engineers design the structures of buildings, or machines, or electronic circuits, or airplanes, or industrial and technological processes. And buildings are more difficult to specify.

This by itself is not as significant as the fact that engineering problems are more explicitly constrained than architectural problems in terms of desired performance. Often this is measured by money. A modern aircraft, for example, will be designed to optimize a number of variables: fuel consumption, passenger load, speed, reliability, design and manufacturing cost, and safety. Each of these variables may be specified numerically, and reduced to dollars and cents. In the case of the airline industry, where the profit margins are very small if they exist any more at all, every kilogram of weight, every extra kilometer per hour per liter of fuel, every extra kilometer per hour of speed, will be a factor in the success of the design.

Architecture is different, or at least architects would like to continue believing so. The qualities that architects hold dear, and that are stressed in schools of architecture, are things like aesthetics, comfort, and compatibility with the urban context. These things are not measured quantitatively.

Since the nineteenth century, buildings have increasingly been specified in quantitative ways, and in ways in which specific aspects of performance are explicitly laid out. As shown by Willis (1995), the design of skyscrapers in New York and Chicago came about largely because of financial constraints not unlike those which guide the engineering design of aircraft. Several variables are optimized in the design of a skyscraper: the total rentable area, the likely rent per square foot, the construction cost, and the cost of financing. When these variables are resolved, they lead to configurations and construction types that are predictable: there is not much variation possible. And architects understand that because of that, their role in the design of these buildings is seriously limited; it is often said that architects have control over what the building looks like – the zone of space that is six inches or so deep, around the outer skin. And even here they are seriously constrained by available products, and issues of building codes, product warranties, and demands for low energy consumption.

The same is true for other complex projects such as housing developments, where the cost of land and infrastructure improvement, along with building construction costs, and cost of financing (and therefore necessary speed of construction) all interact with likely sales price to help make the architect a tool of the developer and the developer's banker, who turn out to have the most control over the form of the development.

With these kinds of projects, that make up the preponderance of what is built today, the architect looks very much like an engineer. S/he is optimizing well-defined quantitative variables, that are often connected to money, and the evaluation of the product depends on how well this optimization has taken place.

And the engineer, at least the nineteenth-century engineer, had some of the qualities of the architect.

The pre-twentieth century architect and engineer came out of similar worlds. James Watt, the inventor of the steam engine, grew up in a family of craftsmen and apprenticed himself to an instrument maker in London. He was thoroughly immersed in the world of physical things, and this immersion was critical to his

success as an engineer. (Dickinson, 1935) Robert Stephenson, the great railroad engineer, came out of a mining community, and a family deeply involved in mining operations. (Bailey, 2003) Indeed, the culture of eighteenth and early nineteenth century Britain was one in which the professions were closely tied to the trades, and in which the trades were close to the everyday life of many people.

The nineteenth century engineer, like the architect, was able to think intuitively and not only quantitatively. There is little doubt that architects and engineers may both work in ways in which the design process is a cyclical one, in which conjectures are made, tested and refined. A biographer of the great British engineer Isambard Kingdom Brunel quotes his wariness of "mathematical calculations, dependent as they are upon an unattained precision, which are likely to lead far from the truth as not. By the same mode of calculation did Dr. Lardner arrive at all those results regarding steam navigation and the speed on railways which have since proved so erroneous." (Vaughan, 1991)

Some of the diary entries of Robert Stephenson, inventor of the steam locomotive, also point to the use of intuition in the design process.

> I have just received the model and like the idea exceedingly, but I fear the truth of the motion is rather questionable, although it may not perhaps be to such an extent as to render it useful. I shall have the accuracy of it tested before I reach Ncastle – On the first blush it is very satisfactory and I sincerely hope a more mature investigation will prove equally so. –
>
> My impression is that at certain parts of the stroke the motion of the slide valve will be backwards instead of forwards and vice versa. – I think it can hardly be otherwise and the working of the model supports this opinion, but it is so small that no detailed conclusion can be drawn from it – I should wish a full sized model to be made for that alone can decide the point – If it answers it will be worth a jew's eye and the contriver… (Bailey, 2003)

In this case Stephenson is acting rather like an architect, who is making a tentative conjecture, but withholding judgment until that conjecture is further tested with a more detailed investigation. It is common practice in architecture to shift scales, as Stephenson was suggesting, to test a proposed design.

The architect is however, working with a single artifact that may take months or years to make, and the engineer is either doing the same thing, as with a bridge or tunnel, or designing the prototype for an artifact that may be mass-produced. In the latter case, there is no question of design and construction being intertwined, nor is there the possibility of an imprecise specification of the object, as there might be with a building. The architect's ability to apply intuitive judgment in the design of the artifact itself is not shared by the engineer. What the engineer is doing that is similar to the architect is applying intuitive judgment to the design of the prototype or process.

Conventional wisdom sees architecture as an artistic pursuit, and engineering as a mathematical/technical one. Both professions involve design. I have argued above that normative architecture has become less "artistic" than it might appear. As a process or mode of activity, architecture and engineering are not diametrically opposed. The architect, working to a large extent within a technological system that is highly constraining to artistic pursuit, needs to adopt some of the stance of the engineer who is working to pre-specified, quantitative goals. And the engineer, although s/he is working within definable, quantitative constraints, is a designer,