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ORIGINAL PAPER

Describing the Necessity of Multi-Methodological Approach for Viable System Model: Case Study of Viable System Model and System Dynamics Multi-Methodology

Amin Vahidi[1] **· Alireza Aliahmadi**[1]

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Abstract The purpose of this paper is to develop a framework based on the Viable System Model (*VSM*) and the System Dynamics (*SD*) that dynamizes and simulates *VSM*. Failure in non-systemic solutions for management problems, urges managers to search for alternative management solutions. Therefore, managers chose Systems Thinking to tackle management complexity in organizations. In recent years, the need for alternative management solutions has given rise to increased popularity of methodologies such as system dynamics and viable system models. Moreover, managers are the victims of systemic failure in non-systemic organizational methodologies due to the one-dimensional and non-holistic views of the organizations (each methodology presents one dimension and viewpoint to the organization). To address the above issues and to facilitate complexity management in organizations, such methodologies should be reconciled and applied together in the form of a complementary multi-methodological approach. Therefore, to close this gap in the literature, this paper seeks to develop a new multi-methodological approach based on Viable System Model (*VSM)* and System Dynamics (*SD*). In this context, a dynamic model is developed that handles and manages knowledge throughout the organization together with a general *SD* framework that models organizational problem-solving. VSM literature review shows there are demands for such dynamic knowledge-based organizational design and diagnosis methodology. The developed multi-methodological approach enables the design of a dynamic complexity handling structure and its associated processes in any given organization. This research result is providing an approach that is more suitable and comprehensive as it dynamizes VSM and covers for the weaknesses of both *SD* and *VSM*. Then, the multi-methodology is applied in a management consulting company and the results are presented. The application of the multi-methodology and proposed policy results demonstrates improved organizational problem-solving abilities in terms of speed and manageability of problems.

✉ Alireza Aliahmadi
aliahmadi@iust.ac.ir

[1] Industrial Engineering Department, Iran University of Science and Technology, Tehran, Iran

Keywords Systems thinking · Organizational structure · System dynamics · Viable system model · Multi-methodology

Introduction

Managers are compelled to survive in the face of complexity, diversity, and changes in their organization's environments (Ashby 1952; Kamran 2013; Preece et al. 2013). Complexity is a byproduct of the interconnected nature of the problems in today's in terms of complexity handling structure and its associated processes (von Foerster, 1974; Beer 1990). Thus, leading to bigger problems with more stakeholders being involved. To tackle such problems effectively, systemic thinking and its related methodologies should be utilized (Jackson 2007).

In the present time, customer preferences are subject to more rapid changes (Elezi et al. 2014) and global interactions and technological advances make these changes occur even faster.

Failure in non-systemic management solutions due to inappropriate prioritization, complexity, poor connection to the strategies and goals and a late and incomplete adaptation to change urges organization managers to seek alternative management solutions (Jackson 2007). Therefore, holistic systems are developed to better cope with more complex and versatile issues and analyze different metaphors and aspects of a system (Espinosa et al. 2008; Dominici 2013; Bohórquez Arévalo and Espinosa 2015).

As Systems Thinking has gained increasing popularity over the recent years, a rich repository of systemic methodologies now exists (Jackson 2007). Managers are the victims of failure in organizational methodologies due to the one-dimensional views of the organizations. Such one-dimensional views lead to improvements in a given organizational aspect, but may impair another. For example, human resources may experience a lapse where productivity is improved. As a result, system methodologies should be applied together in the form of a multi-methodological approach in order to address complex issues effectively.

A multi-methodology can be developed only if the two methodologies are in the same paradigm and have different metaphors (Mingers 2010). Here, *SD* is in the so-called *Functionalist* paradigm and has the *Flux and Flow* metaphors (Jackson 2007). *VSM* is also in the so-called *Functionalist* paradigm but has the *Brain and Organism* metaphors (Jackson 2007).

SD and *VSM* are such that the benefits of each cover other one disadvantages. So, these two methodologies are complementary and the combinational methodology does not have the disadvantages of each single methodology. These complementary features are explained in "Complementary features of *VSM* and *SD*" section.

All such methodologies are considered systemic but not all of them can be applied together (Mingers 2010). Schwaninger (2004) suggests that *VSM* and *SD* methodologies are complementary (Schwaninger 2004). The combination of *VSM* and *SD* could be useful in the design and analysis of an organization. However, no operational model of this combination has ever been made. In the present research, a complementary multi-methodological approach is developed to address complexity management in organizations.

The challenge of complex organizational issues calls for joining forces between the methodologies (Bohórquez Arévalo and Espinosa 2015). Such interaction is fertile, given at least two methodological developments. In this paper, first Multi-methodology, then System Dynamics and its features are described. In "Viable System Model" section, *VSM* and its subsystems are described. In addition, its strengths and weaknesses are examined. In the next section, feasibly of combining these two methodologies based on their theoretical dimensions is examined. In "Complementary features of *VSM* and *SD*" section, the complementarity of these two methodologies and the need for their combination are described. Subsequently, the suggested combinational methodology and dynamic model of *VSM* are presented. In "Case Study" section, the Dynamic Model is implemented in the *SMARTCO* management consulting company. In addition, its results are presented and show that the benefits of the proposed method are proven in practice. Finally, the research summary is presented.

Multi-Methodology

Multi-methodology is the joined utilization of various methodologies, in a solitary intervention (Mingers and Brocklesby 1997). Mingers (2002) see multi-methodology as an inventive combination of methodologies for complex systems. Multi-methodology is consequently, a type of methodological pluralism that is introduced on a multi-paradigm approach as mentioned by Mingers (1997a, 1997b). Multi-methodology in this way, uses methodologies and methods which are both qualitative and quantitative (Mingers, 2000a), and both hard and soft methodologies can be taken after (Sterman 1988; Mingers and Gill 1997).

These system methodologies are consistent with the above-mentioned explanations that formulate multi-methodologies, should be combined with a procedure. This procedure described in many researches (Mingers and Brocklesby 1997; Mingers 1997a; Milanzi 2000; Munro and Mingers 2002; Jackson 2007; Mingers 2010). A brief review of these researches is as follows.

This procedure is governed by the rules that will be discussed below. These rules are based on two terms, paradigm, and metaphor (Jones 1995; Mingers 1997a; Mingers and Brocklesby 1997; Munro and Mingers 2002).

According to studies (Curram & Mingers 1994; Milanzi 2000; Mingers 2000b, Mingers 2001, 2003, 2004, Mingers 2006, Mingers 2010; Rosenhead & Mingers 2001; Munro and Mingers 2002; Mingers & Rosenhead 2004; Mingers 2011), which are the most well-known researches in the multi-methodology, the basic principle behind the establishment multi-methodologies are:

1. Methodologies with different paradigm should be used sequentially and in series.
2. Only the methodologies with the same paradigm (which pursue a single objective) have the ability to merge and apply parallel.

    1.1 Methodologies with the same paradigm and different metaphors can be used molded and parallel to complete the analysis of system dimensions (metaphors).

    1.2 Methodologies with the same paradigm and the same metaphors can be used to validate the results of each other because they all examine the same objective and dimensions (metaphors) of the system.

Paradigm and metaphors of well-known systemic methodologies described in Fig. 1 (Mingers & Rosenhead 2004; Mingers 1980, 1984, 1987, 1989, 1994, 1997a, b, 2000a, 2011; Milanzi 2000; Rosenhead & Mingers 2001; Munro and Mingers 2002).

As it is shown in Figs. 1 and 2, *VSM* could create parallel multi-methodologies with methodologies such as System Dynamics, Complexity Theory, and SODA. SODA has Culture paradigm (Georgiou, 2011). These methodologies provide combinational aspects (metaphors)

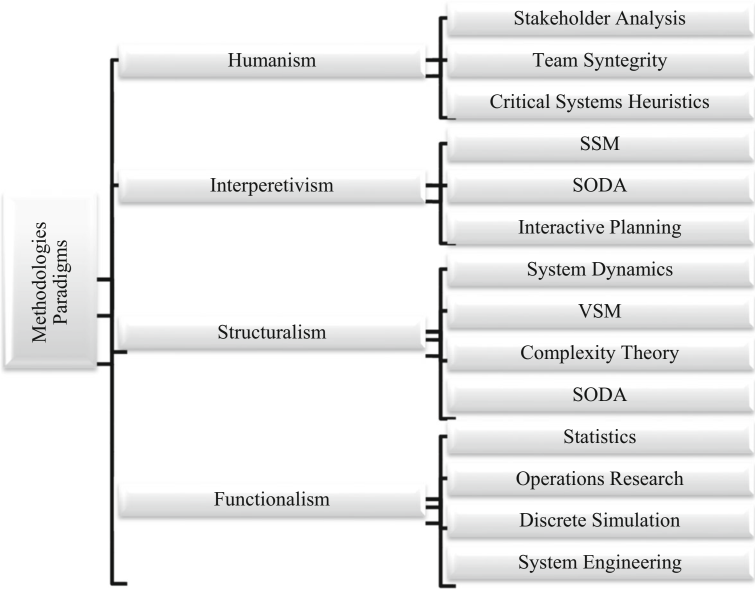

Fig. 1 Most well-known systemic methodologies paradigms (this research findings)

for the system. Also, based on multi-methodology rules, *VSM* could create a series multi-methodologies with methodologies such as Stakeholder Analysis, Team Syntegrity, Critical Systems Heuristics, SSM, Interactive Planning, Statistics, Operations Research, Discrete Simulation, and System Engineering.

