Invited Editorial

An enquiry into the place of systems analysis in the politics of water and the environment

J. Philip O'Kane

ABSTRACT

In many jurisdictions, the participation of stakeholders in decisions concerning their environment, and their water environment in particular, is still carried out, if at all, on an *ad hoc* basis. This paper envisions a legislative structure that allows a natural participation by the people in decision-making. While systems analysis and models may inform opinion in the ideal Legislature, especially among its members who are systēm analysts (economists, engineers, and physical scientists), the models carry with them the bias of the systēm viewpoint: the 'whole', within which particular environmental and water problems arise, is externalized as a solid-like, inanimate, analyzable, and quantifiable object, reduced to the sum of its parts. The representation of such objects by web-enabled hydroinformatic systems does not erase the bias; it may even amplify it. The alternative 'intuitive way of seeing in the mind's eye the whole in every part' is the appropriate way for those members of the Legislature who have not learned the systems viewpoint. Quiet and observant immersion in (1) the company of those who know first-hand the issues at stake; (2) rhetoric, dialectic, and face-to-face eye-contact with those who are concerned; and (3) practice in Goethe's way of science may help us become better participants in the creation and deliverers of social justice for our fellow beings.

Key words | anti-system, legislature, power-sharing, social justice, stakeholder, water resources

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PREFACE

This paper was originally presented in a shorter form as a keynote address at the Dooge-Nash International Symposium, Dublin Castle, 24–25 April 2014. In response to questions from the Press, Jim Dooge sometimes explained his outstanding career as hydrologist, hydraulic engineer, academic, and politician, as a consequence of his decision to keep these disciplines separate from each other as much as possible – in their respective silos. This paper salutes his memory by enquiring into the intersection of two disjoint areas of his expertise: systems and politics. The text may be regarded as notes for a conversation that were, alas, written too late for his scrutiny.

The paper has seven parts. The first three are concerned with the concepts of 'system', 'not-a-system', and 'water-resource systems design and planning'. The fourth part forms a coda leading into section 5 on 'politics', and section 6 on a grand challenge for the 21st century: 'how might the political class share power with the people?'

The coda takes the form of a long quotation from W. H. Auden on crowds, societies, communities, and orders (with exercises for the reader) to highlight the difference between associations of people and the synchronized parts of a machine or system.

The seventh and final section draws the conclusions together.

Extensive endnotes provide depth to this enquiry, which may also be read as a partial response to the recent work of Michael B. Abbott and Zoran Vojinović on *Flood Risk and Social Justice: From Quantitative to Qualitative Flood Risk*

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SYSTĒM

The concept of 'systēm' is common to all branches of engineering.[1] It is so fundamental, so taken for granted, so mathematically simple, that many engineering texts never discuss it; they just work it. However, the pejorative use of the word in 'I blame the systēm' should prompt us to enquire into the meaning of 'systēms analysis', and in this essay, into its relevance to the politics of water and the environment. The overstrike on the letter ē used throughout this essay is explained in the second endnote in the next paragraph.

A 'systēm' is an object consisting of many parts that stand, act, or function together. The root of the Greek word *σύστημα systēma* is two-fold, the prefix *σύμ sym/syn* meaning 'together', and the verb ἵσταναι *histanai* (ἵστημι *histēmi*) 'to cause to stand'.[2] The togetherness of a systēm demands an absence of contradiction, conflict, denial, absurdity, paradox, or illogicality, among its parts.

The word 'analysis' is also from the Greek: a prefix *ana* meaning 'from' and the verb *luein* to loosen or release. The contemporary meaning of 'analysis'[3] is a dissolving, a lysis, a cutting, a separation, or division of a physical or abstract 'whole' into its constituent parts in order to examine or determine the relationship of each to one another. The parts of analyzable solid bodies have the properties of 'separation, externality, quantity, fragmentation, identity, fixity, solidification, and mechanical causality',[4] properties, which are self-evident at the human scale, but are not so at the atomic scale of the physical world.[5]

The clock-like, energized machine, made of many solid parts, is the archetypal systēm. The machine functions correctly, when all its parts are made to stand properly together in relation to one another at all times. When the parts are synchronized the machine is ready to hand, as designed, as intended, a useful working systēm.

Philosophy, logic,[6] and mathematics also use the word 'systēm'. Euclid's Geometry is the first systēm of knowledge about our world of solid objects[7]: axioms and theorems made to stand together in systēmatic order by a process of logical deduction free from contradiction. Since this was achieved by design, mathematics, especially geometry, has ever since stood as a much-loved metaphor[8] for engineering, and for the design of engineering systēms.

The mathematical structure of an analyzed systēm begins with two related sets: a set of elements P (parts) and a set of relations R between these elements, forming a directed graph of points (vertices, nodes) and arrows (arcs, edges) when P is a finite set. The concept of the 'whole systēm' is simply the directed graph of its two constituent sets, the 'sum' of its parts. Directed graphs with at least one circuit in the arrow diagram describe systēms that are closed with respect to feedback of matter, energy, or information. Otherwise, they are open, exchanging without feedback, matter, energy, or information, with an unspecified environment across the systēm boundary, a synonym for the membership criteria of the set P. When proper subsets are present in P, different symbols may be used to highlight them. When subsets exhibit an inclusion relationship, they also form a hierarchy.

The goal of further systēms analysis is an abstract quantitative mathematical model that facilitates the description, understanding, prediction, and control of the corresponding real systēm. Such models are usually built from the bottom up by adding parts and relations seriatim to the original model.[9] World climate and environment models have been built in this manner.[10] Input–output black-box models are restricted to the flows across the systēm boundary, i.e., the relationships between the sets P and not-P.

WHEN IS AN OBJECT NOT A SYSTĒM?

