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ENGINEERING AND URBAN DESIGN: WHO LEADS WHOM?

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ABSTRACT: Works of civil engineering not only perform crucial functions within cities, they also create significant visual impacts on the urban landscape. Although society rightly expects engineers to assume responsibility for the functional aspects of design, there is considerable disagreement on the role engineers should play in the design of the visual aspects of these works.

This paper draws on case studies of recent and historical bridges to identify the primary opportunities and difficulties associated to the following three models of the design process as it relates to the visual impact of civil engineering works: architect-led, community-led, and engineer-led. Although there are significant problems with all three models, there is strong historical evidence in support of allowing engineers to assume leadership of both the technical and visual aspects of design.

Both the architect-led and the community-led models are based on the premise that the visual aspects of design can and should be separated from the technical aspects. The engineer-led model admits that the two can be linked. At its best, this model allows technical aspects of design, such as the flow of forces in structural components, to become rich sources of inspiration for visual design. When non-engineers are given leadership of the visual aspects of design, owners thus deprive themselves from the outset of an important range of aesthetic possibilities.

1. THE BASIC QUESTION

Who should lead the design of bridges, highways, towers, and other works of urban infrastructure? The answer is clear if we consider these works to be purely functional objects, which must serve their intended purpose efficiently, and must also be safe, serviceable, and cost-effective. The design decisions required to create works that satisfy these objectives require a sound basis of scientific knowledge. This knowledge, and the insight underlying its effective use, is held by engineers.

Bridges, highways, and towers, however, do not merely perform useful functions in society. Because of their size and permanence, works of infrastructure are as much objects to be seen as they are objects to be used. Because they are visible objects, we react to their appearance and attach values to them that describe this reaction, just as we would with other visible objects such as houses, furniture, or sculptures. Bridges are commonly described, for example, using words such as graceful, elegant, awkward, or ugly. Because works of infrastructure are attributed values related to their visible characteristics, their impact on quality of urban life is thus determined not only by the way they perform their intended function, but also by the way they look.

The impact of the visible characteristics of works of infrastructure has the potential to transcend the simple question of whether a given work is beautiful, ugly, or somewhere in between. Any object we create, be it a house, a chair, or a bridge, can be given a visible form that endows the object with a larger significance.

These works awaken within us new and complex emotions, challenge us to question previously held assumptions, and remain etched in our memory long after they are out of our physical sight. Such works are the reflection of a greater and more noble human spirit. We call these qualities *aesthetic significance*, and say that objects that possess these qualities are *works of art*. It is a fundamental premise of this article that works of infrastructure can, when designed with inspiration and care, be endowed with aesthetic significance.

If works of infrastructure can affect the quality of urban life by the way they look, and if they have the potential to become works of art, then should they still be designed by engineers? Obviously, engineers will always need to contribute to the design of such works because only engineers have the specialized scientific knowledge required to ensure that designs can perform their intended function in a safe, serviceable, and cost-effective way. There is no obvious argument, however, in support of engineers leading the design of the visual aspects of infrastructure.

The significance of this question goes far beyond a mere squabble over market share. The visual form of bridges, highways, and towers is intimately related to the function of these works. Whoever defines the primary visual characteristics of these structures thus also effectively defines, to a large extent, how the work will satisfy its primary functional requirements and how much it will cost. Given this link between form, function, and cost, allowing engineers to take a leadership role in defining the visual aspects of design would appear to make sense, at least from the perspective of a responsible use of public funds.

It could be argued, however, that art should not be bound by mere considerations of cost. Why not spend more money to create a work of art rather than something prosaic? Although this question appears reasonable on the surface, it is based on the assumption that the more we spend, the more beautiful will be the product. The reality of urban infrastructure, however, is more complex than this.