Based on above descriptions, multi-methodology based on *VSM* and *SD* could be useful because it covers *VSM* deficiencies and dynamizes it.

System Dynamics

System Dynamics was originally conceived as a methodology for modeling and simulating dynamic, non-linear systems to address real-world issues. It grew out of the positivist tradition, even though its originator, Jay Forrester (1961), criticized the limitations of traditional modeling approaches, pioneering an effort to transcend them. System dynamics (*SD*) help to understand the nonlinear behavior of complex systems over time using stocks, flows, internal feedback loops, and time delays as its components. *SD* was first developed in the late 1950s in an effort to investigate and eliminate the complexity of dynamic issues (Kirkwood 2001) and is used today to simulate public and private sector systems over long periods. A group of researchers led by Jay Forrester introduced *Industrial Dynamics* (Schwaninger 2004). Industrial Dynamics later became basics of System Dynamics. Feedback, accumulation of flows into stocks, and time delays are the components of *SD* diagrams.

The real power of SD is realized through computer simulation why varieties of software packages are readily available. *SD* Simulation is made up of the following steps (Sterman 2000):

1. Definition of problem boundary conditions,
2. Identification of the most important stocks and the flows that affect the stock levels,
3. Identification of the sources of information that affect the flows,
4. Identification of the main feedback loops,

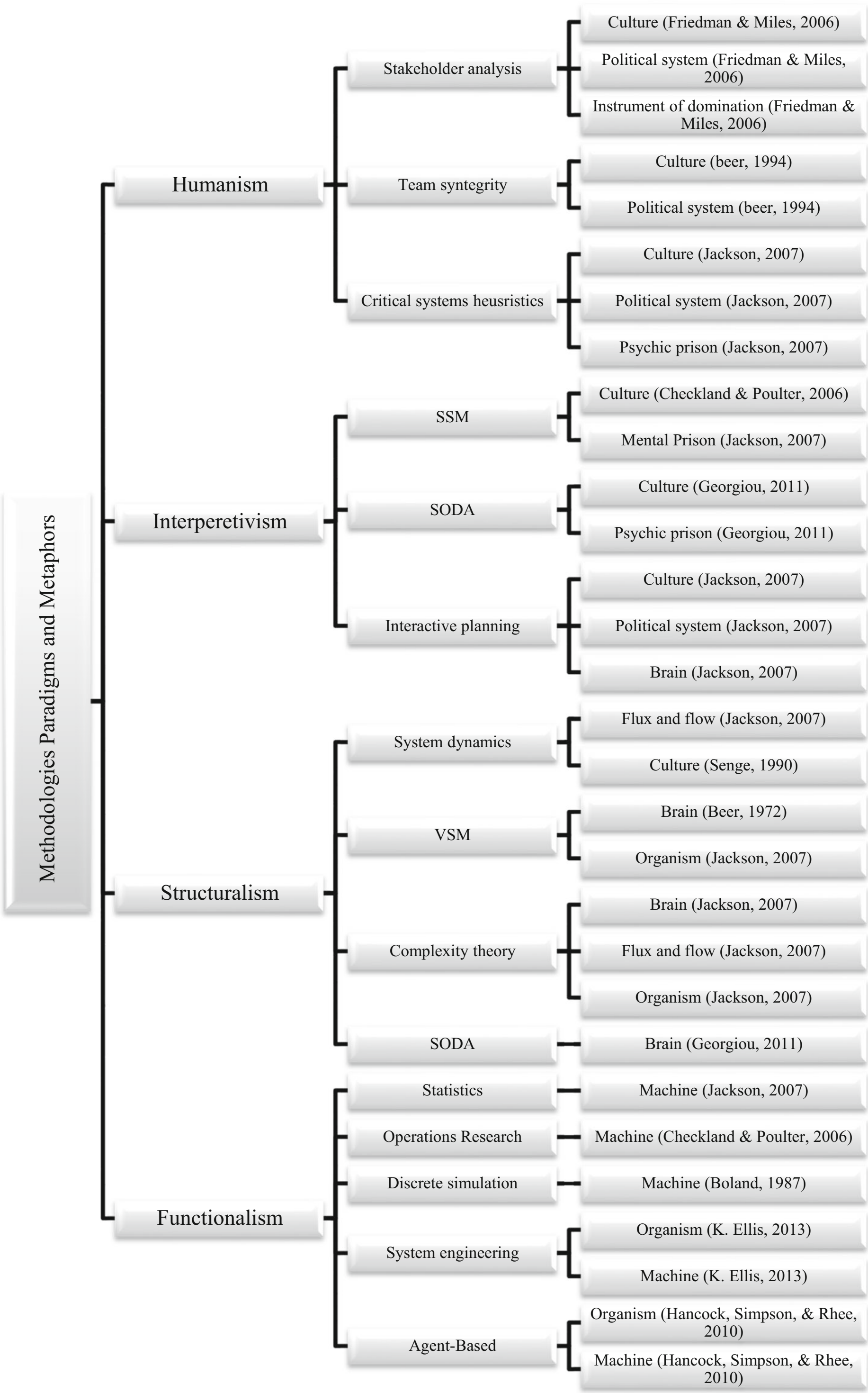

Fig. 2 Most well-known systemic methodologies paradigms and metaphors (this research findings)

5. Construction of a stock and flow diagram that links the stocks, flows, and auxiliaries,
6. Formulation of the equations that determine the flows,
7. Estimation of the parameters and initial conditions that can be estimated using statistical methods, expert opinions, market data or other relevant sources of information,
8. Simulation of the model and analysis of the results.

SD has various application domains, including population, ecological, and economic systems that usually interact strongly with each other. *SD* also has various "back of the envelope" management applications and is a potent tool for:

- Teaching Systems Thinking reflexes to individuals receiving training,
- Analysis and comparison of the assumptions and mental models in order to explore how organizational matters work,
- Gaining qualitative insight into the workings of a system or the consequences of a decision,
- Recognition of the archetypes of complex systems in everyday practice.

In this research, *SD* methodology has been chosen because:

- It is designed to meet the complex behavior of nonlinear systems (Kirkwood 2001),
- It simulates the human collective behavior easily,
- It can find appearance of *emergent properties* and enable management of many complex problems (Jackson 2007),
- It is capable of modeling knowledge and learning,
- It is a comprehensive method (Schwaninger 2004),
- It is gaining increasing popularity (Jackson 2007),
- It enables quantitative simulations (Kirkwood 2001),
- It can be implemented in easy to use software (Kirkwood 2001).

Viable System Model

Stafford Beer was a theorist in systems who compiled several books on the topic of management systems. Beer's efforts led to the introduction of a new multidisciplinary field called "management cybernetics" (Beer 1959, 1962, 1966, 1979, 1985) in his book *Brain of the Firm* (Beer 1994).

The model is based on five sub-systems that sustain both identity and survival In other words; this model identifies five subsystems that make up the operations and the meta-system of any viable system. These subsystems are denoted as systems 1, 2, 3, 4, and 5 (Brecher et al. 2013; Preece et al. 2013; Rahayu and Zulhamdani 2014).

The principle of viability implies that every system, which effectively maintains its existence, includes the invariant structure of a Viable System. This structure enables the system to recognize internal disturbances and changes in its environment and to react appropriately (Espejo and Harnden 1990; Espinosa et al. 2008; Espinosa et al. 2015).

A closer look at *VSM* reveals the following regarding each of the above subsystems:

- System 1 is the collection of operating units that carry out the primary activities of the organization. Thus, the system 1 is composed of all the units that carry out operations in practice and is analogous to the muscles and organs in the human body (Dominici 2013).

- On the other hand, system 2 is analogous to the autonomic nervous system that monitors the interactions between the muscles and organs in the body. System 2 is responsible for resolving potential conflicts between the operating units and maintaining the system's overall stability (Espejo 2013).
- System 3 optimizes the collective operations of the muscles and organs in the body via a thorough screening. In addition to carrying out the functions of system 2, system 3 is additionally responsible for finding ways to generate synergies between the operating units (Beer 1994).
- System 3* meets the requirement for an audit channel that can control details, regardless of detailed-management (Reyes 2001). Financial auditing is the clearest example, but it can be an energy audit, a security audit, an IT compliance audit, customer complaints, and others (Leonard 2009).
- System 4 is analogous to the human conscious nervous system and looks out at the environment, collects information, and makes predictions and forecasts about the environment. System 4 also adopts the necessary strategies and plans to best adapt to the environment (Espejo 2013).
- Finally, system 5 is analogous to the human higher brain functions. It defines the system's identity and its overall vision or reason for being. This system decides which operating policies and guidelines the system will follow (Beer 1994).

Note: "Higher" and "lower "subsystems in this paper refer to the S5, S4, S3, S2, S1 sequence.

In addition, *VSM* is a recursive model, meaning that every subsystem is supposed to be a *VSM* in itself. However, in this paper first recursive level of *VSM* used. *VSM* methodology has advantages as listed below (Leonard 2009):

- It offers a conceptual framework for organizational structure development,
- It is a comprehensive methodology in various sectors including public, private, and political sectors,
- It has not been rejected to date,
- It is finding increasing application,
- It is based on a strong theoretical framework
- It is based on the Ashby law of requisite variety,
- It has a holistic view of the system,
- It is a straightforward methodology with clear complexity handling steps. Therefore, it handles the external and internal complexities based on the Ashby law of *requisite variety* for reaching a balance in system complexity (An example of *VSM* and *SD* complexity handling shown in the "Case study" section).