A physical object is not a systēm[11] when either the set P of its parts, or R, the set of relations between the parts, is a null set, or, of much greater significance, when two or more of its parts stand in contradiction to each other, that is when they do ***not*** stand, act, or function ***together***.[12]

The human operatives of an ergonomically designed machine, by definition, accept and resolve all lesser contradictions (in contrast to the greater contradiction of ignoring the free will of the operatives), and in so doing willingly act as parts of a man–machine systēm maintained in operation. The International Ergonomics Association (http://en.wikipedia.org/wiki/Ergonomics) defines ergonomics as:

> "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a systēm, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall systēm performance."

This engineering definition is disquieting. It fails to include the creative exercise of free will by human operatives, which is essential to their well-being and human dignity, however well their activities may be facilitated by ergonomic design. But if we recognize the free will of the operative, we leave open the possibility that he or she may not be 'in systēm' with either the engineered machine or fellow operatives. Consequently, the machine may not function as designed, as intended, and we may then say it is 'out of systēm' because a greater contradiction is present. New words: 'apo-stēm', 'kata-stēm', and 'anti-stēm'[13] are needed to describe such eventualities.

The computer scientist Gerald M. Weinberg in Chapter 3 'System and Illusion' of his book *An Introduction to General Systems Thinking*[14] asks (in italics),

> "What is a system? As any poet knows, a system is a way of looking at the world. The system is a point of view – natural for a poet, yet terrifying for a scientist! As soon as she recognizes the path we are about to take, she rebels, …, as if we are about to impose some falsehood on her. To speak of systems in this way is to play a game, not to acquire knowledge. Knowledge is "truth". Knowledge is "reality". If two scientists viewing the same scene have different "systems", then science will be "no better than" poetry, where one man can see a "wild civility" in another man's "sloppy clothes". Very well, let us assault fears. Look at (Figure 1 of this paper) Figure 3.1? What do you see? A young maiden, … or a crinkled hag, … ?"

Figure 1 | What do you see? (Figure 3.1 in Gerald M. Weinberg 'An Introduction to General Systems Thinking', Dorset House, New York; Silver Anniversary Edition, 2001. Loc. 1215. Kindle edition).

Observe the ambiguous ear–eye of this poet–scientist.

When we wish to see the 'wholeness' of a phenomenon in our mind's eye, conceived as an object of our perception or experience, analyzing it into a set of interrelated parts destroys what we seek. By separating and then interrelating the parts as a systēm, we externalize as a solid-like object the 'whole' we strive to know. The physicist Henri Bortoft (1938–2012) calls this a 'counterfeit whole' reduced to the sum of its parts, in contrast to the 'authentic whole' in our mind's eye where each part is an intuitive[15] expression of the whole. He concludes[16] that 'Goethe's (neglected scientific) procedures are practical exercises for educating the mind to function intuitively instead of intellectually' and lead the *Naturschauer* (Goethe's observer of nature; *schauen* to look) to a 'phenomenology[17] of nature'.

To quote Henri Bortoft,

> "Systēms theory cannot be the basis of a science of wholeness, as is often claimed. When this kind of thinking is applied to life it results in an absurdity. The notion of a living systēm, as opposed to one which is non-living, is a contradiction in terms. … If it is a systēm, as defined above, then it cannot be living because what is living cannot consist of parts which are external to one another, i.e. which are separate. If we treat what is living in this way we kill it. Systēms theory is no more than 'systēms analysis' ('lysis': to separate). A living organism cannot

be 'analysed', whereas what is non-living can be, since the possibility of analysis is the very characteristic of the inorganic – cf. Galileo's discovery that the motion of a projectile can be analysed into horizontal and vertical components and conversely can be synthesized from such components. … We can now see that, far from being a new way of thinking, systēms theory has its roots in the mechanical philosophy of the 17th century.[18] Thus we are able to avoid the mistake of believing that systēms thinking[19] is the way to understand the organic."[20]

The 2009–2012 strategic plan of the United Nations University 'Towards Sustainable Solutions for Global Problems' in Section 1.4 'Leading through a systēms approach' says

> "Today's problems connected with sustainability are too complex to be dealt with in a discipline-by-discipline manner. In particular, the division between social and natural sciences is often in the way of a thorough understanding of critical problems. What is called for is a "systēms" approach making substantial use of modern modeling techniques and of high-speed computers" (http://unu.edu/).

The view expressed in this essay agrees with the first two sentences, but disagrees with the conclusion since most social, environmental, economic, and political objects are not quantitative systēms. The spectacular failure of systēm models of the US and UK economies and their financial services sectors to predict the recent economic crisis should make us pause and reflect,[21] and likewise the continuing weakness of world climate models to reproduce climate data.[22]

When stakeholders seek to develop and manage their environment, their hydraulic and living world, we may observe the exercise of overt and covert power, and the presence of misunderstanding, doubt, helplessness, and cynicism. Contradiction among stakeholders feeds conflict over water, the associated engineering systēm hardware, socio-economic benefits, and aquatic life. It is a world lacking in systēm, to a lesser or greater extent, and it is abhorrent to human values to impose systēm on stakeholders by force.[23]

Resolving these contradictions requires a process, a political process, in which design and planning are embedded.

WATER-RESOURCE SYSTĒMS DESIGN AND PLANNING

The methodology of systēms design, presented in the seminal book edited by Arthur Maass,[24] involves four related steps as follows:

(1) identifying the objectives of design;
(2) translating these objectives into design criteria;
(3) using these criteria to devise plans for the development of specific water-resource systēms that fulfill the criteria in the highest degree; and
(4) evaluating the consequences of the plans that have been developed.

These four steps provide the answers to the three questions that constitute the engineers' philosophy of action as follows:

- Why do it at all?
- Why do it this way?
- Why do it now?[25]

The unification of benefit–cost analysis and water-resource engineering (hydro-power, water supply, irrigation, recreation, etc.) that was achieved by Arthur Maass and his academic colleagues[26] is now part of standard practice among international development banks. The design problem is reduced to a computerized search for those alternatives that maximize economic efficiency benefits subject to constraints on the distribution of those benefits by region and/or by social class.

