The role of systems thinking in modern society**

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Advanced and increasingly complex societies have hitherto managed quite well with their administrators looking for a course of action that is "good enough" (or that satisfices, in the terminology of H.A. Simon), achieved by creating or using a drastically simplified model of the world, taking into account just a few of the factors, those that they regard as most relevant and crucial. The administrator thereby ignores interrelatedness, "so stupefying to thought and action" (Simon). It does not seem too daring to lay the blame for the serial conspicuous administrative failures of recent years at the door of the proponents of satisficing. The Systems Management Panel (SMP), several members of which are presenting papers at the SIMposium, embraces the real complexity of the world and seeks to understand it in such terms, with the aim of providing clear recommendations for practical action to solve seemingly insuperable problems. During the last two years the NHS crisis has been the main focus of attention, and last year the SMP organized a symposium exploring the potential role of smart sensor systems to revolutionize healthcare delivery. Key outcomes of the symposium will be summarized.

1. Introduction

Systems are in vogue nowadays. Traditional disciplines such as engineering and biology have been augmented by the subdisciplines of "systems engineering" and "systems biology". The development of "general systems theory" was under way in the 1950s. Boulding called it "the skeleton of science".[1] But, *prima facie* systems are intractable. Ross Ashby has pointed out that "reality" may encompass an infinite number of variables; it is therefore prudent to consider the system as a minimal list of variables that must be considered in order to give a practically useful description.[2] It may, however, be troublesome to find that or those sets of facts capable of

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1 K.E. Boulding, General systems theory—the skeleton of science. *Management Sci.* **2** (1956) 197–208.

2 W.R. Ashby, *An Introduction to Cybernetics*. London: Methuen (1964).

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yielding closed and single-value transformations, usually necessary to fulfil the criterion of "practically useful". Such finding is an important part of the work of the investigator. A civil engineer knows that he or she does not need to know the temperature (within reasonable limits) to design a bridge; the thermal motions of the atoms constitute noise that is averaged out. This is often the case, but it can happen that there are paths for random noise to be amplified up to macroscopic dimensions.[3] It then becomes troublesome, and can no longer be neglected. An example of such amplification is the "butterfly effect" discovered by the meteorologist Lorenz.[4] The system in this case is the atmosphere, which of course has countless constituents—think of all the volatile molecules drifting around a chemical factory or forest, dust from deserts, particles from combustion processes and so forth—but a good basic understanding of the weather may only need the air *qua* oxygen and nitrogen (it is probably unnecessary to distinguish between them) and water to be taken into account. Water itself is, however, a highly complex material, capable of existing in many phases (solid, liquid, multimer, gas;[5–7] the solid can exist in different forms (snow, hail) and the liquid can have a quasi-infinite number of degrees of hydrogen bonding). Such systems are, nevertheless, strictly deterministic. If we could know, or define, the starting conditions with a fantastic and quite unattainable precision, then we could indeed predict their dynamics,[8] even to the extent of mastering the butterfly effect. In this context, it is sobering to be aware that only three dimensions are needed to approximate all possible chaotic dynamics.[9]

It follows that the task confronting systems engineers is clearly formidable. On the other hand, any meaningful discussion about biology has always been confronted with the fact that any living organism is a system (and current attempts to create the discipline of "systems biology" represent a quite superfluous relabeling exercise). Gowland Hopkins already realized the importance of a minimal list of variables in 1912,[10] and the living organism as a system received thorough mathematical description in Sommerhoff's *Analytical Biology*.[12] Furthermore, ecology, indubitably part of biology, is nothing but systems.[13]