The following figure illustrates the extent to which cost and aesthetic significance can be completely uncorrelated. Both the Gardiner Expressway (in Toronto, completed in the early 1960s) and the Salginatobel Bridge (in Switzerland, completed in 1930), for example, were considered to be economical structures at the time of their construction. The cost effectiveness of the Salginatobel Bridge, in particular,

Figure 1. Gardiner Expressway and Salginatobel Bridge

has been extensively documented (Billington 1979, 84). The Gardiner Expressway is visually indistinguishable from hundreds of other urban viaducts, demonstrates practically no sensitivity to visual issues in design, and is generally regarded in Toronto as the epitome of ugly urban infrastructure. The Salginatobel Bridge, on the other hand, has been widely acknowledged as a work of profound aesthetic significance. Salginatobel shows us that aesthetically significant works need not be expensive; the Gardiner Expressway and Salginatobel together show us that there is no direct relation between cost and aesthetic significance.

The complex relationship between cost and aesthetics is one of the primary issues to be examined in this article, in an attempt to find a valid answer to the question of who should lead the design of major works of infrastructure. The focus is on bridges, since in these works we find the strongest links between visible form, function, and cost. The article is based on the premise that aesthetic impact needs to be considered within the broader framework of the public good, and thus begins with a discussion of what constitutes the public good from the perspective of bridge design. This is followed by a critical examination of several bridge projects to assess the effectiveness of design leadership provided by engineers, architects, and the public. The article concludes with a discussion of how best to define a public policy that encourages good design of urban infrastructure.

2. INFRASTRUCTURE DESIGN AND THE PUBLIC GOOD

Although the question of who should lead the design of bridges originates from concerns over the way bridges look, the answer needs to consider how bridges contribute to a more broadly defined public good. Bridges have a clear public function within the transportation system and they entail a significant public cost. When these issues are not considered, bridges are effectively transformed into large sculptures that cost nothing and carry load as an afterthought. This is obviously a very distorted picture of the essence of bridges. Conversely, by extending the debate on the way bridges look beyond aesthetics to include other issues such as function and cost, we gain a more realistic perspective on the value of bridges to society.

2.1. Functional Requirements

The public good is served when bridges perform their intended function safely and efficiently over their intended service life. Because these requirements are so fundamental, they are generally not treated as measures of quality. Increasing margins of safety beyond minimum limits defined in design standards, for example, is not regarded as increasing the quality of a given bridge. The point is to design structures that guarantee an acceptable level of safety, not to design the safest possible structures.

In the hierarchy of criteria that define how bridges serve the public good, functional requirements are often ranked as highest, recognizing the fundamental essence of bridges as objects that are built to serve a practical purpose. We usually take it for granted that all bridges will satisfy these requirements completely, regardless of cost or visual impact.

2.2. Economic Requirements

The public good is likewise served when bridges are built and operated economically. Bridges require major expenditures of public funds. As with any public initiative, it is reasonable for taxpayers to expect that these funds will be spent responsibly. This does not necessarily imply that bridges must be built at minimum cost, but rather that the public receive value for each dollar spent. Taxpayers can rightly decide to build the more expensive of two bridge alternatives, provided it delivers higher value commensurate with the difference in cost.

It is tempting to speak in terms of an ideal “minimum cost” bridge for a given situation. Bridge engineers are usually aware, for example, that a specific structural system (e.g. precast concrete I-girders with cast-in-place deck slab) is the most economical solution for a specific range of spans. This perspective is faulty, since it denies the capacity of innovative thinking to create concepts that are more cost-effective than conventional solutions. The ideal “minimum cost” bridge must therefore not be understood in absolute terms, but rather in terms of what can currently be achieved using conventional structural systems and methods of construction.

Value should be regarded not just in terms of a given bridge, but also in terms of opportunity cost within the larger public economy. In spending an additional five million dollars to “beautify” a bridge, for example, have we best served the public good when this money could otherwise have been used to fund another public project, such as needed improvements to the water distribution system?

2.3. Aesthetic Significance

Finally, the public good is served when bridges enhance the cityscape visually. This goal can be achieved in many ways, depending of the wishes of the owners and the community they serve, available resources, and the talent of the designer. On a very basic level, one can design bridges so that they are at least not ugly, by following simple guidelines relating to selection of materials, proportioning, and detailing. At the other extreme, it is possible to design bridges to endow them with aesthetic significance, transforming objects intended to perform a useful function into works of art.

There are no absolute rules by which the visual impact of bridges can be evaluated. Fundamentally, individual observers need to decide for themselves, using their own criteria, the value of a given bridge's contribution to the visual landscape. In this regard, judgements originating from careful reflection are generally preferable to gratuitous statements of personal taste.