Economic efficiency benefits are defined to be the aggregated notional willingness of beneficiaries to pay for water benefits less the opportunity costs of capital works and discounted life-time costs of systēm operation, maintenance, and replacement. While the systēms way of seeing (hydrology and hydraulics) is appropriate for the physical water-resource hardware, it is not so for human political and economic agents and stakeholders who do not form a systēm. In the latter case, quantitative systēms analysis may be a delusion.[27] In the public sector, a political process is required.[28]

In the final chapter of his book, Arthur Maass (1918–2004)[29] embeds large-scale water-resource systēms design and planning in the political institutions of the USA in accordance with the goals of the Founding Fathers of the 18th century: equality, liberty, and community. At the federal level, he argued the debate should be about objectives for the development of federal water resources: economic efficiency, redistribution of benefits, hydro-power, water quality, etc. from the top down, and which are finally expressed as specific facilities proposed at the lowest level of the political pyramid. Maass recognized that this is an ideal view far from pork-barrel politics where local issues feed back onto the political agenda at the federal level.

Fifty years on, urban and regional planners now speak of a crisis in planning[30]; political scientists speak of a growing democratic deficit, and activists speak of environmental time-bombs, disasters and mass-extinctions in a globalized world.[31] A look at www.gapminder.com – a fact-based view of the world – shows that access to the media of today demands exaggeration. Nevertheless, such problems suggest a political response of a different kind, a re-imagining of the political process itself, a grand challenge for the 21st century.

POLITICS – CROWDS, SOCIETIES, COMMUNITIES, AND ORDERS

In order to highlight the difference between associations of people and the synchronized parts of a machine or system, we begin by asking: Which of these pluralities: crowds, societies, communities, and orders, in the following quotation from W. H. Auden,[32] are 'authentic wholes'[33] wherein the whole is perceived intuitively in each and every part, or 'counterfeit wholes' where the whole is reduced to the sum of its parts, a solid-like analyzable systēm?

"A crowd

A crowd comprises $n > 1$ members whose only relation is arithmetical, they can only be counted. A crowd loves neither itself nor anything other than itself; its existence is chimerical. Of a crowd it may be said, either that it is not real but only apparent, or that it should not be. (Is R (crowd) a null set? Is the revolutionary mob simply a crowd?)

A society

A society comprises a definite or an optimum number of members, united in a specific manner into a whole with a characteristic mode of behavior, which is different from the modes of behavior of its constituent members in isolation. A society cannot come into being until its component members are present and properly related; add or subtract a member, change their relations, and the society either ceases to exist or is transformed into another society. A society is a system, which loves itself; to this self-love, the self-love of its members is totally subordinate. Of a society, it may be said that it is more or less efficient in maintaining its existence. (May we say a political party, a parliamentary party, a cabinet, a house of parliament, is a society? Is a professional body such as Engineers Ireland a society?)

A community

A community consists of n members united, to use a definition of St Augustine's, by a common love of something other than themselves. Like a crowd but unlike a society, its character is not changed by the addition or subtraction of a member. It exists, neither by chance, like a crowd, nor actually, like a society, but potentially, so that it is possible to conceive of a community in which at present, $n = 1$. In a community, all members are free and equal. If out of a group of 10 persons, 9 prefer beef to mutton and 1 prefers mutton to beef, there is not a single community containing a dissident member; there are two communities, a large one and a small one. To achieve an actual existence, it has to embody itself in a society or societies, which can express the love, which is its 'raison d'être'. … Such an embodiment of a community in a society is an order. Of a community, it may be said that its love is more or less good. Such a love presupposes choice, so that in the natural world of the Dynamo, communities do not exist, only societies, which are submembers of the total system of nature, enjoying their self-occurrence. Communities can only exist in the historical world of the Virgin, but they do not necessarily exist there.

> Whenever rival communities compete for embodiment in the same society, there is either unfreedom or disorder. In the chimerical case of a society embodying a crowd, there would be a state of total unfreedom and disorder; the traditional term for this chimerical state is Hell.
>
> **An order**
>
> A perfect order, one in which the community united by the best love is embodied in the most self-sustaining society, could be described, as science describes nature, in terms of laws-of, but the description would be irrelevant, the relevant description being 'Here, love is the fulfilling of the law' or 'In His will is our peace'; the traditional term for this ideal order is Paradise. In historical existence where no love is perfect, no society immortal, and no embodiment of the one in the other precise, the obligation to approximate to the ideal is felt as an imperative 'Thou shalt'."

At the end of this quotation from Auden, we may ask: Is the political class in a modern democracy a community? Is the higher civil service a community? Is the business class, the rentier class, and the working class, a community? If not, what are they?

While people may try to bind themselves with a system of behavioral rules, the freedom enjoyed by each person to act against the rules, whether according to conscience or not, ensures that the concept of a socio-economic-environmental-political 'system' is at best a fragile approximation: an 'apostem', at worst a contradiction in terms: an 'antistem', or simply a delusion waiting to be beaten down: a 'katastem'.

RE-IMAGINING THE POLITICAL PROCESS

The grand challenge for the political class in the 21st century is to say publicly to the people as follows:

> 'We, the political class, will share power with you, the people, in order to fulfill the promise of liberty, equality and fraternity'.

It may no longer be said that the people are uneducated, incapable of understanding what is in their interest, and lacking in love for their fellow beings. If this is accepted, the issue is how to share power. The sharing should be experimental, progressive, and subject to revision. In the first instance, it requires a re-imagining of the Legislature, as the source of political action. The engineers' philosophy of action suggests that the Legislature should have three houses in one-to-one correspondence with the three questions that must be answered before action is sanctioned. These are

(1) The House of Representatives of the people where the question is
   - Why do it now?

(2) The Senate of the brightest and best where the question is
   - Why do it at all?

(3) The House of the Taxpayer where the question is
   - Why do it this way?

