'A dialogue between the real-world and the operational model' – The realities of design in Bruce Archer's 1968 doctoral thesis

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The article centres on a single document, the 1968 doctoral thesis of L. Bruce Archer. It traces Archer's earlier publications and the sources that informed and inspired his thinking as a way of understanding his influential work at the Royal College of Art from 1962. Analysis suggests that Archer's ambition for a rigorous 'science of design' inspired by linear algorithmic approaches was increasingly threatened with disruption by his experience of large, complex design projects. Reflecting on Archer's engagement with other models of designing, the article ends with Archer's retrospective view and an account of his significantly altered opinions. Archer is located as both a theorist and someone fascinated by the commercial and practical aspects of designing.

Keywords: design history, philosophy of design, science of design, design research, systematic method

This article is centred on a single document, the 1968 doctoral thesis of L. Bruce Archer, entitled *The Structure of Design Processes*. At the Royal College of Art (RCA) for 27 years, Archer was a key figure in early Design Research and a driving force behind the attempt in the 1960s to be rigorous, and in particular 'systematic', about the nature and practice of designing. He sought to establish a philosophy of design (Archer, 1981a, p. 33), even a 'science of design' (Archer, 1968: foreword), a phrase often associated with Herbert Simon's *Sciences of the Artificial* (Simon, 1969; Cross, 2001). Essential to this science was an understanding that Design Research was the study, not only of design's methods, but also of its ontology as a discipline and an activity. Archer was a vital contributor to the work of the Design Council, as a member of Council for ten years and of many of its committees. Partly through his work with Michael Farr, a design management entrepreneur and editor for many years of *Design* magazine, Archer engaged deeply with the commercial world; in the acknowledgements section of his thesis he thanks Farr for giving him 'many opportunities to put his theories to the test' (Archer, 1968). Archer lectured extensively to business audiences. His influence extended internationally through his work

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in Germany, the United States, Canada, Turkey, India and elsewhere. Archer acknowledged that he learned more from such interactions than he might have realised at the time (Archer, 1981b).

Archer wanted to grasp the nature of design as well as find better ways of designing. Of these two ambitions, he favoured the first. Christopher Frayling, who held a variety of roles at the RCA from 1979 to 2009, recalls Archer insisting, ‘I am not doing this to help practising designers. I am doing this to completely understand the design process’ (Frayling, 2013). Archer’s doctoral thesis exemplifies a tension between theory and practice that is still with us. Subtle features within it indicate the beginnings of a change in his thinking that later led to a radical reformation of his views, derived from his increasing real-world experience. J Christopher Jones, in an article for *Design* (Jones, 1966), complains of ‘substantial but not always very practical publications’, ‘both vague and dogmatic, [with] little reference to the work of practising designers’. Archer’s thinking about design during this period was increasingly affected by practical design projects.

We will not rehearse here the many criticisms of ‘design methods’ that have been made over the years, a rebellion initiated early on by Jones (1969) and Alexander (1971). These debates have been discussed by Cross (1993, 2007), Glanville (1999), Dorst (2003), Bayazit (2004), Margolin (2010), Pavitt (2012) and many others. Our topic is instead the changes generated within Archer’s own thinking and his attempts to match his theories to the messy realities he encountered.

When Archer completed his thesis in 1968 he was 46 and had worked at the RCA since 1962, first in the School of Industrial Design as a researcher invited by Misha Black. He later became Research Professor of the newly named ‘Department of Design Research’ (DDR) in 1972–73; this Department should not be confused with the Design Research Unit, a commercial consultancy co-founded by Black (Cotton, 2010). Prior to the RCA, Archer had worked for a year at the Hochschule für Gestaltung Ulm with Horst Rittel among others (Krippendorff, 2008). The Hochschule has been characterised by Woodham (1997: p. 180) as moving from intuition to method, from component to system, from product to process, and from individual to interdisciplinary approaches — all features of Archer’s later thinking. Archer’s own education had been in mechanical engineering at what is now City, University of London. In an article for the RCA’s *Ark* magazine (Archer, 1972a), Archer said ‘he was a painter before being drafted into industry by the then Ministry of Labour’. Serving in World War II from 1941 to 1944, he was discharged on medical grounds. By 1953 he had set up an engineering consultancy and was teaching in the evening at the Central School of Art and Design; he was a full-time lecturer there by 1957 and concurrently writing articles for *Design* magazine, promoting what he called ‘a rational approach to design’. It was from the Central School that

Archer was invited by Tomás Maldonado to work at Ulm. There he discovered two factions, the 'mathematician/scientists' (including theoreticians and applied psychologists) and the 'designers'. He inclined to the 'mathematicians' camp (Lawrence, 2001, pp. 43–44).

