CAMBRIDGE URBAN AND ARCHITECTURAL STUDIES

GENERAL EDITORS

LESLIE MARTIN
Emeritus Professor of Architecture, University of Cambridge

LIONEL MARCH
Professor of Design, The Open University

ASSISTANT EDITOR: STEPHEN ZOLL

4. THE ARCHITECTURE OF FORM

VOLUMES IN THIS SERIES

1. *Urban Space and Structures*, edited by Leslie Martin and Lionel March
2. *Energy, Environment and Building*, by Philip Steadman
3. *Urban Modelling*, by Michael Batty
4. *The Architecture of Form*, edited by Lionel March

The architecture of form

EDITED BY
LIONEL MARCH

CAMBRIDGE UNIVERSITY PRESS
CAMBRIDGE
LONDON · NEW YORK · MELBOURNE

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore,
São Paulo, Delhi, Dubai, Tokyo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521136396

First published 1976
This digitally printed version 2010

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data

Main entry under title:
The Architecture of form.

(Cambridge urban and architectural studies; 4)

Biblography: p.

1. Architectual design–Addresses, essays, lectures. 2. Architecture–Composition, proportion, etc.–Addresses, essays, lectures.
I. March, Lionel, 1934– II. Series.

NA2750.A6815 721 74–80354

ISBN 978-0-521-20528-3 Hardback
ISBN 978-0-521-13639-6 Paperback

Contents

Cambridge University Press
978-0-521-13639-6 - The Architecture of Form
Edited by Lionel March
Frontmatter
More information

Foreword

In 1928 L. Komarova and N. Krasil'nikov, writing in *Sovremennaya Arkhitektura*, asserted that

> a scientific theory of the calculation of form is possible through the dialectical method of thinking and with the application of mathematical methods of analysis...We only encounter scientific analysis in building affairs in such specialised disciplines as concrete structures, heating, ventilation and the like. And while in these areas we do get good results from such scientific investigations, it remains a fact that these scientific disciplines which have application in architecture are too detached and do not consider the whole interrelationship of requirements...nothing has been done until now on the analysis of the actual form of the building. There is no comparable method for tackling a *socio-economic* analysis of a building and no scientific discipline occupied with this question... The successes which have been achieved in the last decade in the fields of mathematical analysis and statistics must anticipate an even more progressive development of these disciplines in the future, which to a considerable degree will facilitate the solving of the problems we have posed...In projecting a building design the architect tries to find the most correct, i.e. the most economic, arrangement of its individual parts by taking different variants of the basic geometrical form of each, and divining empirically, by intuitive means, the most successful of all the variants he has put to the test. Our task is to extend this by more advanced paths, to give a scientific-objective assessment of all the possible variants available to the projecter...the intuitive-graphic method of designing...can be replaced by the mathematical-graphic – a process in which intuition does not fall away, but occupies its proper place.

Catherine Cooke has written 'Perhaps more than any other single piece of work in *Sovremennaya Arkhitektura* this warms the Cambridge architect's heart to a sense of intellectual community with the members of OSA [the Association of Contemporary Architects – the constructivists].' Indeed she is right, but the connection is not merely coincidental. From 1956 to 1972, Leslie Martin directed the intellectual life of the Department of Architecture. In 1937, Martin with Naum Gabo and Ben Nicholson published *Circle*: *International Survey of Constructive Art*. Martin wrote:

> it is important to recognise that the building of a new 'reality' is a task not confined to modern art alone. It is a matter of common knowledge that in science, the world of 'appearances', of parallel systems in which the dead world and the world of the living organisms are clearly marked off from each other, has been abandoned. The world of appearances has given place to a world in which things unrelated to each other in appearance are united in the completeness of a single system. In science as in art, 'appearance' has been jettisoned in favour of a world discovered only through the penetration of appearances.