This point is important, since it relates to the question of who should decide on whether a given design serves the public good from the perspective of its visual impact. Members of the community are the ones who must live with the bridges that are built, which are invariably exposed for all to see and from which there is little escape. It would therefore follow that the concerns of the public can and should be taken into account by designers. In this regard, however, designers and owners are cautioned that the public is often best served not so much by designs that are intended to please them, but rather by designs that are worthy of them (Ouroussoff 2005).

2.4. Other Issues

The public good is a complex ideal, and advancing it through design of infrastructure encompasses much more than the three issues described in this section. Minimizing temporary and permanent disruption of communities due to construction of a new bridge, for example, can be just as important as the aesthetic impact of the final structure. This article concentrates on the aesthetic aspects of works of infrastructure, and thus assumes that, for a given bridge, issues related to location and impact on existing neighbourhoods have been adequately resolved.

3. DESIGN LEADERSHIP IN RESPONSE TO DEMAND FOR AESTHETIC QUALITY

As mentioned previously, there is no direct link between artistic significance and cost. Bridges can look awkward in spite of millions of dollars spent to enhance their appearance. By the same token, bridges that have been built to very tight budgets have gained recognition for their visual artistry from art critics and scholars as well as from the public. After construction is complete, the aesthetic quality of a given bridge is defined by what we see, not by how much money was spent. Nevertheless, it is useful to consider the aesthetic impact of bridges in relation to the cost required to create that impact. Because this cost can be significant, the parties involved in the development of bridge projects have a responsibility to be aware of the actual cost of specific aesthetic enhancements, to allow them to determine whether or not the expense is justified. The amount of money spent on aesthetics is often determined by who led the design (engineer or non-engineer). Understanding the relationship between design leadership and cost of aesthetic enhancements will thus help to answer the question of who is best suited to lead the design of major works of infrastructure.

We begin by dividing bridges into two groups. The first group, which will be called *regular bridges*, contains structures for which there was no significant willingness by owners to spend money specifically to improve appearance. This group includes the vast majority of bridges built in Canada and the USA. The second group of bridges contains structures for which owners are willing to spend money to enhance appearance, in addition to what would have been spent to construct a regular bridge in a similar setting. The common parlance for this type of bridge is the *signature bridge*. (One can surmise that this term originates from the expectation that the bridge will become a "signature" of a city or region through an association of its visual image with its surroundings, much as the Eiffel Tower has become a visual symbol (a signature structure) of Paris.)

In this section, models for design leadership will be identified and described for both regular bridges and signature bridges. The effectiveness these models of leadership in advancing the public good is investigated by considering how well the example projects satisfied functional requirements, created economic value, and created aesthetic significance.

3.1. "Regular" Bridges

Although owners generally will not go as far as to state officially that visual appearance of regular bridges is not important, it is clear that the primary issues driving the design of "regular" bridges are to satisfy functional requirements and to minimize construction costs. Because specific resources are not provided to enhance the appearance of this class of bridges, owners see no need to involve parties other than engineers in the design process. The design of regular bridges is thus led by engineers in practically all cases. Engineers take responsibility for all major design decisions, including those relating to visible form. What have engineers made of this leadership? As demonstrated by the two structures discussed previously, the aesthetic impact of regular bridges varies widely.

The *Gardiner Expressway*, shown in Figure 2, is an elevated highway that passes through Toronto's downtown, following the shore of Lake Ontario. Construction began in the late 1950s and was completed in the early 1960s. The structural system as originally built consisted of parallel steel I-girders, simply supported on multiple-column bents. This technology was in common use in Canada and the USA at the time of construction and was by no means innovative for the 1960s. Economy was achieved not through a major feat of creativity, but rather through the more prosaic minimizing of the dimensions of components such as steel plates and reinforcing steel.

Figure 2. Gardiner Expressway

The only concession the designers appear to have made to aesthetics is the use of horizontal rustications on the legs of the bents. At a distance, these details are no longer visible, leaving an overall impression of an awkward structure, conceived by designers who had no apparent concern for the visual legacy they were leaving. The level of aesthetic quality is consistent with the mundane nature of the technical aspects of the viaduct.

