle spacing.

Regardless of the imprecise nature of this element of the evaluation, his understanding and inclusion of some measure of the speed related spacing required to prevent vehicle collisions was prescient. "Every motorist knows that to keep from hitting the car ahead, should it show down, he must have time to operate his brakes. That is, he must maintain a certain time-spacing, depending upon how quick he is. Sigvald Johannesson was perhaps the first to recognize this time-spacing factor."[308] In spite of the work still to be done in this area, Johannesson made a strong point in favor of economic roadway planning, stating without hesitation that economic theory – even if sometimes incorporating imperfect, but still the best available, information - was not

307 *Ibid*.
308 Bruce D. Greenshields, "Road to Fit the Drive," *The New York Times*, March 5, 1939.

only applicable but essential to road engineering. His assumptions and estimations were an important stepping stone in the ongoing process of evaluating this key issue in the behavior of highway traffic. By 1934 a new process of photographing vehicles to aid in traffic studies had been presented in an article published by Ohio's Denison University professor Bruce D. Greenshields. This report, which referred to Johannesson's valuable work in the area of assessing vehicle spacing versus speed, presented "a new method of securing accurate data on traffic behavior by means of pictures and [illustrated] the use of such data in the development of a new formula for expressing the relation between the number of vehicles passing a given point, their average speed, and spacing."[309]

An early comment in his 1933 article entitled "Lincoln Highway From Jersey City to Elizabeth, New Jersey" simply stated the importance of economic theory in the design of a highway that would have to accommodate an enormous volume of traffic and that was "expected to become one of the most heavily traveled roads in the world."[310] The highway location, passing through a heavily urbanized area and crossing railroads, rivers and other roadways, meant that

> "when the project was originally conceived it was appreciated that these conditions would affect, materially, its economics as applied to construction and use, and, for that reason, a careful study of this phase was made prior to actual design, so as to co-ordinate, as far as possible, the cost of vehicle operation with the cost of construction."[311]

309 Bruce D. Greenshields, "The Photographic Method of Studying Traffic Behavior." *Highway Research Board*, Proceedings Number 13, 1934, 382.
310 Johannesson, "Lincoln Highway from Jersey City to Elizabeth, New Jersey," 94.
311 *Ibid*.

The closing statement in his separate 1933 article entitled "Cost of Traffic Delays" further explained his belief in the significance of economic consideration in highway design. He pronounced that

> "the cost of highway improvement necessary to avoid delays may be found by standard engineering methods, and a comparison between this amount and the estimated cost of delays will indicate whether or not the improvement is economically justified, unless there are other tangible or intangible benefits gained by the improvement. Generally speaking, an improvement is not economically justified unless its estimated cost is materially less than the estimated cost of the delays eliminated."[312]

Johannesson and Lavis both went on to write other articles expounding the advantages of highway economic theory and explaining the process that had been used in the design of the Route 1 Extension but ultimately the most important contribution to the field of early economic roadway theory – what was termed the "seminal work" on the topic - was Johannesson's 1931 book entitled "Highway Economics."

Much of Johannesson's text consisted of a more thorough and detailed presentation of the basic concepts and design elements previously discussed by Lavis in the years leading up to 1931, and followed on Lavis' description of the Route 25 highway design analysis as contained in his "Highways as Elements of Transportation." Stating that any proposed highway improvement or construction project was economically justifiable if the derived benefits were worth the cost, Johannesson reiterated the importance of the analysis of distance, rise and fall, curvature and elimination of delays.

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312 *Ibid.*

Noting that economic benefits were often less evident in highway analysis than they had been when utilized in railway design, the benefits were, nonetheless, similar in nature. The body that spent the money and saw the benefits for railway improvements was the railroad company. The "body" that spent the money and reaped the benefits for highway improvements was essentially the people of the community who paid with their taxes and then utilized the roads.

Although advances had been made in the decade prior to the publication of this book in both the understanding of the need for an economic theory and in advancing actual economic design practices, those advances remained primarily within the engineering community and had yet to spread to the general public. "It [was] only during the last few years that the public [had] commenced to appreciate the fact that it, as the users of the highways, has a direct economic interest in their development, and much missionary work [had] yet to be done before that [was] fully understood."[313] Hence the need for advancement and education – especially as the benefits of economic design were both tangible and intangible, and the intangible ones, in particular, were not always easily acknowledged or understood. Johannesson explained that the tangible benefits of good economic management were the reduced operational costs for vehicles and maintenance costs for the highway. Intangible gains, such as traveling comfort, improved business facilities, fewer accidents, and increased real estate values, should also not be overlooked. However, he added that "unless the intangible benefits [were] of sufficient importance to influence the conditions, the money value of the tangible

313 Johannesson, *Highway Economics*, 3.

benefits should be materially in excess of the cost of the project, in order to make it worth while."[314]

The book explained why each individual cost item of the Route 25 analysis had been included in the design process, and that some items had been introduced as capitalized costs to ensure that all items were assessed on a comparative basis. For example, some items, such as construction cost, were single, non-recurrent expenses, while other items, such as those associated with maintenance, occurred at varying levels every year. "In order to place these annual expenditures on a basis which [made] it possible to compare them with the nonrecurring charges, it [was] convenient to introduce the maintenance costs in the form of Capitalized Cost of Maintenance."[315] Therefore, yearly maintenance expenses were considered to be equivalent to annual interest on a loan. The capitalized cost was equal to that amount of money that was required for the expense of yearly maintenance at a predetermined interest rate. "Highway Economics" provided example problems for the computation of the operational costs from various sources of increased expense. For these calculations, it was assumed that two-thirds of passenger cars on the nation's highways were traveling for non-commercial purposes, that eighty percent of trucks were of relatively light capacity (two tons or less), and that nationwide norms could be utilized for commercial drivers' wages, vehicle maintenance and fuel costs, and the number of working days per year.

314 *Ibid.*, 5

315 *Ibid.*, 37

Johannesson used these determinations to present his case for the effective economic analysis of highway layout. He recognized and acknowledged the existence of criticism on the part of other engineers who believed that some efforts then being made in the area of economic planning were deliberately exaggerating the time or monetary savings associated with the work. For example, University of Tennessee professor, N.W. Dougherty wrote in *Roads and Streets* magazine in 1931 that the money value of time savings was not always sufficient to justify expenditures and that economic analyses could easily be not only misunderstood but even misused. He argued that he had "come to the conclusion that the monetary value placed on business time [was] high and that the monetary value on pleasure and recreation [did] not exist."[316] Johannesson definitely disagreed with this statement and went to great length to explain why, stating within his book that

> "it has been suggested by some that no money value can be assigned to the time lost on the road where it amounts to a few minutes only; in other words, that it is of no economic importance that additional minutes, or even additional half-hours or more, are spent on the road, because if this time were not spent in traveling, the motor vehicle and the driver might be idling away the same time at the home garage. For commercial vehicles, this does not appear to be the proper viewpoint.... A commercial vehicle is, in fact, a commercial plant of which the cost of operation must be distributed according to the time spent on various jobs.... Let us suppose ... that an attempt is made to determine for each vehicle individually the money value of vehicle minutes lost.... [A] truck may be going to a warehouse to pick up a load. It might take a few minutes only to receive the load but, on account of a delay on the road of some minutes, the car arrives at the warehouse just as the noon whistle blows. The truck may

[316] N. W. Dougherty, "Evaluation of Distance and Time in Highway Location," *Roads and Streets*, Volume 71, (1931), 232.

> then be wasting a whole hour on account of the short delay. Another truck may, on account of a delay on the road, arrive with its load at the point of destination just when the day's work is over. It may be necessary then, either to return with its load, wasting the whole journey, or to pay overtime for the work of unloading."[317]

Five other examples were provided for different but similar scenarios with the concluding statement that "these cases might be multiplied indefinitely but they are sufficient to indicate the wide range of losses which may be incurred by delays on the highway, as well as the probable reasonableness of the money value of one vehicle minute assumed."[318]

The book provided calculations and results from the Route 25 analysis related to the costs of added distance, of ascending or descending gradients, of maneuvering around curves, and of being slowed or stopped due to delays. Johannesson offered extensive details about the analysis of vehicle speeds, vehicle spacing, and expended work, and included equations defining every element of his delay cost analysis. He provided the reader with the means for determining how many vehicles would be stopped and, therefore, delayed during a given traffic interruption, the length of time of the stoppage, the number of vehicles both originally stopped and later delayed by the earlier disruption, and the total number of vehicle-minutes lost by all motor vehicles involved in a given delay occurrence. He observed that "the total time lost is proportional to the square of the time of the stoppage, [and that] it is apparent that less

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317 *Ibid.*, 54
318 *Ibid.*, 55

time will be lost if the time of stoppage is decreased, even though the number of stoppages may have to be correspondingly increased."[319]

The terms traffic density and maximum traffic density were also defined and discussed. His definition of highway capacity was derived from density which was defined as the greatest number of vehicles traveling past any point along a route within a set period of time. Johannesson's capacity characterization differed from that which had recently been issued by the Highway Research Board in the proceedings of their eighth annual meeting: "The traffic capacity of a roadway is reached when any further increase in traffic volume, all other factors remaining constant, results in a marked decrease in traffic speed."[320] Johannesson believed that his description more accurately reflected the fact that vehicles on a given highway were rarely spaced evenly or traveling at equal rates of speed and stated that, although high density urban traffic was often addressed through the construction of high level routes that frequently resulted in increased construction costs, this type of construction could still be used to economic advantage depending upon regional needs. In other words, although the structural costs of erection of a high level highway were substantially greater than those for a surface route, the former alternative could be proven to be economically viable for addressing heavy volumes passing through densely populated areas because the elimination of sources of delay could save more money than the simple reduction of initial

[319] *Ibid.*, 86
[320] *Ibid.*, 93

construction costs by permitting improved traffic flow and reduced transportation expenses.

