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Influence and Intercultural Exchange: Engineers, Engineering Schools and Engineering Works in the Nineteenth Century

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Jorge Luis Borges made the observation that Kafka's work influenced all the writers who preceded him. Borges wrote: "Each writer *creates* his precursors. His work modifies our conception of the past, as it modifies the future."[1] The same is true of designers of objects deemed "technological." When a new object is developed, our conception of apparently related objects is transformed; this change permits us to understand the make-up and origins of the new, to place it within a context. We notice aspects of existing objects and contexts that we never noticed before.

During my ongoing study of the development of the long-span framed-beam bridge, it became evident that the determinant innovations of civil engineering took shape through intercultural exchange. A large number of persons, including technologists, entrepreneurs, and statesmen, exchanged "technological" and "non-technological" ideas and objects of various types and of many perceived origins. The exchanging parties may have been part of an officially recognized institution; or they may have had indirect contact through publications and hearsay. In any case, interaction between technologists who worked in many countries was both deliberate and decisive. Most of the key civil engineers of the the nineteenth century possessed an international outlook.[2]

During the early decades of the nineteenth century, several of the predominantly agricultural countries of Western Europe, as well as the United States, began to transform themselves into industrial powers. The exchange of information, spurred by cooperation and competition between governments, public and private institutions, and individuals working within various countries, allowed a scale of technological development which could not have occurred in one country alone. Which is to say: there was a lot of influence being exerted and felt. This type of activity has been described as "idea-" or "stimulus diffusion" by anthropologist A.L. Kroeber, who viewed it as a "process [that] combines development within a culture with influence from outside." He noted that such diffusion "will ordinarily leave a minimum of historical evidence": "the specific items of cultural content, upon which historians ordinarily rely in proving connection, are likely to be few or even wholly absent."[3] In other words, ideas are spread, but we often can't see them or their traces. If we can't see them, can we understand the intercultural web of artifacts, ideas, and methods that we call *technology*?

In order to begin to understand how a technological result was achieved, I have been trying to detect relationships and understand their governing biases. In this article, I investigate the role of influence in the development and selection of a particular system of construction: the lattice bridge (figs. 1 and 2). I must emphasize that I make a distinction between the official presentation and what occurred behind the façade. This means that I highlight, rather than ignore, gaps in our knowledge. The following is a brief discussion of technological influence.

Under the Sign of the Engineer

I will begin with Wilhelm Nordling (Stuttgart, 1821-Paris, 1908), an engineer who studied as an *auditeur externe* in the *Ecole polytechnique* and *Ecole des ponts et chaussées* at the beginning of the 1840s. Was he influential?

Nordling became a chief engineer on the Orléans Railroad and one of the most eminent designers of lattice railroad viaducts in Europe during the nineteenth century. He contributed to or was responsible for the design of various structures, including the Grandfey Viaduct (1857-62), built over the Sarine at Freiburg in Switzerland by the French firm Schneider (fig. 3). Thanks to Nordling, who was in charge of the design and construction of four viaducts on the Orléans Railroad, building contractor Gustave Eiffel erected in 1868 and 1869 his first towers: the iron piers that supported two of the viaducts. Nordling awarded the contract to Eiffel, who later wrote of the importance of Nordling's pier design in his subsequent projects.[4] Nordling worked in France for at least thirty years. He wrote articles that appeared in the *Annales des ponts et chaussées* on the design of his bridges.[5] He was appointed *grand officier* of the Legion of Honor; a decree of Napoleon III made him a French citizen in 1870. Although he participated in the construction of several French railway lines, and reached the grade of *ingénieur en chef*, he did not promote himself as Eiffel did. While Eiffel for the most part built the designs of other engineers, it seems that Nordling designed several of the most well-known long-span frame structures of his time.[6]

The name Nordling has been virtually forgotten. Considering the relatively unexamined state of the history of building technology, perhaps historians' treatment of Nordling should not be considered surprising; yet surprise is appropriate, because Nordling was involved in a series of large-scale works, the kind historians traditionally have focussed on. While Bernard Marrey's recent bridges-of-France anthology takes brief note of Nordling's contribution, this is an exception. Eda Kranakis presents Wilhelm Nordeling [sic] as an example of someone who left France because of "[frustration] with a system that offered . . . no possibility for advancement." Nordling did in fact go to Austria-Hungary, where he remained nine years, rising to the position of Austrian Railway Director; due to political and technological differences, he resigned and and returned to France, where he spent most of his life and was apparently highly esteemed. Considering his rank, activities, and the honors bestowed on him, it seems that Kranakis deemed Nordling "frustrated," in order to fit him into a schema of national "engineering cultures," that is, enclosed areas of influence. In fact, Nordling's career and work is a strong indication of the tenuousness of the national character concept. David P. Billington wants to substitute Eiffel, a "great artist" who towered above the influences that surrounded him, for Nordling. He observes correctly that "little if anything has been written on Nordling's . . . designs," and presents this as proof that Nordling was not a significant designer; Billington does not cite Nordling's numerous publications and credits Eiffel with a tower design that Eiffel explicitly attributed to

Nordling. Billington claims "that a work of structural art comes from the mind of a single artist." Finally, Antoine Picon, writing of the "influence of the *Ecole des ponts et chaussées* " cites Nordling as an example of a "foreign" student who left France for a "brilliant career" abroad: per Picon, Nordling was "the Wurtemburger who became director of the Tisza-Pest Railroad." But this foreigner was also French -- and brilliantly so.[7]

Nordling represents a hidden influence; that is, an engineer who worked within a team, perhaps with limited political and economic power, perhaps outside of the reigning institutions. He may move easily within several countries and may be considered a foreigner in some or all of them -- and thus be considered unworthy of attention by a historian with a nationalistic mindset. The hidden influence may not promote himself, and so it is likely that he has neither hagiographer nor fans to keep his name alive. His contribution disappears without a trace.