We compare the Gardiner Expressway to the Salginatobel Bridge, designed by the Swiss engineer Robert Maillart and built in the mountains of eastern Switzerland in 1930. The primary structural element of this bridge is a three-hinged concrete arch spanning 90 metres. The Salginatobel Bridge makes a visual statement that is balanced yet at the same time bold. It conveys an impression of lightness, energy, and efficiency; even non-engineers get a sense that no component of the bridge is out of place or excessive. Although it was built seventy five years ago, its looks as though it could have been built yesterday.

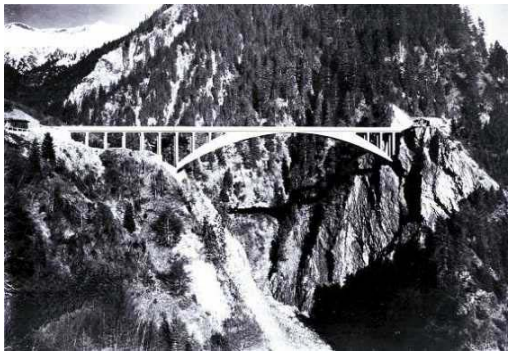

Figure 3. Salginatobel Bridge

The aesthetic significance of this bridge has been recognized in the writings of eminent scholars of visual arts (Giedion 1952). Photographs of Salginatobel have been exhibited at the New York's Museum of Modern Art (Mock 1949). This bridge has been acknowledged by artists as having influenced their work (Bill 1969). By any conventional measure, therefore, Salginatobel can certainly be called an important work of visual art.

Although this bridge is an aesthetic masterpiece, it is still very much a “regular” bridge according to our definition. As described by Billington (1979), the municipal authorities wanted an economical bridge and selected Maillart’s design because it had the lowest cost. There is no record of any willingness of the owners to pay more for aesthetics.

The Gardiner Expressway and the Salginatobel Bridge were thus created from similar circumstances. For both structures, the owner required low construction cost and had no expectations regarding aesthetics. In both cases, design was led by engineers. How, then, did these two bridges turn out to be so different?

The Gardiner Expressway’s structural system is identical to systems used on dozens of viaducts built in the 1950s. Although we have no record of the decisions that led the designers to this choice of system, it is plausible to consider that the designers chose the structural system because experience with similar viaducts showed that multiple steel girders, concrete deck slab, and multiple column bents were the most economical choice. Once this choice had been made, minimizing cost was reduced to an exercise in minimizing the dimensions of structural components. The imperative of economy thus did not give rise to radically new ideas, but rather led to the optimization of existing concepts. Even in the hands of a gifted designer, it is hard to imagine how this approach could have produced a work of aesthetic significance.

Maillart, on the other hand, recognized both the limitations of existing technology as well as the possibilities held by new ideas to create economic value. His response to the imperative of economy was to create value not only through the disciplined dimensioning of structural components but, more importantly, by the application of innovative thinking on a much larger scale. These new “technical” ideas created new possibilities for aesthetic expression, which he exploited with boldness and sensitivity.

The significance of Salginatobel’s technical achievement can be understood when the bridge is compared to other reinforced concrete arches built in the first half of the twentieth century. The Tunkhannock Creek Viaduct (Fig. 4), built in 1915 in Pennsylvania USA, is representative of the structural systems used for concrete arches in Maillart’s time. The bridge is reminiscent of masonry structures: the arches are heavy, span to rise ratios are low, and there is little integration, functional or visual, among the primary components of the structure (arches, main piers, spandrel columns, and arched deck). In contrast, the Salginatobel Bridge is lighter and more slender. It tightly integrates arch, side walls, and deck slab into a box girder section that efficiently resists unsymmetrical live load, one of the most critical load cases for any arch.