The work of Lavis and Johannesson, and the book "Highway Economics" clearly illustrated how economic design theory could be – and had been – put into practice. "Routes 1&9 was designed in the era when predictive formulae for assessing future traffic load was emerging.... Admittedly, these formulae were based on well-established railway engineering principles, but, nonetheless, this appears to be the first time that these basic concepts were applied to a highway."[321] An extensive review of period literature reveals no indication that other designers or another project utilized a fully realized economic process of evaluation such as that which resulted from the completion of the new "superhighway." The New Jersey corridor and the integral Pulaski Skyway, and the analysis undertaken in their planning, provided the basis for the widespread use of economic design of engineering works that was to follow. Additionally, the design and ultimate construction of the structures resulted in significant time, and therefore, financial, savings for the operators of vehicles utilizing the highway during the years following its completion.

Time Savings Realized

When the new highway opened fully to traffic there was much discussion and speculation regarding the "real world" value of the huge financial cost of the undertaking. The current and former governors both believed the expense to have been

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[321] *Routes 1 & 9 Corridor Historic Engineering Survey*, 42.

worthwhile due to the fact that manufacturing companies were considering making New Jersey their home now that travel across the region would be so greatly improved. During the opening day speeches,

> "General Hugh L. Scott, the chairman of the New Jersey State Highway Commission, said that the investment of $350,000,000 would have been economically justified in the construction of the road between the Holland Tunnel and Elizabeth. Actually, he said, the link cost $40,000,000. The use of $100,000,000 would have been justified for the viaduct, and that cost $19,000,000."[322]

Regardless of sweeping generalities such as these, it was important that the state be able to show conclusively that the results were worthy of what had certainly been an enormous cost. When the Pulaski Skyway was nearing completion, New Jersey requested that the Bureau of Public Roads conduct a traffic study to compare the effects of the new route to conditions existing prior to its opening. As the Highway Department had expended approximately $5.2 Million per mile for the viaduct, and the most critical saving analyzed during the design phase of the project had been that of travel time, it was of great importance to evaluate the ultimate effectiveness of the new highway.

The Bureau's Division of Highway Transport responded with a twelve month long traffic census performed during 1932 and 1933 to evaluate delays between Newark and Jersey City. To ensure that the study would incorporate figures that reflected the variation in drawbridge openings on the Lincoln Highway, wide time variations were

[322] "Auto Express Route Dedicated in New Jersey," *The New York Times*, November 24, 1932.

used in the collection of data. The traffic analysis of the old route was performed in late September and early October of 1932 over staggered eight hour periods during each project day, and traffic counts on the Skyway itself were made six months after the opening, during May of 1933, "in order to allow traffic to adjust itself to driving conditions."[323] The studies compared vehicular time spent crossing the area via the old, 4.2-mile long, route versus that required to traverse the new, 3.7-mile long, route between the same end stations. Consideration also had to be made of the fact that the new highway permitted vehicles to enter and exit at limited locations and that many drivers using the old route made use of the existing underpassing roads and did not utilize the main highway for the entirety of its length.

Study personnel developed a method, specifically for this study, of recording license plate numbers at the end points and at intermediate observation points, and used punch cards to transfer vehicle information to others for tabulation. Vehicles were documented by direction of travel and were classified by size and type. Hourly volumes were computed by class of vehicle to permit the determination of weighted average trip times per class. Weighted average trip times were established by compiling estimated hourly volumes for each vehicular class in each direction of traffic and combining it with existing information on bridge openings on the original route. The Port Authority provided Holland Tunnel traffic records for comparison with equivalent counts at the old Hackensack River span. Trip times and traffic counts for the longer route were

323 Lawrence S. Tuttle, "A Time Study of Traffic Flow on the New Jersey High-Level Viaduct," *Public Roads*, Volume 14, Number 12, (1934), 225.

divided into hourly periods to offer a realistic presentation of the variations seen in overall volume and number and duration of drawbridge openings. "The average trip time for each type of vehicle was obtained by multiplying trip time for each hour and each direction by the number of vehicles for each corresponding hour and direction, totaling these products and dividing by the total number of vehicles of the given type for the day."[324] Vehicular volumes at various sections of the original route were plotted against the total computed trip times. Mathematical curves were defined to represent the comparative volume versus time for both the old and the new routes. Using this information, the Bureau was able to determine the minimum estimated time saved for vehicles that had previously utilized the old ground-level route, and the maximum estimated time saved for vehicles diverted to the viaduct (refer to Table 12).

Table 12 - Summary of Vehicle-Minutes Saved Per Year by Type of Vehicle

	Minimum estimate	Maximum estimate
Passenger cars	47,407,000	57,445,000
Light trucks	3,521,000	4,833,000
Heavy trucks	3,744,000	3,827,000
Total	54,672,000	66,105,000

Although the overall process of evaluation – with its manual documentation format - was extremely simplistic by today's standards and when weighed against currently available technology, in the early 1930s little had yet been accomplished in the

[324] *Ibid.*, 226

analysis of motor vehicle movement. A separate 1932 vehicle movement study to assess traffic flow and delays at the intersection of Constitution Avenue and Seventeenth Street in Washington, D.C. (a length of only several hundred feet) used a time-recording machine activated by telegraph connections placed at various points along the route. This apparatus was new to traffic study and "probably no more accurate or inclusive information could [have been] obtained with methods … available to traffic investigators"[325] of the time. This system made precision to the nearest second possible; however, this degree of accuracy was critical for the short roadway length under consideration. On the other hand, the manual documentation used for the Pulaski Skyway, wherein recording was made to the nearest minute, was of more than adequate precision for the purposes of the 13-mile long study area. Despite the differences between the two methods, in 1934 the Bureau of Public Roads recognized both systems to not only be appropriate for use but also to be the most advanced means of performing traffic movement analysis then in existence in the country. It was also the starting point of the development of the more advanced methods for studying traffic behavior. For example, assessment processes such as that described by Professor Greenshields in his 1934 discussion of new photographic traffic study methods would lead to continuously more advanced means of evaluating vehicular movement in the years of significant highway construction that followed.

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[325] E. H. Holmes, "The Effect of Control Methods on Traffic Flow," *Public Roads*, Volume 14, Number 12, February 1934, 242.

The Bureau's study results indicated that there was a significant time savings associated with the new Route 1 Extension and Pulaski Skyway. "The great difference in the volume of traffic traveling between Tonnelle Avenue [in Jersey City] and the west end of the viaduct, before and after the opening of the viaduct,… [was] considered as a measure of the traffic … diverted to the viaduct, and which unquestionably benefit[ed] by the saving in time between these points."[326] Additionally, a large amount of area traffic bound for the newly opened George Washington Bridge had previously used roads north of the Tonnelle Avenue circle, and time was saved due to the reduced volume of traffic on the old route – much of which had been diverted onto the Skyway. The state had provided area counts for the study that indicated that increases in regional traffic during the decade prior to the opening of the Skyway had averaged well over 300 percent. However, it was observed that the number of cars on the old river crossings exceeded the volume of a decade before by less than sixty percent, despite the much greater overall regional increase. In addition, those vehicles that utilized the new route were able to cross the region more rapidly than had been possible in earlier years. Johannesson had originally assumed a savings of 15 to 45 minutes in his calculations; during the year of the highway opening the trip was observed to take 20 rather than the original 55 minutes to complete. Even at an estimated one cent per minute per car savings, which was conservative in comparison with Lavis' and Johannesson's original

[326] Holmes, "The Effect," 228

two cent approximation, in 1932 it was evident that a $6.36 Million vehicle cost savings would be realized annually.