The Archer who arrived at the RCA in 1962 therefore had experience of many aspects of life, but not of large, complex design projects. That would soon change. Black had invited him to lead a research project on non-surgical hospital equipment funded by the Nuffield Foundation (Archer, 2004). Archer saw the initial task as 'the development of an organised body of knowledge that will assist manufacturers to design and hospital planners to select fixed and moveable equipment' (p. 1). Four problems were chosen as the focus of the 'organised body of knowledge', including the need for a standard design of hospital beds. There were over three hundred bed types in use, made in small numbers by many companies. The Royal College of Nursing had reported the high incidence of permanent back injury among nurses due to the poor design of beds (p. 2).

Probably because the outputs of this 'organised body of knowledge' project appeared too theoretical and produced no prototype products, the first year's report to Nuffield was rejected and the follow-on three years of funding were denied. As Lawrence (2001: p. 51) puts it, 'In the design method which Archer was devising, a precise formulation of the design problem was essential, and this was what, in his view, the Report represented'. The notes of Archer's and his assistant Reinhart Butter's deliberations 'exhibited a preoccupation with methodology, with rigorous, often self-referential, definition and with stepwise progression' (Lawrence, 2001, p. 47). This insistence on requirements capture prior to designing would be tested to the full as Archer gained more experience.

Following the rejection of the Report, Archer worked nights in an ice cream factory and without pay at the RCA during the day (Archer, 2004, p. 3). Black found ways of keeping the rest of the hospital bed team together, and recruited 'one of his star graduates' (p. 3) Kenneth Agnew. Each of the four hospital projects was addressed, including the King's Fund hospital bed which 'turned out to be a very big exercise' (p. 5), and is exceptionally well documented by Lawrence (2001). Prevented by official policy from creating a single design, the team had to create a specification that manufacturers could respond to with their own solutions. Nevertheless, it was clear that the team would need to build real prototype beds and evaluate them against many criteria. The beds needed to be high to minimise injury to nurses, but low for the patients to get in and out: the solution was an adjustable-height bed (Figure 1). But straight-forward resolutions like this were unusual. During the project, the team had to deal with intersecting issues of manufacturing, materials, healthcare, hands-on nursing, standards, safety, hospital management, patient satisfaction, industrial commerce, external relations, and institutional culture and politics at a number of levels. Such experience seems to have

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Figure 1 Bed height adjustment mechanism – a simple (though quite costly) resolution of two opposing requirements. Prototype for the King's Fund Hospital Bed designed by Kenneth Agnew at the Royal College of Art under Bruce Archer's leadership 1963–67. Photo: Kenneth Agnew Collection, RCA

modified Archer's thinking and led him to question the simplicity of his original model of designing.

1 The prehistory of the Archer thesis

Archer's thesis was completed in 1968 (a remarkable year worldwide) but much of it had already appeared in print in a series of seven articles, 'Systematic method for designers', roughly 27 000 words, published in *Design* magazine from April 1963 (Archer, 1963–64).[1,2] An article in *The Guardian* in 1964 had announced the award to Archer of $10 000 by the Kaufmann foundation, which would 'enable him to take his studies a stage farther, and produce a thesis and a book' (Wainwright, 1964). The book never appeared. Archer was a long-term contributor to the magazine founded by Alec Davis, its first editor, in 1949 and edited from 1952 by Michael Farr. 'Systematic method' was published under the third editorship, that of John E. Blake. The trajectory of Archer's thinking in these articles is not a simple one, but some key ideas emerge that later informed his work and thesis at the RCA. His first *Design* article (Archer, 1954), published under Farr, argued the importance of both creative invention and profound technical knowledge in an industrial designer, a theme reprised a year later (Archer, 1955b). He then contributed a design analysis of a new typewriter (Archer, 1955c), this time highlighting poor British industrial innovation compared with competitors, a topic often revisited that highlights his interest in the commercial world. Four articles from 1956 (Archer, 1956a) began a series that again argued against purely technical engineers working by rule of thumb: the industrial designer needed to be informed by both art and science. At this stage, Archer clearly saw the intuitive part of designing as preceding the scientific part (in italics he states 'It is necessary that a hypothetical design shall first be laid

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down before analysis can begin' p. 14) and explicitly says that design is not about 'the evolution of forms by scientific methods'. In his 1955 article on agricultural equipment, he had similarly distanced himself from any idea that 'the final appearance of any product, whether pleasing or otherwise, is the result of calculation alone' (Archer, 1955a, p. 35). Much later, *making* would take on a crucial role in Archer's model of the design process.

In the second article of the series, Archer complains at the low proportion of 'trained men engaged in scientific and technological work' compared with other nations (Archer, 1956b, p. 32). Design Research is envisaged as including the calculation of the bounding space of optimal solutions, based on data about requirements, materials and manufacturing methods – later a key part of Archer's thesis. Archer notes how 'amateurism in management plays a very big part' in Britain's industrial failure (p. 33). In the thesis this will lead him to think about management, game theory, and business decision processes. Still disenchanted with technicians who neither think creatively nor are up to speed with the state of their art, he is increasingly sanguine about science: 'Herein lies the brightest hope for progress in design research and for the recovery of the art of designing from its present intimidated state' (p. 35). The final series article (Archer & Zaczek, 1956) calls again for more rigour in designing – from whatever discipline. Archer's next article (Archer, 1957a) again calls for more science *in* design, but still does not necessarily require a science *of* design.

