On the Origins and the Applications of the Steady-State Model

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Abstract

Some publications have referred to the so-called steady-state model, a 'cybernetic model' that should not be confused with its namesake in mathematical systems; it is rooted in preceding publications about general systems theories, something that is explored in this paper. To this purpose, first the origins of steady-state and homeostasis as biological concepts are briefly addressed. Afterwards, the concepts of boundary zones from socio-economic theory, Shannon's information theory, control mechanisms and engineering principles are added as a multi-disciplinary amalgamation to primary processes. The resulting cybernetic steady-state model offers a generic transdisciplinary framework for depicting regulatory and control processes within organisational and engineering systems as well as interaction between agents in networks. In the latter sense, it provides an explanatory concept for self-criticality in complex adaptive systems. Hence, it does not only have a rich heritage but also a wide-ranging potential for research.

Keywords: Business processes modelling; general systems theory; homeostasis.

Introduction
Works (e.g. Dekkers, 2015: xxv–xxviii, 146; Veeke et al., 2008: 77–81) have been elaborating the so-called steady-state model, not be confused with its namesake in mathematical systems. Though first mentioned by in 't Veld (1975: 193), a Dutch version of systems theories based mostly on general systems theories and cybernetics, it is factually rooted in the preceding publications about general systems theories as a multidisciplinary amalgamation, which this paper explores in addition to its potential applications.

Tracing the Steady-State Model Back to Its Roots
Thinking about the steady state of systems and its implications goes back to the time that theories for systems were conceived. To better understand the emergence of the steady-state model, it is worthwhile to look at the thoughts of four dominant thinkers.

Advocating the Steady-State by Ludwig von Bertalanffy
In the context of the general developments of systems theory, the concept of 'steady-state' as foundation for the steady-state model can be attributed to Ludwig von Bertalanffy (1973: 40), though some, such as Gorelik (1987), trace it back to Bogdanov's interpretation of tectology. In addition, Bogdanov's tectology is seen by Gorelik (1975: 348, 351) as already advancing the notion of systems, called complexes, which are in interaction and which are striving for equilibrium with other complexes and hitherto their environments; note that Bogdanov's notions came about in the 1920s but were not further advanced due to an early death and political opposition to his ideas. In earlier writings von Bertalanffy advocates the concept of the steady state (e.g. von Bertalanffy, 1950a: 157) or refers to it (e.g. von Bertalanffy, 1972: 418). The concept of the steady state implies that a system tries to retain its state, no matter the pertubations in its environment; this is also called maintaining homeostasis. It should be noted that he was well aware of its biological roots (von Bertalanffy, 1950b: 23), though that appeared to be more the background in

later writings about general systems theory (e.g. von Bertalanffy, 1973). In most of his writings, though, his approach to the steady state was based on mathematical systems.

Subsequently, homeostasis by maintaining a steady state is seen by many as keystone for systems theories, as Drack and Schwarz (2010) and Lloyd et al. (2001) attest for the influence of von Bertalanffy. In addition, Johnson et al. (1964) mention the early impact on systems thinking for management, particularly for an organisation maintaining a dynamic equilibrium with its environment; this appears notably in Katz and Khan (1966: 14–29; 2015: 353–4). Among other advocates of systems thinking for management science are Kast and Rosenzweig (1972). It has also influenced some in education, e.g. Biggs' work (1993). The notion of steady state also appears in geomorphology (e.g. Chorley, 1962), though Chisholm (1967: 49) contests the concept of open systems by reducing it to inductive reasoning. Strauss (2002: 169) offers a different point when indicating that systems in steady state might still be out of true equilibrium; hence, the steady state is termed a pseudo-dynamic equilibrium, which implies its restriction to recursive processes.