Bureau of Public Roads personnel computed travel time savings for both traffic between Newark and Tonnelle Avenue and vehicles diverted from the Lincoln Highway Hackensack River bridge to the Route 25 crossing, and designated the results as the minimum and maximum savings estimates. New Jersey's final Skyway construction cost had been $19,300,000 and a six percent rate of capitalization had been used for the design. Using these figures, it was determined that "in order to justify the construction of the viaduct on the basis of the … minimum and maximum estimates a vehicle-minute [had to] be valued at 2.12 or 1.75 cents."[327] The viaduct cost was, therefore, justified, as Lavis' original estimated average 2.20 cent cost per vehicle-minute exceeded both of these figures. The February 1934 volume of *Public Roads* focused almost entirely on the time savings evaluation of the New Jersey highway with articles entitled "A Time Study of Traffic Flow on the New Jersey High-Level Viaduct" and "The Effect of Control Methods on Traffic Flow." The first of these articles was written by Lawrence S. Tuttle, who opened his discussion as follows:

> "the recently completed High-Level Viaduct between Newark and Jersey City in New Jersey has created wide interest because of the magnitude of the project and the engineering problems involved in its construction. Less publicity has been given to the economic problems. Costing $5,200,000 per mile, it is one of the most intensive pieces of highway construction in the world. A careful preliminary investigation indicated that of the various economies which would be effected by the construction

[327] Holmes, "The Effect," 231

> of the express highway from Elizabeth to the Holland Tunnel, of which the viaduct is a part, the most important was the saving in travel time."[328]

This article was discussed in the March 18, 1934 *New York Times* noting that "a report by Lawrence S. Tuttle, assistant highway economist of the United States Bureau of Public Roads, … tends to show that the elevated structure is justifying its cost of approximately $19,000,000, particularly as a time-saver for the millions of vehicles which annually traverse this route."[329] Tuttle's documentation provided specific figures related to the amount of time that drivers were now saving thanks to the construction of the new Route 25 highway.

> "Mr. Tuttle estimates the saving at a maximum of 66,105,000 vehicle minutes per year – in other terms, a saving of 1,101,750 hours, or 45, 906 days. Before the high-level road was opened, it would take passenger cars, on an average, 12 minutes on weekdays and Saturdays and 14 minutes on Sundays and holidays to cover the distance over the ground-level route…. The viaduct cut that time by more than 6 minutes daily and by 8 minutes on Sundays and holidays. Trucks made even larger savings, in most cases cutting the time by more than half…. The estimate … does not include 'all the savings which may be credited to the viaduct,' Mr. Tuttle declares. For one thing, the value of the shortened distance was not taken into account. For another, 'the traffic on the viaduct to which the average saving in trip time was applied is not [based on more recent traffic counts of] the total volume of traffic actually using the viaduct.'" [330]

It was clear from the Bureau's study that there were real savings in time spent accruing to both vehicles diverted from the old route to the new express highway and those using the viaduct over its entire length. In addition, as Holmes noted, there was

[328] Tuttle, "A Time Study," 223
[329] *The New York Times*, March 18, 1934.
[330] *The New York Times*, March 18, 1934.

"every reason to believe that the traffic on the viaduct [would] increase during the next few years to a volume which could not have been adequately served by the old route."[331] Based on this acknowledgement that the future would only bring more cars and trucks to the highway, Bureau economists felt certain that time (and financial) savings would only continue to be realized as more years passed.

Lavis and Johannesson had reason to be proud, well into the future, to have played key roles in bringing economic design theory to the world of the highway. While much of Lavis's future writing, aside from that associated with Central and South American railroading, focused on the issue of highway safety as it related to speed, Johannesson continued to work in the area of economics throughout the remainder of his career. In 1950 he still wrote in favor of the construction of controlled access expressways in urban areas – but only following the requisite evaluation of the economic soundness of such endeavors. He observed that "some of the benefits gained by those that travel on the highways may include some or all of the following:

a. Saving in cost of vehicle operation due to decrease in travel distance, improved alignment and profile, better roadway surface and uninterrupted progress.
b. Saving in time of travel due to the same causes as above and due to increased speed of travel.
c. Increased safety of travel.
d. Improved physical and mental comforts of travel.
e. Improvement of traffic conditions on present streets."[332]

[331] Holmes, "The Effect," 231

[332] "Controlled Access Expressways in Urban Areas, A Symposium," *Highway Research Board Bulletin No. 25*, 1950, 24.

After the completion of the Route 1 Extension project, Sigvald Johannesson remained with the New Jersey State Highway Department for the remainder of his engineering career. In 1935 New Jersey established a state planning board, and in 1944 the board's functions and personnel were transferred to the newly established Division of Planning and Engineering of the Department of Economic Development. Johannesson was ultimately selected to head the division, spending much of his time through the 1940s authoring reports on New Jersey's highway needs and making recommendations on a comprehensive state highway system. He retired in 1948, was given an honorary doctorate in 1951 by the Technical University of Denmark[333], and died following a brief illness in 1953 at the age of 75.

333 "Honorary Doctorates," Technical University of Denmark, accessed March 6, 2019, http://www.dtu.dk/english/Research/Research-at-DTU/Doctorates/Honorary-Doctorates.

Chapter Four – From the Skyway to the Present

Before the Coming of the Interstates

The Big Shift to Limited Access

The period between the arrival of limited access highways and the creation of the Interstate Highway System was one of expansion, particularly around major cities where motor vehicle traffic continued to increase rapidly. Interestingly, although traffic engineers saw the construction of more limited access roads as the best – if not only – solution to managing traffic, it took time and some legal hurdles had to be overcome before the public was willing to "go along for the ride." People were frequently unable to understand and unwilling to accept the concept of roads that did not serve their traditional function and might, and now often did, pass by residential, and even commercial, areas without nearby entrances or exits. "From earliest times, … highways were built and utilized primarily for the purpose of giving access to farms and homes and business establishments. This [was] the concept of the 'land service road.'"[334] However, "the development of high-speed automobile transportation … brought a promise and a problem … [as] the limited-access highway [would] affect the rights of property owners abutting on the highway."[335] It gradually became clear that "the time [had] come when the courts must follow the public and the times in considering the

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334 "Freeways and the Rights of Abutting Owners," *Stanford Law Review*, Vol. 3, No. 2, (1951), 300.
335 *Ibid.*, 298.

concept of a road whose purpose [was] not land service, but traffic service … [and make] a conscious attempt to balance public safety and convenience against private rights."[336]

> "Engineering efficiencies contradicted history in the form of the long-ingrained precept of common law that property owners adjacent to a public highway had the right of access from their property. That tradition had to be overturned before any limited-access highway could be built. In 1935, Colorado enacted a weak law permitting the construction of limited-access highways; starting two years later, Rhode Island and New York passed stronger laws establishing the right to limit highway access. By 1950, thirty states had enacted similar legislation. Limited-access highways gained acceptance only gradually, with some states first allowing restrictions that limited the enabling legislation. Model legislation prepared by the Bureau of Public Roads helped facilitate the transformation from common-law precedent to contemporary expedience."[337]

Funding was also a significant impediment to the construction of such highways as could be clearly understood when looking at the price tag of the Route 1 Extension project. Major highway projects required significant investments never before envisioned in the construction of roads and, while the federal and state governments were certainly making money available, other costs were often borne by people living in a given state or region even if the drivers who would ultimately utilize the new improvements were merely passing through the area. The $21 Million price tag of the Pulaski Skyway portion of the Route 25 project alone was something that many people still could not comprehend, and years after its opening the cost of the Skyway continued to be a source of fascination. On January 31, 1935 a Ripley's "Believe it or Not" drawing

[336] *Ibid.*, 310-311
[337] *Ibid.*, 147

of the Skyway appeared in newspapers across the country over the caption: "The most expensive highway in the world. The Pulaski Skyway in New Jersey cost $7,000,000.00 a mile to build! The viaduct is 3 miles long."[338] In spite of the financial investments required, the nation's increasing traffic demands and concerns with roadway durability and safety overrode other issues and, "following experimentation during the 1930s, states in the eastern part of the country began construction of limited-access highways in earnest in the 1940s."[339] During that decade, with the Second World War on everyone's minds, "studies addressed the way new highways would support defense and economic growth. The limited-access design of the Pennsylvania Turnpike, which opened in 1940, became the model for future superhighways."[340]

The Pennsylvania Turnpike

The corridor that would become the Pennsylvania Turnpike came into being in 1934 when members of the State Planning Board and the Pennsylvania Motor Truck Association proposed that the roadbed and tunnels left in place by the unused and unfinished Pittsburgh, Westmoreland and Somerset [short line] Railroad be repurposed for the construction of a toll highway. Construction began in 1938 on an aggressive schedule set by the Public Works Administration that required completion in mid-1940.