Should we care about people such as Nordling? In terms of Great Works and Great Men, both of which loom large in popular and scholarly histories of engineering, we must. But we must also wonder: were the Great Men more influential than the Little People? Most historians will hope not, as identifying Little People is even more difficult than finding overlooked Great Men. Yet it takes a constellation of technologists to design a bridge and to design a construction method. The greatest influence may not rest with the brightest star.

A Bridge's Sway

The type of bridge Nordling built, the lattice, provides us with a documentable case of influence. Prior to 1820, when engineer-architect Ithiel Town (1784-1844) of New Haven, Connecticut, registered his patent, such a bridge system did not exist. In brief, the original Town patent described a bridge supported by rectangular frameworks that contained multiple diagonally intersecting members (fig. 1). In other words, a latticework was connected at the top and bottom by horizontal beams. The wooden planks were pinned together at the intersections with wooden pegs. Town's second patent (1835) retained the basic design, while doubling the lattice in each framework (fig. 2).[8]

As a beam-like framed structure intended to bridge long spans, conceived without vertical members and without the support of an arch, the bridge was highly unusual, if not unique.[9] It was a systematic, repetitive scheme based on ease of construction and maintenance, intended for use where skilled labor was scarce. Town's intention was not to design a single bridge; he wanted to create a "general mode of constructing" which could be carried out on a mass scale.[10]

In addition to demonstrating the power and potential of a lattice structure, Town's bridge spread the idea that a horizontal beam made of relatively small parts could bridge long spans. While the former concept was of great import, the possibilites suggested by the latter were even greater. Both were a stimulus to bridge builders at many points on the globe. Descriptions and images of the lattice bridge were diffused to such an extent during the nineteenth century -- through books, newspapers, journals, lithographs, and models, as well as the bridges themselves -- that it would be impossible for a civil engineer not to have been familiar with it.[11]

The lattice bridge, the springpoint for many bridges labelled "American" in Europe for over fifty years, became a fundamental long-span structure in modern construction.[12] The system astonished engineers who saw it for the first time. It was a light and rigid and could be rapidly constructed; it was considered inexpensive and beautiful.

The lattice swayed many engineers. Those who would subsequently conceive of framed beam bridges became familiar with the Town bridge through publications and travel, and referred to it when explaining the superiority of their conceptions. Stephen H. Long took extra care to distinguish his system from the lattice, which was the patent against which he and his contemporaries had to measure and distinguish themselves, if they were to get patents of their own. William Howe, in 1840, took the bridge and put the lattice members into compression by introducing vertical iron tension rods: a system that attracted much attention in Europe. An article accompanying an illustration of Howe's bridge (fig. 4) concluded: "The writer will add his conviction, that . . . the peculiar truss above described, will be found superior in strength, stiffness, and durability, to . . . Town's double lattice plan." Johann Mohnié, in 1857, stated at the beginning of an article in which he described his improved lattice bridge design, that he "had the opportunity to be able to observe and investigate many iron Town lattice bridges."[13]

The mid-nineteenth century theoreticians of framed structures would also develop their theories and methods in response to the lattice bridge and framed structures subsequently designed. Herman Haupt, West Point graduate and railroad engineer and manager who distinguished himself in the Civil War, studied lattice bridges before patenting his own lattice bridge and publishing his book on bridge analysis. Karl Culmann, a professor and eventually head of the Bauschule at the polytechnical school of Zurich, gained reknown as the developer of graphic statics; his first major publication in 1851-52 analyzed bridge building in the United States and England. Culmann emphasized his belief that the lattice bridge was a theoretical and practical failure. D.J. Jourawski in Russia, Franz Maschek in Prague, and William Thomas Doyne and William Bindon Blood in England would also employ the lattice as an object in the development of their methods of analysis.[14]

The lines of influence led to wherever bridges were being built in great number. But how had Ithiel Town come up with his idea? We will never know exactly, because the patent system is a guarantee that the inventor will try to hide his influences. Town had access to libraries containing a very large number of books on construction; that is, he had access to many of the same publications as builders in Europe and he was undoubtedly familiar with internationally-known structures such as Hans Ulrich Grubenmann's Schaffhausen Bridge over the Rhine in Switzerland (1757) and Philibert de l'Orme's structural system (conceived c. 1561).[15] Was Town subject to "European" influence? And did all civil engineers who worked in Europe and knew of the Town bridge bear the "American" brand on their work?

Town was a United States citizen. He worked in the United States. His bridges were known (outside of America) as "American." But neither the ideas nor the structures that influenced Town, nor the influences tht emanated from the ideas and structures that Town developed and built, can be shoved into national ghettos. A perceived national origin may give force to influence, but the contents of that influence are not bound to a single point of origin.

Influence in Print

Engineering books and journals are the bearers of influence. Their words and images operate on the impressionable minds of young engineers. How do they influence? Does a book have one particular influence, or several contradictory ones?

Textbooks published in France were used in engineering instruction in the United States; for example, professor of civil engineering Joseph-Mathieu Sganzin's (1750-1837) text, long a part of instruction at the *Ecole polytechnique* as well as the *Ecole des ponts et chaussées*, was translated into English and used at West Point.[16] Concerning bridges, Sganzin explained:

> [Wooden frame bridges] are grouped into two principal classes.
>
> In the first, the paving stones are supported by a deck erected on horizontal beams; these are held up at their ends by points of support which rest on the ground.
>
> The second is a frame system in which the points of support are placed at the bottom of the arc of a circle [i.e. an arch] . . .
>
> The first is applicable only for small spans.
>
> The second is for larger spans.[17]

I cite this explanation, which appeared in the French editions of 1809 and 1821, because in 1820, Town filed the lattice patent. Town's bridge was a horizontal beam -- that is, class number one -- but it was a *long* span structure. Sganzin did not know that his text was no longer valid. This was becoming apparent when the translation of Sganzin's text appeared in the United States in 1827.