James G. Miller's Quest for Pathological Enumeration

Whereas von Bertalanffy has emphasised the steady state, the approach of Miller (1955, 1971) has focused on descriptions of systems. Miller (1955: 521) distinguishes five levels of hierarchy for systems (cell, organ, individual, group and society) and presents a model of a computer as archetypical (ibid.: 524). In a next stage of development, living systems (Miller, 1965) embrace nineteen subsystems and seven levels of hierarchy; see also François (1999: 212). Later, this concept was completed with a twentieth subsystem, the timer (e.g. Jessie Miller and Miller, 1992: 8), and an eighth level, the community level (Jessie Miller, 1996: 265). The concept of living systems theory is not only extensive but can also be considered pathological (Miller and Jessie Miller, 1991: 246 (in their own words)), when considering organisations; the maintaining of homeostasis is not explicitly part of living systems theory but present in the way systems interact with the environment.

The extent of these descriptions, for both subsystems and hierarchical levels, and the interaction of systems with the environments leads Bailey (2005: 45) to laud the concept of living systems for its analytical power. In this spirit, Bailey (2006: 292–6) identifies sixteen contributions by living systems theory. The ninth, tenth and nineteenth contributions seem mostly related to the maintenance of the steady state, although for Miller (1965, 1972) the maintenance of homeostasis is encapsulated in the transducers for input and output, and the decoder and encoders. It should be noted that originally the maintenance of steady state is related to entropy (Miller, 1965: 203). According to Bailey (2006: 295) a joint subsystem was introduced by Miller (1978: 32). However, it should be noted that Glassman (1973) introduces the idea of loose coupling of systems, before Maturana (1975: 320; 1978: 35–6) and even before Luhmann (1985). Moving back from autopoiesis to living systems theory, the application to organisations and processes is demonstrated by Járos (2000) and Járos and Dostal (1999). In more detail, Nechansky (2010: 103) details a schema for living systems based on all twenty subsystems; in this conceptualisation the principles of maintaining homeostasis can be distinguished. Thus, the concept of Miller's living systems has inspired many to advance theoretical conceptions, including those touching on the steady-state, albeit implicitly at times.

Viable Systems Model by Stafford Beer

The viable systems model by Beer (1972: 161 ff.) also offers a perspective of maintaining steady-state. According to an interview with him by the Kybernetes Editorial Team (2000: 562) , the viable systems model builds on the pursuit of fundamental principles of how self-regulatory systems are constructed, particularly the human nervous system. It aims mainly at human activity systems (Checkland, 1976: 131–2). The core of the viable systems model consists of five subsystems with particular roles. These subsystems interact to maintain homeostasis, albeit that they include adaptive (and evolutionary) processes.

The viable systems model found its way into many writings. A notable book (Morgan, 1997: 73–118) is one about images of organisations in which the viable systems model features as part of the chapter on organisations as brains. Others involved with systems theories have used the conception to link their developments to it. For example, Mlakar and Mulej (2008) position the model in the context of what they call dialectal systems thinking, akin to the boundary critique (Midgley et al., 1998; Ulrich, 2000: 254) and teleological thinking; in that sense, Mlakar's and Mulej's proposition does not differ greatly from Churchman's (1971) dialectical inquiring systems method. In addition to these methodological deliberations about systems theories, the viable systems model has been contributing to building theoretical conceptions (e.g. Green and Welsh, 1988; Hedberg et al., 1976; Safayeni et al., 2005; Tsoukas, 1994); expanding methodologies (e.g. Ackoff and Gharajedaghi, 1996; Checkland, 1983; Flood, 2010; Oliga, 1988); and solving organisational challenges (e.g. Garud and Kotha, 1994; Grandori, 1984; Rouse and Putteril, 2003), to mention but a few. It should be noted that the application of the viable systems model seems mostly directed at organisations and less to other domains of application, such as society, and other disciplines, for example, psychology, even though Beer himself sees a far wider range of applications (Kybernetes Editorial Team, 2000).