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[3] R. Shaw, Strange attractors, chaotic behaviour, and information flow. *Z. Naturforsch.* **36a** (1981) 80–112.
[4] E. Lorenz, Deterministic nonperiodic flow. *J. Atmos. Sci.* **20** (1963) 130–141.
[5] W.P. Holland, The phases of matter. *Nanotechnol. Perceptions* **7** (2011) 99–140.
[6] W.P. Holland, Snowflakes, snow crystals, hail and rain. *Nanotechnol. Perceptions* **10** (2014) 164–172.
[7] W.P. Holland, The critical temperature and the atmosphere. *Nanotechnol. Perceptions* **11** (2015) 106–115.
[8] D.S. Chernavsky, Synergetics and information. *Matematika Kibernetika* **5** (1990) 3–42 (in Russian).
[9] J.C. Robinson, All possible chaotic dynamics can be approximated in three dimensions. *Nonlinearity* **11** (1990) 529–545.
[10] F. Gowland Hopkins, Feeding experiments illustrating the importance of accessory factors in normal dietaries. *J. Physiol.* **44** (1912) 425–460. See ref. 11 for a thorough account of one of these "accessory factors".
[11] R.D. Semba, On the 'discovery' of vitamin A. *Ann. Nutrition Metabolism* **61** (2012) 192–198.
[12] G. Sommerhoff, *Analytical Biology*. London: Oxford University Press (1950).
[13] In contrast, economics, especially in the standard neoclassical–Keynesian synthesis, ignores the environment. This may have been an acceptable approximation when the human population was very small, but by the time economics began as a subject in its own right human activities were already prominently impinging on their surroundings.

2. Systems and administration

One might suppose that the administration of human affairs would be amply suffused with systems thinking, given that those affairs are hugely influenced by connexions between individuals, each of whom is himself a system, as has long been realized.[14] This supposition is, alas, far from the truth. As H.A. Simon has remarked, "administrative man recognizes that the world he perceives is a drastically simplified model … He makes his choices using a simple picture of the situation but takes into account just a few of the factors that *he regards* as most relevant and crucial"[my emphasis].[15] His reason for so doing is "Because he treats the world is rather empty and ignores the interrelatedness of all things (so stupefying to thought and action), administrative man can make decisions with relatively simple rules of thumb that do not make impossible demands upon his capacity for thought".[15] It is unexceptionable to assert that the mental constitution of administrative man is very different from that of the systems engineer or cyberneticist. Typically—especially if he is an official in the British civil service—he will have had a classical education. The choice of factors will have been made largely intuitively, without the systematic search for those that yield closed and single-value transformations. Simon is sanguine about that state of affairs: "Administrative man satisfices—looks for a course of action that is satisfactory or 'good enough'." Were the results generally satisfactory, those who are administered would have little cause to complain. Unfortunately the results of government projects are generally unsatisfactory. Some recent and ongoing failures in the UK are:

- The NHS National Programme for Information Technology[16]
- The (existing) railways of Britain—gravamina include the extraordinary slowness of planning and implementing sorely needed additions to the network (including reopening closed sections), as well as the general lack of competition between the different train operating companies (private but closely state-regulated), primarily because so many of them have been consolidated into the same company
- HS2 (a brand-new, high-speed railway)—construction has not yet started but in a sense it has already failed because the initial budget (2010) was 33 milliard GBP, and it was approved on that basis, but more realistic current estimates indicate that the project may cost three times that sum
- "Smart" meters for electricity and gas
- Planning and building houses
- The "clean growth strategy"
- The Cambridge–Milton Keynes–Oxford corridor, also known as the Oxford to Cambridge arc—at present merely a proposal, much championed by the National Infrastructure Commission, but lacking democratic assent and riddled with self-contradictions, such as plans to construct a million houses, but also a giant expressway for road vehicles and several incinerators for municipal and medical waste etc.[17]

[14] A. Bain, *The Senses and Intellect*. London: John Parker (1855).
[15] H.A. Simon, *Administrative Behaviour: A Study of Decision-Making Processes in Administrative Organizations*. New York: Macmillan (1948).
[16] G. Sampson, Whistleblowing for health. *J. Biol. Phys. Chem.* **12** (2012) 37–43.
[17] A more extensive survey is to be found in *The Blunders of Our Governments* by A. King and I. Crewe (London: Oneworld Publications, 2013); however, the authors' definition of "blunder" seems somewhat esoteric, and the attempts to explain them are trite.