And in 1959, having played a central role in the post-war reconstruction of London as the capital's Chief Architect and Planner and having lately become the first Professor of Architecture in the University of Cambridge, he summed up the RIBA Oxford Conference on Architectural Education in these words:

> The characteristic feature of architectural education is that it involves widely different types of knowledge. If architecture is to take its proper place in the university and if the knowledge which it entails is to be taught at the highest standard, it will be necessary to establish a bridge between faculties, between the arts and the sciences, engineering, sociology and economics. Furthermore, the universities will require something more than a study of techniques and parcels of this and that form of knowledge. They will expect and have a right to expect that knowledge will be guided and developed by principles: that is by theory. Research is the tool by which theory is advanced. Without it teaching can have no direction and thought no cutting edge.

Today, over a decade later, it is possible to look back to see how these views have shaped architectural research in Cambridge. The problem of research in architectural studies is, as Martin says, that 'widely different types of knowledge' need to be brought to bear upon the subject if anything significant is to be said. During the first half of the 1960s research work in the Department of Architecture had been done by individual graduate students registered for the Ph.D. degree. It is generally agreed that although some worthwhile research was achieved this way – in particular, certain historical contributions – not much progress was made towards a coherent intellectual framework for the discipline. The principal reason, which can now be seen, is that the study of architectural and urban situations requires concerted effort by a number of people at once, often bringing a variety of academic skills together. The nature of the environment is that of a complex system: the whole not to be understood as a configuration of irreducible atomic elements, but the elements themselves constantly being redefined according to our approach to the system as a whole. The research tends, therefore, to adopt what has become known as 'the systems approach'. In taking this direction the research has paralleled work in other disciplines and it is here, at present, that the 'bridges with other faculties' are to be found.

In 1963 there was Mary Hesse's little book *Models and Analogues in Science*. In May 1965 the *American Institute of Planners Journal* was devoted to models in planning. In 1967, Richard Stone's *Mathematics in the Social Sciences and Other Essays* was published, as well as Richard Chorley and Peter Haggett's *Models in Geography*. This was followed in 1968 by David Clarke's *Analytical Archaeology*, which seemed to outsiders to be as much an iconoclastic assault on the archaeological establishment as Edmund Leach's spirited *Rethinking Anthropology* had been in its field in 1961. These are largely Cambridge contributions. The curious thing is that despite our obvious propinquity to the authors there was hardly any personal contact: the material was culled from their publications and we might as well have been in Los Angeles.

Or perhaps not. Models, quantitative techniques, structuralism seemed to be in the Fenland air. As we read these books, there opened up the prospect of disciplines merging together through the form of approach, despite the ever-increasing specialisation in content. For architects, *Models in Geography*, with its synoptic view of the study of spatial organisation, and *Analytical Archaeology*, which adopted a system views of artifacts, were both very telling. Yet it was Richard Stone's uncommonly (then) firm conviction about modelling in the social sciences which convinced us that our own discipline could be approached with success in this way.

During the last decade many skirmishes have established a beach-head for what has been called the mathematisation of the human sciences. Geographers speak of the 'quantitative revolution'; anthropologists, more commonly, of the 'structural'. Even economics, which has a longer tradition in this approach than the others, has in recent years broadened its mathematical base out into the fields of new mathematics.

Mathematics in the most general sense deals with the definition and manipulation of symbolic models. A mathematical model involves a class of undefined elements and relations between these. Such a mathematical model will reproduce suitable chosen features of a physical situation if it is possible to establish rules of correspondence relating specific environmental elements and relationships with corresponding mathematical elements and relations. We then have what is technically known as an isomorphism. The most generally familiar mathematical models are the integral and real-number systems and Euclidean geometry; the defining properties of these models are more or less directly abstracted from day-to-day experience (counting, ordering, comparing, measuring). However, many of the most significant advances in modern science and technology have resulted from the application of less familiar mathematical models: groups, rings, fields, vector spaces, linear and boolean algebras; topology, graph theory, and varieties of algebraic geometry; linear, non-linear, dynamic and boolean programming.