Capturing Interaction by Claude E. Shannon

Whereas systems thinking related to the steady state in the previous three strands roots in biological concepts, the contribution of Shannon (1948) arrives from information and communication technology. His mathematical theory of communication posits that signals from information sources are encoded, processed and decoded, while developing concepts for information entropy, as a measure of uncertainty and randomness, and redundancy. The influence of Shannon's thinking is attested by Guizzo's (2003) book, Verdú's (1998) praise, Weaver's (1953) deliberations and Wyner's (1974) overview; these give but an impression of the tremendous progress made and the impact of this theory for information and communication technologies. Beyond these technologies it has been extended to epistemology for heterogeneity (e.g. Laxton, 1978; Maruyama, 1977); knowledge management (e.g. Liyanage et al., 2009; Nonaka, 1994); linguistics (e.g. Mandelbrot, 1953; Nowak et al., 1999); consumer behaviour in marketing (e.g. Malhotra, 1982; Swait and Adamowicz, 2001); and psychology (e.g. Koerner and Fitzpatrick, 2002; Luce, 2003). Later works (e.g. Shannon, 1949) augmented his original thoughts, which started to include steady state, something also picked up by Kalman (1960). Other than conceptual approaches in ecology (e.g. Müller, 1997), the concept of steady state related to Shannon's theory has been used only by those that seek mathematical modelling.

Putting These Contributions Together

That notion that the theory of communication seems weakly linked in literature raises the question as to how the theoretical conceptions of Beer, von Bertalanffy, Miller and Shannon are related to each other. In the second Bertalanffy memorial lecture, Miller (1976: 220–1) connects his living systems' approach to von Bertalanffy's general systems theory explicitly, though implicitly he seems to view his theory as advancement. In addition, Miller (1955: 517) refers to Shannon (and Wiener) in the context of coding, although without including them in the list of references, and subsequently it appears in his diagram (ibid.: 524); in subsequent papers by Miller (1965, 1971) this anomoly persists. Also, Beer (1984) refers to the influence of Shannon's theory of communication on his own ideas; akin to Miller he refers to von Bertalanffy, though some slight differences of opinion seem to be present (Beer, 1981: 192). However, it is mostly others, for example, Robb (1986), who bring the four theoretical contributions together, Duffy (1984), who makes the case for cybernetics and systems theories being interwoven, and Pierce (1972) from the perspective of investigating problems. Cases in point that focus on connecting a few of these four are Schwaninger (2006), who exploits the connection between Miller's concept of living systems and Beer's viable systems model, with Nechansky (2010, 2011) doing the same. Some have sought classification, for instance, Adams (2012). Van Gigch and Kramer (1981: 185) categorised the living ystems theory and the viable systems model as belonging to the same class as 'living systems theory', whereas von Bertalanffy's general systems theory is seen as part of an 'ontological-theoretical' strand and Shannon's theory of communication as part of the 'conceptual-theoretical' stream.

These classifications and the acknowledgements of each other's concepts denote that for modelling the steady state, beyond mathematical terms, relatively little has been done.

Building the Steady-State Model

The steady-state model put forward in this paper builds on the pathological approach, the interaction approach and modelling by the viable systems model to describe recurrent processes for maintaining homeostasis. It expands the viable systems model by separating better primary processes and control processes, by including more explicit boundary zones and by focusing on homeostatic processes; the latter as opposed to adaptive processes (particularly, these are System Four and System Five of the viable systems model).