A series of articles with J. Beresford-Evans (later a visiting lecturer under Black and a key styling designer with him of diesel locomotives for British Rail (Jackson, 2013, p. 63)) shows Beresford-Evans focusing on the aesthetic aspects while Archer subjects cooking pans (Beresford-Evans & Archer, 1957a), hand axes (Archer & Beresford-Evans, 1957), and a free-standing fire (Beresford-Evans & Archer, 1957b) to a series of tests. Archer continued these design analysis articles into the next decade. The 1957 articles emphasise the need to combine subjective and objective evaluation. There is a focus on qualities that matter to people, 'almost atavistic' and 'endowed with life' in the case of the domestic hearth (p. 53). In *Electronic Instruments* Archer (1957b) rails at the assumption that a problem has only one solution (p. 29). In *Honest Styling* (Archer, 1957c) Archer makes the telling remark that the manufacturer has considered 'not merely a machine, but a man/machine/work system' and notes with approval that its dial has 'been redesigned close to principles enunciated by the Applied Psychology Research Unit, Cambridge, and was developed with the aid of advice obtained from the RAF Institute of Aviation Medicine, Farnborough'.

On first studying the thesis, one might sense a simple transition: that Archer as a mechanical engineer was attempting to scientise design. But the preceding material modifies this view. Archer's original emphasis was on the need for

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creative design in engineering. He was arguing for rigour, not confined to scientific rigour, in industrial practice. Design decisions should be based where appropriate on objective data, and calculation used to identify the limits on optimal designs. No process would provide a single best solution. He assumed that the designer's vision preceded any application of logic. There is a strong emphasis on the commercial world, of survival and success in international markets, and the inadequacy of current management.

2 Some influences on the Archer thesis

By the time Archer wrote *Systematic Method* and the thesis, he was increasingly optimistic about a science of design. Now little is said about the need for creative input – most of the work of this period emphasises the power of a range of scientific disciplines. What led to this change? Titles in his bibliography are illuminating, including: *Scientific method: optimising applied research decisions* (Ackoff, 1962); *General systems theory, skeleton of a science* (Boulding, 1956); *Prediction and optimal decision* (Churchman, 1961); *Problem analysis by logical approach* (Latham, 1965); *New product decisions: an analytical approach* (Pessemier, 1966). This was a period of high optimism about rational methods, systematic thinking and calculation in decision-making and execution. Operational Research (OR) and Organisation and Methods (O&M) were seen to have yielded significant benefits in war (Kirby, 2003) and administration. Much later, Archer (1999: p. 566) recalled the general excitement about OR's systematisation. Archer's thesis is unequivocal: 'A logical model of the design process is developed, and a terminology and notation is adopted, which is intended to be compatible with the neighbouring disciplines of management science and operational research. Many of the concepts and techniques presented are, indeed, derived from those disciplines' (Archer, 1968: foreword).

Optimism about systematisation was closely allied to the adoption of computing. Agar (2003: Chapter 8) charts the relationship between 'Treasury O&M' and the computerisation of government work, the 'government machine' metaphor instantiated in actual computational machinery. In 1968 computing was the key feature of the exhibition *Cybernetic Serendipity* held at the Institute for Contemporary Art (ICA) in London, and in 1969 *Event 1*, the first major public activity of the Computer Arts Society, was held at the RCA (Mason, 2009). Many exhibitors from both arts and science backgrounds were influenced by cybernetics, OR and Systems Theory (von Bertalanffy's (1951) article 'General System Theory' is cited in Archer's thesis and von Bertalanffy's book of that name came out in 1968). On the continent, *New Tendencies* in Zagreb included 'Computer and Visual Research' from 1968, while computing featured in the 1969 Nuremberg and 1970 Venice biennales. Max Bense, whose pursuit of 'rational aesthetics' involved him in one of

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the first computer arts exhibitions in Stuttgart in 1965, taught at Ulm in the 1950s and 'was the intellectual backbone of the school at that time' according to Krippendorff (2008: p. 57).

The 1962 *Conference on Design Methods* was a seminal event that brought together a range of individuals seeking new approaches to the process of designing, and led to the founding of the Design Research Society (Cross, 2007, p. 1). Jones opened his paper there with the words, 'A trend towards more logical and systematic methods of design has been evident throughout the 1950s. In many cases they have appeared as the result of new technical developments such as computers, automatic controls and systems' (Jones, 1963). Under Archer the RCA pioneered computing for design through the work of George Mallen and Patrick Purcell (Boyd Davis & Gristwood, 2016; Gristwood & Boyd Davis, 2014; Mallen, 2011). It is clear that for Archer this included the advancement of computing as methodological inspiration. He suggested that 'the logic by which computers work, and the clarity and fullness of expression which is necessary to prepare a real-world problem for computing, are valuable indicators of the sort of logic which might work even without a computer' (Archer, 1963). This logic was as important as actual use: 'In recent years Mr. Archer has devoted himself to the development of a system of logic for the solution of design problems and has become deeply involved in the application of computer techniques' (Granada Television, 1964, p. 6). A report on government computing in 1956 had explained that all computing systems include input of data and instructions, storage, control, operations for calculation or processing of data, and output (National Physical Laboratory, 1956, p. 3). This linear approach was in many ways just what appealed to Archer, Jones and many others. They were stimulated by the need to be explicit about the problem they were trying to solve and by the requirement to gather data at the outset. But alternative models would also claim Archer's attention, even within the thesis, as discussed below.

