COMMENTS ON THE SUBJECT OF "TECHNOLOGY AND TECHNOLOGY SCIENCE"

Ernst Werner

The development undergone by building construction in the nineteenth century was much influenced by the ever increasing use of iron and, together with that, by the improvements which were also made in the theoretical substance of architecture. It is said that traditional, non-technical convictions - such as, for instance, architecture as it had been up until then - were not able to withstand the persuasive force of the former. It is certainly not proposed to dispute that a new theoretical dimension entered architecture and began to exercise an effect there. However, it is possibly overrated, because both respect for the presumed rationality of technical theories and also uneasiness about this phenomenon tended to obscure the view of the actual content of the development.

This raises the question as to whether at that time there was such a thing as technical theory as we understand it today, and even if there is no evidence of technical theory in a unified form for the whole field of technology, whether there was at least such a theory for building technology. There is still no such thing as uniform technology science, even today, which does not mean to say that technical creations do not follow a typical course pattern.

With regard to building technology, it should be pointed out briefly that a bending theory in a form suitable for putting into practice was not developed until 1826, and a lattice-work theory not until 1851. Now, quite independently of the fact that it is here a question of parts of theories, and not of a unified theory framework encompassing the whole of architecture, these modest beginnings - for all their - importance - only gained acceptance with difficulty, and can only be regarded as widely spread in the latter part of the second half of the nineteenth century. But even then, they were still not common practice for those engaged in building.

Nowadays we do undoubtedly have a unified framework for a statics theory, but, in my opinion, even today, there is still no one theory covering the whole complex of building. Such a theory would indeed have to combine the mass of all phenomena, methods and relationships in order to produce a viable system from the propositions reciprocally supporting one another.

I have the impression that what there was in the way of theory in the field of technology in the nineteenth century did not meet up to the requirements which all other cultural objects could justifiably make of a well-founded theory. These systems, matured and based on a long tradition, were not confronted on the technical side by any contingent system in the sense of an all-embracing theory: a deductive derivation from an efficient paradigm on the technical side was confronted by a mass of unconnected, singular technical novelties, lacking in any over-all concept.

This is then an indication that the technical sciences have not developed beyond the methods of thinking and perception valid previously, but are apparently in contradiction to that. They were felt to be alien to what one was accustomed to, even though the practical side - that is technology itself - had permeated, and is still permeating, all aspects of life, and was, and is, accordingly felt to be part of this.

The peculiarity of technical theories, that they become more and more mathematized - something which was not always the case - gives them the appearance of being indisputably rational. Thus technology is often linked with a considerable degree of rationality. Although technology did not itself raise any claim to possess total rationality, the same was, nevertheless, soon ascribed to it.

Technique and Technology

Nowadays we distinguish between technique and technology. Technique is the term used for the sum total of all procedures and objects. Technique is not understood as a group of expressions of life, complete in itself, which is now to be found completely separated alongside the customary expressions of life handed down by tradition. Only by starting out from the assumption that technique is a phenomenon of a more recent kind would it be conceivable to regard technique as an innovation in addition to what one is accustomed to. Thus, to be more accurate, technique is, it is true, regarded on the one hand as a specific form of expression of life, closely linked on the other hand with all the differentiations of life, and is effective there, being derived, rather, from the same, than that it developed anew alongside it. It is not without reason that we speak of technique in all fields of culture, and then really to mean technique there. Seen that way, technique is thus not so much the content and aim of a behaviour, but, more, the method of procedure (Hans Sachsse: Anthropologie der Technik.Braunschweig: Vieweg & Sohn, 1978, p. 2).

Technology, on the other hand, is the designation for the theory of the technique or of the various techniques. Thus technology is the designation for technology science or for the technology sciences.

Technology science and Technique have a similar relationship to one another as do, for instance, theoretical medicine and practical medicine; a distinction which is perfectly common. This distinction is also not an absolute division, but is rather characterized by fluid transitions and reciprocal permeation. It can thus be shown in many cases that the (practical) technique is far ahead of (theoretical) technology; many theories owe their origin to the analysis of a construction which had already practically come into existence. Some aspects here below are intended to help clarify the image of technology.

The missing central science

Technology, i.e. technology science, does not have any one central science, that is to say it does not have any one guiding discipline. In contrast, for instance, to another applied science, namely medicine, the structure of the technology sciences is heterogeneous.

Medicine as a central science has, so to speak, crystallized off the individual specialist branches of medicine, without the latter losing their relationship to the all-embracing central discipline. It is possible to speak of a centripetal tendency here.