> "Highways had always been built with flat curves to discourage speeding. Now, the engineers were expected to design easy grades, to allow cars and

[338] "Believe it or Not!," *Lincoln Evening Journal*, Lincoln, Nebraska, January 31, 1935.
[339] Ballard C. Campbell, *The Growth of American Government, Governance from the Cleveland Era to the Present*, (Bloomington, Indiana: Indiana University Press, 2015), 144.
[340] "On the Interstate – A Nation of Highways," accessed March 6, 2019, http://americanhistory.si.edu/america-on-the-move/interstate-10.

trucks year round use. Long, sweeping curves would give ample room for high speeds and safe stopping distances. The engineers decided on the following standards:

- A right-of-way width of 200 feet.
- A four-lane divided configuration, with 12-foot wide concrete traffic lanes, a ten-foot-wide median strip and ten-foot-wide shoulders,....
- A maximum grade of 3%....
- A maximum curvature of six degrees,....
- Substantial superelevation, or banking, on curves.
- Limited access, with 1,200-foot-long entrance and exit ramps to provide plenty of distance for accelerating and decelerating.
- A minimum 600 foot sight distance from motorist to traffic ahead.
- No cross streets, driveways, traffic signals, crosswalks or railroad grade crossings."[341]

One of the most significant elements of the plan was the intentional continuous, end-to-end design that was unlike the more typical American highway systems of the time wherein design standards changed constantly depending upon when each section of roadway had been constructed. "By July 1939, the highway, seven tunnels, and more than 300 structures were under contract, and a month later construction was underway. The contracts were awarded to 155 companies from 18 states."[342] Contractors worked around the clock to meet the previously imposed deadline for the completion of a total of 160 miles of highway, seven tunnels, eleven interchanges, and ten service plazas. As work neared completion, "officials made test drives over the new highway sometimes at

341 "Pennsylvania Turnpike, Early Years," page updated May 22, 2016, accessed March 6, 2019, http://www.pahighways.com/toll/PATurnpike.html.
342 *Ibid*.

speeds of 100 MPH or more. Local motorists sneaked onto the Turnpike for their own personal test drive, a practice that was partially discouraged."[343]

As work continued past the original June deadline, finally the turnpike commission announced that the highway would officially "open for business" on October 1st. Although the commission "gave less than 12 hours notice that America's first superhighway would open, word began to spread quickly. The news of the grand opening spread from radio station reports that were broadcast throughout the afternoon [of September 30th], and by 6 PM motorists began lining up at toll booths to become the first or one of the first to travel the futuristic highway."[344] The excitement only died down at the end of the day as the last of the turnpike travelers passed the end of the line. "When they finally reached the other side, they told stories of traveling 80 and sometimes 90 MPH, while not having to worry about cross-traffic."[345] In fact, at the time of the opening, there was no set speed limit and even the Governor agreed that the normal statewide 50 mph limit should not apply to the new highway. However, following some convincing from the state attorney general, the typical 50 mph limit was imposed after all. "The decree was flatly ignored by both motorists and the troopers patrolling the highway."[346] Using the Turnpike quickly became a matter of public interest regardless of the speed of travel. During the first weekend following the grand opening, there was so much traffic that the toll-takers ran out of tickets and traffic was

343 *Ibid.*
344 *Ibid.*
345 *Ibid.*
346 *Ibid.*

backed up for miles at interchanges where motorists were trying to exit. To avoid these early problems, by the second weekend of operation there were temporary toll booths and extra tickets in place to help handle the volume. During the first four days of operation the Turnpike had carried 24,000 vehicles, which was nearly double the figure anticipated by the highway's traffic planners. However, as much of this volume was due mainly to curiosity, the Commission did not see it as indicative of future trends.

By the end of 1940 – only three months after the grand opening - over ½ Million vehicles had traveled on the Turnpike, and it was hailed by engineers and motorists for not only the savings it brought in terms of travel time, but also the comfort with which it could be traversed. "The Pennsylvania Turnpike, a toll express highway to cut time and distance between Harrisburg and Pittsburgh, was described as a yardstick by which the demand for such construction might be judged."[347] Major extensions – from Carlisle to Valley Forge, from Irwin to the Ohio state line, from Valley Forge to New Jersey, and from Montgomery County to Scranton – were completed during the 1950s, as were tunnels at Lehigh and Allegheny. The mainline was finally completed in 1956 when the bridge over the Delaware River was opened. During the three decades that followed, additional tunnels, extended segments, and safety upgrades were performed, and "by the 2000 decade, the [route was] carrying 156.2 million vehicles a year."[348] Improvement, rebuilding, widening, and the addition of new interchanges continue to this day.

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347 "High-Speed Roads of Future Depicted," *The New York Times*, February 17, 1939.

348 "Turnpike History," accessed March 6, 2019, https://www.paturnpike.com/yourTurnpike/ptc_history.aspx.

The Queen Elizabeth Way

Meanwhile, outside the United States, other countries were also developing limited access highway networks to address their own traffic control problems. One system was the Queen Elizabeth Way. The Queen Elizabeth Way was constructed during the 1930s, opened to traffic in 1939, and completed in its entirety in 1960, connecting Toronto with Niagara Falls. "The highway is the oldest inter-city divided highway in Canada and has arguably been one of the most influential highway developments in Ontario's history."[349] Planned, not unlike the Route 1 Extension in New Jersey, as a completely new highway corridor intended to accommodate increasing traffic volumes on Highways 2 and 5 between Hamilton and Toronto, an existing rural route – then called the "Middle Road" - was proposed for conversion into a "superhighway." Originally intended to be a four-lane undivided highway, safety concerns soon resulted in the addition of a median to separate traffic. The new highway

> "boasted a full cloverleaf interchange at Highway 10 in Port Credit and a partial cloverleaf (trumpet) interchange in Burlington. These were the very first traffic interchanges ever built in Canada.… Several more interchanges were built along [the extended] section [to Niagara Falls], including a large traffic circle at the Highway 20 Junction in Stoney Creek."[350]

Before it was opened to Niagara Falls in 1939, the "Middle Road" was renamed in honor of Queen Elizabeth who attended a special dedication ceremony. Little

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349 "Queen Elizabeth Way (QEW)," accessed March 6, 2019, http://www.thekingshighway.ca/Queen_Elizabeth_Way.htm.
350 *Ibid.*

additional construction took place during World War II, but work on highway extensions, including high-level bridges such as the Burlington Beach Skyway, continued until 1960 when the entire route was deemed essentially complete. Much of this later construction consisted of upgrades needed to address traffic concerns that had arisen subsequent to the original opening. Unlike the Pennsylvania Turnpike that had been designed from the start to have no interference from cross traffic, the Queen Elizabeth Way, as originally intended, did not follow a consistent design standard from end to end. Therefore,

> "by the 1950s, it became obvious that the QEW was inefficient as a non-controlled access highway. While there were some interchanges along the highway, there were many at-grade intersections and most of the busier intersections had traffic signals. Throughout the 1950s and 1960s, the at-grade intersections were closed off along the QEW and replaced by overpasses and proper interchanges."[351]

During the decades that followed, sections of the Queen Elizabeth Way were widened to accommodate increasing traffic, and all of the remaining at-grade crossings were eliminated. After forty years in use access onto and off of the highway was finally completely controlled. Repair and reconstruction projects have continued in recent years. In a country where all freeways are designated with route numbers, the Queen Elizabeth Way is the only highway that is unnumbered; all route markers simply indicate "QEW."

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[351] *Ibid.*

The Autobahnen

Perhaps the best known system of limited access roads was that which was constructed in Germany before, during and after World War II.