Schwaninger described the necessity of combining *VSM*, *SD,* and other systemic methodologies in 2004 (Schwaninger 2004). The strength of VSM lies primarily in its diagnostic potency, but it is also a powerful conceptual tool to orientate organization design (Schwaninger 2004). However, not a detailed framework, neither an operational model of this combination has ever been made.

The trend in *VSM* literature shows a clear demand for a multi-methodological approach that combines *VSM* and *SD*. Several researchers over a number of years emphasize the need for combining *VSM* and *SD*. Haslett and Oka (2000), Schwaninger (2004) and Schwaninger and Ríos (2008) emphasis on the necessity of combining *VSM* and *SD*. However, not a detailed framework, nor a simulation model of this combination has ever been made.

Combination of *VSM* and *SD* Feasibility

Combination of *VSM* and *SD* can minimize defects and handle complexity in organizations. Moreover, Minger suggests that a multi-methodological approach can be developed only if the two candidate methodologies are in the same paradigm and have different metaphors (Mingers, 2000b; Mingers 1980, 1997a, b, 2006, 2010; Mingers and Brocklesby 1997; Mingers 2001; Munro and Mingers 2002). Here, *SD* is in the so-called *Functionalist* paradigm (Mignot 2000; Mingers 1997a; Morgan 1980). *SD* uses stock and rate variables as the main concepts of its model building process so it has the *Flux and Flow* metaphors (Morgan 1980; Mignot 2000). *VSM* is also in the so-called *Functionalist* paradigm (Mingers 1997a; Morgan 1980; Mignot 2000; Raúl Espejo 2013). *VSM* is based on the human nervous system (including the brain) and models system similar to nervous system organs. So, It has the *Brain* and *Organism* metaphors (Morgan 1980; Mignot 2000). So, in principle, the combination of *SD* and *VSM* can be useful for improving the organizational framework (Jackson 2007).

From a practical viewpoint, *SD* does not cater for organizational architecture. On the other hand, *VSM* provides a suitable framework for diagnosis and design of modern system architecture. Then, *SD* can provide the dynamic view *VSM* required (Espejo and Harnden 1990; Haslett 2000; Hoverstadt 2010; Preece et al. 2014; Espinosa et al. 2015). Therefore, the combination of these two methodologies will be useful from both theoretical and practical perspectives (Table 1).

Complementary Features of *VSM* and *SD*

The trend in *VSM* literature shows demand for a multi-methodological approach that combines *VSM* and *SD*. Several researchers such as Haslett and Oka (2000), Schwaninger (2004), Schwaninger and Ríos (2008) over these years emphasize the need for combining *VSM* and *SD*.

Combination of *VSM* and *SD* can minimize defects of each methodology (especially *VSM*) and handle complexity in organizations. In addition, as it said before, both methodologies have a Functionalist paradigm (Mingers 1997a; Morgan 1980; Mignot 2000) but *SD* has the Flux and Flow metaphors (Morgan 1980; Mignot 2000) and *VSM* has Brain and Organism metaphors (Morgan 1980; Mignot 2000). Therefore, the combination of *SD* and *VSM* is useful.

Both *VSM* and *SD* are general-use approaches. *SD* lacks general goal (Jackson 2007) but *VSM* is emphasizing on viability and survival (Yolles 2004). *SD* has a holistic view of the system, but *VSM* has difficulty to see all effects and consequence together (Schwaninger 2004). *SD* lacks a clear system for diagnosing and developing the organizational structure, but *VSM* is an information-based conceptual organization structure (Jackson 2007). *SD* lacks a specific procedure to deal with increasingly complex systems, but *VSM* has a clear method to reduce external and internal complexity (Schwaninger 2004). *SD* has a simple model deployment and user-friendly software. Also, There are some software for *VSM* like *ViPlan* and *VSmod* but they generally just demonstrate or add some supplementary tools to *VSM,*

Table 1 Complementary features of *VSM* and *SD* (this research findings)

Features	SD	VSM	Selected feature from …	SD and VSM multi-methodology features
Paradigm	Functionalist	Functionalist	Both	Could form multi-methodology
Metaphor	Flux and Flow	Brain and Organism	Both	Provides both Flux and Flow Brain and Organism metaphors
Scope	General approach	General approach	Both	General approach
Goal	No general goal (Case-Based)	Emphasizing on viability and survival (S5)	VSM	Emphasizing on viability and survival
Holism	Holistic view of system	Difficulty to see all effects and consequence together	SD	Holistic view of system
Framework	Lack of a clear framework for diagnosing and developing organizational structure	Information-based conceptual organization structure (S3*)	VSM	Information-based conceptual organization structure
Complexity Handling	Lack of a specific procedure to deal with increasingly complex systems	A clear method to reduce external and internal complexity	VSM	A clear method to reduce external and internal complexity
Simplicity	Simple model deployment and user-friendly software	Difficulty in use of the model and lack of operational software that could run, simulate and diagnosis a VSM model with its varieties	SD	Simple model deployment and a user-friendly software
Content	Relation with content level of the system	Inability to communicate with the content level of system	SD	Relation with content level of system
Emergent Properties	Understanding emergent properties of policies	Lack of emergent properties understanding	SD	Understanding emergent properties of policies
Quantitative	Quantitative detail	Can't provide quantitative simulation	SD	Quantitative detail
Users	High and increasing number of users	Increase of Application	SD	High and increasing number of users

*e*specially for learning *VSM*. But *VSM* has difficulty in the use of the model because it lacks operational software that could run, simulate and diagnosis a *VSM* model with its varieties (based on the law of requisite variety) (Schwaninger 2004). *SD* has a relation to the content level of the system, but *VSM* is unable to communicate with the content level of the system (Jackson 2007). *SD* has an understanding of emergent properties, but *VSM* lacks it (Schwaninger 2004). *SD* has quantitative details, but *VSM* cannot provide quantitative simulation. As will be shown in the next section, *SD* has a high and increasing number of users, but *VSM* has lately increased its users.

From a practical viewpoint, *SD* does not cater for organizational structure. On the other hand, *VSM* provides a suitable system for diagnosis and design of modern system structure. *SD* can provide the dynamic view *VSM* required (Espejo and Harnden 1990; Haslett 2000; Hoverstadt 2010; Preece et al. 2014; Espinosa et al.

2015). Therefore, the combination of these methodologies will be useful from both theoretical and practical perspectives (Table 1).

Feature titles for ***SD*** and *VSM* are given in the first column of Table 1. SD and *VSM* features under each title are given in columns two and three, respectively. For each title, either SD or VSM feature is more suitable. Therefore, the multi-methodology has more suitable features than each one of the single methodologies. This is indicated in column four of Table 1. As a result, features of the multi-methodology is listed in column five. The complementary nature of *SD* and *VSM* methodologies is evident from Table 1. In other words, where *SD* does not present a suitable feature (bold cells) *VSM* presents a suitable feature (bold italic cells), and vice versa. Therefore, it is believed that the combination of *VSM* and *SD* could provide a more comprehensive approach that surpasses the existing ones.

In terms of application scope, both methods and can be used in a wide range of systems (Jackson 2007).

From Holism viewpoint, *SD* is a holistic approach that can see all the dimensions of the system simultaneously, but VSM does not have such a capability (Schwaninger 2004).

From the user's viewpoint, *SD* is used extensively by users, but *VSM* is not known as much as *SD* for practitioners and researchers (Jackson 2007).

Proposed Multi-Methodological Approach

In this section, we propose a model for the multi-methodological approach based on VSM and *SD*. The key policy-making lever in this model is the delegation of authority in every subsystem to the subsystem one below (authority delegation). Authority delegation (Delegation of authority) is the process by which a manager or supervisor transfers some part of his/her legitimate authority to others without losing responsibility (Dominici 2013). Authority delegation exempts managers from having to resolve everyday problems and allows them to focus instead on issues that are more important. In addition, authority delegation allows other members of the organization await an opportunity to develop their knowledge and ability for solving future problems. Today, authority delegation is becoming increasingly important in the lifetime of a system given the increasing number of complex problems. With authority delegation, the system would be able to handle increasing numbers and forms of environments according to the Ashby law of requisite variety (Ashby 1952; Ashby 1958).

In the proposed model, the classical *VSM* variables such as environmental variety (the first column of Fig. 3) and the five aforementioned subsystems, their varieties and absorbing rates (second and third columns of Fig. 3) are modeled. Moreover, implicit knowledge levels of each subsystem are generated over time (fourth column of Fig. 3). Authority delegation is given in the fifth column of Fig. 3.