The raising and spending of taxes is the primary political act on which depend security and the law, social justice and welfare, health and education services, etc. A parliament of three houses makes this explicit: the Senate 'proposes', the House of Representatives 'disposes', and the House of the Taxpayer 'surposes' demanding economic efficiency, transparency, probity, and accountability in the collecting and spending of taxes. Its expertise arises from 'ex post' evaluation of previous decisions. The Senate proposes to the other two houses a range of alternatives. The House of the Taxpayer appends a commentary with proposed amendments; it does not set the overall level of taxation or how it falls on social class or region. The House of Representatives selects one alternative for action by the Executive Branch. The tri-cameral parliament is pictured in Figure 2.

THE SHARING OF POWER WITH THE PEOPLE

Power may be shared with the people in three ways. The first is through the method of appointment to the each of the three houses for a fixed term of office. The second is by popular referendum on the web moderated by a president with

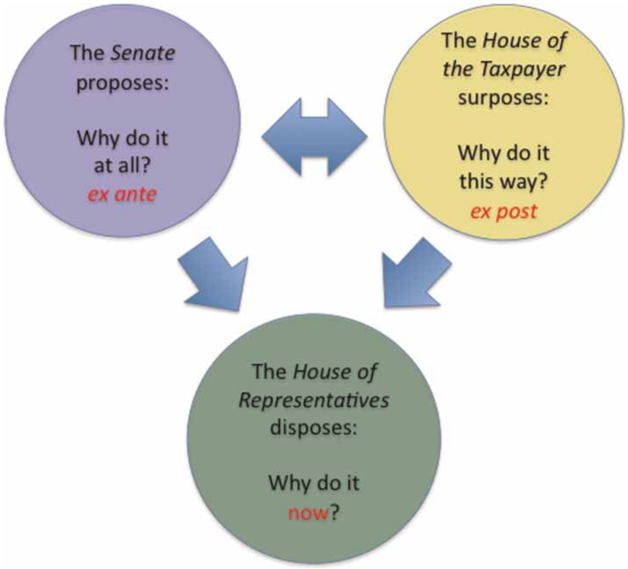

Figure 2 | The tri-cameral parliament.

appropriate powers. The third is the application of the principle of subsidiarity.

In the case of the House of the Taxpayer, appointment is by weighted random sampling[34] from the register of taxpayers maintained by the branch of the executive that collects all[35] taxes. The weighting is in proportion to tax paid on personal income or expenditure. The two mottos of the House are: 'one euro of tax, one vote' and 'no taxation without representation'. The intention is to provide 'high-net-worth' individuals, who pay their taxes, with a place where they can play their part in politics without recourse to covert funding of political parties, their members, or the media. The members of the House will note a natural stratification into those who are net beneficiaries of taxation (for example, public and civil servants, and social welfare recipients) and those who are not. Members vote according to conscience, seek no publicity, and do no constituency work.

The House of the Taxpayer addresses the question: why do it this 'way'? It may select one 'way' from several proposed by the Senate. It may comment on, but does not set, the overall level of taxation. Members are advised by a Secretariat on socio-economic, cultural and environmental issues, social justice, 'ex post' evaluation of previous decisions, value for money, stability of the banking and financial services sector, etc. All advice is published on the web. Oversight is by the president.

We may distinguish between two modes of representation of the people, active and passive. Half the seats in the House of Representatives are by election via the web in accordance with the traditions of the political class.[36] Successful candidates at the polls publicly represent their constituency and are subject to scrutiny by the media.

The remaining 50% of the seats are filled from the citizenry by stratified random sampling of the register of electors. These are the passive representatives of the people, who undertake no constituency work and seek no publicity in the media. They vote according to conscience. The stratification is intended to correct the bias produced by the election of the public representatives. For example, if only men are elected, random sampling to fill the remainder of the seats will be confined to the female half of the voting register. Age bias can also be corrected in the same way. This solves two problems that have confounded the mostly male political class for generations.

The mottos of the House are: 'one citizen, one vote' and 'no representation without taxation', the opposite of the House of the Taxpayer. The House of Representatives must levy taxes, or be dissolved and formed again, by presidential decree.

The seats in the Senate are filled in two halves with the brightest and best expertise in the land. The first half is by public election of candidates proposed by the political class using a list system. Each candidate provides the electorate with a curriculum vitae on the expertise she brings to the Senate and the proposals she might originate. The remaining seats are filled from bodies representing the social partners (trades unions, business representatives, and the higher civil service), research laboratories and institutes, universities, etc. Committees of public and private sector scientists meeting in closed session frequently deal with technical, health, social, and environmental issues. These discussions have political implications and should be brought into the Senate.[37]

The members of all three houses elect the cabinet, on merit, from among themselves.

The role of the political class in this model Legislature is to provide leadership. The whip systēm is no longer required and there are no spoils of public office for election winners. When there is no agreement in the Legislature, or when the citizens demand it in sufficient number, the president puts the matter to the people in a popular web-based referendum.

The people elect the president from those who have served at least one term in the Legislature. This may prove attractive to tax-exiles, or businessmen, who by chance are offered a seat in the House of the Taxpayer, or House of Representatives.[38]

This legislative model can be reproduced in a hierarchy (UN, EU, nation state, region, town, and district) so that decisions are made at the appropriate level in accordance with the principle of subsidiarity (http://en.wikipedia.org/wiki/Subsidiarity), sharing power with the people in the spending of taxes raised separately at each level of the hierarchy. The governing principle is that each layer of the hierarchy has the power to tax and spend on matters, which cannot be devolved to a lower level. In the case of the development and management of water and environmental resources, the basis of the hierarchy is the river basin, and its tributaries. In the case of cities it is, in the first instance, the whole urbanized area.[39]

CONCLUSIONS

In many jurisdictions, the participation of stakeholders in decisions concerning their environment, and their water environment in particular, is still carried out, if at all, on an *ad hoc* basis. This paper envisions a legislative structure that allows a natural participation by the people in decision-making. The procedural rules of a Legislature form a systēm; however, its operation within those rules cannot be a systēm, because of the contradictions in the political positions of its members. It is better described as a 'legislative apostēm' always falling 'away from' the purposeful 'standing' together of all the citizens. Consequently, there is a continuous need for revision of the Legislature by the people.