Roughly speaking we might distinguish between models of a structural kind, such as those associated with, for example, the study of kinship patterns or aspects of linguistics; and models of a programming kind in which many-dimensional spaces are searched for optimal solutions or strategies, such as those associated with many economic applications, engineering and planning problems. Furthermore, we might distinguish between deterministic models (given this, then that), and probabilistic ones (given this, it is probable that); and again between static models in which time is not relevant, and dynamic ones in which it is.

In our architectural researches, widely different studies have called for the same mathematical model. For example, time-tabling, the generation of house plans, the taxonomy of organisations, and the analyses of road networks have all led to applications of graph theory. The distribution of floor space in cities, the patterns of urban locations and trips, the modelling of the daily activity patterns, the micro-economic behaviour of the housing market, the study of built forms with respect to thermal performance, costs and land use, all of these fall within a general model of optimisation under constraints. What we have learnt over the past few years is that a class of architectural problems can, under suitable conditions, be transformed into a class of mathematical problems for the solving of which, very often, powerful methods already exist. Furthermore, because of its symbolic nature mathematical manipulation is more versatile than any verbal or graphic equivalent. As Herbert Simon writes:

> Mathematics has become the dominant language of the natural sciences not because it is quantitative – a common delusion – but primarily because it permits clear and rigorous reasoning about phenomena too complex to be handled in words. This advantage of mathematics over cruder languages should prove of even greater significance in the social sciences, which deal with phenomena of the greatest complexity, than it has in the natural sciences.

But perhaps more importantly, the mathematical model often gives us insight into the structure of the architectural situation we are investigating. This method of model building is relatively novel in both architectural and environmental enquiry. Whether or not, at this stage, any important practical conclusions can be drawn is less important than the fact that we are now learning to use an approach in our researches which has proved extremely fruitful in other fields, from both the scientific view of increasing our understanding, and the technical one of aiding our application.

To some research workers this may appear to be over-stating the importance of the mathematical approach. After all, most of their time is spent in organising surveys, collecting data, coding and processing the unwieldy data banks which represent an urban region or a complex building, the patient analysis of results, the writing and debugging of programs. Most of the work is mundane and routine. The part that has been described involves the creative leap, the inspired guess, which is needed to make research more than a library of information – and how much architectural and planning 'research' is just that; which is needed, in fact, to conject a theory. Edmund Leach in his lecture *Rethinking Anthropology* of 1961 had this to say on this point:

> Instead of comparison let us have generalization; instead of butterfly collecting let us have inspired guesswork. Generalization is inductive, it consists in perceiving possible general laws in the circumstances of special cases; it is guesswork, a gamble, you may

Cambridge University Press
978-0-521-13639-6 - The Architecture of Form
Edited by Lionel March
Frontmatter
More information

be wrong or you may be right, but if you happen to be right you have learnt something entirely new. In contrast, arranging butterflies according to their types and sub-types is tautology. It merely reasserts something you know already in a slightly different form. But if you are going to start guessing, you need to know *how* to guess. And this is what I am getting at when I say that the form of thinking should be mathematical. Our task is to understand and explain what goes on in society, how societies work. If an engineer tries to explain how a digital computer works he doesn't spend his time classifying different kinds of nuts and bolts. He concerns himself with principles, not with things. He writes out his argument as a mathematical equation.

There is much to be said for Dr Leach's view. But he exaggerates for the purpose of his polemic. He presumably would agree that theorists may often be inspired by a well-laid-out collection of information; but equally they can be inhibited by having their data pre-catalogued. And then doesn't the theorist himself need to be something of a collector, not of objects but of mathematical models, of abstract schemata into which the data can be organised? The theorist who has a wide range of mathematical models will be far more likely to recognise appropriate isomorphisms than the man without. It is for this reason that a positive effort to transplant high-level mathematical thought into architectural research must be encouraged. It is not a matter of leaving it as part of the normal work of academic architects as they exist today. If it is we shall waste much time bungling our efforts and squandering our all too rare research resources. A scholar of the history of science, Joseph Clark, SJ, has written with great clarity on this theme:

The history of physics is thus a progressive search for more suitable isomorphisms for the better comprehension and control of other and more complex physical relational situations. For his own professional reasons and prompted by his own artistic motivations and aesthetic ideals the mathematician creates and preserves an expanding stock of isomorphism classes of systems of abstract relations. Now and again, at moments of crisis, the physicist borrows and makes use of a new one from that store.