In 1834, engineer Guillaume Tell Poussin (1794-1876) published one of the earliest descriptions of the Town bridge to appear in Europe; this description was reproduced in the revised edition of the civil engineering text of Sganzin in 1839.[18] It also appeared with Poussin's detailed illustrations in the brand-new *Annales des ponts et chaussées*.[19] By

1838, French state engineer Joseph Hyacinthe Garella (1807-1866), grandson, son, and brother of state engineers, built the first of two provisional Town bridges, over the Rhone in Lyon. Garella would later complain to his superiors that he did not receive the technological information from beyond France's borders quickly enough.[20] During the same period at West Point, American engineer Dennis H. Mahan published his engineering text. Between 1826 and 1830, Mahan had toured Europe and studied at the military school at Metz; he was apparently "under the influence," because his textbook as late as 1839 made only a passing, vague reference to U.S. bridges, while it lauded French theoretician-engineer Navier.[21] One could imagine that West Point cadets read "French" texts while crossing lattice bridges which should not have existed, whereas in France, students and engineers began to study and build "American" bridges.

I have to admit, however, that I am recounting this tale of engineering textbooks without the conviction that their influence on the students resulted in the conception of bridge structures. I want to look beyond the text into the context, and into the context's context -- that is, I want to know how the book, the school, and the nation functioned together to influence thousands of students.

Schools of Influence

Historians concentrate on what some believe to be an irrefutable influence: engineering schools. They consider these academies veritable molders of character. But the effect of education is not easy to gauge. It is necessary to examine the institutions on many levels: textbooks; courses; hierarchies; esprit de corps; mythology; and the relationship between the school, the state, and the society. At each level there are influences. And there are interactions between all levels.

We are told that many influential nineteenth-century engineers were trained in France. The texts and instruction of the engineering institutions must have been decisive for bridge design. For example, Bavarian engineer-theoretician Karl Culmann, studied at Wissembourg and Metz; and the American William Le Baron Jenny, so-called father of the skyscraper, studied at the *Ecole Centrale* in Paris.[22] French engineering institutions would seem to have been very influential. In France, however, it appears that few if any of the key designing, building, and entrepreneurial engineers were part of the *Ponts et chaussées* hierarchy, the bureaucratic bastion where even the marriages of the engineers had to be approved. They were outsiders. The "outsiders" included Nordling, the Seguin family, and Eugène Flachat, one of the key nineteenth-century engineers in France, whose "professional school" consisted of "frequently visiting English engineers." In this group, the industrialist engineers must also be included: for example, Ernest Gouin, Jean-François Cail, Pierre Schaken, Eugène Schneider.[23]

What has been described as a "gulf" and a "barrier" separated the state engineers whose "functions . . . were almost totally lacking in scientific and engineering content" from the designing engineers who created the civil engineering industries based in France.[24] While many studied in one or several engineering schools in France, they also carefully studied the practices and models of other countries. This was true of administrators and theorists inside and designers -- and industrialists outside -- the state apparatus. In the case of the lattice and other framed beam bridges, this meant scrutinizing "American" practices and models, where the railway network was built with what was considered to be great rapidity and economy. In other words, Town could easily be said to have founded his own "school." He had many students. As did Flachat. Both are at least as worthy of study as the most venerable of the technical institutions.

What does the study of these institutions tell us about their influence on technological conception and method? At the *Ecole Centrale*, for example, students selected one of four specialties in addition to general courses: chemistry, metallurgy, mechanical or civil engineering. Yet the choice of subject area did not always determine the direction of each graduate's work. Eiffel is a well-known case: he studied chemistry. As historian John Weiss has shown, social and economic factors were as influential as the contents of the courses at the *Ecole Centrale*.[25] While the prominence of its alumni in industry can be traced to the the social value of its diploma, this diploma cannot account for technolgical development, because engineers studied within and without educational institutions -- and within and without the country where they happened to be born. The influence of engineering institutions on technological design is therefore something to be considered only with extreme caution. As Weiss explained at the beginning of his study of the *Ecole Centrale*:

> Graduates of Centrale, of course, went on to achieve great things. But would they not have achieved just as much if they had been trained in some other school? As will be noted, engineers trained in "lesser" schools or merely by apprenticeship made outstanding contributions to French industrialization, a pattern that only the most recent scholarship has begun to elucidate.[26]

Whether the name of a particular engineer is known today may have a lot to do with his or her (perceived) nationality, and how close he or she was with the official institutions which still today exert great political influence.

Textbooks and schools cannot be automatically considered decisive in the conception of engineering systems. Their influence must be carefully investigated. University courses, like the displays of the universal exhibitions, reflected the status quo of engineering knowledge, something already known by active, creative engineers. Much or some of what was taught may have been ignored or quickly forgotten. Each engineer may actually have studied in many "schools." It is not immediately apparent which had the greatest effect.

The National Zodiac

Can one then speak of a French or an American or a German influence?

Engineers such as Nordling, who designed new bridges, redesigned existing ones, or were responsible for choosing bridges for construction in France, selected types that did not necessarily issue from the theoretical-hierarchic system of France. In the United States, the wooden lattice bridge was rejected by most railway engineers by 1850, just when this type was adopted, in iron, in Europe, as a preferred system for long spans. Thousands were constructed.[27] In the United States, on the other hand, alternative types were designed. These were systems that could be easily analyzed -- which was not the case with the statically indeterminate lattice bridge. In these alterntive systems, members worked either in tension or compression, but not both. The type which apparently enjoyed the greatest popularity in the U.S. during the 1850's was the Fink bridge. Albert Fink was an American engineer, that is, born and trained in Darmstadt; his system resembled that of French engineer Polonceau.[28] The Fink bridge was therefore extremely "American," that is, conceived by a German, possibly after a French model that may have been conceived as a result of an American influence.