The technology sciences are in direct contrast to this. They do not have a standardised technology theory from which the other specialist technologies can be fed. Consider, for instance,

> architectural statics, which are heavily influenced by Newton's axioms

> whereas mechanical engineering is largely dependent on the second fundamental law of thermodynamics, thus on the enthropy term.

It is, rather, centrifugal tendencies which are at work here. It is certainly not possible to speak of a central technology from which the specialist technologies are fed. Instead it is more the picture of a heterogeneous collection of various technologies standing alongside one another. That is also very understandable if one considers the

fact that technology is not a discipline complete in itself and distinct from other cultural attainments, but is rather - as has already been said - an admittedly specific method of interaction with nature, albeit within the structure of the cultural differentiation in each case.

The concept of economics

In fact, this occurs on three levels:

Firstly

Every formation of theory, thus also the thinking process itself, is subject to economic criteria, because any attempt to reduce the variety of phenomena down to one single concept cannot be accomplished other than by the conceptual economic method.

Secondly

We encounter the concept of economics within the field of technology itself. Technological attainments are, in fact, only conceivable if technology deals with the resources economically. You can, after all, fill up a valley in order to cross it! The specifically technological dimension is encountered, for instance, when it is possible for an Eiffel Tower to be produced from an iron cube with 10 metre long sides. The technological content sui generis only comes about when optimum use is made of labour, material, technology and capital.

Thirdly

Economics become a decisive criterion when technology is employed in the form of a craft, or - as we have been particularly concerned with here - on the plane of industry.
In the business world, in which particular importance is attached to the cost and benefit account, it is, of course, the quantitative arguments which predominate, their peculiarity being that they abstract from qualities. That is the price which has to be paid for an otherwise efficient system for the supply of goods and services.

Technology and industrial economics have a close relationship with one another, because, as has already been mentioned, technology too has economic aspects. But what appears even more important is that both possess the characteristic of reduction to purely quantitative arguments. That then leaves no room for qualities such as those occurring in literature, art, music and religion.
It is only when market strategy considerations make it seem necessary that these parameters are introduced again, not out of conviction, but just as a means to the end.
Nowadays, the exploitation of a technology, that way disposed and just reduced to quantitative aspects, gains a different dimension. Even a mere hundred years ago it was still possible to ignore the fact that resources are not inexhaustible and it was also possible to disregard the environmental recirpocal effects.
As a result of the fact that many connections were not duly regarded, this type of technology was reduced to simple linear cause and effect links.
This can be likened to a piece of material comprising many stitches. This reduction, as described, now divides off one single stitch from this reciprocally determined connection with great meticulousness, and then one thread is extracted from one side of the stitch. This method of procedure presupposes that there are no reciprocal relationships and also has the advantage of producing very simple, almost mechanical, cause and effect relationships of very great persuasive power.

This reduction can be traced back to Galilei and Descartes. It is little wonder that the Roman Catholic church, with the intellectual elite among its leadership, turned against such an abbreviated view of the world.

Natural Sciences and Technology Sciences

It appears important to draw attention to the fact that natural science and technology science are, on the one hand, very close or indeed identical in their method, but that on the other hand the decisive difference is in the way in which the question is placed.
Natural science - like all the old sciences up until then - asks how something is what it is; it thus endeavours to recognise the essence. Initially it was deductive in structure, like all science up until then, and was concerned with the whole; as a deductive science it did, at least in principle, have the possibility of taking a look at the whole.
Since the Renaissance, this view of a uniformly structured science landscape, in which the natural sciences also had their place within the framework without disturbing the whole, has changed a great deal. A change in trend occurred in the natural sciences, away from deduction and towards inductive methods of perception, whereby it was thus also more the individual object than the relations between each other which increased in importance. The reasoning link in the natural sciences was now shaped much more by monocausal structures, which, in addition, had been striving towards a simplified mechanism since Galilei and Descartes.
The dilemma of natural science, which has been under great monocausal influence since the Renaissance, thus wanting, as far as possible, only to allow one principle to apply, became apparent at the beginning of the present century when the double quality of light and matter remained inexplicable. Heisenberg compensated this by means of the indeterminacy principle bearing his name for the microcosm, and Niels Rohr extended the same to cover macrophysics. Since that time, even within the natural sciences a lively trend has been perceptible which is directed towards complementarity, whereby the variety of even the individual phenomena was now completed to form a whole using various monocausal theories, which were equally matched to one another, even if the same were mutually exclusive by reason of the limitations of their possibilities of perception. The efficient monocausal principle is thus maintained, but several are combined in such a fashion that the object of perception is illuminated and shown from several sides.