But mathematics as such offers no obstacles to such use of its wares by other scientists than the physicist. In particular and by way of a suggestion it may be said that the social sciences will come of age and become really 'scientific' when and only when they consciously *undertake* to discover and exploit similar instances of isomorphism. And it is to their very great advantage that the informed members of their profession can begin with a clear conception of this methodology and thus avoid, unlike physics, a long era of hit-and-miss efforts...

Thus, the creative aspect of research requires recognition of an appropriate abstraction or idealisation of our subject by which we may represent it in order to reveal its essential structure. This is at root an aesthetic activity which the arts and sciences hold in common. Our task in architectural research is to understand and explain what goes on in the environments we build, how people and their environments relate. But is this the only task? No. Unlike the descriptive sciences such as geography, anthropology, sociology, psychology and so on, our task is twofold. Certainly to describe past and present situations, but also to design new situations which, if executed, will create new resources by the conversion of existing ones such as labour, capital, time, space and natural resources. Design may then be judged on the basis of whether the values produced on implementation are likely to outweigh the values destroyed. In this view, no distinction can be drawn between engineering and architecture.

If this is accepted, the old Vitruvian view of architecture which related it to the study of classics, divinity, fine arts and music (some of the subject areas in Group I of the Faculties in which Architecture finds itself in Cambridge) has long since been outgrown, although as little as twenty years ago Rudolf Wittkower and Le Corbusier, perhaps unwittingly, gave renewed conviction to such thoughts. Today most of our research workers would connect most easily to engineering, geography and geology, mathematics, and even physics and chemistry: indeed many of them come to us from these disciplines and not from architecture. This change of view can also be seen, not only in the content and form of research, but also in its style and organisation. Whereas 'Vitruvian' research is done by lone scholars working in museums and libraries, 'post-Vitruvian' is done by research teams working in what the Americans call 'systems laboratories'. Such a shift of style is also to be seen in practice where the lone designer is becoming increasingly rare compared to the multifaceted groups which have been emerging in recent years in both public and private offices.

In 1967 the Centre for Land Use and Built Form Studies* was created with Martin as director. The aim of the Centre was, and remains, to foster research and to advance theoretical knowledge in the fields of architectural design and physical planning with special emphasis on the study of urban systems, activity patterns, the organisation of space and environmental design. The common method of LUBFS's work is to formulate abstract models which make it possible to define and explore ranges of spatial and physical forms, accommodating varieties of human activity, under 'laboratory conditions'. This method is shared by studies ranging over a continuum of scales from sub-systems of an individual building to the urban system as a whole. Thus the work consists on the one hand of the spatial and material description of the building, the site or urban area; and on the other the modelling of relevant patterns of activities. In general there are three stages to this kind of research: in the first, descriptive models are formulated and where appropriate these are tested against empirical evidence; in the second, the models are used predictively to study the probable performance of possible designs; and in the third, search procedures are introduced to provide aids in decision-making and the selection of a satisfactory design under specific constraints.

* Now the Martin Centre for Architectural and Urban Studies.

The staff is increasingly recruited from disciplines other than architecture – from mathematics, statistics, computing science, operational research, engineering, geography, economics and so on. These skills reflect the Centre's present bias towards the spatial and physical aspects of architectural and urban studies rather than the behavioural or psychological. But having an emphasis should not be confused with narrowness of view. Rather should it be seen as a concentration on a particular central body of theory out of which radiate lines of thought to penetrate other areas of discussion. For example, work on the relationship between activities and the use of space in universities has extended itself quite naturally into the study of activity patterns in towns, at which level the research begins to be recognised as an important sociological contribution to our knowledge concerning aggregate human behaviour and 'time-budgets'. Another example is the work on simulating the heat, light and sound response of complex building forms. This leads on to the technological study of 'energy-budgets' within buildings, and to the possibilities of reducing energy-consuming mechanical equipment for controlling the internal environment of a building by showing how architectural form may itself be designed more effectively as a self-controlling structure. Or again, the work on housing demand which, making use of the massive computerised data base assembled by our urban systems study, applied modern micro-economic consumer demand theory to a mixed housing market for the first time. This in turn has led on to a reappraisal of environmental design theory in terms of modern utility and decision theories which lend support to the evolutionary approach to design advocated by Steadman on the basis of an analogy with natural and artifactual evolution.