In France, systems were used which were not developed with a "sophisticated" knowledge of mathematics; thus one has to ask about the influence of "theory" in the conception and decision-making processes -- and wonder at length about the influences which operate on historians who claim that mathematics and science were paramount. One must be especially careful, since "the evidence suggests that claims that the technical quality and duration of formal schooling constitute the principal determinants of job performance spring not so much from methodologically convincing tests of such propositions as from the needs of educators to justify their activities."[29]

It is not at all obvious that the graduates of the *grandes écoles* who conceived technological systems depended more on "theory" than the non-institutionalized "practical" engineers. Nor is it obvious that their designs and choices will be imbued with a "theoretical" character. Nor are the most "sophisticated" designs dependent on mathematical theory. While knowledge of engineering theory may have been important for career advancement, there is no proof that this knowledge was required for engineering creativity, that is, for the design of bridges and their construction processes.[30] The case of the suspension-bridge deck designs of the "empirical" industrialist Seguin, with his light deck, and the theoretician Navier, with his heavy deck, is a good example. So is the design of Robert Maillart's reinforced concrete structures.[31]

Although some historians and sociologists support a worldview of "theory" and "practice" contained within national borders and perpetuated by national educational institutions, what we know of technological design practices does not seem to confirm this view. Engineers in both the United States and France, for example, have made statements in which they placed theory at the highest level. The similarity between the statements of Navier and Eiffel is pointed out by Kranakis: Eiffel is said to have "assimilated the approach of the corps engineers."[32] This "corps approach," however, was as "American" as it was "French"; look, for example, at the statements of Town and prominent U.S. bridge engineer Theodore Cooper (1839-1919). Town, like theorist Culmann, advocated a theoretically precise strucure: Town stated that each plank should bear "either a tension or pulling strain, or a thrust or pushing strain." Cooper, in an enumeration of the "essential characteristics" of "the typical American railroad bridge," gave as characteristic number one: "So formed as to reduce all ambiguity of strains [i.e. stresses] to a minimum." Theoretical clarity and precision -- which mean different things to different engineers -- are not the property of one nation or institution. Nor are the influences that result in an engineer's paying tribute to "theory." Similar influences probably spurred Town and Eiffel to make their statements -- and these influences were not based in any single nation or culture.[33]

Technologists' pronouncements may tell us nothing about how they designed: the influence of rhetoric on design (and vice-versa) is a question that demands attention. But the lack of study in this area presents a problem for historians who attempt to identify the key designing engineers, show how they worked, and then explain how an educational system influenced them. The influence of education on students is, nevertheless, a crucial question, because, for example, as historian Theodore Zeldin has written, "in the history of France . . . education became almost a substitute for religion." (Yet, as Zeldin, points out, this religion could reward memory and stifle creativity.) Moreover, education served as "one of the greatest stimulants of national uniformity": it was an attempt to create "Frenchness" within a nation that was anything but culturally unified.[34] It is necessary therefore to examine the totality of the results of this national/technological construction process. Did individual designing civil engineers in each country really operate differently?

Did differences remain uniform and constant? Or might the situation be closer to what historian Peter Lundgreen described, when he observed that his "analysis of the German system of organizing science and technology [in technical schools] implies the need for some modification of the notion that it has always possessed certain fundamental characteristics. [. . .] A similar point could be made about France."[35]

If one wants to speak in terms of national influence, one must immediately admit that, as often as not, the "American" influence is not very strong in the United States, and that the "French" influence was not very successful in France. Because, despite the heavy, professionally conservative theory-drenched administration, French citizens used an "American" system for long-spans. And practical Americans presented themselves as theoretical fundamentalists.

While there may be an educational and professional "well-known major divide between Continental Europe and England or the U.S.A.," this "divide" may tell us little, perhaps nothing, when we want to know about the way technologists thought when they designed or invented, and about their influences -- whether "national" or otherwise.[36]

Adjectives such as *French* and *American* belong to the same category as terms such as *first*, *logical*, *practical*, *theoretical* and *(the most) economical*. Which is to say, at best, they have meaning within a limited context: a short period of time, a circumscribed locality, or a single engineer. Their explanatory power diminishes as their scope is broadened. Of course, we can interpret the work of an engineer who worked within a constellation of "American" engineers so that it is "practical." Likewise, we can interpret the behavior of a person born on January 17th as serious and reflective, that is, as typically "Capricornian."

The Influence of Influence

There is no question that specific systems were employed during specific periods by specific engineers whose influences stemmed from many places, periods, and technologies. Their choices -- and the published justifications of these choices -- have caused some historians to detect a strong national scent. But the evocation of "national character" cannot explain technology; on the contrary, technology helps us understand what a nation or a culture is.[37]

Once an engineer is defined as "French," his influences are seen to be "French" -- even his bridges are "French." Likewise, an object invented within the North American continent is imbued with "Americanness." How does this explain the popularity of the redesigned lattice bridge in Europe? How does this explain Eiffel's typically "American" entrepreneurial career? Or the fact that a technologist born in one nation had a major role in others?

It is difficult to separate the influences claimed or denied during a particular period, and the accounts of historians who subsequently echoed uncritically the period's debates and commentaries. It is tough to avoid clichés and stereotypes, to disentangle rhetoric from actions and objects. The histories produced by the institutions and technologists whose power and prestige depended or depends on their influence weighs heavily on our understanding of the history of technology.