Variety is a technical term for complexity. For example, in our case (*SMARTCO* management consulting company) variety could be new competitors, new rival products, and services, human resource issues, etc. These varieties could be absorbed by solutions for these issues (varieties). For modeling *VSM* with the System Dynamics, variety amount of each subsystem is considered a stock variable. The unit of measurement of these variables is the "number" of variations. The number of issues is considered an input rate. In addition, the number of solutions (absorbed variety) plus the number of remained

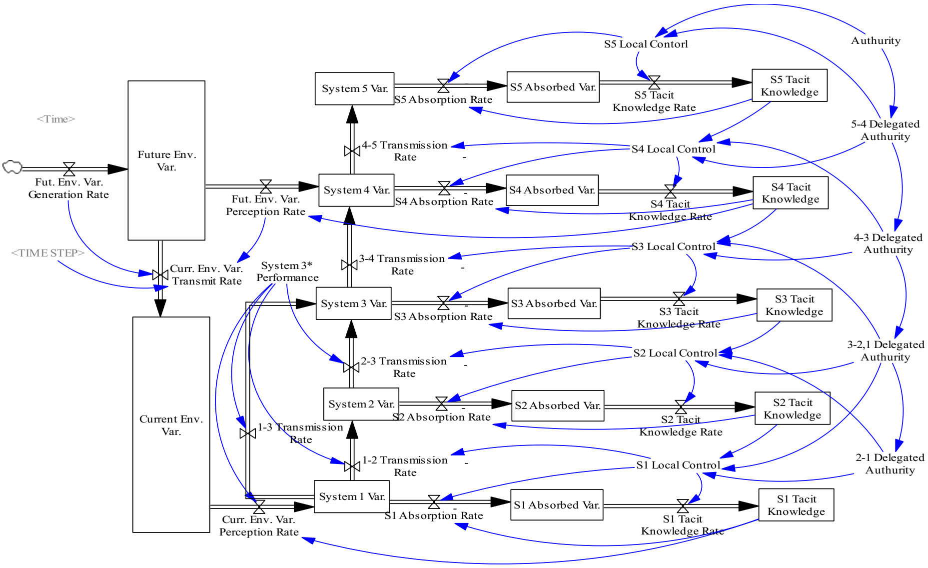

Figure 3- The viable *SD* stock and flow model (this research findings)

Fig. 3 The viable *SD* stock and flow model (this research findings)

issues is referred to above subsystem (variety not absorbed) is considered an output rate. The law of requisite variety states, 'Only variety can destroy variety' (Ashby 1956). Therefore, the number of these issues (varieties) should be less than number of related solutions (absorbed variety). Variety would be destroyed by amplifying subsystems variety absorption capacity. This amplifying occurs by adding "tacit knowledge" to the model. Tacit knowledge is mainly the ability and know-how of solving an issue or problem. In our model, it increased when more and more variety is absorbed (experience gained). More description came in Tables 2 and 3. In addition, tacit knowledge increasing results in subsystem absorption capacity increasing. Because tacit knowledge increase could result in finding more solution for a problem. This modeling provides the simulation of the Ashby law of requisite variety (Ashby 1956) in *VSM*. In addition, it makes *VSM* dynamic.

In this model, varieties are considered as stock variables because of variety's accumulative essence and its importance in *VSM*. In addition, variety transformation and absorption variables are considered as rate variables for these stock variables. Another stock variable is the amount of tacit knowledge produced in each subsystem after variety absorption (decision-making and problem-solving). These stocks are measured by absorbed variety. More descriptions are provided in Figs. 4, 5, Tables 2, and 3. In addition, there are adequate descriptions about what variety means in this case and how it is measured and many other detailed descriptions of input, process, and output of the model were presented in the case study section.

Case Study

In this section, the multi-methodology has been applied in *SMARTCO* management consulting company. In this company, some personnel and units have a lot of workloads,

Table 2 Descriptions and equations of the most important model variables (this research findings)

Variable Name	Variable description	Equation	Relationship Description
“1–2 Transmission Rate”	Rate of variety transmitted from subsystem 1 to subsystem 2	9*(1-S1 Local Control)*"System 3* Performance”	This variable is equal to the basic variety that should not be absorbed in this subsystem (1-S1 Local Control) and monitored by the audit system (“System 3* Performance”).
“2–1 Delegated Authority”	Percent of authority transmitted from subsystem 2 to subsystem 1	0.5*"3–2 Delegated Authority”	This variable is the percent of subsystem 2 authority that should go to subsystem 1.
Authority	Total authority	1	This variable is the total authority divided between subsystems.
“Curr. Env. Var. Perception Rate”	Rate of perception of current environmental variety by subsystem 1	20*(S1 Tacit Knowledge/1000)*"System 3* Performance”	This variable is equal to the fraction of total current environmental variety level affected by subsystem 1 tacit knowledge (S1 Tacit Knowledge/1000) and audit system performance (“System 3* Performance”).
“Curr. Env. Var. Transmit Rate”	Rate of transmitting future environmental variety to current environmental variety	DELAY FIXED (“Fut. Env. Var. Generation Rate”-"Fut. Env. Var. Perception Rate”, TIME STEP,0)	Total amount of future environmental variety transmitted to current environmental variety by a time step long delay
“Current Env. Var.”	Level of current environmental variety	INTEG (+"Curr. Env. Var. Transmit Rate”-"Curr. Env. Var. Perception Rate”,100)	Calculated due to its inflow and outflow rates.
“Fut. Env. Var. Generation Rate”	Rate of variety will be generated in future	15	Predefined
“Fut. Env. Var. Perception Rate”	Rate of perception of future environmental variety by subsystem 4	5*(S4 Tacit Knowledge/1000)	This variable is equal to the fraction of total current environmental variety level affected by subsystem 4 tacit knowledge (S4 Tacit Knowledge/1000) and audit system performance (“System 3* Performance”).
“Future Env. Var.”	Level of future environmental variety	INTEG (+"Fut. Env. Var. Generation Rate”-"Curr. Env. Var. Transmit Rate”-"Fut. Env. Var. Perception Rate”,100)	Calculated due to its inflow and outflow rates.
INITIAL TIME	Simulation starting time	0	Predefined
“System 1 Var.”	Level of subsystem 1 variety		Calculated due to its inflow and outflow rates.

Table 2 (continued)

Variable Name	Variable description	Equation	Relationship Description
		INTEG (+"Curr. Env. Var. Perception Rate”-"1–2 Transmission Rate”-S1 Absorption Rate,0)	
“S1 Absorbed Var.”	Level of variety absorbed by subsystem 1	INTEG (S1 Absorption Rate-S1 Tacit Knowledge Rate,0)	Calculated due to its inflow and outflow rates.
S1 Absorption Rate	Rate of variety absorbed by subsystem 1	1*(S1 Tacit Knowledge/1000)*(1-S1 Local Control)	This variable is equal to the basic variety that should be absorbed quickly in this subsystem (1-S1 Local Control) affected by subsystem 1 tacit knowledge (S1 Tacit Knowledge/1000) (because more control means more time and creative ways)
S1 Local Control	Amount of control ability exists in subsystem 1	MIN(1,1*(S2 Tacit Knowledge/1000)*"2–1 Delegated Authority”)	Subsystem 1 control ability is the minimum of 1 and its upper-system (subsystem 2) confremented authority (2–1 Delegated Authority) affected by its tacit knowledge (S2 Tacit Knowledge/1000)
S1 Tacit Knowledge	Level of tacit knowledge of subsystem 1	INTEG (S1 Tacit Knowledge Rate,500)	Calculated due to its inflow and outflow rates.
S1 Tacit Knowledge Rate	Rate of tacit knowledge of subsystem 1 creation	10*S1 Local Control	This variable is influenced by its local control. (Because more control means more time and creative ways)

Table 3 Descriptions and equations of the most important model variables of *SMARTCO VSM* (this research findings)

Variable Name	Equation	Equation Data from *SMARTCO*
"System 1 Var."	INTEG (+"Curr. Env. Var. Perception Rate"-"1–2 Transmission Rate"-S1 Absorption Rate,0)	Calculated by summing the current accumulated variety and variety come from environment minus variety transmitted to system 2 minus variety absorbed (issues solved) in system 1, in each week. For example, in a week for system 1: • Accumulated variety is 10 (4 new customers, 3 new software, 4 new competitors, and 1 new IT technology). • It has 10 amounts of variety came from the environment (5 new features to competitors software, 3 key personnel want to leave the company, and 2 labor law changes happen). • 3 varieties handled by system 1 (2 personnel persuaded to remain in company, 1 labor law changes included in company HR rules) • 4 varieties sent to system 2 (1 competitor review and 1 labor law sent to system 2 for finding solutions). So, at the end of the week system 1 variety becomes 10 + 10–4-3 = 13. It means 13 issues remained unsolved and unhandled (unabsorbed) in system 1, and 7 varieties (issues) handled (absorbed) in system 1.
"2–1 Delegated Authority"	0.5*"3–2 Delegated Authority"	It shows how much of the total company works should be done in system 1. In *SMARTCO*, half of the tasks assigned to system 2 sent for system 1 to handle. Because *SMARTCO* is in a complex knowledge-based market system 2 (HR, Strategy, and System unit directors) decide to handle half of the tasks assigned to them themselves and sent the other half to system 1 (HR, Strategy, and System unit operational units) to be handled. This matter directly affects the amount of System 1 and System 2 local controls. In addition, local controls directly affect absorption and transmission rates. These variables described in the following parts.
Authority	1	1 = 100% is the total authority divided between systems. It means how company total tasks (100%) divide between systems 5 to 1 on a top-down chain of command framework. Each system receives part of its upper system authority and sends some of its authority to lower system.
"Curr. Env. Var. Perception Rate"	20*(S1 Tacit Knowledge/1000)*" System 3* Performance"	Ordinary subsystem 1 can perceive maximum of 10 issues every time step (as described in Fig. 4 and its related texts). However, every 1000 units of system 1 tacit knowledge increase its perception ability by 1. Tacit knowledge will be described after but for information, it is calculated by the number of issues each system solved. As has been seen in *SMARTCO*, every increase in system 1 tacit knowledge (a new variety that operational units solved) increase their variety perception ability by 0.1%. It means after 1000 amounts of increase in tacit knowledge (solving 1000 new issues) system 1 can perceive 1 more variety each week. In addition, the above amount affected (multiplied) by System 3* Performance. System 3* Performance means how much links between systems are effective and not defected. System 3* Performance is a number between 0 (completely corrupted) and 1 (completely healthy). In *SMARTCO*, the links between systems are completely healthy. So, System 3* Performance value is 1.
"Curr. Env. Var. Transmit Rate"	DELAY FIXED ("Fut. Env. Var. Generation Rate"-"Fut. Env. Var. Perception Rate", TIME STEP,0)	Future environmental issues (varieties) added to current environmental Issues (varieties) every time step. It means after each week, next week issues become current week issues. If system 4 could not import these issues so far, these issues come into the current environment variety and imported into system 1.
"Current Env. Var."		