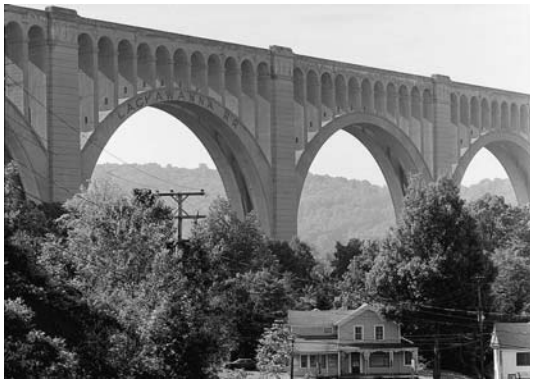

Figure 4. Tunkhannock Creek Viaduct

Maillart understood that he was working in a new material, the benefits of which could be realized only when it was used in structural systems that are designed specifically to use the material with maximum efficiency. These benefits could not be obtained by “optimizing” existing structural concepts, i.e., by using concrete as cast-in-place masonry. Only by creating entirely new structural systems could the full potential of reinforced concrete construction be realized. The functional, economic, and aesthetic aspects of the Salginatobel Bridge are thus intimately linked. The visible form is neither abstract nor symbolic. Rather, its unique shape expresses the forces in the structure; the arch is thickest where bending moments are the largest. The efficiency of the structural system is thus made visible.

Notwithstanding the strong links between Salginatobel’s structural behaviour and its visible form, the aesthetic impact of this bridge did not simply result from the application of mathematical formulas. Maillart cared deeply about the appearance of the bridges he designed (Billington 1997). The body of articles, lectures, and letters he left behind bears witness to a mature and personal philosophy on bridge aesthetics as well as the role played by this philosophy in his design decisions. It is also significant that the owner of the Salginatobel Bridge, in addition to providing the impetus for creative thinking by insisting on an

economical solution, allowed his designer to accomplish this objective in the best way he knew how, by agreeing to bold new technical solutions and by not inhibiting the creative process with preconceived notions of what was good looking.

Regular bridges designed by engineers on their own can therefore be endowed with aesthetic significance. Economical bridges are not by nature aesthetically pleasing and economy is not an aesthetic value. The imperative of economy, however, creates impetus for new technical solutions, which in turn create new opportunities for aesthetic expression. Turning these opportunities into aesthetically significant bridges requires engineers who are talented technically and who have a strong desire to create beautiful bridges, as well as owners who are willing to accept the leadership of their designer.

3.2. "Signature" Bridges

Signature bridges are intended to create aesthetic impact. When owners are willing to pay more than the cost of a "regular" bridge to accomplish this, we observe greater variety in design leadership. The design of "signature" bridges has been led by engineers, but also by architects and, increasingly, by lay people in community groups. This situation is at least partly due to a lack of confidence in the ability of engineers to design aesthetically pleasing bridges, especially structures that are expected to take on the role of monument or symbol of a city or region. Given the track record of engineers in churning out projects such as the Gardiner Expressway, this attitude can certainly be understood. This section takes a critical look at three models of design leadership for signature bridges (architect-led, community-led, and engineer-led), and seeks to identify what is gained and what is lost when a given approach is followed.

3.2.1 Architect-led projects

Architects lead the design of building projects. Although building design is a complex endeavour involving a large number of requirements, the activity that defines the essence of what architects do is arguably the creation of a the visible form of buildings. It is reasonable to assume that the skill they bring to this task could be applied equally well to the definition of the visible form of bridges. In such a situation, the role of engineers would be similar to their role on building projects, i.e., making sure that functional requirements related to structural behaviour are satisfied, within budgetary constraints.

Figure 5. London Millennium Bridge

In recent years, several high-profile bridges designed by architects have been built. An example of this type of bridge is London's Millennium Bridge (Ridsill Smith 2001), shown in Figure 5. Its architect was Norman Foster; the collaborating engineering firm was Ove Arup. The visible form of the bridge is bold, exceptionally slender, and meticulously detailed.

Architects bring to the design process a perspective that engineers lack. For example, architects are trained to be aware of the way structures interact geometrically and symbolically with their surroundings. This awareness can help to create bridges that somehow "fit" better into their visible environment, rather than looking like they were intended to be built for a completely generic setting. Because structural behaviour is only one of many design issues for them, architects can draw on a wider range of conceptual tools to use in the creative process, and thus produce bridges of greater visual complexity than works designed only by engineers. At their best, as eloquently demonstrated on the Millennium Bridge, architects can endow bridges with glamour and sophistication befitting an important capital city. Incidental to the way a given bridge actually looks, but sometimes important to owners and the public nonetheless, is the cachet of having a work in one's city designed by the current "star" architect.