> "What is regarded as the world's first motorway was built in Berlin between 1913 and 1921. AVUS, a 19 km [11.8 mile] long section ('Automobil-Verkehrs-und Übungsstraße') in southwestern Berlin was an experimental highway that was used for racing (occasionally it still is). It had two 8 meter [26 foot] lanes separated by a 9 meter [30 foot] wide median.... [Germany's] first 'car-only roads' [opened] in 1929 between Dusseldorf and Opladen and in 1932 between Cologne and Bonn."[352]

Therefore, although it is widely believed that Adolf Hitler was the man behind what would later be known as the Autobahnen, the first section of this highway system predated his rise to power. Once Hitler became Chancellor of the Third Reich, he quickly recognized not only the military and economic (employment) worth of such a roadway network but also its propaganda value both inside and outside Germany. He set his chief highway engineer, Fritz Todt, to work building the first Reichsautobahn - an expressway between Frankfurt and Darmstadt - in late 1933, and by the time German highway construction ceased in December 1941 to focus on the war effort, 2,400 miles had already been completed and over 1,500 additional miles were underway. However, as was clear to many Americans traveling in Germany during the 1930s, "the autobahn

[352] "German-Autobahn, Autobahn History," accessed March 6, 2019, http://www.german-autobahn.eu/index.asp?page=history.

was built before the country had enough motor vehicles to justify the expense."[353] Hitler's hope at the time had been to build an automobile that would be affordable to the masses and he "intended to provide a small affordable 'people's car' (Volkswagen) that his people could fill the autobahn with."[354]

Although the people did not receive their Volkswagens as the German leadership shifted its full attention to the needs of the war, the Autobahn was a critical national asset during the early period of World War II, "[enhancing] Germany's ability to fight on two fronts - Europe in the west, the Soviet Union in the east."[355] Despite early advantages, Germany's limited industrial base, and the seemingly limitless number of trucks and personnel transported to Europe by the powerful United States, ultimately shifted the war in favor of the Allies.

> "By the time the Allied forces reached Germany, they could take full advantage of the autobahn. E. F. Koch, a U.S. Public Roads Administration (PRA) employee who observed the Autobahn in 1944-45 as a highway and bridge engineer with the Ninth Army … and his engineering unit spent the unusually cold winter maintaining roads in Belgium, Luxembourg, and the Netherlands that, after the pounding of military vehicles and the thaw in early 1945, were in terrible shape. Conditions changed when they reached Germany in early 1945. 'After crossing the Rhine and getting into the areas of Germany served by the Autobahn . . . our maintenance difficulties were over. Nearly all through traffic used the Autobahn and no maintenance on that system was required.'… As the Allies pursued the German forces across Germany, the Autobahn proved invaluable, especially to the supply trucks racing behind the troops."

[353] "Highway History – the Reichsautobahnen," Federal Highway Administration, accessed March 6, 2019, https://www.fhwa.dot.gov/infrastructure/reichs.cfm.
[354] *Ibid.*
[355] *Ibid.*

Immediately following the war, General Eisenhower oversaw the preparation of reports on the German highway system, and "the vision of the autobahn was strong in his mind as he became President. Years later, he would explain that 'after seeing the autobahns of modern Germany and knowing the asset those highways were to the Germans, I decided, as President, to put an emphasis on this kind of road building.'"[356]

Even before the United States entered the war, American engineers viewed the Autobahn program as important to the advancement of limited and controlled access, high-speed highways. In an article published in the 1938 Highway Research Board Proceedings, author C. M. Upham noted that in the Autobahn system the roads were

> "designed for maximum speeds of from 80 miles per hour in mountainous regions to 100 miles per hour in flat country.... Most of the safety features that [had] long been recommended by highway engineers in the United States [had] been built into the German highways, including the elimination of all highway and railroad grade crossings, all pedestrian, bicycle, and animal traffic [was] excluded.... There [was] complete separation of opposing traffic streams and there [were] no collision points caused by the crossing lines of traffic. There [were] no means of direct access to the highways system."[357]

Upham also praised the system for its ability to provide extremely safe driving conditions despite the high speeds permitted on its roads, saying that "from the safety standpoint the highway system as designed and constructed in Germany is conclusive proof that if highways are built, eliminating all danger points, the accident toll can be

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356 *Ibid.*

357 C. M. Upham, "German Highway Design," *Highway Research Board Proceedings*, Volume 18, Part 1, (Washington, D. C.: Highway Research Board, 1938), 181-182.

reduced to almost a negligible figure."[358] He noted that, as recorded accidents consisted primarily of those resulting from heavy snow conditions, obscured parked cars at the roadsides, and "side-swipes" caused by lack of attention on the part of motorists, these collisions "were not in any way caused by faulty highway design…. [and] inasmuch as there are no danger hazards on the highways, the danger signs have been eliminated."[359] American engineers of the 1940s looked seriously at ways to emulate the German highways, frequently finding fault with the highways of home.

Eight years after the end of World War II Autobahn construction resumed and, "starting in 1959, the Federal Republic began Autobahn expansion in earnest by embarking on a series of four-year plans that expanded the 'Bundesautobahnen' system." [360] Major additions, and a series of five-year construction and extension plans, continued during the decades that followed, and the existing network is now over 8,000 miles in length. Although the design standards of the earliest Autobahnen, and even the first Reichsautobahnen, were crude in comparison with those of modern highways, they were high when evaluated alongside the standards of most highway construction undertaken in America at the time. The Autobahn system's standards significantly influenced the U.S. interstate system[361] and the growing "popularity of limited-access expressways moved Congress in 1956 to authorize a national network of 'free' (non-toll) interstate highways."[362]

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358 *Ibid.*, 184
359 *Ibid.*, 185
360 "German-Autobahn, Autobahn History,", http://www.german-autobahn.eu/index.asp?page=history.
361 Kreuger, Marcel. "How German Autobahns Changed the World," *CNN Today*, December 7, 2020. Accessed August 30, 2021.
362 Campbell, *The Growth of American Government,* 144-145

Highway Safety

The Skyway and Safety

Despite the best efforts of its designers, very soon after its opening safety concerns prompted upgrades to the Pulaski Skyway, and it was not long before traffic volumes proved to be too great for the viaduct and associated highway. Only a month after the October 1933 renaming ceremony, Jersey City passed an ordinance on November 21st that was to take effect early the next year banning trucks on the Skyway within the city limits "after two policemen were killed and another was seriously injured in a series of accidents."[363] The state highway commission elected not to endorse the ban but also chose not to interfere. Soon after Jersey City notified the public of the ban in January 1934, "the Elizabeth chamber of commerce … sent a resolution urging that the ban be postponed for 60 days for an impartial trial of safety methods. The [state highway] commission replied it did not have jurisdiction in the controversy."[364] However, only a week later, the commission reversed its decision on the matter and, on January 24, 1934 chose – at least informally - to endorse the Jersey City heavy truck ban.

> "An ordinance of Jersey City, barring trucks from the super highway, [was soon] … assailed by commercial interests with threats made to carry a test case to the supreme court. Plans for expenditure of $60,000 for safety and policing equipment on the skyway have [been] made but might be

[363] "Skyway Bans Trucks Monday," *Asbury Park Press*, January 8, 1934.
[364] "State Won't Act," *Asbury Park Press*, January 17, 1934.

> abandoned, Major William G. Sloan, highway engineer, said, if trucks were barred."[365]

It was not long before the ban was actually tested in the courts when a "trucking company, in contesting the ordinance, set up that it was deprived of equal protection of the laws as guaranteed by the 14th amendment of the federal constitution."[366] But on August 14, 1934 "the supreme court … upheld Jersey City's ordinance banning heavy commercial vehicles from the Pulaski skyway as a safety move, … [and] ruled that the ordinance was not unreasonable nor discriminatory and the city had exercised proper judgment in the regulation of traffic 'even tho such regulation may be considered drastic in its operation.'"[367]

Unfortunately, even without the added danger of truck traffic, local newspapers of the 1930s continued to be filled with reports of speeding and serious, sometimes deadly, accidents on the Pulaski Skyway. The original concrete surface proved to be extremely slippery and sometimes difficult to navigate even for the relatively small amount of traffic of the 1930s. An element of the design that proved to be problematic at best was the limited intermediate access provided via "two single-lane ramps [that] rise to the inner lanes of the elevated structure, requiring traffic to enter or exit from the left."[368] Another unfortunate design impact that likely resulted from utilizing past railway theory as a basis for the design of the highway – and perhaps from an

365 "Truck Ban Backed," *Asbury Park Press*, January 24, 1934.
366 "Truck Ban Upheld in Supreme Court," *Asbury Park Press*, August 14, 1934.
367 *Ibid*.
368 "Pulaski Skyway," accessed march 6, 2019, https://en.wikipedia.org/wiki/Pulaski_Skyway.

underestimation of just how busy the roadway would quickly become - was the fact that almost from the start the Skyway was simply too narrow.