Table 3 (continued)

Variable Name	Equation	Equation Data from *SMARTCO*
	INTEG (+"Curr. Env. Var. Transmit Rate"-"Curr. Env. Var. Perception Rate",100)	The amount variety exists in the environment (environment variety definitions came before). Some of these issues imported into system 1 and circulate in the system until getting their solution (become absorbed).
"Fut. Env. Var. Generation Rate"	15	Every time step (week) 15 new issues (varieties) generates on average. *SMARTCO* strategists anticipate that *SMARTCO* will face these varieties every week in the next years: • 6 new competitors for HR, Strategy, or System *SMARTCO* solutions. • 1 change in laws. • 4 new customers for HR, Strategy, or System *SMARTCO* solutions. • 2 new suppliers • 2 technological changes in HR, Strategy, or System *SMARTCO* solutions industry. So, averagely, there will be 15 new varieties every week in the next years.
"Fut. Env. Var. Perception Rate"	5*(S4 Tacit Knowledge/1000)	Ordinary subsystem 4 can perceive maximum of 5 future issues every time step. It means *SMARTCO* R&D, Marketing, and Strategic Planning experts by average could intercept and import 5 future issues and work on them every week. However, every 1000 issues they solve (tacit knowledge increased) increase their perception ability by 1.
"Future Env. Var."	INTEG (+"Fut. Env. Var. Generation Rate"-"Curr. Env. Var. Transmit Rate"-"Fut. Env. Var. Perception Rate",100)	The amount of accumulated variety in the future that is not imported into system 4. It increases every week by the amount of future variety generation rate.
INITIAL TIME	0	Here 0 means the starting point of simulation (2017).
"1–2 Transmission Rate"	9*(1-S1 Local Control)*"System 3* Performance"	Every week averagely, HR, Strategy, and System Services and Solution units can document and send respectively 4, 2, and 3 issues (varieties) from the environment to their directors. It is because HR unit has 4, Strategy unit has 2, and System unit has 1 personnel. It means totally they can send an average of 9 issues per week to System 2 (Units Directors).
"S1 Absorbed Var."	INTEG (S1 Absorption Rate-S1 Tacit Knowledge Rate, 0)	Amount of issues handled by system 1 until this time. Each variety absorbed (issues handled) produce 1 unit tacit knowledge.
S1 Absorption Rate	1*(S1 Tacit Knowledge/1000)*(1-S1 Local Control)	Ordinary subsystem 1 can absorb a maximum of 1 issues every time step if it has full authority (1-S1 Local Control). However, every 1000 issues it solves increase its perception ability by 1.
S1 Tacit Knowledge	INTEG (S1 Tacit Knowledge Rate, 500)	Tacit Knowledge of each system calculated by the number of issues each system solved until this time (as described in "S1 Absorbed Var."). Therefore, its unit is as "S1 Absorbed Var." (number of issues solved). As it has been seen in *SMARTCO*, every increase in a system tacit knowledge (new variety that system solved) increases their variety perception ability by 0.1%. It means after 1000 amounts of increase in tacit knowledge (solving 1000 new issues) system can solve (absorbs) 1 more variety each week.

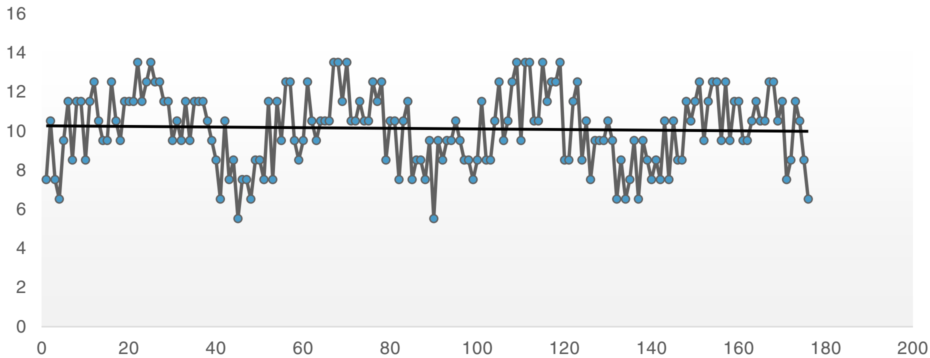

Fig. 4 *SMARTCO* current variety perception rate from 2014 to 2017 (this research findings)

and some units are idle at the same time. To solve this problem, the combinational model is used and the results are presented (parameters definition, values, and formulas are completely described in Tables 2, 3, and 4). The formulas and parameters data are based on the varieties, structure, and issues of the *SMARTCO* and its environment. Varieties are new competitors, new rival products, and services, human resource issues. Table 2 is the equations and variables of the subsystem 1 in the proposed model. More description of *SMARTCO* model variables and parameters came in Table 3. Other subsystems equations and variables are same as subsystem 1. In addition, their detailed descriptions and equations are given in the appendix. Note that all subsystem 1 s could be considered

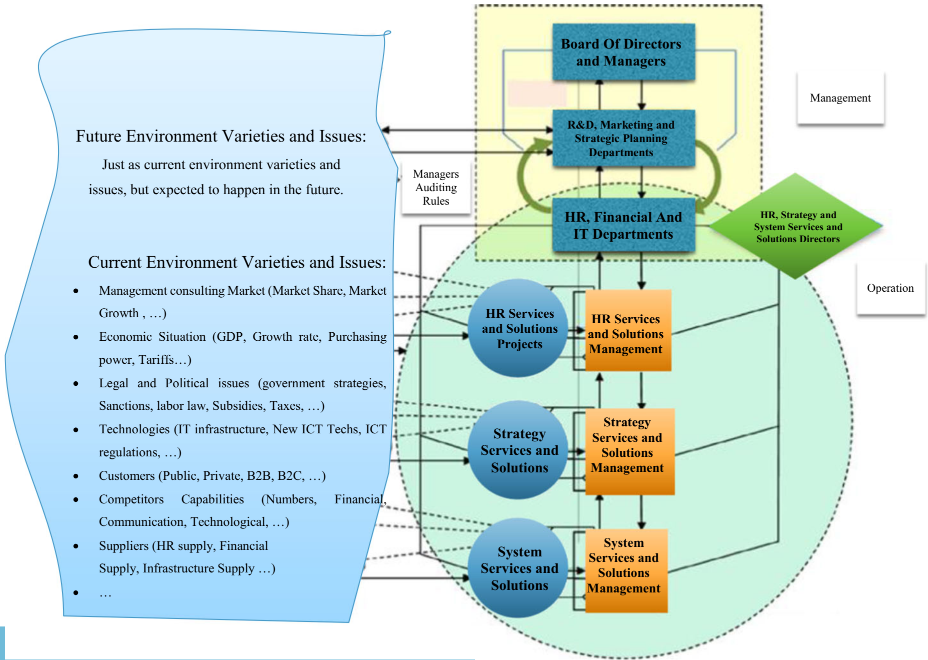

Fig. 5 *SMARTCO* Viable System Model (this research findings)

Table 4 Current and Improved policy results

System	Current result	Improved policy result	How much improved policy result is better	How much improved policy result is better (Percent)
System 1	4800	600	4200	700%
System 2	2500	2500	0	0%
System 3	600	800	−200	−25%
System 4	7500	2500	5000	400%
System 5	0	0	0	0%
Total	15,400	6400	9000	140%

1: As mentioned above *VSM* is a recursive model. Therefore, if after implementing improvement policy varieties levels exceed absorption capability, recursion levels should be expanded. However, there is no need to go through levels of recursion because in our case varieties came under control

2: S3* role in amplifying or attenuating the variety is not the concern of this research it could be discussed as a future research

as one (operation) if we do not want to model the horizontal variety transfer. This kind of *VSM* modeling represented by Beer (1972). *SMARTCO* is a management consulting company that provides business solutions. These solutions consist of projects or software. Varieties for this company are new competitors, new software and services, new technologies, new regulatory issues, etc. Some more regular issues for *SMARTCO* have been added in Fig. 6. Environment regular Varieties and Issues:

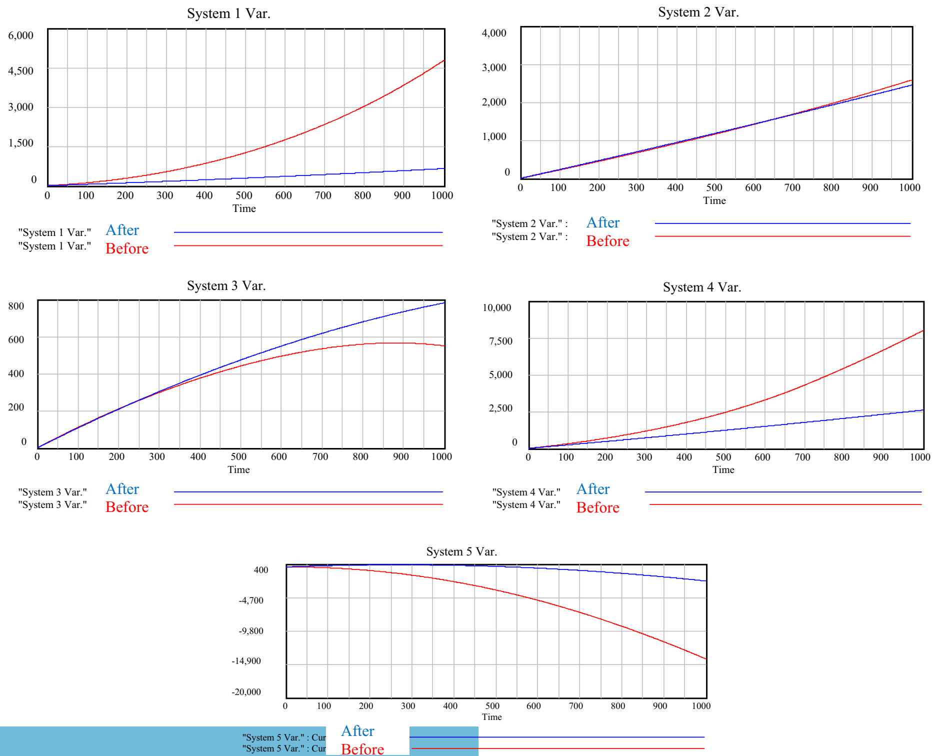

Fig. 6 The variety of subsystems - blue curve corresponds to the policy (this research findings)

- Management consulting Market issues (Market Share, Market growth, etc.)
- Economic Situation issues (GDP, growth rate, purchasing power, tariffs, etc.)
- Legal and Political issues (government strategies, sanctions, labor law, Subsidies, Taxes, etc.)
- Technologies issues (IT infrastructure, New ICT Techs, ICT regulations, etc.)
- Customers issues (Public, Private, B2B, B2C, etc.)
- Competitors issues Capabilities (Numbers, Financial, Communication, Technological, etc.)
- Suppliers issues (HR supply, Financial Supply, Infrastructure Supply etc.)
- Etc.

SMARTCO regular varieties or issues examples are such as:

- Every New software developer in HR, Strategy, and System Services and Solution industry is a unit of variety
- Every New feature in competitors software is a unit of variety
- Every Competitor lower price for same projects is a unit of variety
- Every New IT technology affects our market is a unit of variety
- Every New Private Customer found is a unit of variety
- Every New Public Customer found is a unit of variety
- Every New B2B market found is a unit of variety
- Every labor law change is a unit of variety
- Every new sanction affects our industry or market is a unit of variety
- Every supplier for financial, scientific, infrastructure needs is a unit of variety
- Etc.

Generally, every change in the environment that affects us (our market or industry) is a variety. In *SMARTCO*, averagely environment perception rate is 10 variety every week. It means our operational unit could perceive 10 issues of the above-mentioned types every week. For example, they could perceive 2 new competitors, 4 new customers, 2 new ICT changes, and 2 new changes in labor or tax laws. The following figure shows how many issues understood by operational units from 2014 to 2017 in *SMARTCO*. As Fig. 4 shows, averagely 10 varieties imported to the system 1 every week.

These issues (varieties) could be handled (absorbed) by different units in *SMARTCO*. Every issue a unit handles, increases its tacit and problem-solving skills. Of course, the problem-solving authority level in each unit, depending on the authority delegated from the upper unit. Also, better performance of the audit subsystem (3*) makes a better condition for transmission channels. Therefore, it is possible to transfer issues to the higher subsystems more quickly.

This company has operational units that perform projects and deploy software. The units' directors provide tactical planning for their units. In addition, *SMARTCO* has administrative departments such as HR, Financial, and IT departments. They are responsible for operational planning and control. In addition, managers, and directors have a responsibility to audit units. R&D, Marketing, and Strategic Planning units are responsible for long-term planning in the *SMARTCO*. Finally, the Board of Directors makes decisions about company missions, values, and general policies to maintain both company identity and viability. Therefore, the *SMARTCO* organization in *VSM* framework will be as follows (Also see Fig. 5):

- System 1: Operational Units (HR, Strategy, and System Services and Solutions Projects)
- System 2: Units Directors (HR, Strategy, and System Services and Solutions Directors)
- System 3: HR, Financial, and, IT Departments
- System 3*: Managers and Directors Audit Responsibility
- System 4: R&D, Marketing, and, Strategic Planning Departments
- System 5: Board of Directors and Managers

Detailed descriptions and equations are given in the appendix. By simulating these equations in Vensim software results of subsystems varieties have been provided. These results show that which policy in authority delegation could help *SMARTCO* managers to have more controlled and managed subsystems. In addition, this simulation verifies the correctness of our previous claims about the proposed multi-methodological approach (the usefulness of the combination of *VSM* and *SD* for managing complexities and cover *VSM* and *SD* limitations). In *SMARTCO*, half of the divided labor (delegated authority) in every subsystem is transferred to the lower subsystem.

The combinational model will help to improve the company so it could have more problem-solving abilities in terms of speed and manageability of problems (more absorbed varieties). Therefore, the appropriate improvement policy is to increase the authorities of the unemployed (have low stocked variety) subsystems and reduce the authorities of the fully employed (have excessive stocked variety) subsystems. Such policy would enable the fully employed subsystems to work faster. In addition, this policy allows accumulated variety to be transferred to the less crowded subsystems.

The red lines are varieties simulation before implementing improvement policy and the blue lines are varieties simulation after implementing improvement policy. Results are given in Fig. 6.

As evident in Fig. 6, modification of the authority delegation results in an 8 times reduction of the various level of subsystem 1 (Operational Units) compared to the previous state, as explained in the above-mentioned policy. The policy reduces system 1 variety in the last time stepped from 4800 to 600.

In addition, modification of the authority delegation results in no significant change in the variety level of subsystem 2 (Units Directors), as explained in the above-mentioned policy. The policy maintains system 2 varieties in the last time step in about 500.

As has been shown in Fig. 6, authority delegation modification results in a slight increase in subsystem 3 (HR, Financial, and IT Departments) variety level compared to the previous state. However, it causes lower variety levels for subsystem 1, 2, and 4. The policy slightly increases system 3 varieties in the last time step from 600 to 800.

As evident in Fig. 6, modification of the authority delegation results in a 3 times reduction of the variety level in subsystem 4 (R&D, Marketing, and Strategic Planning Units) compared to the previous state, as explained in the above-mentioned policy. The policy reduces system 4 variety at the last time step from 7500 to 2500.

In addition, authority delegation modification results in an increase in subsystem 5 (Board of Directors) variety level compared to the previous state. However, it causes lower variety levels for subsystem 1, 2, and 4 as explained in the above figures. The policy increases system 5 variety at the last time step from about −15,000 to −2500. However, it should be noted that negative variety means that the system has no issue to solve. So, negative variety is as zero variety. By this explanation, system 5 variety remain 0 in both before and after this policy simulations. Therefore, this policy did not affect system 5 variety.

As demonstrated in the red lines of above figures (varieties simulation before implementing improvement policy), varieties are fully absorbed only in some subsystems (2, 3, 5) and remain uncontrolled in the rest (1, 4). Clearly, such authority delegation in *SMARTCO* would not yield reasonable outcomes. It means by the regular way in *SMARTCO* cause failure in managing systems variety in the future. Clearly, in this way, system 1 (operational units) and system 4 (R&D, Marketing, and strategic planning department) cannot solve assigned problems and many problems remained unhandled in these systems. It means *SMARTCO* current issues such as reacting to HR losses, saving and increasing market share and other vital tasks will not be done. In addition, future issues such as providing solutions for future technology pushes or market pulls will not be done too. These results mean by the current way, *SMARTCO* will not do its primary processes and just occupied by non-primary processes. This will cause the death of the company (not becoming viable).

Instead, the appropriate improvement policy is to increase the authorities of the subsystems (3, 5) and reduce the authorities of subsystems (1, 4). This policy enables the fully employed subsystems (3, 5) to work faster and allows accumulated variety to be transferred to the less crowded subsystems (1, 4). The blue lines of above figures (varieties simulation after implementing improvement policy) show that simulation of this policy would yield more suitable and easier way to manage varieties in each subsystem of *SMARTCO (see* Table 4).

The improvement policy results show that in the last time step, system 1 and 4 variety reduced and controlled. System 1 variety reduced by 4200 and system 4 variety reduced by 5000. System 2 and 5 issues remained at an acceptable level. Just system 3 variety increased slightly by about 200. It means *SMARTCO* variety in this policy reduced by about 9000 units *(see* Table 4). This cause *SMARTCO* to respond to current (system 1) and future (system 4) issues extensively more effective. Also by this policy, other systems will maintain an acceptable performance during time. These results mean by the improvement policy, *SMARTCO* will do its primary processes and non-primary processes both effectively. This will cause the viability and accomplishment of the company that is the purpose of VSM. Therefore, without *SD*, *VSM* could not reach its main objective.