Boundary Zones as a Central Tenet for the Steady-State Model

In order to maintain such homeostasis for a process, E.J. Miller and Rice (1967: 9) propose boundary zones for primary processes. The primary process, a generic concept in systems theories, converts input into output (see Figure 1). It means that flowing elements as input are converted into a system as output; one could take the paper for the invidual pages that are folded, binded and cut to size into a book as an example. For it to happen, resources are needed for conducting the primary process, sometimes just called process from now on. That means that a process is the interaction between flowing elements and resources. In this perspective, boundary zones represent a discontinuity for the input and output in the exchange with the environment of an open system of resources. Again referring to the example, the paper for the pages are provided by a supplier with a different process and belonging set of resources, and the book is distributed by publishers with their specific processes and related set of resources. Hence, the transfer from one set of resources to another can be considered a discontinuity. This reasoning leads to distinguishing an input boundary zone and an output boundary zone (Figure 2 also distinguishes a regulatory boundary zone; see next paragraph). Whereas E.J. Miller and Rice arrive at boundary zones from a socio-technical perspective, others, such as Koch (1941: 145), discuss them from a physiological perspective. Closely related to the concept of boundary zones, Shannon's (1948) theory of communication adds the processes of encoding and decoding to the primary process (see Figure 3); this concept can also be found in Miller (1955: 514). In the spirit of the theory of communication encoding means that the state of the flowing elements as input for a process should be converted to the capabilities of that process; a case in point is the permuation of keyboard characters into binary code as input for a microprocessor. Similarly, decoding makes the output of the primary process suitable for the environment of a system or the subsequent primary process of another set of resources as system. Blegen (1968: 19) too highlights the coding process as part of an organisation's open systems, although he refers to Katz and Kahn (1966: 22–3) as his source for this thought. Note that in the Zeitgeist of the 1950s and 1960s, for an open system (and related processes) it is only possible to sustain homeostasis with energy (for instance, Chorley, 1962: B3; Katz and Kahn, 1966: 23–5); the concept of energy may be substituted by the generic term resources, which could include energy but might also be a wider range of resources (for example, labour, equipment). Building on these thoughts of E.J. Miller and Rice, and Shannon, as recognised by other systems theorists, makes encoding and decoding an essential part of the primary process for boundary zones to maintain a steady state for resources.

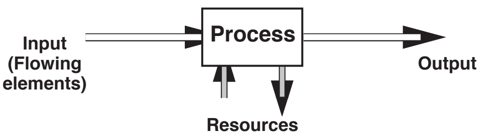

Figure 1: Primary process with resources.

This concept of transitions of input from the environment into output to the environment also implies that the crossing of these zones leads to

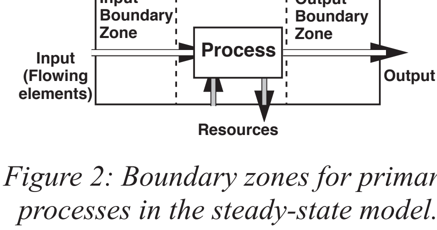

Figure 2: Boundary zones for primary processes in the steady-state model.

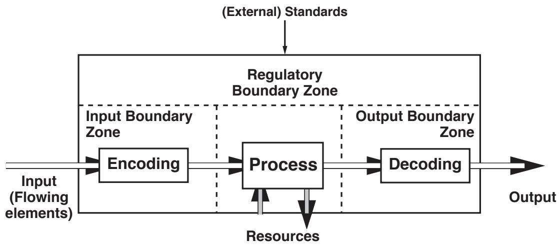

Figure 3: Boundary zones of steady-state model with coding for input and decoding for output.

regulatory activities as a third zone mentioned by E.J. Miller and Rice (1967: 9); see Figure 3. Also, Simon (1975: 328) underlines their importance. These regulatory activities can comprise interventions in the primary process, when the output does not meet standards, revision of those standards and feedback to the environment about the capability of the primary process to maintain its steady state. More detail about regulatory activities can be derived from Beer's (1972) viable system model by looking at the interaction between System Two and System Three. Within Beer's model Systems Four and Five are long-term oriented (and, therefore, might imply a change of structure beyond maintaining homeostasis as such). Also Blegen (1968: 16) mentions so-called self-regulation. Thus, part of regulatory activities is a feedback loop commensurate with the thoughts about the importance of feedback for maintaining homeostasis (for instance, Blegen, 1968: 15; Katz and Kahn, 1966: 23–5; von Bertalanffy, 1972: 421). Hence, Figure 4 extends Figure 3 by including processes for the regulatory zone; note that both initiating and evaluating processes can be considered as encoding and decoding respectively.