> "A central railway principle was keeping land acquisition costs down by employing the narrowest possible right-of-way. Applied to the Pulaski Skyway, the result [was] inadequately narrow roadways … [with] no space for a shoulder, and very little margin of error for the … driver. 'The value of shoulder was not fully understood in the early days of highway design.' … One element of [having a shoulder] is to give drivers a breakdown lane … [and] as the width of a shoulder shrinks it also affects how people drive…. 'If you have a shoulder that's smaller than 6 feet wide, and you've got a guard rail or barrier wall, that will impact operation. Drivers become nervous. They overreact and slow down. They weave. And all of these behaviors affect the capacity of the road.'"[369]

"When the skyway first opened, it [had] carried five lanes; the center one was intended as a breakdown lane, but was used as a 'suicide lane' for passing slower traffic. By the 1950s, the skyway was seeing over 400 crashes per year; an aluminum median barrier was added in mid-1956, in addition to a new pavement coating designed to make the road less slippery."[370] Following "a mounting toll of accidents that [in 1954] … alone reached 430, a new coarse sandpaper finish [was] applied to the skyway's … glass-like pavement."[371]

Traffic accidents continued, despite these early improvements, through the decades that followed due partly to the design of the roadway itself and partly to the

369 "5 Terrible US Road and Highway Designs: Lessons Learned," *Popular Mechanics*, accessed March 6, 2019 online at: http://www.popularmechanics.com/technology/infrastructure/a6420/5-terrible-us-road-and-highway-designs./

370 "Pulaski Skyway," Wikipedia.org.

371 "Pulaski Skyway to Get New and Safer Surface," *New York Times*, September 13, 1955.

open alignment that "tempted" foolishly high speeds. The earlier low (only 16-inch high) median was finally replaced with a new aluminum "safety shape" barrier in the late 1970s, and the roadway was resurfaced with latex modified concrete in 1982. "Several alterations to the original structure [were] … made over the years, including the addition of new ramps to and from South Kearny."[372] At the time of the writing of this document, the New Jersey Department of Transportation is in the midst of a major construction project that will result in the replacement of the Skyway's deck, the rehabilitation of the superstructure and substructure components, including concrete encasement removal, the strengthening of the structure against seismic events, barrier replacement, the improvement of the roadway's drainage and systems, and the installation of new traffic signals and security cameras. This extensive, multi-year effort will both address deterioration that has occurred over the past decades and ensure the continued functioning of the Skyway well into the future.

Lavis and Highway Safety

It is interesting to note that Fred Lavis became one of the leading voices not only for economically designed highways but also for the design of safer roads – but not for highway designs that permitted greater speed. In speaking before the Highway Research Board in 1937 he

> "asserted that additional expense to make a highway suitable for sustained fifty-to-sixty mile an hour speeds was unjustified. The main job before the

[372] "The Pulaski Skyway, History and Background," State of New Jersey Department of Transportation, last updated September 5, 2014, accessed March 6, 2019, http://www.nj.gov/transportation/commuter/roads/pulaski/history.shtm.

highway engineer …, Mr. Lavis told his colleagues, [was] to increase the car-carrying capacity of American highways. Increasing the speed of traffic to more than fifty miles an hour will actually reduce the number of cars that can use a given road with sufficient safety."[373]

Amid the national clamor for faster speeds and claims that the country's existing road network was obsolete, Lavis argued that highways designed and built to accommodate such speeds could not be justified on an economic basis. He wrote a lengthy article for the Highway Research Board in 1938, stating this in his synopsis:

> "There has been considerable agitation in recent years for highways designed to permit 'safe driving' at high speeds. It is claimed by some that much of our main road system is obsolete, and that we need to build safety into the highways to provide adequate accommodations for modern high speed traffic. Speeds of 90 to 100 m.p.h. today and even higher speeds in the future are advocated by certain engineers as proper bases for such design…. it is pointed out by the author that there are other road requirements than those of the superhighway, and that available funds must be distributed equitably among all classes of highways. Moreover there may be a net loss in excessive vehicle operating costs resulting from high-speed travel, and traffic accidents are known to be numerous on the so-called 'safe' straightaway stretches where higher speeds are possible. It is felt that none but a few very experienced drivers are really capable of driving safely at speeds over 50 to 60 m.p.h., and that the education and selection of drivers is of far greater importance that the provision of speedways. One of the greatest problems now confronting highway officials is the relief of traffic congestion, and maximum capacity on highways of heavy traffic is attained at speeds less than 50 m.p.h. Although the laying out of highways should include all the improvements of design economically feasible, there appears to be no justification for designing high-speed roads when such design will entail additional expenditures for construction. It is inconceivable that any considerable

[373] "Car Costs Higher Over Dirt Roads, Survey Reveals," *Dunkirk Evening Observer*, December 14, 1937.

volume of traffic will move over a highway at speeds in excess of 50 to 60 m.p.h."[374]

This subject was one about which Lavis felt strongly; he had written an article to *The New York Times* two years earlier in response to Regional Plan Association comments indicating that the United States was lagging behind the Germans in highway construction. Aptly entitled "High-Speed Roads Can Wait," Lavis' comments argued that

> "there [was] no country in the world which [had] a high-class highway system to compare in adequacy of conception, design and execution with our Westchester County, Eastern State and Long Island parkways.... We have here in the metropolitan area the ... West Side elevated highway, ... and dozens of other examples, including the New Jersey State Highway from the Holland Tunnel to Elizabeth, suitable for any traffic at any safe speed."[375]

However, his primary focus was that high-speed roadway construction could not always be justified in the light of the economic needs of roads across the country, and he stated that "it [would] be time enough to talk of building roads ... for high speeds when we have attended to other much more important matters connected with the operation of motor vehicles, especially the education and control of drivers and inspection of vehicles."[376] Although Lavis' discussion of safety, speed and economic design sense were

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[374] Fred Lavis, "Safety and Speeds as Affecting Highway Design," *Proceedings of the Seventeenth Annual Meeting of the Highway Research Board*, Part I, 1937, 79.

[375] Fred Lavis, "High-Speed Roads Can Wait – We Must First, It is Held, Teach Our Drivers How to Use Them," *The New York Times*, December 9, 1936.

[376] *Ibid*.

backed by extensive knowledge and experience, his views would gradually be lost among the cries for a national network of high-speed highways.

The Skyway as Example

Even with its safety issues, and regardless of the regular comments still being made in the 1930s press concerning the cost of the construction, in the years following its opening the Skyway was widely publicized and continued to be seen as an almost glamorous construction. It was also certainly viewed as the example of a working controlled access highway to be followed by others.

For example, engineer and University of Illinois President, Arthur Cutts Willard, recommended an elevated roadway to address Pittsburgh's traffic problems. While attending a 1937 university reunion, he was quoted as saying that "elevated traffic lanes, similar to the Pulaski 'Skyway' over sections of New Jersey, would relieve congestion in Pittsburgh's 'horse-and-buggy' streets by diverting the 'through' traffic."[377] A year later, local Director of Streets and Sewers, Frank J. McDevitt, noted in his annual report that elevated highways were needed to handle Saint Louis's downtown traffic. His city planning "dream" consisted of an elevated downtown loop with elevated highways branching outward that would be able to separate traffic and keep it moving, and he argued that raised highways such as the one in place in New Jersey were critical for crowded cities like Saint Louis. A newspaper article on this issue noted that

[377] "Overhead Traffic Lanes Predicted in Pittsburgh," *Pittsburgh Post Gazette*, March 23, 1937.

> "the West Side Highway of New York and the Pulaski highway leading into New York through New Jersey towns [were] the only elevated highways built so far, according to McDevitt. Chicago [was] completing plans to build 160 miles of such highways. Engineers who studied the problem for San Francisco recommended the construction of 26 miles of them and an elevated highway [had] been proposed in Boston."[378]

Although certainly a national example and the United States' largest single highway construction project of its time, the Skyway was already relatively insignificant – in terms of size – in the context of the highway construction that soon followed. Furthermore, once the Interstate Highway System came into being beginning in 1956 the nation truly became one where the Pulaski project's basic goals – decreased travel times and limited access – were virtually the norm. "The American Association of State Highway and Transportation Officials … defined a set of standards that all new Interstates must meet unless a waiver from the Federal Highway Administration [was] obtained. One almost absolute standard [was] the controlled access nature of the roads…. [In addition], being freeways, Interstate Highways usually [had] the highest speed limits in a given area."[379]

By the 1940s, as the country continued to evaluate and construct better highway systems to accommodate increasing numbers of cars and trucks, states like New Jersey were also constantly evaluating their evolving highway needs. During the 1920s and 1930s, New Jersey had developed a number of unique strategies to deal with traffic. The state's first traffic circle was opened in Camden in 1925. "By its design the circle

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378 "Proposing a System of Elevated Highways for St. Louis," *St. Louis Post Dispatch*, March 27, 1938.

