

## New Opportunities for Efficiency, Economy, and Elegance in Bridge Design

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### Abstract

This article examines the relation between efficiency, economy, and elegance in the bridges of Robert Maillart, current bridge design practice, and a future design practice that has evolved in response to an expected intensive use of autonomous robots in construction.

Efficiency, economy, and elegance are the qualities used by David P. Billington, the foremost scholar of the works of Maillart, to characterize Maillart's bridges. In these works, efficiency is the primary enabler of economy. In the first half of the twentieth century, the cost of labour was relatively low compared to the cost of materials, so overall economy was best achieved by minimizing materials. Efficiency is also an important source of aesthetic significance, since a minimal use of materials enables the flow of forces to be made visible.

It is currently difficult if not impossible to design bridges that embody all three qualities. Because the cost of labour has increased significantly relative to the cost of materials since Maillart's day, economy is best achieved by minimizing the quantity of labour, leaving few economic incentives for designing efficient bridges. Because it is difficult to make the flow of forces visible in inefficient structural systems, designers currently seek other sources of aesthetic significance, most of which have required an economic premium to be paid.

It is almost certain that the primary means of production in bridge construction will soon be transformed from human labour to autonomous robots, in a similar manner to the transformation that has already taken place in manufacturing. The resulting reduction in the cost of production relative to the cost of materials will restore the economic incentives for designing efficient structures. This will enable engineers to create aesthetic significance through the visual expression of the flow of forces. It will thus become possible once again for bridges to embody efficiency, economy, and elegance.

This alone, however, is unlikely to result in the design of a greater number of works of "structural art", the term used by Billington to describe the bridges of Maillart. What makes these bridges stand out from other works that are efficient, economical, and elegant is that they also give visual expression to new ideas that enabled them to perform their practical function better than had previously been possible. The intensive use of robots in bridge construction will offer unprecedented opportunities for the creation of new and better structural systems, and in so doing will create conditions that will enable the design of a new generation of bridges that are worthy successors to the works of Maillart.