As it is shown in Table 4 improvement policy cause 700% and 400% better results for system 1 and 4 (primary processes) and just −25% lower (but highly acceptable) results for system 3 (non-primary process). In addition, totally it causes 140% increase in the *SMARTCO* performance in responding to issues and absorbing variety.

As a final remark, the proposed model and its mentioned benefits are valid because:

1. It is completely designed, formulated, and simulated based on SD and *VSM* multi-methodology principles, and the law of requisite variety.
2. Simulation results are in agreement with the above statements on optimal authority delegation.
3. Classic and non-dynamic *VSM* could not provide the results and improved policy that the proposed model provided.
4. The multi-methodology will cause the viability and accomplishment of the company that is the purpose of VSM. Therefore, without *SD*, *VSM* could not reach its main objective.

Conclusion

Today, managers have a tendency to use Systems Thinking given the advantages of systemic methodologies in coping with complex problems. The necessity of providing a multi-methodological approach based on VSM and *SD* methodologies has been emphasized in the literature. However, not a detailed framework, neither an operational model of this combination has ever been made. In this paper, this multi-methodology has been provided. The proposed multi-methodology exhibits surpassing performance as demonstrated in the *SMARTCO* case study. Advantages of the proposed model include the theoretically complementary features of *VSM* and *SD,* covered weaknesses of *VSM* and *SD*, more suitable and comprehensive solutions found for systems and organizations, and availability of a general *SD* framework for modeling organizational problem-solving. Moreover, the method dynamizes VSM. *VSM* needs this dynamic knowledge-based organizational design and diagnosis methodology. The multi-methodological approach has complexity management and dynamic organizational process and structure development abilities. In the next step, *VSM* has been modeled by *SD*. In addition, the mechanism of tacit knowledge creation, accumulation, and its effect on absorption capacities has been provided in this model. Finally, *SMARTCO* case study simulation results demonstrate that the proposed multi-methodology model and policy exhibit improved organizational problem-solving abilities with increased speed and manageability of the problems.

As mentioned in Multi-methodology section, *VSM* and *SD* have both a Functionalist paradigm (Jackson 2007). *VSM* presents Brain and Organism metaphors for the system (Curram & Mingers 1994). Therefore, it could provide a structure for the system based on the human nervous system (Milanzi 2000; Mingers & Rosenhead 2004). This matter is shown in the case study. However, *VSM* could not provide detailed and quantitative description of system behavior especially during time (Rosenhead & Mingers 2001; Munro and Mingers 2002). So*, SD* with Flux and Flow metaphor could be used to provide a multi-methodology that have Brain, Organism, and Flux and Flow (Mingers & Rosenhead 2004; Jackson 2007). In the other word, an information-based structure with dynamics behavior model for the system could be built. As we can see in the case study this type of multi-methodology could handle complexity in system dynamically during time.

The summary of this method implications and advantages are as follows:

- Help managers to have more controlled and managed subsystems.
- Multi-methodology that covers *VSM* and *SD* limitations.
- Aid in diagnosing and analyzing organizational dynamic problems during time
- Framework for dynamic authority delegation
- A basis for new Information Technology and knowledge management tools by emphasizing on tacit knowledge
- As it is shown in the case study, without the multi-methodology that includes *SD*, *VSM* could not reach its main objective solitarily.

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Appendix

Equations of all model variables are given in Table 5.

Table 5 Equations of model variables

Variable Name	Variable equation
(01) “1–2 Transmission Rate”	9*(1-S1 Local Control)*"System 3* Performance”
(02) “2–1 Delegated Authority”	0.5*"3–2 Delegated Authority”
(03) “2–3 Transmission Rate”	7.5*(1-S2 Local Control)*"System 3* Performance”
(04) “3–2 Delegated Authority”	0.5*"4–3 Delegated Authority”
(05) “3–4 Transmission Rate”	5.5*(1-S3 Local Control)
(06) “4–3 Delegated Authority”	0.5*"5–4 Delegated Authority”
(07) “4–5 Transmission Rate”	3*(1-S4 Local Control)
(08) “5–4 Delegated Authority”	0.5*Authority
(09) Authority	1
(10) “Curr. Env. Var. Perception Rate”	20*(S1 Tacit Knowledge/1000)*"System 3* Performance”
(11) “Curr. Env. Var. Transmit Rate”	DELAY FIXED (“Fut. Env. Var. Generation Rate”-"Fut. Env. Var. Perception Rate”
(12) “Current Env. Var.”	INTEG (+"Curr. Env. Var. Transmit Rate”-" Curr. Env. Var. Perception Rate”,100)
(13) FINAL TIME	1000
(14) “Fut. Env. Var. Generation Rate”	15
(15) “Fut. Env. Var. Perception Rate”	5*(S4 Tacit Knowledge/1000)
(16) “Future Env. Var.”	INTEG (+"Fut. Env. Var. Generation Rate”-"Curr. Env. Var. Transmit Rate”-"Fut. Env. Var. Perception Rate”,100)
(17) INITIAL TIME	0
(18) “S1 Absorbed Var.”	INTEG (S1 Absorption Rate-S1 Tacit Knowledge Rate,0)
(19) S1 Absorption Rate	1*(S1 Tacit Knowledge/1000)*(1-S1 Local Control)
(20) S1 Local Control	MIN(1,1*(S2 Tacit Knowledge/1000)*"2–1 Delegated Authority”)
(21) S1 Tacit Knowledge	INTEG (S1 Tacit Knowledge Rate,500)
(22) S1 Tacit Knowledge Rate	10*S1 Local Control
(23) “S2 Absorbed Var.”	INTEG (S2 Absorption Rate-S2 Tacit Knowledge Rate,0)
(24) S2 Absorption Rate	1.5*(S2 Tacit Knowledge/1000)*(1-S2 Local Control)
(25) S2 Local Control	MIN(1,1*(S3 Tacit Knowledge/1000)*(“3–2 Delegated Authority”-"2–1 Delegated Authority”))
(26) S2 Tacit Knowledge	INTEG (S2 Tacit Knowledge Rate,500)
(27) S2 Tacit Knowledge Rate	10*S2 Local Control
(28) “S3 Absorbed Var.”	INTEG (S3 Absorption Rate-S3 Tacit Knowledge Rate,0)
(29) S3 Absorption Rate	2*(S3 Tacit Knowledge/1000)*(1-S3 Local Control)
(30) S3 Local Control	MIN(1,1*(S4 Tacit Knowledge/1000)*(“4–3 Delegated Authority”-"3–2 Delegated Authority”))
(31) S3 Tacit Knowledge	INTEG (S3 Tacit Knowledge Rate,500)
(32) S3 Tacit Knowledge Rate	10*S3 Local Control
(33) “S4 Absorbed Var.”	INTEG (S4 Absorption Rate-S4 Tacit Knowledge Rate,0)
(34) S4 Absorption Rate	5*(S4 Tacit Knowledge/1000)*(1-S4 Local Control)
(35) S4 Local Control	MIN(1,1*(S5 Tacit Knowledge/1000)*(“5–4 Delegated Authority”-"4–3 Delegated Authority”))
(36) S4 Tacit Knowledge	INTEG (S4 Tacit Knowledge Rate,500)
(37) S4 Tacit Knowledge Rate	2*S4 Local Control
(38) “S5 Absorbed Var.”	INTEG (S5 Absorption Rate-S5 Tacit Knowledge Rate,0)
(39) S5 Absorption Rate	10*(S5 Tacit Knowledge/1000)*(1-S5 Local Control)
(40) S5 Local Control	Authority-"5–4 Delegated Authority”

Table 5 (continued)

Variable Name	Variable equation
(41) S5 Tacit Knowledge	INTEG (S5 Tacit Knowledge Rate,500)
(42) S5 Tacit Knowledge Rate	10*S5 Local Control
(43) SAVEPER	TIME STEP
(44) "System 1 Var."	INTEG (+"Curr. Env. Var. Perception Rate"-"1–2 Transmission Rate"-S1 Absorption Rate,0)
(45) "System 2 Var."	INTEG ("1–2 Transmission Rate" + S2 Absorption Rate-"2–3 Transmission Rate",0)
(46) "System 3 Var."	INTEG ("2–3 Transmission Rate"-"3–4 Transmission Rate"-S3 Absorption Rate,0)
(47) "System 3* Performance"	1
(48) "System 4 Var."	INTEG ("3–4 Transmission Rate" + "Fut. Env. Var. Perception Rate"-"4–5 Transmission Rate"-S4 Absorption Rate,0)
(49) "System 5 Var."	INTEG ("4–5 Transmission Rate"-S5 Absorption Rate,0)
(50) TIME STEP	1

References

Ashby WR (1952) Design for a Brain. Chapman & Hall

Ashby WR (1956). An introduction to cybernetics. New York, Wiley (Vol. 16). doi:https://doi.org/10.2307/3006723

Ashby WR (1958) Requisite variety and its implications for the control of complex systems. Cybernetica 1(2): 83–99

Beer S (1959) What has cybernetics to do with operational research? J Oper Res Soc 10(1):1–21. https://doi.org/10.1057/jors.1959.1

Beer S (1962) Towards the cybernetic factory. In Principles of Self-Organization. Transactions of the University of Illinois Sympo-sium on Self-Organization

Beer S (1966) Decision and control: the meaning of operational research and manage, Wiley

Beer S (1972) Brain of the firm: a development in management cybernetics. McGraw-Hill

Beer S (1979) The heart of Enterprise. The Journal of the Operational Research Society Wiley doi:https://doi.org/10.2307/2581902