379 "Interstate Highway System," accessed March 6, 2019, https://en.wikipedia.org/wiki/Interstate_Highway_System.

lowered speed by forcing through-traveling vehicles to change their travel path around the island. In their prime, New Jersey's [eventual] 75 traffic circles offered a practical method of allowing traffic from several directions to cross paths relatively safely without always being forced to stop."[380] Major roads were expanded from two to three lanes and the first divided highway was constructed on Route 1 in Elizabeth in 1936. "Highway engineers [had] noticed that the worst accidents occurred when two 'streams' of traffic crossed each other."[381] Grade separations helped to reduce the number of such accidents. In 1943 "a nine-man highway department planning bureau to promote 'greater efficiency in meeting road problems, especially in the post-war period,' was announced,"[382] and Sigvald Johannesson was, appropriately, selected as its head. In that same year Johannesson authored his draft report on state highway needs, and by the following year he had issued "A Comprehensive State Highway System: Report." This document was followed in 1947 by his "Monographs on the Highways of New Jersey." In 1953 New Jersey renumbered many state highways in an effort to address concerns with the confusion caused by the then existing numbering system that had first been observed several years earlier. For example, after 1953 motorists would no longer be puzzled by state and US routes having the same designation. Route 1 was broken into several sections, and the former Route 25 became Business Route US1.

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380 *PEOPLE The Transportation Connection*, 15.
381 *Ibid.*, 17
382 "N. J. Group Named for Road Study," *Harrisburg Telegraph*, June 24, 1943.

Highway Economic Theory Moves Forward

Highway Economics Through the 1980s

Johannesson wrote about highway related issues for nearly all the remaining years of his life. In 1950 the Highway Research Board held a symposium and issued a bulletin entitled "Controlled Access Expressways in Urban Areas," for which Johannesson authored the sections on "Design Considerations," "Economics of Expressway," and "Traffic Economics." Some of his comments reflected both past highway economic theory – in which he had played such an important role – and the future of evaluations of this type.

> "In the early stage of modern highway development the economic and social problems of highway planning and construction were less complex than they are today.... At that time and with the volume and weight of traffic they then carried, the cost of the improvements was comparatively low. It was only in a few cases that the existing or foreseeable traffic volumes were so large that economic studies evidently were warranted, and it was there that the rational study of the economics of highways had its birth. With the present and evidently continuously increasing traffic volumes as well as unit costs of construction, the economic studies have become a necessity."[383]

Over the years following the publication of Johannesson's "Highway Economics," highway design theory continued to evolve and economic considerations became a more integral part of that process. Ongoing nationally-led research, and new articles and

[383] "Controlled Access Expressways in Urban Areas – A Symposium," *Highway Research Board*, Bulletin No. 25, 1950, 28.

books, helped to ensure that the highway engineers of the mid-20th century were adequately equipped to deal with the needs of the motor age. However, even a decade after the construction of the Route 1 Extension, data remained relatively limited. The authors of a 1942 college textbook entitled "Highway Economics" explained that, while federal agency investigations had, by that time,

> "disclosed a variety of useful data and much information that, it [was] believed, now made it possible to prepare a book on highway economics, … highway engineers [were still] not in entire agreement [upon the subject] among themselves, and … it [was] hardly necessary to point out that, in all too many cases, there [had] been a lack of good factual data upon which to base an entirely sound and definite conclusion that could not be controverted."[384]

Nevertheless, as more significant projects were completed, and particularly as the nation moved into decades of major highway construction, economic analysis and justification became an ever greater and more important element of highway layout and design. In the 1960s and 1970s, with the aid of newly available computer based means of obtaining and evaluating data, the traditional approaches to selecting transportation routes using economic input morphed into design processes that incorporated modeling for the development of transportation systems. During this period, some interesting new methods were evaluated and a number of research efforts were undertaken. For example, "much work [was] done in the Civil Engineering Systems Laboratory at M.I.T. [Massachusetts Institute of Technology] to develop new techniques and

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[384] Harry Tucker and Marc C. Leager, preface to *Highway Economics*, (Scranton, Pennsylvania: International Textbook Company, 1942).

computer-oriented analysis methods for use in the location, design, and economic analysis of highway systems."[385] A 1966 M.I.T. study indicated that "with the advent of disk storage and time-sharing, … a single 'route location system' [had become] feasible [allowing an engineer] to describe completely his problem in highway terminology, analyze those phases in which he [was] currently interested, and obtain the resulting information in the form of listings and automatically prepared plots."[386]

> "Modern applications of EEA [Engineering Economic Analysis] to highway systems could be said to have begun in the late 1960s, with the sponsorship by The World Bank of its Highway Design and Maintenance (HDM) Standards study. This study built in active research in road user costs and the emerging technology of computer hardware and software, including programs that addressed highway design, road surface deterioration and maintenance, and highway cost estimation. The result was the Highway Cost Model, a simulation model built on tradeoffs among road design and construction, road maintenance, and road user costs, with the objective to minimize life-cycle costs."[387]

The initial efforts of the World Bank resulted in the 1973 development of the first comprehensive highway cost model. "This was the first prototype model for interrelating life-cycle costs of highway construction, maintenance, and vehicle operation. The objective of the model was to estimate significant highway costs for a given set of data without performing any optimization. The input to the model was

385 Paul O. Roberts and John H. Suhrbier, *Highway Location Analysis: An Example Problem, M.I.T. Report No.* 5, (Cambridge, Massachusetts, the MIT Press,1966,) 1.

386 *Ibid*., 92

387 *Engineering Economic Analysis Practices for Highway Investment - A Synthesis of Highway Practice, NCHRP Synthesis 424*, (Washington, D. C.: National Cooperative Highway Research Program, Transportation Research Board, 2012), 7.

huge and not very user-friendly."[388] However, by 1987 this initial model had been superseded by an improved, simulation-based system called the Highway Design and Maintenance Standards (HDM-III) Model.

> "The broad concept of the HDM Model is quite simple. Three interacting sets of cost relationships are added together over time in discounted present values, where costs are determined by first predicting physical quantities of resource consumption which are then multiplied by unit costs or prices.... The HDM model is used to make comparative cost estimates and economic evaluations of different policy options, including different time staging strategies, either for a given road project on a specific alignment or for groups of links on an entire network."[389]

By the 2010's the software version HDM-4 was in widespread use and as of the date of this document "HDM-4 [was] regularly used as the World Bank's model for appraising road investment proposals in developing countries."[390]

Highway Economics Today

Although the earliest computer models were limited in their effectiveness due to inadequate computer performance and the need to collect field survey data manually, with "the advent of sophisticated computers and GIS [Geographic Information Systems] technology, it [became] ... possible to solve problems accurately and efficiently that were [previously] unsolvable."[391] During the decades that followed the 1987 development of

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388 M. K. Jha, P. Schonfeld, J. C. Jong and E. Kim, *Intelligent Road Design*, (Southampton, UK and Billerica, Massachusetts: WIT Press, 2006), 6.

389 *The Highway Design and Maintenance Standards Model, Volume 1 – Description of the HDM-III Model*, (Baltimore and London: The World Bank, The Johns Hopkins University Press, 1967), 6.

390 hdmglobal.com, accessed October 17, 2019

391 M. K. Jha, et al., *Intelligent Road Design,* 8

the HDM series, Engineering Economic Analysis (EEA) continued to advance. Textbooks on engineering economy offering information on the various parameters and methods associated with EEA became readily available to those in the engineering profession. In addition, "there are [now] a number of policy statements and guidelines that govern application of EEAs to highway investments nationwide…. The references are issued primarily by the federal government … and national organizations."[392]

The Federal Highway Administration (FHWA) established the Highway Performance Monitoring System (HPMS) in 1978 "as a national highway transportation system database…. The HPMS data form the basis of the analyses that support the biennial Condition and Performance Reports to Congress [and] … provide the rationale for the requested Federal-aid Highway Program funding levels, and are used for apportioning Federal-aid funds back to the States."[393] The FHWA began the development of its Highway Economic Requirements System (HERS) model in 1987. In 1994 federal Executive Order 12893 mandated that any federal "infrastructure investments shall be based on systematic analysis of expected benefits and costs, including both quantitative and qualitative measures."[394] A pilot program for the use of national-level HERS software was undertaken in 1999 and, following years of updates and improvements, a state-level version of the software (HERS-ST) became available for use. HERS-ST

[392] *Engineering Economic Analysis Practices*, 12.
[393] "Highway Performance Monitoring System (HPMS)," https://fhwa.dot.gov/policyinformation/hpms/hpmsprimer.cfm, accessed October 2, 2019.
[394] *Federal Register Vol. 59, No. 20.* Monday, January 31, 1994, accessed October 3, 2019, https://archives.gov/files/federal-register/executive-orders/pdf/12893.pdf.