While systēms analysis and models may inform opinion in the ideal Legislature, especially among its members who are systēm analysts (economists, engineers, and physical scientists), the models carry with them the bias of the systēm viewpoint: the 'whole', within which particular environmental and water problems arise, is externalized as a solid-like, inanimate, analyzable, and quantifiable object, reduced to the sum of its parts. The representation of such objects by web-enabled hydroinformatic systēms does not erase the bias; it may even amplify it.

The alternative 'intuitive way of seeing in the mind's eye the whole in every part' is the appropriate way for those members of the Legislature who have not learned the systēms viewpoint. Quiet and observant immersion in (1) the company of those who know first-hand the issues at stake, (2) rhetoric, dialectic, and face-to-face eye-contact with those who are concerned, and (3) practice in Goethe's way of science[40] may help us become better participants in the creation and deliverers of social justice for our fellow beings.

ACKNOWLEDGEMENT

I thank many friends and family for stimulating discussion on these matters and especially for their tolerance and understanding.

NOTES

Square brackets indicate an insertion in a quotation to make it read more clearly.

1. See, for example, Richard de Neufville's *Applied Systems Analysis – Engineering Planning and Technology Management*, second edition, McGraw-Hill, New York, 1990, 470 pages. This text was written for a foundation course taken by all students of engineering at MIT. The index contains only two references to 'systems analysis': 'Applied Systems Analysis is the use of rigorous methods to help determine preferred plans and designs for complex, often large-scale systems.' (Page xiii). 'The design of a system represents a decision about how resources should be transformed to achieve some objectives.' (Page 3). Neither system nor analysis is defined.

2. In use from 17th century French (*système*) from Late Latin *systēma*. *Collins English Dictionary & Thesaurus*, standard edition, 1993. Harper Collins, Glasgow. The *y* in *système* stands for the Greek letter upsilon: Υ (capital), υ (lower case), 'appelé *i grec* en raison de l'emprunt de la lettre upsilon dans l'alphabet grec ancien où il dénote tout d'abord le son [y] (u français) absent du latin avant de se prononcer – en latin comme en grec'. The letter *e* occurs twice in the Greek alphabet, as the short *epsilon*: uppercase Ε, lowercase ϵ, and as the long *eta*: uppercase Η, lowercase η. Since there are no accents in English, the overstrike on *ē* in this paper

corresponds to the grave accent (*l'accent grave*) in French denoting the long letter *e* in Greek, η. The overstrike also avoids any confusion with the noun 'stem', as in the stem of a plant, or the verb 'to stem', which have a Germanic origin. The infinitive form of the verb *histanai* denotes purpose, or causality. (http://logeion.uchicago.edu/index.html#%CF%83%CF%D%CF%83%CF%84%CE%B7%CE%BC%CE%B1).

3. In use from 16th century French: from New Latin, from Greek *analusis*. *Collins English Dictionary & Thesaurus*. Op. cit. ante.

4. Henri Bortoft's *The Wholeness of Nature – Goethe's Way toward a Science of Conscious Participation in Nature*, Lindisfarne Press and Floris Books, Edinburgh, 1996. Page 392.

5. The visible distinction between particle motion and wave motion in continuous media at the human scale dissolves into the paradox of wave-particle duality at the atomic scale of quantum physics. See, for example, the double-slit experiment: 'In 1999, the double-slit experiment was successfully performed with buckyball molecules (each of which comprises 60 carbon atoms). A buckyball is large enough (diameter about 0.7 nm, nearly half a million times larger than a proton) to be seen under an electron microscope.' (http://en.wikipedia.org/wiki/Double-slit_experiment; http://de.wikipedia.org/wiki/Doppelspaltexperiment; http://fr.wikipedia.org/wiki/Fentes_d%27Young).

6. The Aristotelian laws of traditional logic are the principles of 'identity' (A is identically equal to itself), 'non-contradiction' (not at the same time A and not-A), and 'excluded middle' (either A or not-A; there is no other possibility). Henri Bergson argued that these principles describe 'the logic of solid bodies' and are not three self-contained and separate principles since each one implies the other two. Quoted in Bortoft op. cit. ante, pages 179 and 358.

7. Leonhardt Euler and the Bernoullis (James, John, and Daniel) in the 18th century extended the rational mechanics of space-filling solid bodies to include compressible fluids (liquids and gases) and deformable rods and strings, thereby separating particle and wave motion in continuous media.

8. The metaphor merits examination. The modern concepts of logical completeness, consistency, and decidability have their counterparts in the idealized Turing machine of computer science: 'Either mathematics is too big for the human mind or the human mind is more than a machine' Kurt Gödel. (http://simplycharly.com/godel/links.htm).

9. Jay W. Forrester. *Principles of Systems*, Productivity Press, Portland, OR, USA, 1971.

10. These models are finally reduced to sets of simultaneous ordinary and partial differential, or difference, equations evolving from prescribed initial conditions. They have the property of 'local memory' and have difficulty reproducing longer-term systēm behavior when non-local memory, i.e., hysteresis, is present. (http://en.wikipedia.org/wiki/Hysteresis).

11. This possibility is not universally accepted: Patrick Doyle. *Every Object is a System – A Cognitive Basis for System Description*, Interprint, London, 1976, 250 pages.

'While it is true to say that everything is a system, this does not help us very much to build up a consistent theory of hydrologic systems' from page 3 of J.C.I. Dooge. *Linear Theory of Hydrologic Systems*. European Geosciences Union Reprint Series, 1, 2003, Katlenburg-Lindau, Germany. ISBN 3-936586-10-1, 327 pages.