There are, of course, many more (the above are merely some of the more prominent—and expensive—ones). Nor is the phenomenon new—a well-known example of failure some decades ago is the Tanganyika groundnut scheme. Given the weight of evidence, one might be inclined to propose that projects administered by government are never satisfactory. It is, however, difficult to say simply that government should not be involved in such kinds of activity. The United Kingdom anyway has no written constitution defining roles, responsibilities and powers. Even the federal constitution of the USA, which is written down, is rather vague, defining the purpose of government as "to establish justice, insure domestic tranquility, provide for the common defense, promote the general welfare, and secure the blessings of liberty to ourselves and our posterity." Presumably projects such as those listed above, all of national significance, could be said to be intended to "promote the general welfare". Could such promotion be left to the private sector, which is necessarily geared to providing what the market desires? The railways of Britain, constructed by private capitalists, were at one time the envy of the world. On the other hand the Swiss Federal Railways, which date back to the end of the 19th century as a state enterprise, became the envy of the world after the Second World War, when the railways of Britain were nationalized. Interestingly, in the early years of telephone service in the UK, the providing companies were private, and were only nationalized because it was felt that the government could be better trusted to strictly respect the confidentiality of communications. Perhaps the biggest weakness of the market is that its institutions "and the kind of behavior which is involved in commercial life, are inadequate to generate the motivations of responsibility and of concern for others which are both desirable in themselves and necessary as a cement of the social fabric" (Boulding).[18]

The record of the private sector is mixed. A spectacular recent failure was that of the company Carillion. Interestingly, in July 2017, just 6 months before the collapse, Keith Cochrane, who had been a member of the board of directors since 2015, was appointed interim chief executive with a mandate to simplify the company, which "had become too complex". Looking at some of the spectacular recent failures in the privatized rail sector (such as the collapse of the East Coast rail franchise in May 2018, and the new timetable chaos, especially on the Great Northern and Thameslink railways, also in May 2018), it would appear that projects of comparable size and complexity are prone to failure, whether administered by the government or privately.

3. Reasons for failure

Simon lists three or four accepted administrative principles: administrative efficiency is increased by: specialization; by arranging administrators in a determinate hierarchy of authority; by limiting the span of control; and by grouping workers according to purpose, process, clientèle and place (this is simply making the specialization of the first principle more explicit).[19] All these principles manifestly militate against systems thinking. But they give no clue regarding the mechanisms underlying failure. Insight into the roots comes from C.N. Parkinson, and his eponymous law: work expands so as to fill the time available for its completion.[20] It is based on two axioms: (1) An

[18] K.E. Boulding, The principle of personal responsibility. *Rev. Social Economy* **12** (1954) 1–8.
[19] H.A. Simon, The proverbs of administration. *Public Administration Rev.* **6** (1946) 53–67.
[20] C.N. Parkinson, *Parkinson's Law*. Harmondsworth: Penguin Books (1963).

official wants to multiply subordinates, not rivals; and (2) Officials make work for each other. Parkinson is careful to point out that these two statements are "almost axiomatic". They have, in fact, deeper roots: cupidity and venality,[21] roots which are shared by both the public and private sectors, and this sharing leads to their convergence, an effective mechanism for which is the zealous lobbying undertaken by private companies to win government contracts.[22]

4. Some principles relevant to complex systems

At the 2007 "Complexity & Security" workshop, Peter Allen presented his "cloud diagram" (Fig. 1), showing the successive imposition of assumptions that distance understanding from reality but at the same time render it tractable. The first assumption, assuming a boundary, allows a model with some local sense-making possible, without supposing any particular structure. The second assumption is to impose classification; this permits strategic, open-ended evolutionary–structural change to occur; statistical distributions can be multimodal. The third assumption is that every type is represented by its average. Models at this level encompass operational, probabilistic, nonlinear equations, master equations and Kolmogorov equations, all assumed to be structurally stable. Statistical distributions are often power laws. The fourth assumption is that statistical attractors exist; self-organized criticality belongs here; in essence these models suppose that events are represented by their averages. The fifth assumption is that we are at equilibrium, the model of classical economics.