When collaboration became competition, engineers often spoke of small differences as if they were enormous, in order to deny their relationships and influences. (They did this even though the differences *within* each nation may have been as great as the differences *between* nations.) The danger is that the historian will be duped by exaggerated claims of influence, that she or he will see puny ephemeral "national" differences instead of a supranational development where the influences are so dense they can't be sorted out.

It's necessary to note that one is "influenced" by what one already has in one's mind, and by the things that one desires; there is a preparation before one seeks and chooses. In this sense, during much of the nineteenth century, the United States served as an overwhelming "influence" on technologists working in Europe and elsewhere. As soon as attitudes toward the United States changed, however, the "American influence" evaporated; one finds that it never even existed . . .[38] And the historical context shifts accordingly.

In any case, the claim that an influence has been at work must be backed by a belief that two distinct entities really exist -- not just two elements with different names. If not, in the end, it's only a question of autoinfluence. Nations such as France and the United States were anything but cultural monoliths during the period examined here. Yet historians, profoundly influenced by a convenient notion of national difference as a basis for examining influence, have avoided this fundamental issue.

Technological objects are developed through a process -- intercultural exchange -- that is often hidden from the eyes of the observer. Most of the engineers of the nineteenth- and twentieth-century engineers who designed and built structures and founded civil engineering industries have yet to be studied; we know a few of their names and a little about their influences. Even if one is able to distinguish between engineering activities on the basis of geographical or national borders -- those lines on maps seem to some historians so impermeable and reassuring! -- influences are difficult to detect. The search can become kafkaesque.

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[1] Jorge Luis Borges, "Kafka and His Precursors," in *Other Inquisistions 1937-1952*, (Austin, Texas: U. of Texas Pr., 1964), 108.
[2] A concept related to *exchange*, international "dialogue," is proposed by Arnold Pacey, *Technology in World Civilization: A Thousand Year History* (Cambridge, Mass.: MIT Press, 1990), vii-viii, 24, 119-20, 207. *Exchange*

is touched glancingly by some historians, usually by *transfer* theorists. Brooke Hindle and Steven Lubar, *Engines of Change: The American Industrial Revolution, 1790-1860* (Washington, D.C.: Smithsonian Inst. Pr., 1986), 71-72, refer to "reverse transfer"; Darwin H. Stapleton, *The Transfer of Early Industrial Technologies to America* (Philadelphia: American Philosophical Society, 1987), 2, states: "Reciprocal transfer of technology among the advanced industrial nations is now an accepted phenomenon of the modern world." "Reverse/Reciprocal transfer" (i.e. two discrete one way actions between distinct entities) is typically the closest transfer theorists get to exchange. Neither "advancement" nor "industry," nor "the modern world," however, is required to explain reciprocal relationships between "nations."

The cosmopolite-engineers who played a role in the development of the bridge system examined in this article include: Robert Fulton, Howard Douglas, Franz Anton Gerstner, Karl Ghega, Mocure Robinson, and Carl Etzel. Others are mentioned below.

[3]A.L. Kroeber, "Stimulus Diffusion," *American Anthropologist* 42 (1940): 1-2, 20.

[4]Nordling awarded the contract to Eiffel to build viaducts over the Neuvial (1868) and the Sioule (1869) in the department of Allier, on the Orléans Railroad, Commentry to Gannat line. Eiffel made a contribution to the design of the connection hardware of the towers, rather than design of the towers themselves.; on the other hand, he probably determined the St. Andrews-cross configuration of the bridge spans. G. Eiffel, *Travaux scientifiques exécutés à la Tour de trois cents mètres de 1889 à 1900*

(Paris: L. Maretheux, 1900), 229; Bertrand Lemoine, *Gustave Eiffel* (Paris: Fernand Hazan, 1984), 32, 34.

[5] Wilhelm Nordling, "Mémoire sur les piles en charpente métallique des grands viaducs," *Annales des ponts et chaussées* 4/2 (1864):1-126 [Also printed separately, Paris: Dunod, 1864]; "Documents relatifs aux viaducs métalliques de la ligne de Commentary à Gannat.," *Annales des ponts et chaussées* 4/1 (1870): 125-87 [Also printed separately, Paris: Dunod, 1870]. These articles have yet to receive the close attention they deserve. Nordling's bridges include those over the Creuse (1863-65); over the Cère (1863-66); over the Bouble valley (1867-69); and over the Bellon ravine (1868-70).

[6]This brief description does not provide a complete list of Nordling's accomplishments. Some biographical information can be found in A. Birk, *Männer der Technik*, ed. Conrad Matschoss (Berlin, 1925), 191 ; von Röll, ed, *Enzykopädie des Eisenbahnwesens*, 2 ed., (Berlin, Vienna, 1915) 7: 364-65; *Österreichisches Biographisches Lexikon*, 143; *Österreichische Eisenbhanzeitung* 31 (1908): 255. See also Marrey, cited in the next note.

[7]Bernard Marrey, *les Ponts Modernes: 18e-19e siècles* (Paris?: Picard, 1990), 210-212, 310; Eda Kranakis, "Social Determinants of Engineering Practice: A Comparative View of France and America in the Nineteenth Century," *Social Studies of History* 19 (1989): 16. David P. Billington, *The Tower and the Bridge*, (N.Y.: Basic Books, 1983), 93. Billington incorrectly states (66-67) that Eiffel built the four viaducts on the Commentry-Gannat line; he built only two. Billington incorrectly attributes Nordling's tower designs to Eiffel, whose role was slight (see note 5

above). With these errors corrected, by Billington's estimation, Nordling should be considered the primary design source for the Eiffel Tower -- as well as a "great artist." Antoine Picon, *L'invention de l'ingénieur moderne: l'Ecole des Ponts et Chaussées 1747-1851* (Paris: Presses de l'école des ponts et chaussées, 1992), 465, in a section entitled "Le rayonnement de l'Ecole des Ponts et Chaussées."