3 *Archer's thesis document*

The Archer thesis is divided into chapters on the definition of design, the nature of the act of designing, the systematic model, the operational model, the design programme, the logic of design procedure, design factors, the problem of aesthetics, the problem of imperfect information, techniques in problem solving, and finally a summary and conclusions. It comprises about 36 000 typewritten words, 80 pages of diagrams and 90 endnotes. The argument proceeds by introducing a simple model of the design process and refining it chapter by chapter. The diagrams are significant; four representative examples are reproduced here, not to convey the substance of the points that Archer was making – which can only be tackled by reading his full argument – but to capture the character of his thinking at this period. Many are graphs (for example

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Figure 2). Many resemble algorithmic flow charts (Figure 3). Others show the relation between such models and the real world (Figure 4). This last, which gives the title to the present chapter, illustrates an aspect of Archer's claim to be connecting his schemata to reality, driven by his longstanding commitment to industrial design practice including its commercial context. Nevertheless it is clear that his textual and visual language is at this stage scientific, even mathematical, in its inspiration, and far from the everyday language of design.

An important feature is the calculation of the solution space within which the final design must lie (Figure 5). To calculate this, clearly the requirements and constraints must be known in advance. Archer tended to believe at this stage that the design process began with defining the brief, establishing the requirements and giving them appropriate weights, securing the necessary data and then actually designing. The requirements stand outside the iterative cycle. His diagram (Figure 6), appearing in similar form in several works in the 1960s, seems to show the brief as outside and preceding the design process proper. Data analysis, synthesis and development are all allowed to retrospectively alter data collection (presumably as the need for new information becomes apparent) but none of these seems to alter the brief and therefore the requirements. This fits with the linear computational model that Archer had espoused early on.

Archer originally had a very particular view of designing as being prior to making: 'A key element in the act of designing is the formation of a prescription or model for a finished work in advance of its embodiment' (Archer, 1963, Part Two, p. 70). Thus a sculptor working directly with his or her material is not designing, but 'when a sculptor produces a cartoon for his proposed work, only then he can be said to be designing it' (p. 70). This leads Archer to the odd contention that a couturier is designing even when making a garment on the stand – but only provided this is not the finished item but a prototype for a garment that is going to be made subsequently (p. 70).

The ideal model in which requirements are finalised prior to designing, which then proceeds undisturbed by changes to the brief, shows subtle signs of disturbance in the thesis. The development of the thesis, from the earlier *Design* articles onwards, is contemporaneous with Archer's direct experience of the complex Hospital Bed project which gave him ample evidence of the tendency for requirements to be significantly altered during the design process.

4 *The model disrupted*

There are a number of disturbances to the systematic linear model. These include complexity, the need to revisit the brief and requirements, and the problem of securing good data.

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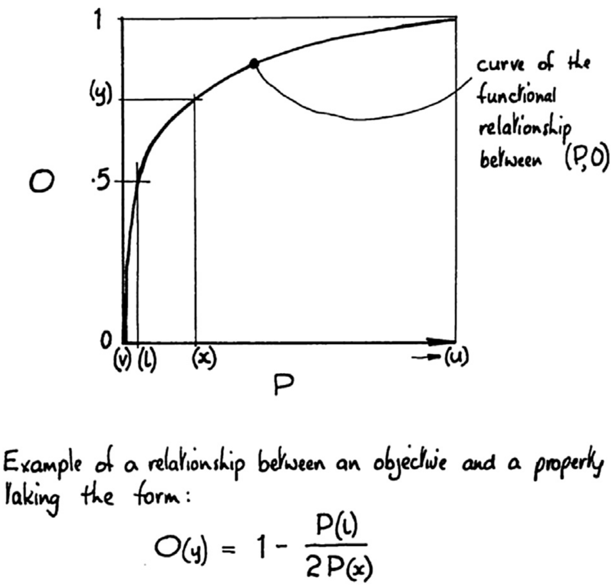

Figure 2 Figure 2.4 from Archer's doctoral thesis illustrating the case where 'a product may be required to be as profitable as possible, with a low limit of profitability, but no high limit'. Archer explains that, 'Where the states of a property P can vary along some continuous scale, such as a scale of centimetres or kilograms, then the relationship between the degree (y) of fulfilment of objective 0 and the state (x) of its associated property P may be expressed in the form of a curve' (Archer, 1968: section 2.9)