Even realistic modeling of simple ecosystems without assumptions 3–5 reveals "unexpected" (to the classical, equilibrium modeler) behavioural features. For example, less-fit mutants may not be eliminated from an evolving population with appropriate stochasticity.[24] This result, incidentally, refutes neo-Darwinism and the neutral drift theory of evolution. A microscopic, cellular automaton model provides a detailed interpretation based on local encounters and fights for dominance.[25]

Another idea to emerge from the 2007 "Complexity & Security" workshop was a development of Ashby's diagram of immediate effects.[26] An example is shown in Fig. 2. The main practical use of these diagrams is to allow self-reinforcing loops to be identified.

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[21] J.J. Ramsden, Commercial integrity. *J. Biol. Phys. Chem.* **17** (2017) 155–162.

[22] Government contracts are perceived as being extraordinarily lucrative, not so much for the company to which they are awarded as for the individuals involved in their negotiation. Thus, there is a certain temptation to lower bids for given pieces of work, in the knowledge that the government tends to choose the cheapest alternative, to the extent that the company winning the contract cannot ultimately fulfil the work without incurring losses.

[23] P.M. Allen and M. Strathern, Complexity, stability and crises. In: *Complexity and Security* (eds J.J. Ramsden & P.J. Kervalishvili), pp. 71–92. Amsterdam: IOS Press (2008).

[24] P.M. Allen and W. Ebeling, Evolution and the stochastic description of simple ecosystems. *BioSystems* **16** (1983) 113–126.

[25] S. Galam, B. Chopard and M. Droz, Killer geometries in competing species dynamics. *Physica A* **314** (2002) 256–263.

[26] J.J. Ramsden, General survey. In: *Complexity and Security* (eds J.J. Ramsden & P.J. Kervalishvili), pp. 1–6. Amsterdam: IOS Press (2008).