12. Students of mechanical engineering are required as part of their education to dismantle and reassemble a gearbox. When all the cogs mesh without contradiction, the gearbox works as intended. The marks awarded for the reassembled gearbox are inversely related to the number of parts left over, the greater the number, the less it works as a systēm, and the lower the mark awarded to the student engineer.

13. When the Greek *phalanx*, a square *sy-stēm* of soldiers, begins to loose its shape in the heat of battle, we may call it an *apo-stēm*, where the prefix *apo* means 'away from' the purposeful standing together (of the soldiers). When the phalanx has been beaten down, it is a *kata-stēm*. The opposite of a *sy-stēm* is an *anti-stēm* composed of contradictory parts.

14. Dorset House, New York. Silver anniversary edition, 2001. Loc. 1207, Kindle edition.

15. 'Intuition is knowledge without recourse to inference' from R. E. Ornstein's *The Psychology of Consciousness*, Harcourt Brace Jovanovich, New York, 1977 (27; 37: 184) in contrast to the logical or rational mode of knowledge 'involv[ing] analysis into discrete elements sequentially (inferentially) linked' from Ornstein's *The Mind Field*, Octagon Press, London, 1983. (32: Chapters 2 and 3; 36: 52ff; 38: 24; 39: 26).

16. See Bortoft op. cit. ante. Chapter 1, and David Seamon and Arthur Zajonc (editors) *Goethe's Way of Science – A Phenomenology of Nature*, State University of New York Press, New York, 1998. A phenomenon (*phainesthai*: to appear,

from *phainein*: to show) is anything that can be perceived as an occurrence or fact by our senses.

17. Phenomenology has its critics. 'In brief, phenomenology is a highly purified empiricism, … a method rest[ing] on an elementary confusion. What is obvious in knowing is, indeed, looking. Compared to looking, insight is obscure, and grasp of the unconditioned [in making a judgment] doubly obscure. But empiricism amounts to the assumption that what is obvious in knowing is what knowing obviously is. That assumption is false, for if one … sought common-sense advice, then one would go to a man that is intelligent and reasonable rather than to a man that is stupid and silly.' (J. F. Bernard Lonergan S. J., *INSIGHT – A Study of Human Understanding*, Longmans, New York, 1965. Pages 415–416 of the revised students' edition.)

Lonergan (1904 –1984) was a Canadian Jesuit priest, philosopher, and theologian, regarded by many as one of the most important thinkers of the 20th century. (http://en.wikipedia.org/wiki/Bernard_Lonergan).

Lonergan distinguishes between 'the knowing men share with animals, the knowing that men alone possess, and the manifold blends and mixtures of the two that are the disorientation and ground the bewilderment of people as they are.' (Lonergan, op. cit. ante; page 397. The English language is impoverished in having but one verb 'to know', whereas most Indo-European languages have two or more: savoir et connaître; wissen und kennen; sapere et cognoscere; fios, eolas agus aithne; …).

As an example of a 'mixture of knowing', consider the first 'law' of paediatrics, which is 'listen to the mother', who seeks 'intelligent and reasonable medical advice' for her sick child. Before any analysis of signs and symptoms by the physician-surgeon in attendance, before any diagnosis, the commandment is: observe and question the mother's 'common-sense, unconditioned, and intuitive understanding of her whole child'. A three-way conversation takes place of looking, listening, examining, questioning, answering, formulating, testing, and judging, grounded in the phenomena presented by the child and perceived as sickness (of an authentic whole) by the mother. It is a metaphor for political discourse in the 'constituency surgeries' of members of a post-imperial Parliament (UK) and in the 'constituency clinics' of Parliamentary Deputies in a post-colonial Dáil. (http://en.wikipedia.org/wiki/Surgery_%28politics%29).

18. For an historical and philosophical discussion of dialectic and systems thinking see H. Bergmann, U. Hedtke, P. Ruben and C. Warnke, *Dialektik und Systemdenken – Historische Aspekte: Nikolaus von Kues, Französische Aufklärung, Schelling* (Dialectics and system thinking – historical aspects: Nicholas von Kues, French Enlightenment, Schelling). Akademie-Verlag, Berlin, 1977.

The philosophical system of G. W. F. Hegel (1770–1831), a contemporary of Schelling, '(re)lies (on a) process that turns positions into their contradictories only to discover in such a reversal a new position that begets its opposite to bring to birth a third position with similar consequences until through successive repetitions the totality of positions and opposites form a dialectical whole' (Lonergan op. cit. ante; pages 421–423).

'Hegel's System is not afraid of facts: it explains any fact alleged against it by showing it to be a manifestation of an incomplete viewpoint included within the System. Hegel's System is not afraid of contradictions: it explains any contradiction alleged against it by revealing what opposed and incomplete viewpoints, accounted for by the System, yield the alleged contradictory terms. The only thing the System has to fear is that it itself should be no more than some incomplete viewpoint, and in fact that is what it is. Hegel aimed at rehabilitating the speculative reason that Kant had dethroned. But the basis of the Kantian attack was that the unconditioned is not a constitutive component of judgment. A complete rehabilitation of human rational consciousness [by Lonergan] will show that the unconditioned is a constitutive component of judgment. This, Hegel did not do. His viewpoint is essentially the viewpoint of a thinker who does not and cannot regard the factual as unconditioned, who cannot acknowledge any factually fixed points of reference, who cannot advance by distinguishing the definitively certain, the more or less probable, and the unknown. Hegel's range of vision is enormous; indeed, it is unrestricted in extent. But it is always restricted in content, for it views everything as it would be if there were no facts. It is a restricted viewpoint that can topple outwards into the factualness of Marx or inwards into the factualness of Kierkegaard. It is a viewpoint that is transcended automatically by anyone that, in any instance, grasps the virtually unconditioned [in judgement] and affirms it.' (Lonergan op. cit. ante; pages 373–374. See also pages 424–430 on Scientific Method and Philosophy, Section 4.6.).