[8]Ithiel Town, Letters Patent, "Containing a description in the words of the said Ithiel Town himself of his improvement in Bridges," 28 January 1820; Letters Patent, "Containing a description in the words of the said Ithiel Town, himself of his improvement on his bridge patented the 28th day of January," 3 April 1835. Both patents may be found in the U.S. National Archives.

[9]Both vertical members and arches were, however, sometimes introduced by other engineers.

[10]Town used the term "mode" in his first sales brochure, *A Description of Ithiel Town's Improvement in the Construction of Wood and Iron Bridges: Intended as a General System of Bridge-Building for Rivers, Creeks, and Harbours of Whatever Kind of Bottoms; and for any Practicable Width of Span or Opening, in Every Part of the Country (*New Haven: S. Converse, 1821), 1; in the 1839 edition of the brochure (5, 10), he referred to it, as in the title just cited, as a " 'general system.' "

[11]Accounts appeared in many books and articles and in various languages. There are far too many to be listed here; the following is a sample of early reports: Ithiel Town, "A Description of Ithiel Town's Improvement," *American Journal of Science* 3 (1821): 158-66, 3 pls; Howard Douglas, *An Essay on the Principles and Construction of Military Bridges, and the*

Passage of Rivers in Military Operations 2d ed. (London: Thomas and William Boone, 1832), 400-401; "Neue Art hölzerne Brüken zu bauen," *Allgemeine Polytechnische Zeitung* (1836): 231; "Town's Brücken," *Polytechnisches Centralblatt* (1836): 48 [From *London Journal* (Oct.1835): 104.]; David Stevenson, *Sketch of the Civil Engineering of North America* (London: John Weale, 1838), 231-234, pl. 9 [Stevenson was excerpted in several French and German-language publications]; Michel Chevalier, *Histoire et description des voies de communication aux Etats-Unis et des travaux d'art qui en dépendent* (Paris, Charles Gosselin, 1840-41), 2: 564-582; de Saint-Claire, "Sur une travée en charpente construite au Vaudreuil, route royale de Mantes à Rouen, dans le système des ponts américains de M. Town," *Annales des ponts et chaussées* 2/1 (1841): 303-09, pl. 9; Franz Anton Gerstner, *Die innern Communicationen der vereinigten Staaten von Nordamerika*, ed. L. Klein (Wien: L. Förster,1842), 1: 107-108, 202-203, 235; 2: 61, 126, 166-67, 170, 187, 245-46, 256, 261, 264, 277, 291; Michel Chevalier with commentary by Léon Lalanne, "Histoire et description des voies de communication aux États-Unis, et des travaux d'art qui en dépendent par M. Michel Chevalier: analyse et extraits," *Annales des ponts et chaussées* 2/2 (1843): 303-309, pl. 56; "Geschiedkundige Herinnerlingen betrekkelijk den Ijzeren Spoorweg van Amsterdam naar Haarlem, Leiden . . . en Rotterdam: . . . Kunstwerken," *De Nederlandsche Stoom Post* 31 (1 August 1847): 131-32.

A key factor in the development of modern technology was the expansion of printing and transportation, both of which put at the disposition of engineers an enormous number of potential influences. See, for example, Euguene S. Ferguson, *Engineering and the Mind's Eye* (Cambridge, Mass., MIT Press, 1992) and Bruno Latour, "Drawing Things Together," in Michael Lynch and Steve Woolgar, *Representation in Scientific Practice* (Cambridge, Mass., MIT Press, 1990),19-68.

[12]In French, *pont à poutres droites en treillis*; in German, *Gitterbrücke* or *Fachwerkbrücke*; in English *lattice* or *truss bridge*. The development of the lattice bridge will be examined in a work in preparation entitled *The Long Span*. See also Gregory K. Dreicer, "Nouvelles inventions: l'interchangeabilité et le génie national," *Culture Technique* 26 (1992): 213-220. The term "American bridge" appeared too often to be cited here. This label was used even in England, where engineer Carl Ghega reported that Town bridges were called "American timber bridges"; Carl Ghega, *Über nordamerikanischen Brückenbau und Berechnung des Tragungsvermögens der howeschen Brücken* (Wien: Kaul Fuss Witwe, Prandel & Co., 1845), 10. It is likely that the same terminology was used in eastern Europe and Russia. Whether built of wood or iron, the term stuck: see, for example, Boulangé, "Notes recueillies pendant une visite rapide de quelques chemins de fer d'Allemagne," *APC* 3/1 (1854): 65, 71, 76. During the nineteenth century, various structures, machines, and systems were at the time of their introduction labelled "British" or "American." In the case of framed bridges, the characterization lasted for decades.

[13]Stephen H. Long, in *Description of Col. Long's Bridges, Together with a Series of Directions to Bridge Builders Concord* (N.H.: John F. Brown, 1836), 40, explained the principle behind his bridge: "It is admitted that this principle is rendered operative in the lattice bridges invented by Mr.