Until recently, little of the work of LUBFS has been directly aimed at improving design methods. The emphasis has been on attempting to gain the fundamental knowledge on which such methods must ultimately depend. This was thought to be the right order of priority. The search has been for an approach to the understanding of complex environmental systems. In view of this twofold division of aims – architecture as the art of engineering a design, and architecture as a scientific study of the built environment – it is useful to distinguish between architectural *engineering* and architectural *science* (or what the Elizabethans called 'architectonics').

Having established some first footings in architectural science, we are confident of its prospects. Now it is necessary to see that architectural engineering is developed to absorb and exploit the new acquisitions of knowledge. It would be quite wrong to see these activities as disjoint – the one as objective, rational, materialistic, and the other as subjective, intuitive, spiritual. As has been said, art and science intersect in their common aesthetic experience. Further, in practical terms, they are now united in their common concern for *structure* and the representation of structure by means of *modelling*. The essays in this volume have been brought together to demonstrate this convergence of art and science in regard to the built form. It represents one further step forward along the constructivist path towards rational design in architecture, and towards fulfilling the ambition of the young Soviet diploma student Krasil'nikov – and thousands of like-minded students throughout the world since – to initiate a scientific discipline concerned with the architecture of form.

This fourth volume in the series Cambridge Urban and Architectural Studies is concerned with recent advances in the study of the built form and especially developments in mathematical and computer modelling. This kind of work has a relatively short history. Indeed it has only been possible to pursue any meaningful line of research in this direction with the coming of large, fast and reliable computers during the latter half of the 1960s.

The essential shift that this style of modelling has caused is to enable architectural scientists and designers to investigate the exceedingly complex interactions between significant factors occurring within a particular built form, or a range of forms – Krasil'nikov's 'continuous sequence of variants'. For example, the laws of physics make it possible to predict analytically, but separately, the behaviour of heat, light and sound in simple environments. In all environmental situations the laws remain invariant, but whereas in simple experimental settings the observed behaviour is readily understood, in the complexity of most architectural situations the behaviour may run against intuitive expectations and become cause for surprise. And indeed as the architectural form undergoes modification (geometrical or material) then light, heat and sound appear to interact on one another through the form.

The first essay in this volume, 'The logic of design and the question of value', is an extended editorial introduction. It sets out the relationship between mathematics, science and design in what may well be a contentious manner. Not all the contributors to this volume can be expected to agree with its argument and it should be looked upon as the editor's own opinion for which he is solely responsible. It was in fact written after all the contributions had been collected together and it is an attempt to provide a framework which relates the papers at a fundamental level rather than by drawing certain superficial connections and distinctions. The last part of this first essay serves as a specific introduction to the succeeding fourteen essays presented in this volume, and the reader is invited to turn to p. 29 to gain a more detailed idea of the contents of the volume. Unlike the first volume, *Urban Space and Structures*, not all the authors have worked at LUBFS; and while most of the contributors are architects by discipline, some are not – testifying to the developing inter-disciplinary nature of the work.

The editor wishes to thank all his colleagues who have contributed to this volume and who have provided such an intellectually stimulating research environment over the past six years. He wishes to thank especially Dr Forrest for contributing his chapter on part of the work conducted by the Computer-Aided Design Group in Cambridge, a group whose presence greatly assisted the growth of computer application in architectural studies in the University; and Dr Derbyshire for extensively rewriting two chapters from his doctoral dissertation presented to the Department of Operational Research at the University of Lancaster.

LIONEL MARCH

June 1973