19. For some exponents of the view criticized (but not named) by Bortoft see Jay W. Forrester, *Principles of Systems*, Productivity Press, Portland, OR, USA, 1971, and their application to Industrial, Urban, and World Dynamics. (http://en.wikipedia.org/wiki/Jay_Wright_Forrester). Ervin Laszlo, *The Systems View of the World – A Holistic Vision for Our Time*, Hampton Press, Broadway, New Jersey, 1996. Ludwig von Bertalanffy, *General System Theory – Foundations, Developments, Applications*, Georg Braziller, New York, revised edition, 1969.

20. Bortoft op. cit. ante; pages 368 and 369.

21. The high-speed computational requirements of such models contributed to their undoing. Moving so fast the modelers failed to see eight centuries of financial folly. *This Time is Different – Eight Centuries of Financial Folly* by Carmen M. Reinhart and Kenneth S. Rogoff, published by Princeton University Press, 2009. The great Venetian 'bank bust' of the early 16th century on the Rialto, the 'Wall Street' of its day, is a regrettable omission from this hurried quantitative study.

22. Hargreaves, J. C., Annan, J. D., Ohgaito, R., Paul, A. & Abe-Ouchi, A. 2013 Skill and reliability of climate model ensembles at the Last Glacial Maximum and mid-Holocene. *Clim. Past* 9, 811-823. doi:10.5194/cp-9-811-2013.

23. The western (Eastern Europe) communist experiment in socio-economic engineering (1917–1990) is the exemplar of a world where systēm was imposed by force. That world was built on the concept of society as systēm, advancing materially in 5-year leaps, a paragon of applied systēms analysis, optimized, simulated, and controlled from the command centre, to achieve precisely the goals of successive 5-year plans, continuously overcoming the contradictions of dialectical materialism by using psychological and physical force whenever necessary. Eventually, the greatest contradiction inherent in society as systēm, the denial of individual freedom, overwhelmed the attempt to cause all members of society to stand together as parts of one enormous, ergonomically designed engineering-economic machine, fulfilling the current 5-year norms for all material needs. Engineers were first the heroes, then the victims of this failure. See Loren R. Graham's study *The Ghost of the Executed Engineer – Technology and the Fall of the Soviet Union*, Harvard University Press, 1993. China is on a different path. See Joel Andreas, *Rise of the Red Engineers – The Cultural Revolution and the Origins of China's New Class*, Stanford University Press, California, 2009.

24. Arthur Maass, Maynard M. Hufschmidt, Robert Dorfman, Harold A. Thomas, Jr, Stephen A. Marglin & Gordon Maskew Fair 1966 *Design of Water-Resource Systems – New Techniques for Relating Economic Objectives, Engineering Analysis, and Government Planning*. Harvard University Press, Cambridge, Massachusetts.

25. E. L. Grant and W. G. Ireson on the first page of their book *Principles of Engineering Economy*, The Ronald Press Company, New York, 1930 (various editions; 4th edition 1960) attribute these three questions to 'the late General John J. Carty, as chief engineer of the New York Telephone Company, [which] he applied to every engineering proposal that came before him for review'. John J. Carty (1861–1932) was an electrical engineer, chief engineer of AT&T, and a recipient of numerous scientific and engineering awards in the early 20th century (http://en.wikipedia.org/wiki/John_J._Carty).

26. The Cambridge (MA, USA) economists, Stephen Marglin and Robert Dorfman locate benefit–cost analysis in the neo-classical 'general equilibrium theory' of a producer–consumer economic systēm with perfect, free, and unregulated markets for land, labour, and capital. It can be proven that it has 'optimal' economic properties. But, two economic contradictions are ignored. If producers do not pay their workers an adequate wage, the effective demand for consumption products is less than full production capacity; consequently, there is a scandalous waste in the presence of poverty. Second, the equilibria of markets are inherently unstable since they depend on the presence or absence of confidence in an uncertain economic future. For a presentation of the eclectic and political nature of economic theory, see Joan Robinson and John Eatwell, *An Introduction to Modern Economics; Book One, Economic Doctrines; Book Two, Analysis; Book Three, Modern Problems*, revised edition, McGraw-Hill, London, 1973, 350 pages. Note: book three is now outdated.

27. In the preface to their book, the Cambridge (UK) economists Robinson and Eatwell (op. cit. ante) state 'Pure economic logic may be regarded as a minor branch of applied mathematics, but we have not found it useful to put much of the argument into symbolic form. The reason is that economic relationships, such as the share of saving in national income, the influence on output of the land to labour ratio, or changes in productivity following technical innovations, cannot be adequately represented in simple, smooth functions.' (Page xvi).

28. Nevertheless, engineers, and economists are agreed on the need for a calculus to separate good investment decisions from bad ones, but they differ on the details. See for example, de Neufville op. cit. ante; Chapter 13, Economic Evaluation.

29. Arthur Maass was professor of Government at Harvard and director of the multi-disciplinary Harvard Water Program from 1955 to 1965. He was a critic of the 'iron triangle': the policy-making relationship among US congressional committees, the bureaucracy, and interest groups. (http://news.harvard.edu/gazette/story/2007/06/arthur-maass/).

30. Walter L. Schönwandt, *Planung in der Krise? – Theoretische Orientierungen für Architectur, Stadt- und Raumplanung*, Kohlhammer, Stuttgart, 2002. English translation: *Planning in Crisis?* Ashgate, Farnham, UK, 2008. (Sub-title: Theoretical orientations for architecture, city and spatial planning).

31. Donella Meadows, Jorgen Randers, and Denis Meadows, *Limits to Growth – The 30-Year Update*, Earthscan, London, UK, 2005. For an antidote to this Malthusian cry that we are running out of strategic materials, energy, land, food, polluting the planet, wrecking the climate, killing ourselves, etc., see the paper by the former ISPRA nuclear physicist and IIASA system analyst, Cesare Marchetti, 'Ten to the twelfth (sic): A Check on the Earth-Carrying Capacity for Man', Energy, 1979. 'Compatible growth is possible with zero pollution provided the appropriate technologies are adopted' (http://cesaremarchetti.org/). These two views are representative of two ends of a spectrum from environmental pessimism to technological optimism, respectively.