4.1 Complexity

Archer always acknowledged that there are multiple solutions to design problems. Figure 5 and its associated thesis text (Archer, 1968: section 2.27) make clear that multiple solutions may occupy the spaces between the bounding surfaces of feasibility and acceptability. Yet one key reason to be pessimistic about any systematic method is the interdependence of factors. Fixing one problem opens another, and typically unforeseen consequences occur, problems of complexity characteristic of socio-technical systems (Johnson, 2010, p. 120) – such as hospital beds. Even exhaustive computation may not do the trick: 'to derive a trend which would point to an ideal solution, is only just becoming feasible and yet might never be attainable because of the large number of variable factors which are not always interdependent' (Archer, 1956a, p. 14); given the argument he is making at this point, it seems likely Archer meant to say 'independent': it is clear that he believes that the problem is interdependence between factors. Archer's colleague at Ulm, Horst Rittel, memorably characterised these as 'wicked problems' in dialogue with C West Churchman at just the time Archer was finalising his thesis. Both authors feature in the thesis (Churchman, 1961; Rittel, 1965), and Archer explicitly notes there the significance of dependence (Archer, 1968: endnote 60). A characteristic passage in the Rittel chapter cited by Archer could be a description of problems like the hospital bed: '…it can be expected that the exchange of

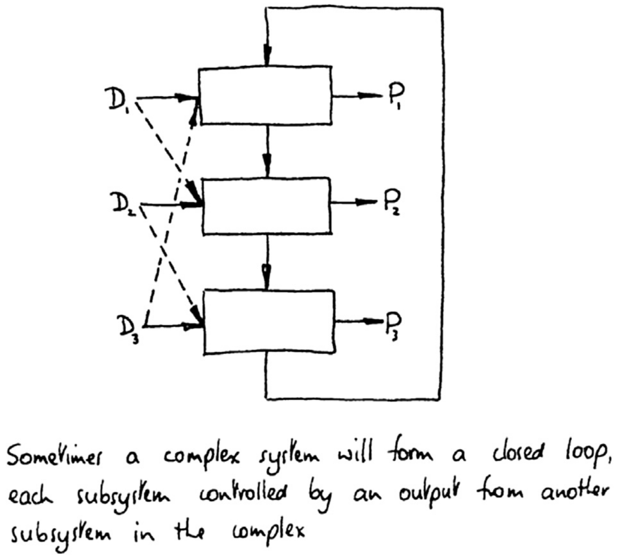

Figure 3 Figure 4.5 from Archer's doctoral thesis illustrating the case where 'a system of systems may form a closed loop, with every subsystem depending on inputs from another subsystem' (Archer, 1968: section 4.9). D denotes Design, P is Performance. The debt to algorithmic flow diagrams is clear

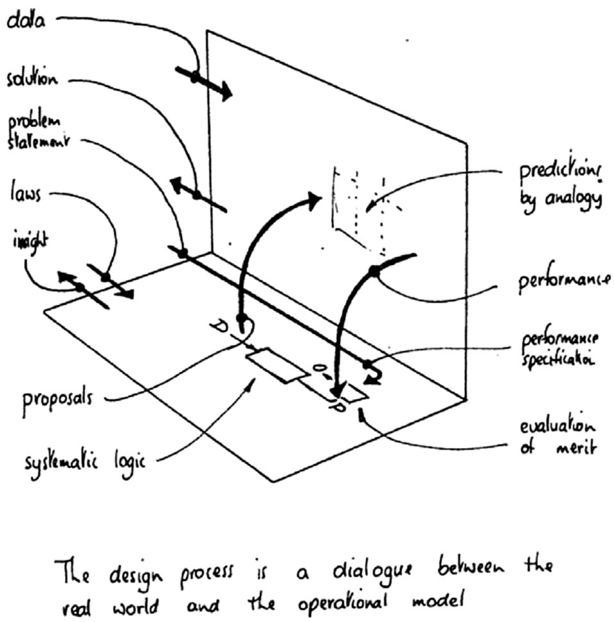

Figure 4 Figure 4.6 from Archer's doctoral thesis. Archer explains that 'In the course of cycling the loop [shown above in his Figure 4.5] the designer's perception of his real-world problem, his concept of the design solution grows. In a sense, the design process is thus a dialogue between the real-world and the operational model' (Archer, 1968: section 4.10)

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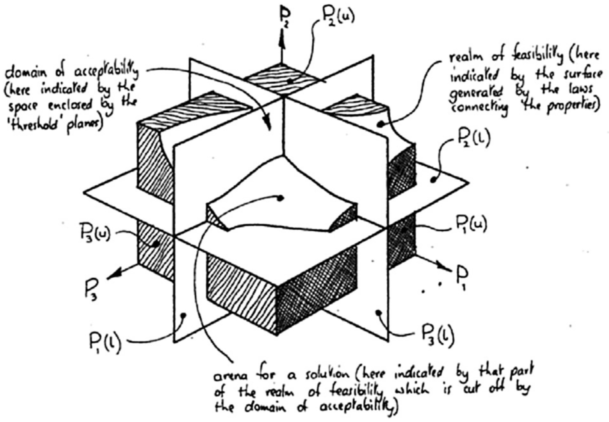