These regulatory activities are related to three basic control mechanisms. Mostly derived from cybernetics and engineering, most famously, feedback is seen as essential to maintaining a steady-state, again leaning on the thoughts of von Bertalanffy. Attributing mechanisms for feedback to Ashby and Wiener, Blegen (1968: 18) typifies this control process as essential for the stability of a system. In terms of controlling primary processes, feedback mainly intervenes upstream of the point of measurement; based on a comparison of a parameter of the output with a standard an intervention is generated in either the process itself or the input of the process or the resources used for the process. As a second control mechanism, feedforward is often attributed to MacKay's (1966) contribution to physiology, although it is also known from control systems (e.g. Lefkowitz, 1966; Morgan Jr., 1964). A characteristic for feedforward is that the intervention happens downstream of the point of measurement. How both control mechanisms complement each other within systems theories is demonstrated by Bogart (1980). In addition to feedback and feedforward, there is a third mechanism that can be called 'completing deficiencies'. Its principle can be traced back to Black (1977), though he wrote this memoir later than its invention by him in the 1920s. Very different from feedback and feedforward, completing deficiencies means that measuring detects deviations from a standard, and then the flowing elements are brought up to that standard in a separate process. In Black's thoughts the input serves as the standard, but that might be appropriate for electronics and not necessarily for other disciplines. Alternatively, completing deficiences could imply that the flowing elements have to be inverted to go partially or wholly through the transformation process; this approach has been used in the steady-state model. The three control mechanisms have been brought together in Figure 5 as part of the boundary zones.

In addition to the three control processes, from engineering – particularly hydraulics, pneumatics and electronics – additional processes are included for the boundary zones. Referring to the perspective of engineering, Blegen (1968: 21) mentions parallels between

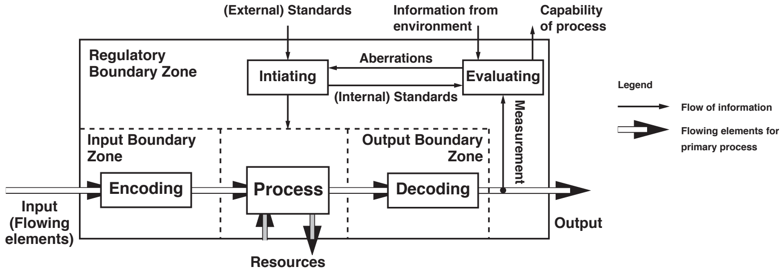

Figure 4: Control processes for the regulatory boundary zone.

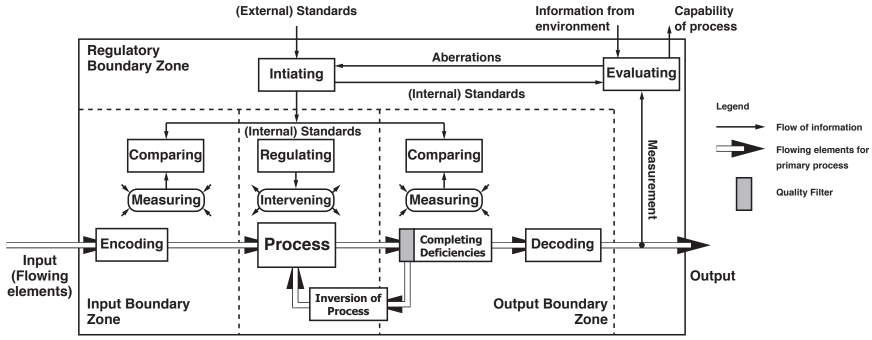

Figure 5: Control mechanisms for the boundary zones in the steady-state model.

hydraulic, mechanical and pneumatic systems as a key notion for control mechanisms. Such systems typically contain buffers, filters and overflow mechanisms. Buffers dampen out irregularities in the flow of elements (primary process), whereas filters ensure that the quality of the flowing elements match the capabilities of the primary process. Overflow mechanisms ensure that the quantity of the flowing elements matches the capacity of the primary process. These additional mechanisms prevent unsuitable input from entering the system and they counteract overload. The necessity for these additional mechanisms has been mentioned by a few but has been incorporated less implicitly. For example, Katz and Kahn (1966: 22) note the rejection and acceptance of materials as an essential process and Miller (1972: 165) explicitly refers to storage at the output boundary zone. The same mechanisms can be used for the output, albeit that the quality filter in the output boundary zone might be related to feedback control processes. Hence, all concepts have been amalgamated into what one could call the steady-state model (see Figure 6).