Town, but it should be borne in mind, that his bridge frames, are not truss frames, inasmuch as they are completely destitute of keys, wedges or trussing of any kind, and are trenailed, rather than truss frames." This argument depended on a particular definition of the word *truss*; this definition was necessary for Long to receive a patent. Lewis M. Prevost, Jr., "Description of Howe's Patent Truss Bridge, Carrying the Western Railroad over the Connecticut River at Springfield, Massachusetts," *Journal of the Franklin Institute* 3d Ser. 3 (1842): 292. Bavarian engineer Mohnié received his patent in 1857: "Der Unterzeichnete hatte Gelegenheit, viele eiserne Town'sche Gitterbrücken beobachten und untersuchen zu können"; Johann Mohnié, with Commentary by H. Scheffler, "Über eine verbesserte Konstruktion eiserner Gitterbrücken," *Organ für die Fortschritte des Eisenbahnwesens in Technischer Beziehung* 12 (1857): 227-236, pl. 20; Mohnié, "Verbesserte Konstrucktion eiserner Gitterbrücken," *Zeitschrift für praktische Baukunst* 17 (1857): 225-232.

[14]Herman Haupt, *General Theory of Bridge Construction, Containing Demonstrations of the Principles of the Art and their Application to Practice* (New York: D. Appleton, 1851), 148-57. Karl Culmann, "Der Bau der hölzeren Brücken in den Vereinigten Staaten von Nordamerika . . . in den Jahren 1849 und 1850," *Allgemeine Bauzeitung*16 (1851): 69-129, pls. 387-97; excerpted in *Polytechnisches Centralblatt* NF5 (1851): 1492-97; and *Eisenbahnzeitung* 9 (1851): 165-6; Karl Culmann, "Der Bau der eisernen Brücken in England und Amerika," *Allgemeine Bauzeitung*17 (1852): 163-222, pl. 478-487. Regarding D. J. Jourawski's activity in St. Petersburg, see Stephen P. Timoshenko, *History of Strength of Materials: With a Brief Account of the History of Theory of Elasticity and Theory of*

Structures (New York: McGraw-Hill, 1953; reprint, New York: Dover, 1983), 141-44, 186-89; Jourawski's object of analysis (1844-1850) was a Howe-lattice. William Thomas Doyne and William Bindon Blood, "An Investigation of the Strains Upon the Diagonals of Lattice Beams, with the Resulting Formulae," *Transactions of Institution of Civil Engineers* 11 (1851): 1-14; Doyne and Blood, like Whipple and Haupt, used the "method of joints" for analysis (Timoshenko, 186). In his theoretical treatise *Neue Theorie der allgemein als der zweckmäßigsten, vollkommensten und wohlfeilsten anerkannten nordamerikanischen Brücken-Konstructionen, nach Town's, Long's and Howe's System, wie auch ihrer in der neuesten Zeit erfundenen Vereinfachung und Verbesserung von Neville und Clark auf eine originelle, leicht faßliche Weise (Ohne höhere Mathematik) dargestellt* (Prague: Johann Spurny, 1860 [1st ed. 1857]), Franz Xav. Jos. Maschek, a Prague architect who has been overlooked by historians, considered, as many did, the Town bridge to be a basis for the inventions of Long, Howe, Neville et al., as well as a basis for a theoretical understanding of framed structures (see, for example, Maschek, 11, 27).

[15]Between 1804 and 1810, Town was trained in Boston under Asher Benjamin, a popular writer of builder's guides; Town was a bibliomaniac who amassed a huge library; see Lydia H. Sigourney, "The Residence and Library of Ithiel Town, Esq.," *Ladies' Companion* 10 (1839): 122-26. Grubenmann's bridge appeared in too many publications to be listed here; re de l'Orme, see Dreicer, "Nouvelles inventions."

[16]Peter Michael Molloy, "Techical Education and the Young Republic: West Point as America's Ecole Poloytechnique, 1802-1833" (Ph.D. Thesis,

Brown University, 1975), 450. Sganzin's text was used, according to Molloy, until 1834.

[17]"On . . . range [les ponts en charpente] en deux classes principales.

Dans la première, le pavé est supporté par un plancher établi sur des poutres horizontales [sic], soutenues à leurs extrémité par des points d'appui qui reposent sur le sol.

Dans la seconde, c'est un systême de charpente dont les points d'appui sont placés vers le bas de l'arc de cercle . . .

La première espèce n'est applicable qu'aux petites ouvertures."

La seconde comporte les plus grandes."

J.M. Sganzin, *Programme ou résumé des leçons d'un cours de constructions*, 2 ed. (Paris, 1809), 194.

[18]Poussin worked in North America between 1817 and 1832. Guillaume Tell Poussin, *Travaux d'améliorations intérieures projetés ou exécuteés par les gouverement général des Etats-Unis d'Amérique de 1824 à 1831* (Paris: Anselin et Carillan-Goeury, 1834/6), 63-66, pl. 10; *Öffentliche Bauwerke in den vereinigten Staaten von Amerika*, trans. H.F. Lehrritter (Regensburg: Friedrich Pustet, 1836/7), 2: 219-223, pl. B. J.M. Sganzin, rev. [Félix] Reibell, *Programme ou résumé des leçons d'un cours de constructions*, 4th ed. (Paris, Carilion-Goeury & Dalmont, 1839-41), 334-35; pl. 242-244. See also A.R. Emy, *Traité de l'art de la charpenterie* (Paris, Carilian-Goeury et Anselin, 1837, 1841), 2: 399-401, pl. 136.

[19] H.C. Emmery, [ed.,] "Analyse et extrait: des *Lettres sur l'Amérique du nord*, du M. Michel Chevalier; des deux ouvrages de M. Poussin, intitulés, le premier, *Travaux d'améliorations intérieures, projetés ou exécutés aux*

Etats-Unis, de 1824 à 1831, et le second, *Chemins de fer américains*," *Annales des ponts et chaussées* 1/2 (1837): 99-101; pl. 134.