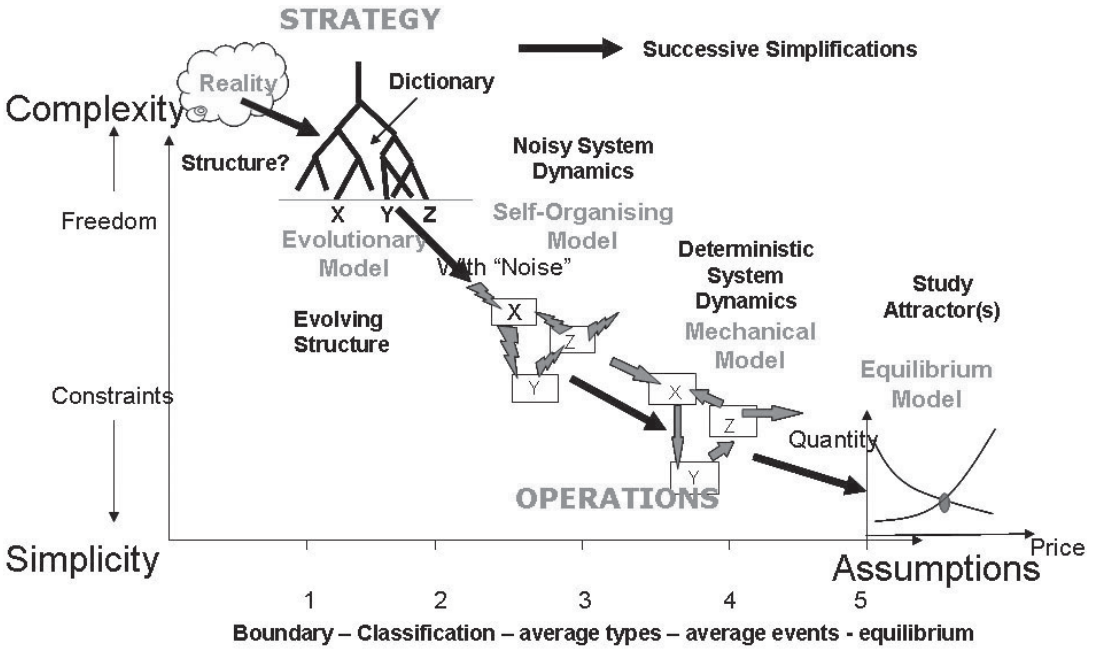

Figure 1. The choice of successive assumptions that lead to "scientific" understanding of a situation. From Allen & Strathern (2008).[23] Reproduced with permission.

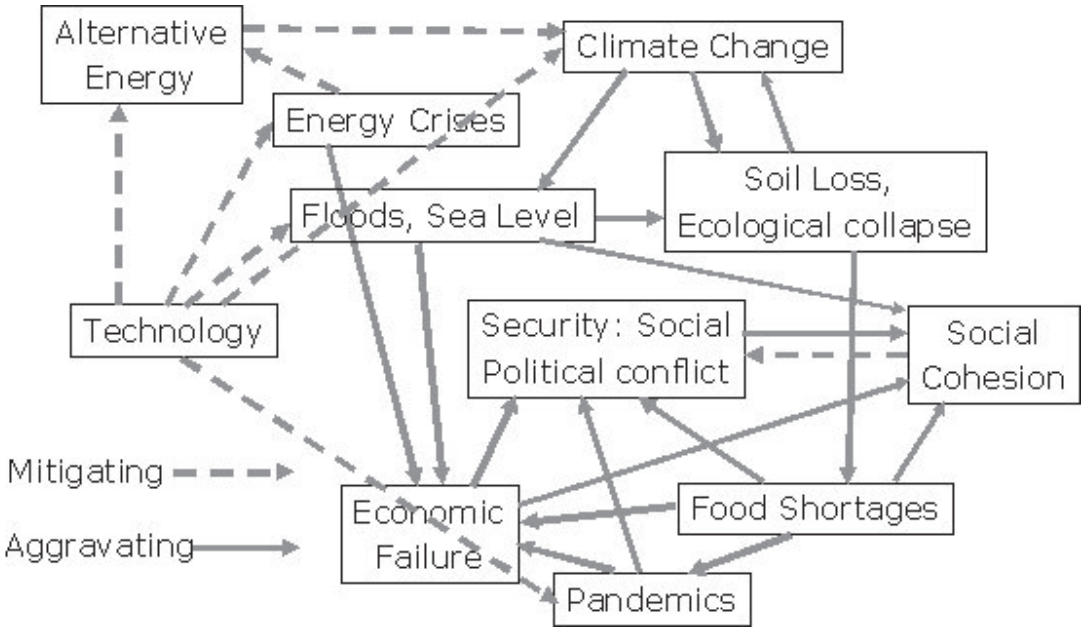

Figure 2. Global diagram of immediate effects. From Ramsden (2008).[26] Reproduced with permission.

At present, these diagrams are constructed heuristically from the knowledge of the experts constructing them, but there seems to be no reason why the process could not be automated with the help of powerful Internet search engines. Fig. 3 shows an example constructed for this paper, in order to serve as a policy guide to whether use of the herbicide glyphosate should be restricted. It may be somewhat reassuring to those concerned about adverse health effects of glyphosate (cf. ref. 27) that this diagram does not contain any self-reinforcing loops.