32. W. H. Auden, *The Dyer's Hand and Other Essays*, Vintage Books, New York, 1989. Part II, Chapter II 'The Virgin & The Dynamo'. Pages 63–64. 'Wystan Hugh Auden (1907–1973) … was an Anglo-American poet (and essayist), born in England, later an American citizen, and is regarded by many critics as one of the greatest writers of the 20th century. His work is noted for its stylistic and technical achievement, its engagement with moral and political issues, and its variety in tone, form and content. The central themes of his poetry are love, politics and citizenship, religion and morals, and the relationship between unique human beings and the anonymous, impersonal world of nature.' In his youth, he considered a career as a mining engineer. (http://en.wikipedia.org/wiki/W_h_auden).

33. Bortoft illustrates his concept of 'authentic wholeness' with the hologram. A hologram is a photograph on a flat plate of a three-dimensional object illuminated with the coherent light of a laser. When the hologram is illuminated with the same light, the optical effect is to make the original object reappear as if in three dimensions, being displaced in apparent position as the observer moves. 'The particular property which is of direct concern in understanding *wholeness* is the pervasiveness of the whole optical object throughout the plate. If the hologram plate is broken into fragments and one fragment is illuminated, it is found that the same three-dimensional optical reconstruction of the original object is produced. There is nothing missing; the only difference is that the reconstruction is less well defined. … With orthodox photography the image fragments with the plate; with holography the image remains undivided' and the 'authentic whole' is present in each and every fragment. See Bortoft op. cit. ante. Chapter 1, Authentic and Counterfeit Wholes. Pages 3–26.

34. Called 'sortition', 'allotment', or 'demarchy' in political science (http://en.wikipedia.org/wiki/Sortition). 'In ancient Athenian democracy, sortition was the primary method for appointing officials, and its use was widely regarded as a principal characteristic of democracy. It is commonly used today to select prospective jurors in common law-based legal systems. … The *klērotērion* (κληρωτήριον) was the randomization device used by the Athenian *polis* [city state] during the period of democracy to select citizens to the *boule* (the council of citizens), to most state offices, to the *Nomothetai*, and to court juries.' See also *A Citizen Legislature* by Ernest Callenbach and Michael Phillips (1985) in the series *The Luck of the Draw – Sortition and Public Policy*, edited by Barbara Goodwin. *ia* imprint-academic.com/sortition. C. Douglas Lummis, *Radical Democracy*, Cornell University Press, Ithaca, New York, 1996.

The justification of *random sampling of a population* may be found in the mathematical theory of statistics in all its forms (systematic, stratified, probability-proportional-to-size, cluster, quota, minimax… ; prospective double-blind, case-control designs, …) (http://en.wikipedia.org/wiki/Sampling_%28statistics%29; http://en.wikipedia.org/wiki/Design_of_experiments).

Randomisation is deeply counter-intuitive. By allowing the toss of a coin, the throw of a die, or other similar unpredictable mechanisms, to govern *ex ante* our execution of an experiment, an enquiry, or an observation, it becomes possible *ex post* to draw definite conclusions, to make secure judgments, to sanction predictable actions, (all very probable, but not absolutely certain) that relate to a population that is unknowable in all its detail because of its numerical size.

See also the 'wisdom of crowds': http://en.wikipedia.org/wiki/The_Wisdom_of_Crowds; http://www.economist.com/node/21541709.

35. In a money economy everyone pays tax (excise duties, VAT, income tax, …) whether on income or expenditure. The wealth of individuals (property, savings, capital goods, bonds, shares, cash, …) is excluded in the random selection to this house, because at issue is the sharing of power in the raising and spending of tax on annual personal income or expenditure. Tax on company profits, dividends, etc. is ascribed to specific shareholders or bondholders, and not to the legal person of a company. The institutionalized, the unemployed, carers for the sick and elderly, workers in the black economy, and mothers at home, all pay tax when they spend their income, whatever its source, and it is often invisible to the state. But, it must be estimated and allocated *grosso modo* to ensure that none are excluded in the process of sortition.

36. Banking ATM machines can be used for those with no web access. We trust the banks with our money and with suitable safeguards we might also trust them with our vote.

37. See, for example, Bruno Latour, *Politics of Nature – How to Bring the Sciences into Democracy*, Harvard University Press, Cambridge, Massachusetts, 2004.

38. The Doge of the Venetian Republic was elected by repeated sortition from the merchant princes who served in the Senate; it was the top job for the merchant class (http://en.wikipedia.org/wiki/Doge_of_Venice).

39. Engineered cities typically have one solid-waste facility, one water-treatment plant, one wastewater-treatment plant, and one power plant, and associated networks. The reason is the presence of geometric returns to scale in engineering plant, which in turn delivers strong economies of scale. The typical two-third rule says total capital cost grows as the capacity raised to the power of two-thirds. If it costs one unit of capital to provide power to one household, it will cost 100 units of capital to provide power to a town of 1,000 households, and 10,000 units of capital to provide power to a city of 1,000,000 households, when power comes from one centralized power plant. The capital cost per household is reduced by a factor of 10 in the case of the town, and by a factor of 100 in the case of the big city when the two-thirds rule applies. A fraction of these very substantial savings may be said to cover the additional capital cost of the distribution network that connects the central facility to each household. Networks also exhibit economies of scale, but weaker than the two-thirds rule. Energy is a recurring cost, and it scales linearly with the number of households. Redundant links in the networks, and duplicate or standby plant, improve reliability at additional cost. The Proximity Principle of Sustainability does not pay attention to economies of scale in physical facilities and networks. The history of cities shows that it may be better economically and socially to provide communal facilities for groups of households, rather than for each household individually.

40. See Bortoft (1996) and Seamon and Zajonc (1998) op. cit. ante.