> "was developed for the Federal Highway Administration as an optimization framework to help federal and state authorities, and others, to develop highway investment programs and policies that maximize economic benefits relative to costs.... Benefit categories considered [include] changes in user travel times [and] changes in vehicle operating costs (fuel, oil, tires, maintenance, depreciation.... Other quantitative impacts considered [include] measures of congestion (peak volume-capacity ratio, speed by segment and averaged by functional class) delays ... [and] selected geometric improvements for each highway segment."[395]

The FHWA makes HERS-ST available to the states free of charge and supports the use of software for Benefit Cost Analysis (BCA) and asset management programs designed by individual states or offered commercially.[396] While different states and transportation agencies have their own guidelines and requirements for EEA, and perform different types of economic analyses in planning their highway projects, economics is now an integral part of their work. For example, the State of New Jersey has a number of resources available for the assessment of highway economics. In 2010 the New Jersey Department of Transportation (NJDOT) prepared a series of federal discretionary grant applications utilizing BCAs conducted by the Rutgers Intelligent Transportation Systems Laboratory (RITS) supported by no-build and build scenarios modeled by a design consultant and/or data obtained from the North Jersey Regional Transportation Model (NJRTM).[397] Originally developed in the late 1980s by the NJDOT

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395 "Transportation Benefit-Cost Analysis," http://bca.transportationecononmics.org/models/hers-st, accessed October 3, 2019.

396 "Common Q's and A's pertaining to Transportation Asset Management," accessed October 17, 2019 at fhwa.dot.gov/asset/faq.cfm.

397 "Cost/Benefit Analysis of NJDOT Route 18/Hoes Lane Improvement Project For TIGER II Grant Application," Rutgers Intelligent Transportation Systems Laboratory, Piscataway, New Jersey, August 2010.

and the North Jersey Transportation Planning Authority, the enhanced version of this software (called NJRTM-E) covers 2,712 traffic analysis zones within New Jersey as well as nearby portions of New York and Pennsylvania.[398] Due, in large part, to the requirement that benefit-cost analysis form the basis for receiving federal funding it is now commonplace to incorporate high-level economic analysis that considers all applicable costs and maximizes the total net project benefits in every new highway design. Not surprisingly, the evaluated categories and impacts of such analysis still include those used in the earliest highway economic analyses.

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398 "Travel Demand Model," accessed October 18, 2019 at https://www.njtpa.org/Data-Maps/Modeling-Surveys/Travel-Demand-Model.aspx

Closing Remarks

Upon its completion, the Pulaski Skyway was the world's longest, high-level vehicular viaduct, and it was a significant achievement in the development of the American "superhighway" at a time when the controlled-access, high-speed highway was just coming into use and the form was seen as the answer to northeastern New Jersey's traffic nightmare.

> "While dualized roads stayed more vision than reality in most places until the late 1930s, a few … states like New Jersey, New York and Massachusetts were building them in urban areas. New Jersey in particular was ahead of other state highway departments in recognizing the need to develop limited access highways in order to segregate local and through traffic. Between 1926 and 1932, when the Pulaski Skyway was finished, the New Jersey Highway Department planned and built what is considered by many America's first super highway. The 13-mile long approach to the Holland Tunnel recognized the severe economic impact of traffic congestion and developed an effective highway to 'unscramble' through and local traffic in fully developed urban areas and stands as a testament to the ability of local solutions."[399]

It also contributed to general design theory in ways not even touched upon in this document. Several features of the Skyway and the adjacent Routes 1 & 9 Corridor were unusual or unique to highway construction of the 1920s and 1930s. The project was the first in the United States in which concrete approach slabs that extended past the abutments were utilized in an attempt to reduce differential settlement. The building of

[399] "The Importance of Using Context to Determine the Significance of Dualized Highways," prepared by James Patrick Harshbarger and Mary E. McCahon, accessed October 18, 2019 at http://www.phmc.state.pa.us/portal/communities/pa-suburbs/files/Using_Context_Determine_Significance_Dualized_Highways.pdf.

ramp systems was in the experimental stages in the early 1930s. The use of ramps entering the highway at the center of the deck was unique, and extensive analysis and detailing were necessary to accommodate the placement of the ramps between the trusses. The viaducts used for the corridor were longer than any being built at the time, and they utilized the relatively new practice, that was first widely used for bridge construction in New Jersey in 1931, of protecting steel members by encasing them in concrete. Experimentation was also used in the design of the deck expansion joints such that different joint types were utilized as construction progressed. In addition, to accommodate the excessive expansion of the long spans, cast "finger" joints, that were later to become a familiar detail on long-span bridges across the country, were designed for use on the Skyway.

However, the greatest significance of the Route 1 Extension project lies in the role it played in the evolution from railway to highway transportation systems in this country, and in particular in the part of that transition associated with the field of economic design. No detailed and definitive work on economic analysis for the layout and design of highways existed in the late 1920s, and the research efforts and compilation of data necessary for the development of such a theory were still far from complete despite the best efforts of states, universities and independent engineers across the country. Former railroad engineers Major William Sloan, Frederick Lavis, and Sigvald Johannesson brought their combined familiarity and extensive experience in railroad design and construction – and thorough working knowledge of Arthur Mellen Wellington's "The Economic Theory of the Location of Railways" - to their work in the planning and design of the New Jersey project. Although not intended to be a "teaching tool" per se, the Pulaski Skyway ultimately did become an illustrative example for the nation of the successful design and erection of a motorway to successfully separate through and local traffic in a heavily urbanized area and justify its cost in measurable travel time savings.

The Route 1 Extension was listed in the National Register of Historic Places in 2005. The National Register nomination form clearly explains the significance of this important historic resource:

> "[The Route 1 Extension] was the first time in this country that economic theories of location and operation were applied to the planning and design of an unrestricted-use, vehicular highway, a concept that was not successfully repeated until the Pennsylvania Turnpike…. It represents the transfer from railroads to highways [of] the idea of a facility design based on safety, traffic service, and economic theory…. The highway set the precedent and the standard for the planning and design of subsequent high speed, limited-access highways…. The highway was built at a time when there were no vehicular precedents or models to emulate…. It was through the genius of Sloan, a veteran railroad engineer, that the seemingly obvious link between trunk, or main railroad lines, and the new 'through trunk highway' was made and implemented. The state used the proven theories of the economics of railroad location to justify the unprecedented cost and complicated design of the highway…. In 1932, Thomas MacDonald … referred to the Route 1 Extension as 'the greatest highway project in the United States today,' and it truly was."[400]

Of significance to state and regional highway history, the route also served as a significant part of the development of the national highway system as a whole, marking

[400] "National Register of Historic Places Registration Form, Route 1 Extension," prepared by Mary E. McCahon and Sandra G. Johnston, December 2003.

the beginning of an era in which engineers became policy makers in transportation planning, utilizing both economic and time saving as means of justifying construction costs. Studies undertaken at the time of the opening of the Skyway definitively confirmed that its high construction cost had, in fact, been worthwhile as the new route enabled cars and trucks to traverse the region more rapidly than ever before. Those measurable time savings were tangible evidence of the value of the economic theory behind its design.

As New Jersey State Highway Commissioner, Spencer Miller, Jr., stated in his contribution to the "Highways in our National Life" symposium hosted by Princeton University's Bureau of Urban Research in 1950,

> "planning and economic factors, long recognized in railroad location and other engineering projects, were introduced for the first time in America in the design and construction of the New Jersey highway system. It was developed under the general direction of Sigvald Johannesson, the designer of the Pulaski Skyway, in 1930 for a Special Board of Inquiry into the best type of facility to construct over the Hackensack Meadows between Jersey City and Newark.... Later the theory and application of economics to highways was embodied in a book, *Highway Economics*, by Mr. Johannesson, the first to be published in this country."[401]

During the two decades that followed the opening of the Pulaski Skyway, designers Fred Lavis and Sigvald Johannesson continued to be strong advocates for the use of a formal economic theory in making decisions regarding the placement and design of new highway systems, particularly in heavily trafficked, urban areas. As the United States

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[401] Spencer Miller, Jr., "History of the Modern Highway in the United States," by Spencer Miller, Jr., *Highways in our National Life - A Symposium*, (Princeton, New Jersey: Princeton University Press,1950), 103-4.

entered the second half of the twentieth century, the construction of limited and controlled access highways expanded dramatically and the need for economic design considerations became even clearer.

Now – more than eighty years after the opening of the Pulaski Skyway – economics is a critical contributing element in local, state and regional highway planning. The Skyway remains a physical testament to the dramatic advances in transportation theory and the inventiveness of engineers that dominated New Jersey and the remainder of the United States so many years ago. The Route 1 Extension through northeastern New Jersey was the first American highway to be designed utilizing earlier railway economic theory, "the first roadway project where public time-saving was used to justify dramatic capital expenditures,"[402] and the project that introduced a fully developed theory of highway economics to the first generation of engineers who would eventually make it a fundamental part of roadway projects to follow.

[402] "Pulaski Skyway Feasibility Assessment Study," August 19, 2010, prepared by Parsons Brinckerhoff for the NJDOT for the Historic Sites Council Meeting, 9.