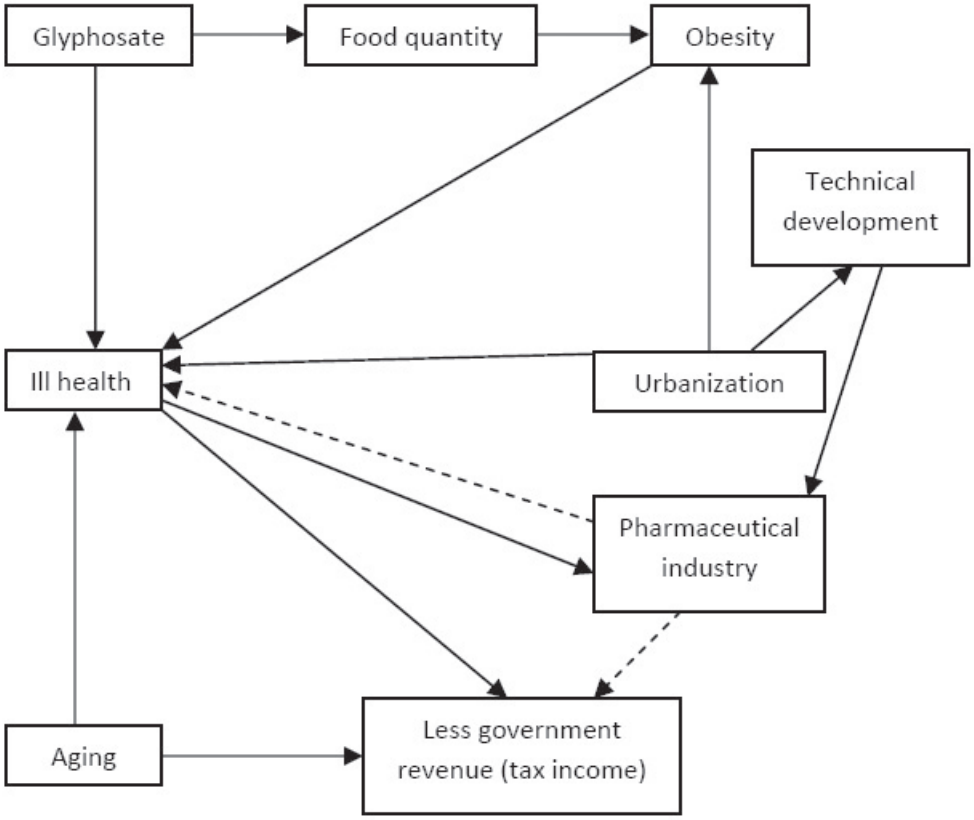

Figure 3. Diagram of immediate effects constructed to assist formulating a policy regarding the use of the herbicide glyphosate. As in Fig. 2, solid lines indicate aggravating effects (that is, an increase of the entity at the origin of an arrow results in an increase of the entity at the end of the arrow) and dashed lines indicate mitigating effects (the opposite).

5. Proposals to improve the quality of administration

It is obvious that the thrust of this paper is for more systems thinking to be incorporated into administrative practice. Before examining how this might be achieved, let us consider how administrators are appointed. There seem to be three main possible pathways:

[27] A. Samsel and S. Seneff, Glyphosate, pathways to modern diseases IV: cancer and related pathologies. *J. Biol. Phys. Chem.* **15** (2015) 121–159.

1. Society needs a certain number of people to do the donkey work of administration; it is a job like any other essential service, such as ambulance driving;

2. Administrators have special skills, which might include the ability to hold more than the usual limit of seven concepts in the mind at any one time;[28] a special ability to make judicious simplifications that do not vitiate the relevance of the resulting model of reality; generalist skills to overcome the "experts' fallacy" (i.e., over-readiness to pigeonhole the problem as one that the expert has already dealt with);

3. Employees in organizations have noticed that administrators are often more powerful and highly paid than staff with expertise relevant to the core mission of the organization. Hence, especially for staff whose expertise is weak, moving to administration offers an attractive career prospect.[29]

Comments on these pathways:

1. This work can be, and indeed is, increasingly carried out by those who are administered, with the help of electronic data-processing;

2. The litany of administrative mistakes (§2) suggests that administrators do not have special skills (whose existence might anyway be doubted from the fact that degree courses in administration nowhere seem to endeavour to inculcate the special skills mentioned); at best the generalist administrator is a humanist, or simply humane, contributing to civilized society;

3. The least palatable pathway; note that weak skills (e.g., in science or engineering) do not imply strong skills in administration.