Potential Limitations

However, such a steady-state model only covers maintaining homeostasis for recurrent processes. As can be derived from Beer's viable systems model, this model resembles only Systems One to Three. Structural changes, such as intended by System Four and Five, will lead to changes in primary processes, (re-)allocation of resources, control mechanisms and boundary zones. Therefore, so-called adaptive processes require a different approach than that covered by the steady-state model (similar to the thoughts of Bogdanov [Gorelik, 1987: 162–3] and the breakthrough model in Dekkers [2015: 210–5]). This is commensurate with Strauss' (2002: 169) notion about the limitations of the steady state; whereas entities might be striving towards maintaining homeostasis during adaptation, so-called adaptive processes are poorly described by the steady-state model.

In addition to being limited to recurrent processes, another limitation is the potential incompability of different control processes. For example, control processes for operations, quality, logistics and financial management might differ entirely. Although some features might come together in persons or departments, it is not hard to imagine how these different aspects require different control mechanisms. Hence, the use of this steady-state model is limited to one particular aspect for control.

Applications of the Steady-State Model

Since this generic reference model limits itself to one aspect of primary processes and the related control mechanisms to maintain homoeostasis, the question abides how this steady-state model can be used in research. One could classify the model as a positivist approach; for example, Mangan et al. (2004: 568) classify models under this label. Beyond this approach, it can be used for qualitative modelling in 'theory-driven' case studies (e.g. Eisenhardt and Graebner, 2007: 26); for visualisation in interviews (e.g. Knigge and Cope, 2006: 2027); and as a representational tool in action research (e.g. Dickens and Watkins, 1999: 129; Flood, 2010: 275). These applications make it also suitable for constructivists and for advocates of participatory approaches; for instance, those using the boundary critique (e.g. Ulrich, 2000) may use the steady-state model for visualisation and analysis. Hence, this steady-state model can be used in different methodological approaches.

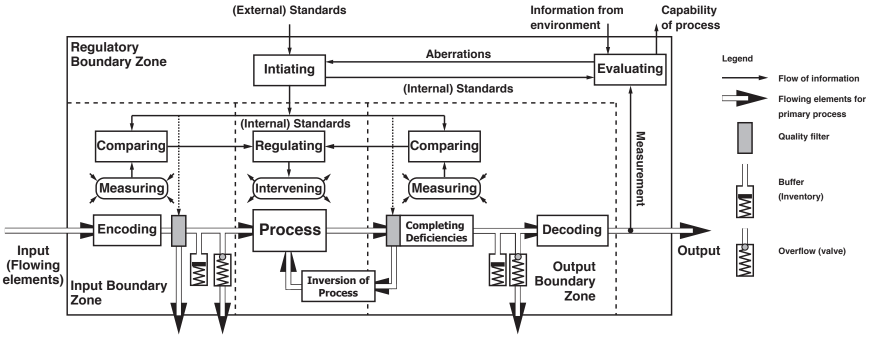

Figure 6: Steady-state model with boundary zones, coding processes and control mechanisms.

Leaving philosophical streams of thought about research aside, commensurate with Simon's (1975: 329–30) call for a comprehensive systems framework for teleological systems, the steady-state model offers a generic model for a range of applications:

- The integration of separate control mechanisms, regulatory activities and processes for the boundary zones makes it suitable as a reference model for technological, biological and social systems (particularly for organisations). This is akin to Miller's (1955, 1965, 1972) visions for his living systems theory and Beer's (Kybernetes Editorial Team, 2000) views for the viable systems model. Compared to these models it offers a different interpretation with regard to control mechanisms and to regulatory activities.
- For organisations, this model can be used for approaches such as business process re-engineering and information systems. Hess and Oesterlee (1996: 81–2) already draw attention to the role of information systems that should be better understood. The steady-state model captures the roles by separating the primary processes from control processes; the teleonic management framework of Járos and Dostal (1999, p. 205–9) hints at the same. Some works distinguish between process and their control, but mostly in an implicit way (e.g. Aguilar-Savén, 2004, p. 133; Childe et al., 1994, p. 24; Janssen-Vullers et al., 2003); they do not use the distinction for modelling or evaluating methods. In other publications about information systems and business process re-engineering, such as Kettinger et al. (1997), List and Korherr (2006) and Scheepers and Scheepers (2008), this difference is absent. The separation of the two processes is important because primary process can be associated with creating value for customers and control processes with performance management. Such distinction between primary and control processes may address Childe et al.'s (1994: 32) concern that processes are not well defined, something to which later works (e.g. Gunasekaran and Kobu, 2002) have not contributed or have left open options for the modelling process (e.g. Adesola and Baines, 2005: 44) or resorted to the use of simplified models, such as IDEF0 and IDEF3 (e.g. Jang, 2003; Melão and Pidd, 2000: 114).
- In this sense, the steady-state model addresses the need for conceptualisation and modelling in operations management research in the context of problem-solving (Sagasti and Mittrof, 1973: 698, 705). This potential for conceptual models fits with the call for Mode 2 type of research and action research (van Aken, 2005: 31); Mode 2 is aiming at solving field problems as they are called (see also Meredith, 1998). Modelling in operations research seems largely confined to regressions models (for example, Grönroos and Ojasalo, 2004; Kohlbacher and Gruenwald, 2011), which only list factors and determinants, and mathematical modelling (for instance, Koulouriotis et al., 2010; Shafer and Smunt, 2004; Vlachos et al., 2007). The steady-state model offers a more comprehensive framework for conceptualisation of processes that could be used to organise factors and determinants a priori empirical research; outcomes may then be used for generalisation across studies and for contextual understanding.
- The generic framework can be used for approaches to designing organisational structures. It links primary processes and control processes as a base for organisational structures; In Figures 2–6 the depiction of resources for control has been omitted for the sake of clarity. The design of an organisational structure may use the steady-state model to group resources for these processes teams, departments, organisational entities, etc.;

Emery and Trist (1972, p. 293) use the terminology differentiation for this purpose. This notion is merely implicitly present in other works, such as Childe et al. (1994: 28–9), Jang (2003: 217) and Melão and Pidd (2000: 112–3, 117–8, 121). Therefore, grouping of processes and resources using the steady-state model as reference model could constitute a systemic approach to analysis and design of organisations.

- Furthermore, the design of collaborative networks might benefit from this steady-state model, especially how two boundary zones from two separate actors in such a network are interrelated. Schuh et al. (2006) hint in their paper towards this, whereas Dekkers and van Luttervelt (2006, pp. 12–3) suggest a reconfiguration approach for industrial networks based on the model; this proposition uses performance criteria to reposition processes and resources in response to orders and changes in markets. Also, the regulatory zone could be viewed as a central concept for self-criticality in networks (see Kühnle, 2009). Self-criticality is the capability of a system to evaluate its own performance, akin teleons as described by Járos and Dostal (1999, pp. 198–9); see the evaluation in the regulatory boundary zone in Figure 4. In addition, it could be a background model for integration of suppliers in the boundary control of focal firms, a notion well-embedded in lean production as supplier integration (see Das et al., 2006; Sánchez and Pérez, 2001, p. 1444), but as yet with no explanatory model. Therefore, the steady-state model could be used a reference model for collaborative networks.
- Finally, the model can be used for operations research and decision sciences in addition to methods for cybernetics, structuring problems, system dynamics and soft systems methodology (Mingers and White, 2010: 1148–53) about advancing investigations in operations research. Moreover, it could be used for simulation modelling in post-positivist and constructivist tradition (see Kabak et al., 2015).

These applications only demonstrate the potential of this model, though the focus in the examples was on organisational arrangements. Its origins and its applications are multidisciplinary – Aboelela et al. (2006: 339) would call it 'trans-disciplinary'.

The steady-state model can be applied recursively. Recursion is not restricted to this model, since Beer (1972) and Miller (1955, 1965) also incorporated it, with Mlakar and Mulej (2008) showing its application to hospital services. Moreover, control processes can be interlaced as echelons of control within levels of recursion. This is not to be confused with Systems 4 and 5 of the viable system model (Beer, 1972: 169–171) and the breakthrough model (Dekkers, 2015: 210–5), which serve a different purpose, namely adaptation. As Beer (1972) recognises, a process model for recurrent procedures might also be partly applied to adaptive process, something not further discussed here.