Figure 5 Figure 2.18 from Archer's doctoral thesis illustrating how 'the interdependence of the curves of feasible mutual states will constitute an n-dimensional hypersurface or realm of feasibility. An important pre-requisite for an ultimate solution is that at least a portion of the realm of feasibility should intersect the domain of acceptability, producing an arena within which a solution must be found' (Archer, 1968: section 2.27). In Archer's view such modelling will not produce the solution to design requirements, but it does indicate the limits within which the effective solution or solutions can be found

associations between several persons is likely to raise this threshold since each association acts as a new stimulus on the other persons. In this manner not only *C* [the number of associations produced by a certain stimulus] is increased but also the diversity of the associations produced. This diversity is greatest when the individual reservoirs of associations overlap least (i.e. they are specialists from widely different fields)' (Rittel, 1965, pp. 209–210). The greater the number and range of stakeholders in a project, the more likely that the variety of potential solutions will increase.

4.2 Requirements in contention

Despite diagrams like Figure 6 that might seem to show the brief lying outside and prior to the design process, Archer actually acknowledges at several points that the requirements to which the designers thought they were responding may be subject to revision at almost any point. As Rittel put it later: '…the irritating thing is that, depending on the state of solution, the next question for additional information is unique and dependent on the state of solution you have already reached' (Rittel, 1972, p. 392). In Archer's words, 'During the course of the problem solving activity new objectives may tend to form and re-form' (Archer, 1968: § 2.29); 'The complete set of objectives is only rarely definable at the beginning of the project. Most of them emerge by mutual consent as the project progresses' (Archer, 1968: § 6:15). He seems comfortable with this, even though we might consider that it undermines some key aspects of his system: 'It is open to the arbiter or arbiters in a problem to manipulate the importance ratings in any way they wish, and to revise their ratings at any stage they wish, so as to represent their true aims and interests as the

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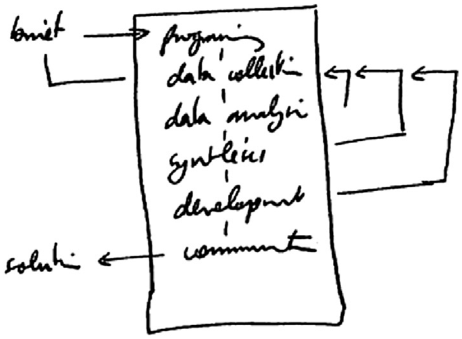

Figure 6 'Simplified checklist' from Archer's (1965) handwritten notes for a lecture. The brief precedes and lies outside the design cycle

consequences of their decisions emerge, or fresh information becomes available' (Archer, 1968: § 3.30). And these are not just minor refinements: 'any effective design procedure must therefore permit *radical reappraisal* of the problem *at any stage*' (Archer, 1968: § 6:17 emphasis added). Again the real-world complexities of design projects seem to have had a progressive influence on Archer's thinking, but without yet undermining his faith in system.

4.3 Lack of good data

For Archer, the designer or engineer must work with the best possible information rather than relying on intuition or custom and practice. OR and O&M had both demanded the provision of adequate data in order to be effective. In ergonomics, Jones had been advocating the use of strong data for more than a decade (Jones, 1954). Dreyfuss' influential anthropometric files had been published repeatedly in the preceding ten years (Dreyfuss, 1959). Yet in key areas that Archer considered essential to design, including aesthetics, he acknowledges the lack of good data. A work cited frequently in the thesis confronts the twin problems of interdependence and uncertainty (Tavistock Institute, 1966). Archer bemoans the lack of 'a corpus of knowledge or a set of techniques capable of providing rational aesthetic decisions'; for example, 'Very little is known about the combinations of properties — shape, proportion, colour, texture and so on — which give rise to aesthetic satisfaction' (Archer, 1968: § 8:17). This for Archer is a lack of usable information, not a fundamental difficulty in processing and using qualitative data: 'it should be possible to collect data and to carry out analyses of trends and probabilities, using techniques well developed in the natural and social sciences' (Archer, 1968: § 8:16); 'The principal distinction between phenomena from the operational point of view is therefore not in their "qualitative v. quantitative" character but in their "known v. not known" character' (Archer, 1968: § 9.4). There are problems of both availability and quality: 'the data is difficult to find, and when found it very often contains redundancies, errors and omissions' (Archer, 1968: § 9.9). This arises from the very nature of design problems,

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dealing as they do with so many kinds of criteria (Archer, 1968: § 9.10). Later, Archer would present an important paper on the potential for computation with qualitative data (Archer, 1972b; see Gristwood & Boyd Davis, 2014,: p. 622).