[20]J.H. Garella, "Note sur deux ponts provisoires en charpente construits dans le système américain de M. Town," *Annales des ponts et chaussées* 2/2 (1842): 371-83, pl. 34. In a letter dated 19 August 1851 to the Ministère de Travaux Publics, Garella, who wanted to visit the tubular bridges in Great Britain, complained that in the *Annales des ponts et chaussées* one couldn't find "en tems convenable" information on important engineering works constructed in Europe: "Ce n'est que dans les journaux ordinaires, et dans des feuilletons très incomplets, qu['on] apprennent seulement le nom, sans qu'aucun détail scientifique puisse les renseigner exactement et leur permettre de proposer pour les ouvrages qu'ils ont à projeter en France, des combinaisons analogues à celles qu [illegible] -issent si bien au dela de nos frontières." Archives Nationales F14, 2231.

[21]D.H. Mahan, *An Elementary Treatise of Civil Engineering* (N.Y.: Wiley and Putnam, 1837; 2d ed.: 1838; London: Wiley and Putnam, 1839). A description of the Town and Howe bridges is finally included in the U.S. edition of 1846. Per Molloy, "Technical Education," 451, Mahan used lithographed notes from Metz as part of instruction at West Point.

[22]Culmann's uncle was a professor at Metz; he completed his studies at Karlsruhe in 1841. C.P.,"Dr. Carl Culmann," *Eisenbahn* 15 (1881): 49-50, pl.; *Dictionnaire historique et biographique de la Suisse* (1924); M.J. Meyer, "Le professeur Culmann," *Memoires et comptes rendus des travaux de la Société des Ingénieurs civils* (1882): 111-115. Re Jenny,

see T. Turak, *William Le Baron Jenny: A Pioneer of Modern Architecture* (Ann Arbor, Michigan, 1986), 25-55.

[23]Re the difficulties of the French engineering hierarchy, see Picon, *Invention* 139-45; 457-464. Re the Seguin family, see note 25. Flachat learned on the job and apparently trained a "school" of engineers on his own. "La véritable école professionnelle de M. Flachat . . . fut la fréquentation des ingénieurs anglais"; Léon Malo, *Notice sur Eugène Flachat* (Paris: Société des ingénieurs civils), 9-10. "L''influence d'Eugène Flachat s'est exercée avec un rare bonheur sur toute la génération des ingénieurs qui ont été les triomphateurs de la merveilleuse Exposition universelle de 1889"; George Barral, *Le panthéon scientifique de la tour Eiffel* (Paris, Nouvelle Librarie Parisienne, 1892), 138. Capsule biographies for several industrialist engineers can be found in Marrey, *Ponts*, 304-312, but information on the lives and activities of these major figures is not readily available. Gouin graduated from the *Ecole polytechnique* and *Ponts et chaussées*, but did not remain in the state system.

[24]Peter Lundgreen, "Engineering Education in Europe and the U.S.A., 1750-1930: The Rise to Dominance of School Culture and the Engineering Professions," *Annals of Science* 47 (1989): 39; Terry Shinn, "From 'Corps' to 'Profession': the Emergence and Definition of Industrial Engineering in Modern France," in Robert Fox and George Weisz, eds, *The Organization of Science and Technology in France 1808-1914* (Cambridge: Cambridge University Press, 1980), 185, 207.

[25]John Hubbel Weiss, *The Making of Technological Man* (Cambridge, Mass.: MIT Press, 1982), passim; 144-45; 182-87.

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[26]Weiss, *The Making of Technological Man* , 5.

[27]Once constructed in iron or with vertical memebers, however, the nature of the structure was in many cases different than that of the original design.

[28]The Fink bridge appears in most surveys of bridges built in the United States. See also: Gasparini, D.A. and Caterina Provost, "Early Nineteenth Century Developments in Truss Design in Britain, France and the United States," *Construction History* 5 (1989): 21-33.

[29]Weiss, *Making*, 5, provides the following citations: Randall Collins, *The Credential Society: An Historical Sociology of Education and Stratification* (New York, 1979), 1-21; Ivar Berg, *Education and Jobs: The Great Training Robbery* (Boston, 1971). For this reason, histories of educational institutions written by persons professionally linked to these institutions must be read with care, and in some cases, with skepticism. See also Lundgreen, "Engineering Education," 33-34.

[30]Picon, *Invention*, 15, has written: "Sciences et techniques entretiennent des rapports tantôt étroits, tantôt plus distants. Leur autonomie est particulièrement prononcée dans le domaine de l'aménagement et de la construction."

[31]See Michel Cotte, "Seguin et Cie (1806-1824): du négoce familial de drap à la construction du pont suspendu de Tournon-Tain," *History and Technology* 6 (1988): 95-144. See also, David Billington, *Robert Maillart's Bridges: The Art of Engineering*, (Princeton, N.J., Princeton U. Pr., 1979), 24, 47, 91.

[32]Kranakis, "Social," 38. Kranakis takes Eiffel's pro-theory and nationalistic rhetoric at face value.

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[33]Town (1839), 6. Theodore Cooper, "American Railroad Bridges," *Transactions of the American Society of Civil Engineers* 21 (1889): 43.

[34]Theodore Zeldin, *France 1848-1945: Intellect and Pride* (Oxford: Oxford University Press, 1980), 140-41.

[35]Peter Lundgreen, "The Organization of Science and Technology in France: A German Perspective," in Robert Fox and George Weisz, eds, *The Organization of Science and Technology in France 1808-1914* (Cambridge: Cambridge University Press, 1980), 323.

[36]Lundgreen, "Engineering Education," 46.

[37]"Far from being the key to the understanding of science and technology, these entities [e.g. "state" or "culture"] are the very things a new understanding of science and technology should explain." Bruno Latour, "Drawing Things Together," 55.

[38]For an introduction to various attitudes toward the United States, see Henry T. Tuckerman, *America and Her Commentators* (N.Y.: Charles Scribner, 1864. Reprint, N.Y.: Augustus M. Kelley, 1970).