However, technology science does not ask the object of its interest what it is like in essence, it asks rather how it is made; it is thus very oragmatic in character.
This pragmatism, coupled with the economics aspect of the industrial economy, and this linked with an ever more monocausally structured natural science, and probably also the lack of any central science, have not succeeded in copint with the very complex technological, and indeed socio-technological, connection or also the technical creations. Technology is thus split up into very special complexes of problems for which it issues instructions on action. Now such a pragmatism does not specifically tackle with theoretical questions of principle without an immediate exploitation advantage becoming recognizable. In the initial period the theory content of technology was limited to such instructions which were intended to provide those engaged in trade with rules for behaviour of a preferentially optimum appearance, rather than new ones.

Taken as a whole, technology science is in general less profound because it can be content with that state of perception which makes the feasibility evident. The accusation which is occasionally spectacularly made against technique is probably nowadays directed not so much against the lack of profundity as against the lack of breadth.

Nevertheless, those natural sciences close to technology, while pursuing their ever increasing specialisation, have lost in breadth. On the other hand, however, they have gained in profundity. Thus technique and technology are open to the accusation of not being able to demonstrate either one or the other. The loss in profundity would be justifiable on the level of the feasible; but not to deal with the breadth of complex connections at the same time, that is indeed a great shortcoming. For it is precisely in such complex connections that technique forms such a particularly lively expression of human activity. Every technological construction is a complex linked technical system, and with the inclusion of man it becomes, over and above this, a socio-technical system of an especially complex nature. Technique and technology which do not bear this in mind do not do complete justice to their task.

The Mathematisation of Technology

In the early period of technology, mathematics found their way in a quite peculiar fashion: Procedures and construction methods which had been proved in long years of experience were formulated into rules which could also be represented mathematically. Thus numerical relations as an aid to construction played a large role. When they were then converted into geometrical relations, such aids to construction gained in graphic quality.

This type of mathematisation still failed to create a link, for example, between the loading of the load-bearing member and the rigidity of the material. Only that would be architectural statics which are, after all, concerned not just with qualitatively testing the bearing behaviour, but also with quantitatively tracing how forces are led into the foundation soil. This thus includes investigation of the building components affected by the flow of force in order to establish with what degree of certainty they can cope with their task. The certainty is not as great as is often thought. But regardless of whether it is great of small, in order to be able to talk of certainty, information is required about the forces prevailing in the component and about the strength of the material selected for a component.

The technology which seeks to do this makes very considerable use of the natural sciences and mathematics. There is a very special kind of relationship to mathematics.

In an earlier period, everything – thus biology too – was included in physics. These physics were restricted to the description of nature as it was to be found and the artificial creations resulting from this.

Apart from the latter, mathematics thus included also those parts of physics just described and like these, were intended for practical application. That means that what was preparing the way for technology was part of mathematics.

But it is not just this formal aspect which is constitutive for the relationship between technology and mathematics. The inclusion of forces, tracing them through the bearing structure down to the foundations and comparison of these forces with the material strengths is not possible without mathematics.

However, it is a fatal characteristic of mathematics that they appear so extraordinarily convincing. That is certainly true for their own original sphere. But even Einstein remarked:

> However exact they may be, they do not describe reality, and if they describe reality, then they are not exact.

That means that the high degree of agreement between mathematics and the natural and the artificial world only comes about as a result of the fact that we take – as I attempted to show – simplified, monocausally structured and simplified copies and not the whole complex of nature into account.

Modern sciences have prepared and selected their subjects so carefully in their connection that they appear simple and thus mathematisable. However, this simplicity is apparently not the sign of the fundamental aspect and can probably also not be ascribed to the phenomena of the world. Only in periods where people failed to recognise this was it possible to claim that nature is apparently mathematisable.

The proximity to the natural sciences has also shaped the technology sciences. Just as a mechanistic, monocausal conceptual structure prevailed in the natural sciences as a result of Galilei and Descartes, the technology sciences are shaped by the fact that, among other things, the results of the natural sciences are avaluated at the same time.

The Rationality of Technology

Technology is by no means as rational as is generally assumed. It is indeed just as little so as closely related natural science.

The theories developed there are also the work of creative fantasy and not, for instance, the culmination of a chain of inductive conclusions. This fantasy is not extrapersonal; on the contrary, it is very subjective, and without doubt subject to the relative character of the time.

The differing paths taken by the humanities with their deductive tendency on the one hand and by the so-called real sciences with their inductive tendency on the other, have formed the basis of the schism which divided science and which is still dividing it even today.

The schism between architecture on the one hand and construction technique on the other is just one part of this. However, it can be seen that this schism penetrates far deeper than would be the case of it were just a chance accident.