Is anything lost when architects lead the design of bridges? Architects create aesthetic meaning through the arrangement of abstract and symbolic forms. Because these forms by definition have no relation to structural behaviour, they usually add cost over and above the price of a “regular” bridge. It is obvious, for example, that a bridge consisting only of structural components will cost less than the same bridge that has been given an ornamental cladding.

In recent years, architects worked with structural form as a means of aesthetic expression. Because the architect’s visual device is a primary structural element, giving it a shape that departs from the most efficient form will definitely have a major impact on cost. The span to sag ratio of the cables of the Millennium Bridge, for example, is approximately 60:1, compared to 10:1 for conventional suspension bridges. The total cost of this bridge per unit area of deck surface, including the retrofit required to address vibration problems that were detected after the bridge opened (Dallard et al. 2001), is approximately $35,000 (Canadian funds) per square metre (Reynolds 2002). As a comparison, conventional highway bridges are currently built in Ontario for a unit cost of approximately $1,300 per square metre.

Although cost does not determine aesthetic quality, it is an important factor in determining the extent to which a given bridge serves the public good. When design decisions intended to create aesthetic impact cause a “signature” bridge to cost over ten times more than a “regular” bridge, designers and owners need to ask themselves if the gain in aesthetic impact is really worth the additional money, especially in cases where this money could have been put to good use elsewhere.

Just as significant, though, is the fact that when owners demand aesthetic impact and money is no object, the imperative of economy becomes irrelevant as an impetus for creativity. This deprives designers of a rich source of inspiration, i.e., the very one which gave rise to aesthetically significant works such as the Salginatobel Bridge. It is no coincidence that Maillart designed no “signature” bridges.

3.2.2 Community-led projects

In recent years, communities have realized that they wield considerable political power when it comes to construction in their neighbourhood. Faced with this situation, public agencies have recognized that projects will go forward more quickly with designs that please the public. What better way to ensure that this is the case than by letting the community design bridges itself?

Figure 6. American River Bridge

An approach to community-led design that has been followed in the past involves members of the community voting on alternatives prepared by design professionals. These alternatives are often based on suggestions from the community. The American River Bridge in California USA, for example, was designed in this way (Gottemoeller 1998). The public expressed a strong desire for the new bridge to have arches reminiscent of the structure it replaces. The design consultants, however, concluded that a haunched girder system was by far the most economical solution. As a compromise, a self-supporting haunched girder bridge was built, from which were suspended arch ribs. These arches have no structural function; they are a purely visual device.

Through this process, the community gained a bridge that pleased them, and the owner eliminated delays that might have occurred as a result of community dissatisfaction. This was achieved, though, with a design that was more expensive than a “regular” bridge. In fact, there is scant evidence that the imperative of economy provided any impetus for bold creative thinking. When the primary objective is to build consensus, there is a strong tendency to maintain the status quo, with solutions that conform to the community’s notion of what a bridge should look like. We observe again that Maillart designed no

“signature” bridges. In fact, none of his significant works could have been built in a major city because they departed radically from conventional good taste in design.

The American River Bridge lacks honesty. As pointed out by Gauvreau (2002), “The bridge appears as though the arch ribs were added as an afterthought to a haunched girder bridge that was already complete, both structurally and visually. Arches are one of the boldest, most expressive elements available to bridge designers. It is unfortunate that in this case they were used merely to deceive.” In the name of consensus, a design was chosen that may have pleased the community, but was not worthy of it.

3.2.3 Engineer-led projects

Engineers are sometimes selected to lead the design of “signature” bridges. The results thus far have been mixed. When owners demand a special aesthetic impact and are prepared to pay additional money for it, engineers have tended to move away from their traditional sources of inspiration. Instead of taking up the challenge of economy and creating new forms that are efficient and expressive, they have tended to employ devices similar to those used by architects, such as structural elements that are visually bold yet structurally inefficient or awkward. Otherwise experienced and knowledgeable engineers have thus embraced inclined towers and unjustifiably long spans to create effect. The imperative of economy appears to have little meaning to many engineers working on signature bridges today.