5 Games and cybernetics

We have discussed Archer's inspiration in OR, O&M, computation and systematic decision-making. How did he deal with the kinds of problems we have just highlighted, which threatened to disrupt such models? Two key areas of his bibliography are concerned with game theory and with cybernetics, disciplines that both deal with ongoing, unpredictable, dynamic systems that have emergent properties. They are thus quite distinct from the pipeline model that at first sight seems fundamental to Archer's system and is the basis of simple OR and O&M. As Pickering (2002) puts it, 'cybernetics grabs on to the world differently from the classical sciences. While the latter seek to pin the world down in timeless representations, cybernetics directly thematizes the unpredictable liveliness of the world, and processes of open-ended becoming'. Pickering distinguishes cerebral, representational American cybernetics from the embedded and embodied UK cybernetics created by Ashby, Beer and Pask, all of whose works appear in the Archer bibliography (Ashby, 1957; Beer, 1959; Pask, 1961). Cybernetics attempts to break the distinction between biological and artificial systems, between brains and bodies, entities and their environments, and 'cuts across the entrenched departments of natural science' (Pask, 1961, p. 11). Cybernetics offered Archer a way to envisage the 'dialogue between the real-world and the operational model' (Archer, 1968: § 4:10) (Figure 4): its dynamic, interactive character provided an alternative to the linear computational model with which Archer had begun.

Two cyberneticians in particular are relevant to the problems of complexity and uncertainty – Ashby and Pask. Ashby notes how complexity had been avoided traditionally: not until the 1920s 'did it become clearly recognised that there are complex systems that just do not allow the varying of only one factor at a time – they are so dynamic and interconnected that the alteration of one factor immediately acts as cause to evoke alterations in others, perhaps in a great many others' (Ashby, 1957, p. 5). Ashby and Pask can often be read as though describing complex multi-stakeholder design projects: 'There is first a set of disturbances D, that start in the world outside the organism, often far from it, and that threaten, if the regulator R does nothing, to drive the essential variables E outside their proper range of values' (Ashby, 1957, p. 209). Ashby writes on emergent properties: 'Often, however, the knowledge is not, for whatever reason, complete. Then the prediction has to be undertaken on incomplete knowledge, and may prove mistaken' (Ashby, 1957, p. 111). Pask also toys with situations 'where the objective is not obvious at the outset and only becomes so when some tentative knowledge has been

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gained' (Pask, 1961, p. 19). 'Uncertainty stems from ourselves and our contact with the World' (p. 21). Perhaps this remark of Pask's appealed to Archer after all the tribulations of complex practical projects: 'Cybernetics offers a scientific approach to the cussedness of organisms, suggests how their behaviours can be catalysed and the mystique and rule of thumb banished' (p. 110). If real projects threatened to escape traditional scientific discipline, cybernetics might be a science adapted to the cussedness of organisms including clients, policy-makers, manufacturers and designers.

6 Looking back

Several of the works that Archer cites exploit the notion of a *black box* (Ashby, 1957; Beer, 1959; Duckworth, 1962; Pask, 1961), the cyberneticians in particular celebrating the idea. Archer does not echo their admiration, perhaps annoyed that designers themselves are so unfathomable: 'meanwhile, the only effective "black box" is the sensibility of a discerning and creative designer' (Archer, 1968: § 8.17). He wanted to open the black box of designing and discover what was inside. Though his 'structure' and his 'systematic method' look very like algorithms for designing, in the end he was, above all, interested to understand what designing is. McIntyre (1995) suggests that Archer's thinking continued unchanged, yet this is clearly not the case. Years later Archer reflected that he had 'wasted a lot of time trying to bend the methods of operational research and management techniques to design purposes' (Archer, 1979). He now offered a dramatically different approach: humanities, science and design as equal points of a triad of disciplines. Archer announced that 'there exists an under-recognised but definable *third area* of human knowing, additional to numeracy and literacy' (1978: foreword, emphasis added). He was no longer assimilating design to science, but saw design as a form of knowledge in its own right. Ten years after 1968, the 'year of revolutions', it was 'Time for a Revolution in Art and Design Education' (Archer, 1978: title), and Archer, through the Design Education Unit led by Ken Baynes, would set about creating it (Green & Steers, 2006).

Given Archer's own negative re-assessment of his earlier systematic method, there is a risk of underestimating what Archer achieved. Looking back, Archer himself felt that 'we had at least established that work study, systems analysis and ergonomics were proper tools for the industrial designer's trade' (Archer, 2004, p. 5). That same year, when the Design Research Society presented Bruce Archer with a Lifetime Achievement Award, Macmillan argued that Archer had largely invented the discipline of design research. Perhaps most pertinent to the present account, Macmillan suggested that Archer 'reflected on his experiences and captured their essence in seminal papers about systematic methods and the design process' (Macmillan, 2004). In our closing paragraphs we itemise the most significant reflections that arose from Archer's

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need for a rationale, indeed a philosophy, for design, built upon his insights into the business of designing.