Conclusion

Thus when there was talk in some of the papers about the importance of the newly emerging technical theories, I only wished to give a warning that this should not be exaggerated for that period (nor, possibly, even for our own period).

Either there was not such a consistent framework of theories still in existence, but just a descriptive system of statements communicating experience, or there was one available which was then possibly not able to do justice to the demands made on theory in the perceptual-theoretical sense.

That is then probably also one of the reasons why art and technology, the roots of which are so close to one another, have such difficulty in gaining access to one another.

The theories on both sides are of a different kind and possibly also of differing quality. There is thus an imbalance with regard to the theoretical content. I have the impression that in the nineteenth century on the one hand, this difference gave preference to uneasiness about technology, and on the other hand, the rapidly accepted rational-

ity of mathematisised structures induced respect for technology. Even today, we still have this attitude towards technology, borne by a mixture of uneasiness and respect.

However, this deficit of theory on the technical side also makes it so difficult for technology to devote itself to a method of observation which is again seeking to keep this complexity in view.

I would recall that technology gives the appearance of being so especially efficient because by tendency it dissolves connections in the framework of complex relationships and reduces them to linear structures. As thus only one part of the whole is seen, it is then hardly any wonder that it does not only not see the side effects, but also its own boundary conditions, and consequently also does not reflect. Boundary conditions are the result of nature as it exists in its limited form althouth technology regards it as an inexhaustible source of material and in which it dumps those of its products which it does not want or no longer requires. This is of particular importance because this does not occur in a closed circuit, as is the case in undisturbed nature in which the circuits return what they have extracted. In this respect there is a balance.

The efficiency of technology also comes about because, on the other hand, by human standards, it leaves an uneven balance because the reciprocal effect between nature and technology is not organised in such balanced circuits.

As the framework of criteria for technology is not directed at such phenomena, technology only inadequately understands the criticism levelled against it. This criticism is not only felt to be a nuisance, but also as being unseemly. Because, of course, in technology's opinion, everything is very rational and also successful, and hence not open to criticism.

Concluding discussion under the chairmanship of Prof.Dr.C.BEUTLER

After Bornheim's supplementary contribution, Beutler points out the similarity between Moller's cupola in Mainz and Madern Gerthener's tower top for Frankfurt Cathedral, which burnt down in 1860, and regards this as a romanticising imperial iconography. There are no simple solutions for the question of iron architecture even after 1850, instead there is a complicated and manifold relationship.
It was proposed that the following individual points should once again be particularly emphasised:

1. Problems of theory.

They must be differentiated, especially as the theory is often not formulated until after the practice, and requires a great deal of fantasy. Werner's paper on the theory of technique is printed here as a separate contribution (pp. 139-145). Strobel draws attention to the mechanisation of the building industry as a decisive prerequisite for the innovations in engineering construction in the nineteenth century. The boom in technical sciences took place outside the universities (technical institutes of education). It was not until the end of the nineteenth century that engineers were granted doctoral degrees. The social component plays a major and prominent role in the century's great projects.

2. Problems of history of style and building typology.

On the basis of considerations of the history of style, Wörner asks at what other point of time in the history of art iron could have been adopted as a construction material to a greater extent. The slender forms of the plans for Neo-Gothic virtually demanded a material with which this could be expressed. He refers to the term of the desire for art in Alois Riegl's work. Beutler believes that iron was available at the right moment in the required amount. The mass society which was coming into existence required new structures (halls, railway stations, department stores, large libraries, etc.). Iron proved to be a material which could be cheaply and quickly processed. It is the concurrence of various phenomena which explains the appearance form of iron architecture. Ullrich refers to the lack of an independent building typology for the architecture of the second half of the nineteenth century, which up to now has primarily been regarded from the aspect of Historicism in the history of art. The bases for the development of iron architecture have still to be found. The building types were, it is true, already formulated as a new construction task in the first half of the century, but it was not until the second half of the century that they really came into their own, when they were given a social function and it was possible for them to be technically realised. According to Nikolaus Pevsner (A History of Building Types, London 1976), the main principle in the development of building types is their differentiation, which Wehdorn considers could be better described as organisation of space. In England and France, the notion of building type is rejected anyway. Königs refers to a partial aspect of construction theory, namely the theory of building forms and building aesthetics which contribute a retarding element to progressive technical theory, as forms taken from stone and wooden architecture are adopted for iron architecture. Beutler mentions the difficulty art historians have in understanding iron architecture which is governed by other laws (e.g. the need for expansion joints). This fact is seconded by Peters. The art historian, with his dependence on visual impressions, cannot necessarily adopt the differing prerequisites of technology, as also the influence of increasing mathematisation on our understanding of the world. Libal supplements this with a reference to the increasing