4. TOWARDS A PUBLIC POLICY

The choice of profession to lead the design of bridges and other visually prominent works of infrastructure is a public policy decision that should be made with the objective of maximizing the public good. Based on observations made in the previous section, however, each choice has problems. Although engineers have designed works that are economical and artistically significant, they have also designed works of great ugliness. Simply choosing to assign leadership of projects to engineers will thus in itself not guarantee a good design. The same holds true for architects, who have also designed works of dubious aesthetic merit, often at considerable cost to the public. Community leadership likewise provides no assurance of high-quality design.

Although good design does not result directly from the choice of the design leader’s profession, this choice still has a significant effect on the outcome of the design process, and should therefore be made wisely. If society wants bridges that serve the public good through efficient function, prudent use of economic resources, and aesthetic significance, then its public officials would do well to study and emulate the conditions that led to the creation of such bridges in the past. Robert Maillart’s bridges teach us that engineers can create works that combine function, economy, and aesthetic significance. They do so by developing new technical solutions to the challenge of scarce resources and by giving these new solutions visible expression.

Because the source of artistic inspiration and the means of visual expression are technical in nature, engineers can create aesthetically significant works without the assistance of designers from other disciplines. Conversely, because designers from other disciplines and laymen do not understand technical matters such as the flow of forces in structures, they are unable to draw from this source of inspiration and to apply this means of expression.

If society wants bridges in the tradition of Robert Maillart’s, then public policy should ensure that:

1. *Design is led by engineers*. Otherwise, the project will not have access to Maillart’s source of inspiration and means of expression.
2. *There are significant economic challenges to overcome*. Without the imperative of economy, there is little incentive to create new technical ideas.
3. *Public officials accept the leadership of their designers*. Designers need the freedom to develop bold new ideas in response to economic challenges and to express these ideas visually. When technical solutions default to the tried and true, then the imperative of economy loses its capacity to stimulate creative thought. In a similar way, public officials should not insist on visual concepts

that conform to conventional notions of good taste, but should rather be prepared to consider bold new ideas on their own merits.

The proposed public policy can be considered somewhat radical in that it does not include spending more money for aesthetic enhancement of structures. Although this runs contrary to conventional wisdom, it is consistent with the historical evidence. Maillart's bridges were built because they were economical. If they had not been the cheapest to build, they would not have been built. Maillart's genius was to regard economic imperatives as a stimulus for creating bold new ideas. When economic imperatives are relaxed, this stimulus loses its power. Spending more for aesthetics can certainly result in aesthetically pleasing bridges, but their visible form will have arisen from a different source of inspiration.

The policy outlined above presents a difficult challenge to society, because the overall track record of engineers as designers of aesthetic structures has been poor. Why would society entrust the design of urban infrastructure to engineers when there are few examples of good design by engineers? Public policy needs to address not only the demand for good design (as discussed above), but also the supply of good designers. The owners of the Salginatobel Bridge were ideal in that they made their decisions according to the policy outlined above. This alone, however, would not have been sufficient to produce the aesthetic masterpiece that now stands. Equally important was the fact that Maillart was an extremely talented designer who was aware of the aesthetic impact of bridges and who wanted to create works of beauty. Some of this was unique to Maillart, but much of this came from his education (Billington 2003).

Education is also guided by public policy, and there is thus a role to be played here to ensure a steady supply of engineers who can design well. Unfortunately, most universities teach students to develop solutions through the application of formulas, not through the exercise of creative thinking. They no longer draw, nor do they study completed works of engineering. They are not challenged to think critically. There is little wonder that they enter practice unable to grapple with issues related to aesthetics, and thus little wonder that the public considers them to be unfit to design. This must change.

Judging from current policies related to design leadership, it appears that the tradition of Maillart is almost extinguished. We are thus at a critical point. This tradition has a valuable contribution to make to society, through the design of works that serve the public good through function, economy, and aesthetic significance. For this tradition to flourish, however, we must ensure that engineers are allowed to lead, that they are challenged to be creative, and that the education of new generations of engineers equips them to rise to the challenges of design leadership for the public good.

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