If administrators lack any special skills, the question might well be asked what added value they offer beyond the people themselves deciding, as in the Swiss system of referenda. This system works well in Switzerland, a relatively small country with a good level of education, enabling the majority of the population to intelligently appraise the measures to be voted upon, and a high general level of prosperity, hence people are not tempted to vote on the basis of financial self-interest. In larger, more heterogeneous societies, it is presumably claimed that the administrator has a better overview than what is perceived from a local standpoint and can, therefore, judge more reasonably what is to be done. Plans for national infrastructure (e.g., HS2) are almost invariably opposed by local residents but their views are almost invariably overridden by the central authorities, supposedly in the national interest.

The above comments provide some clues to what might be done to improve administrative performance:

1. Endeavour to exploit artificial intelligence (AI) to the utmost. Algorithms should be developed to enable diagrams such as those shown in Figs 2 and 3 to be constructed largely or wholly automatically. The insight thus gained should provide powerful policy indications. Ultimately it may still be necessary to decide between two or more alternative actions that are, as far as can be discerned, equally beneficial. A popular vote may be appropriate to make a final decision—with, in all likelihood, as much wisdom as can be expected from government

[28] G.A. Miller, The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychol. Rev.* **63** (1956) 81–97.

[29] In the UK's scientific civil service, great effort was made to avoid the loss of strong expertise by the special merit promotion pathway, allowing excellent scientists to hold posts of high rank without administrative burdens.

ministers who, let it be remembered, are typically appointed after many years of hack work in their political party, and so frequently shuffled between posts that they can scarcely be expected to acquire expertise.[30] It is particularly regrettable that despite the enormous proliferation of universities, think tanks and knowledgeable private citizens, ministers seem to be less and less receptive to the advice emerging from these often well-qualified groups.

A powerful tool for assessing specific proposals for action is the judgment or J-value,[31] in which the maximum reasonable spend on some policy measure is determined objectively on the basis of a quality-of-life index: ultimately every measure prolongs human life, which can be associated with a monetary gain, offsetting the cost of the measure; balancing the two allows the locus of $J = 1$ to be defined.

2. Endeavour to train a new generation of professional administrators by inculcating them with the skills to appreciate such concepts as the "cloud diagram" (Fig. 1), diagrams of immediate effects (Figs 2 & 3) and cost–benefit appraisals based on the J-value, as well as systems thinking in general.[33]

3. Even partial success through following clues 1. and 2. will hopefully render superfluous the appointment pathway 3, which so easily becomes associated with venality and maladministration.

6. Conclusions

Existing arrangements for planning and decision-making are not fit for purpose, as evinced by the large number of administrative failures. Given that reform of the way of thinking of administrators is a rather forlorn hope, the best realistic chance of improvement is to pursue the automation of administrative decision-making. Bodies such as the UK National Infrastructure Commission should be abolished and replaced by a modest office curating the algorithms creating diagrams of immediate effects for policy areas and computing J-values for specific actions; those with $J > 1$ should be summarily rejected. The selection of equally beneficial alternatives can be made by presenting them to citizens or their elected representatives.

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[30] The formal role of the minister is to advise the monarch, but even in former years this has been recognized as often unsatisfactory. When Lord Rochester penned a premature epigram-epitaph for King Charles II:

> Here lies our sovereign Lord, the King,
> Whose promise none relies on;
> He never said a foolish thing,
> Nor ever did a wise one.

he responded with "My words are my own, and my actions are my ministers'."

[31] Thomas (2018)[32] and references therein.

[32] P. Thomas, Responding after a big nuclear accident. *Nanotechnol. Perceptions* **14** (2018) 69–79.

[33] Or simply to appreciate thinking, especially in the light of the assertion, articulated I believe by Bertrand Russell, that "most people avoid thinking".