Archer's thesis, and his practice, makes an implicit case that design includes the entire process from initial concept or problem — it is not a cosmetic intervention at the end. He had increasingly understood that the brief is part of the design, and as such is open to revision: what you thought you were trying to do must change in the light of the multiple human and information interactions in the on-going process. Crucially, the brief may be reflexively altered by the process of *making*.

While the thesis had increasingly acknowledged the ways in which multi-stakeholder interactions, the emergence of new data, and of new needs for data, could — and should — alter the original conceptualisation of the needs and objectives, Archer later adopted far more thoroughly the idea that key aspects of design proceed through what he came to call 'wrighting'[3] — the actual making of artefacts. He justified this by reference to Popper (1963), not cited and perhaps not read by Archer back in 1968. Retrospectively, Archer (1999) wrote: 'The essence of Karl Popper's message in *Conjectures and Refutations* was that we should reject the old Baconian principle that the true scientist should arrive at a scientific theory through inductive reasoning. He argued that we must accept, instead, that most, if not all, scientific discovery is based on the positing of an insightful tentative explanation about the meaning of the evidence'. The applicability of Popper's thinking was questioned at the time (e.g. by March, 1976) and subsequently (e.g. by Cross, Naughton, & Walker, 1981), but for Archer it legitimated the idea (an idea that he himself had previously rejected) of conceptualising solutions, and even starting to make them, in advance of fully understanding the requirements. The emergent design becomes a research tool to advance the understanding of the need. Perhaps only half-humorously, Archer (1999: p. 567) wrote of his relief that the Popperian rationale meant that 'Design activity was scientifically respectable!' Archer had not managed to force design into his original, linear, rigid model of the scientific process, but he had now found an alternative scientific approach that — to his relief — came part way to meet the apparent nature of real-world designing. In some respects Archer had reverted to his earliest assumption that creative activity is a pre-requisite, but now had a credible scientific rationale for his instinctive view.

Dubberly and Pangaro (2015) emphasise how cybernetics offers not only a unifying theory of systems, mechanical and biological, dealing with circular and reflexive interactions: it also grapples with the difficulty of separating the observer from the system. Archer again responded to such models, which chimed with his own experience, describing how he came to see his, and his colleagues', work as Action Research, where, in Archer's words, 'the investigator may of necessity be an actor in the situation' and 'takes some action in and on the real-world in order to change something and thereby to learn something about it'. For Archer, 'a great deal of real-world design activity takes the form of Action Research and this experience represents a useful bridge between design practice and design scholarship' (Archer, 1999, p. 568).

Finally, in the same retrospective essay, Archer discussed Agility. Often associated with the work of Royce in relation to computing, Agile approaches to project development deal with the same problems that Archer documented: if after completing the putative solution, the design fails to satisfy the various external constraints, a major redesign is required. What is more, 'the required design changes are likely to be so disruptive that the [...] requirements upon which the design is based and which provides the rationale for everything are violated. Either the requirements must be modified, or a substantial change in the design is required' (Royce, 1970, p. 329). As a result, for Archer, agility and responsiveness became key concepts in any design and development process (Archer, 1999, p. 570).

In the year of his death, Archer wrote of 'the conflict and pain that theorists and practitioners experience during the transition from one paradigm to another' (Archer, 2005). We have shown how Archer abandoned some of the key assumptions of his early approaches. The linearity which at first seemed sufficient to give design a rigorous basis in terms of both data and method had to give way to more refined, and realistic, approaches. While Archer had always acknowledged the role of the 'creative leap' (Archer, 1963−64: Part five), one senses his relief on finding that philosophers of science too recognised the role of intuition and of early tentative solutions. Archer never ceased to use phrases such as 'science of design' and 'a science for design', but what he came to mean by such terms had altered almost beyond recognition; his 1968 thesis is a pivotal document within that change of view.

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Notes

1. In current terminology, the thesis Archer presented might be considered a submission for doctorate by prior publication. The level of previously published material in it was surely unusual for the expectations and regulations of the time. To date no documents discussing this question have been found in the RCA archives.

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2. 'Systematic Method' was highly valued by the readers of *Design*. A note in issue 38 (1965) p. 73 states: 'The unprecedented demand for this series of articles has made it necessary for DESIGN to publish them as a bound reprint, revised and extended by the author'.
3. Archer generally paired the words 'wrighting' and 'wroughting' in an attempt to recompose the 'three Rs' (reading, writing and rithmetic) of traditional educational thinking (Archer 1977; Baynes, Langdon, & Myers 1977). Archer, Baynes, and Langdon (1979: 9) date an early utterance of these ideas to 'a lecture delivered by Professor Archer at the Manchester Regional Centre for Science and Technology on 7 May 1976 under the title The Three R's'. Linguistically, the separation of wrighting and wroughting does not make sense: 'wrought' is effectively a past participle of 'wright' (both ultimately relating to words for 'work' – OED 2017a, 2017b).

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