In addition to its application in research, the steady-state model can be used for teaching in domains already mentioned and for teaching systems theories in addition to generic concepts (e.g. Banathy and Jenlink, 2004). In the context of teaching, Lane (2013: 328) makes the case that diagrams are an essential part of systems thinking and implies that type of visualation enhances the student learning process. This corresponds with the Sagasti and Mittrof's (1973: 698, 705) thoughts about conceptualisation and modelling for problem solving. It may also apply to action learning, since the steady-state model, as with any other theoretical conception, can be considered part of programmed knowledge; this type of knowledge is seen as part of the action-learning formulae (Marquardt and Waddill, 2004: 192). Popular textbooks represent the primary process from an economic perspective where both flowing elements and resources are considered input; Hill and Hill (2011: 14–5), Jacobs and Chase (2011: 15) and Slack et al. (2010: 11) are cases in point. Using the delineation of flowing elements and systems of resources in Figure 1 would make the explanation for processes as interaction clearer to what both their differing purposes are for operational processes. Hence, the steady-state model could be used for programmed problem solving, conceptualisation and case studies in teaching.

Reflecting on Its Contribution

Moving back to what the steady-state model brings to the table, it shares traits Miller's living systems and the viable system model. It follows the notion that these models should be based on 'process theory' (Sabelli, 1991: 224). However, it goes beyond Potocan et al.'s (2005) position by merging systems theories and cybernetics. It combines both a functional and structuralist approach (Jackson, 2009: S26–8) and should be positioned mostly as 'unitary' (Jackson, 1994: 214–5); it seeks to enhance existing approaches and shares the same objectives as other studies in the domain: the application of systems theories, including cybernetics, for both developing generic concepts and application to real-world problems. In terms of systems theories, it is part of man-made symbols and models (Becht, 1974: 570). Compared to Nechansky's (2010: 103) model, the steady-state model in this paper is more detailed and contains a greater variety of control mechanisms. Hence, the steady-state model in the paper could be seen as an extension of Miller's theory of living systems and as a more complete alternative to Nechansky's model.

The steady-state model offers also a slightly different view on what constitutes input and output. In more traditional views about the theory of living systems (e.g Miller, 1955: 514–5) and general systems theory (e.g. von Bertalanffy, 1972), the interaction with the environment happens primarily through information and energy, and the material flow is often accredited to systems with human interaction; see Laszlo and Krippner (1998) . The proposition here is that primary processes might consist of information, energy or matter, but that this is separated from information for the process of control. A case in point is an order to a firm; as information for the primary processes it holds data about the product specification and as information for the control processes the date of delivery, the costing and data for the quality conformance. This example implies that (process) modelling is an abstraction of reality for generic modelling or problem solving, but not necessarily reality itself (in the spirit of Rosenblueth's and Wiener's [1945] thoughts about models). In this perspective, the steady-state model with its process orientation does not necessarily reflect the physical structure; the structure is determined by how resources for the processes are grouped in (sub)systems. An example is the analysis of order processing by firms, which might include the processes at suppliers when orders are delivered in a make-to-order mode. Therefore, the steady-state model exerts control over the primary process, consisting either of information or energy or materials, but does not directly provide an abstraction of the physical structure, even though the boundary zones suggest this.

The model extends beyond feedback. Many view (e.g. Adams, 2012: 214) feedback as canonical approach to systems for maintaining homeostasis. Feedback is a prominent feature of system dynamics (e.g. Schwaninger, 2006: 588). Furthermore, Brethower and Dams' (1999: 39) model contains two feedback loops; one can be understood as 'canonical' feedback and the other as regulatory. Not only does the steady-state model include traditional feedback and feedback in the regulatory zone, it also includes feedforward and a mechanism called 'completing deficiencies' as interrelated control mechanisms.

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