Beer S (1985) Diagnosing the system for organizations. Wiley

Beer S (1990) On suicidal rabbits: a relativity of systems. Systems Practice 3(2):115–124. https://doi.org/10.1007/BF01060874

Beer S (1994) Cybernetics of National Development evolved from work in Chile. In Zaheer Science Foundation Lecture. Retrieved from http://vidyardhi.org/Resources/books/beer.pdf

Bohórquez Arévalo LE, Espinosa A (2015) Theoretical approaches to managing complexity in organizations: a comparative analysis. Estudios Gerenciales 31(134):20–29. https://doi.org/10.1016/j.estger.2014.10.001

Brecher C, Müller S, Breitbach T, Lohse W (2013) Viable system model for manufacturing execution systems. Procedia CIRP 7:461–466. https://doi.org/10.1016/j.procir.2013.06.016

Curram SP, Mingers J (1994) Neural networks, decision tree induction and discriminant analysis: an empirical comparison. J Oper Res Soc 45(4):440 Retrieved from http://www.jstor.org/stable/2584215

Dominici G (2013) Book Review. Organizational Systems: Managing Complexity with the Viable System Model Kybernetes (Vol. 42)

Elezi F, Resch D, Tommelein ID, Bauer W (2014) Risk and change management in complex systems. Carl Hanser Verlag GmbH & Co. KG, München. https://doi.org/10.3139/9781569904923

Espejo R (2013) Organisational cybernetics as a systemic Paradigm : lessons from the past, progress for the future. Business Systems Review 2(2):1–9. https://doi.org/10.7350/BSR.V01.2013

Espejo R, Harnden R (1990) The viable system model: interpretations of Stafford Beer's *VSM*. Wiley 44. https://doi.org/10.1016/0377-2217(90)90368-L

Espinosa A, Harnden R, Walker J (2008) A complexity approach to sustainability – Stafford beer revisited. Eur J Oper Res 187(2):636–651. https://doi.org/10.1016/j.ejor.2007.03.023

Espinosa A, Reficco E, Martínez A, Guzmán D (2015) A methodology for supporting strategy implementation based on VSM: a case study in a Latin-American multi-national. Eur J Oper Res 240(1):202–212. https://doi.org/10.1016/j.ejor.2014.06.014

Forrester JW (1961) Industrial dynamics. MIT Press

Georgiou I (2011) Cognitive mapping and strategic options development and analysis (SODA). Wiley Encyclopedia of Operations Research and Management Science

Haslett, T. (2000). Using VSM to integrate SD modelling into an organization context. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.143.33

Haslett T, Oka M (2000) Using *VSM* to integrate *SD* modelling into an organization context. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.143.33

Hoverstadt P (2010) The viable system model. In systems approaches to managing change: a practical guide (pp. 87–133). Springer. doi:https://doi.org/10.1007/978-1-84882-809-4_3

Jones M (1995) Organisational learning: Collective mind or cognitivist metaphor? Account Manag Inf Technol 5(1):61–77 https://doi.org/10.1016/0959-8022(95)90014-4

Jackson, M. C. (2007). Systems thinking: creative holism for managers. Wiley. Retrieved from https://books.google.com/books?id=Dvk6pjYTyrQC&pgis=1

Kamran Q (2013) Complexity the sixth competitive force that shapes strategy: a cybernetics approach to "porter"s five forces model' in turbulent and complex environments. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2232901

Kirkwood C (2001) System dynamics methods. A Quick Introduction, 2001. Retrieved from http://nutritionmodels.tamu.edu/copyrighted_papers/Kirkwood1998.pdf

Leonard A (2009) The viable system model and its application to complex organizations. Syst Pract Action Res 22(4):223–233. https://doi.org/10.1007/s11213-009-9126-z

Mignot P (2000) Metaphor: a paradigm for practice-based research into'career' British Journal of Guidance & Counselling, 2000. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/713652314

Milanzi MC (2000) Book review: Multimethodology: the theory and practice of combining management science methodologies. By John Mingers and Anthony gill (Eds), John Wiley & Sons, Chichester, 1997. Syst Res Behav Sci 17(4):407–414. https://doi.org/10.1002/1099-1743(200007/08)17:4<407::AID-SRES363>3.0.CO;2-A

Mingers J (1980) Towards an appropriate social theory for applied systems thinking: critical theory and soft systems methodology. J Appl Syst Anal. Retrieved from http://kar.kent.ac.uk/3877/1/Towards social theory.pdf

Mingers, J. (1984). Subjectivism and soft systems methodology-A critique. J Appl Syst Anal. Retrieved from http://kar.kent.ac.uk/id/eprint/3878

Mingers J (1987) Expert Systems-Rule Induction with Statistical Data. J Oper Res Soc 38(1):39 Retrieved from http://www.jstor.org/stable/2582520

Mingers J (1989) An empirical comparison of selection measures for decision-tree induction. Mach Learn 3(4): 319–342 Retrieved from http://link.springer.com/article/10.1007/BF00116837

Mingers J (1994) Self-producing systems: Implications and applications of autopoiesis. Springer Science & Business Media

Mingers J (1997a) Multi-paradigm multimethodology. Retrieved from https://kar.kent.ac.uk/3805/

Mingers J (1997b) Towards critical pluralism 1997. Retrieved from https://kar.kent.ac.uk/3807/

Mingers J, Gill A (1997) Multimethodology: The theory and practice of combining management science methodologies. Wiley, New York

Mingers J (2000a) What is it to be Critical?. Teaching a critical approach to management undergraduates. Manag Learn 31(2):219–237 Retrieved from http://mlq.sagepub.com/content/31/2/219.short

Mingers J (2000b) The contribution of critical realism as an underpinning philosophy for OR/MS and systems. J Oper Res Soc 51(11):1256 Retrieved from http://www.ingentaconnect.com/content/pal/01605682/2000/00000051/00000011/2601033

Mingers J (2001) Combining IS research methods: towards a pluralist methodology. Inf Syst Res 12(3):240–259. https://doi.org/10.1287/isre.12.3.240.9709

Mingers J (2002) Real-izing information systems: critical realism as an underpinning philosophy for information systems. Inf Organ 14(2):87–103

Mingers J (2003) The paucity of multimethod research: a review of the information systems literature. Inf Syst J 13(3):233–249. https://doi.org/10.1046/j.1365-2575.2003.00143

Mingers J, Rosenhead J (2004) Problem structuring methods in action. Eur J Oper Res 152(3):530–554 https://doi.org/10.1016/S0377-2217(03)00056-0

Mingers J (2006) Realising Systems Thinking: Knowledge and Action in Management Science: knowledge and action in management science. Retrieved from https://books.google.com/books?hl=fa&lr=&id=rhgifrJFoMC&oi=fnd&pg=PR7&dq=%22John+Mingers%22&ots=n2TrzRDs8P&sig=q_v4Xj4Rw_gLCqaIVTJW5cjfMNQ

Mingers J (2010) Multimethodology. Wiley encyclopedia of operations research and management science. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/9780470400531.eorms0973/full

Mingers J (2011) The contribution of systemic thought to critical realism. J Crit Real 10(3):303–330. https://doi.org/10.1558/jcr.v10i3.303

Mingers J, Brocklesby J (1997) Multimethodology: towards a framework for mixing methodologies. Omega 25(5):489–509. https://doi.org/10.1016/S0305-0483(97)00018-2

Morgan G (1980) Paradigms, metaphors, and puzzle solving in organization theory. Adm Sci Q, 1980. Retrieved from http://www.jstor.org/stable/2392283

Munro I, Mingers J (2002) The use of multimethodology in practice—results of a survey of practitioners. J Oper Res Soc. Retrieved from http://www.ingentaconnect.com/content/pal/01605682/2002/00000053/00000004/2601331

Preece G, Shaw D, Hayashi H (2013) Using the viable system model (*VSM*) to structure information processing complexity in disaster response. Eur J Oper Res 224(1):209–218. https://doi.org/10.1016/j.ejor.2012.06.032

Preece G, Shaw D, Hayashi H (2014) Application of the viable system model to analyse communications structures: a case study of disaster response in Japan. Eur J Oper Res. https://doi.org/10.1016/j.ejor.2014.11.026

Rahayu S, Zulhamdani M (2014) Understanding local innovation system as an intelligent organism using the viable system model case study of palm oil industry in North Sumatra Province. Procedia - Soc Behav Sci 115:68–78. https://doi.org/10.1016/j.sbspro.2014.02.416

Reyes A (2001) Second-order auditing practices. Syst Pract Action Res 14(2):157–180

Rosenhead J, Mingers J (eds) (2001) Rational analysis for a problematic world revisited (2nd). John Wiley and Sons, Chichester ISBN 9780471495239

Schwaninger M (2004) Methodologies in conflict: achieving synergies between system dynamics and organizational cybernetics. Syst Res Behav Sci 21(4):411–431. https://doi.org/10.1002/sres.649

Schwaninger M, Ríos JP (2008) System dynamics and cybernetics: a synergetic pair. Syst Dyn Rev 24(2):145–174. https://doi.org/10.1002/SDr.400

Sterman JD (1988) Deterministic chaos in models of human behavior: Methodological issues and experimental results. Syst Dyn Rev 4(1-2):148–178. https://doi.org/10.1002/sdr.4260040109

Sterman J (2000) Business dynamics: systems thinking and modeling for a complex world. McGraw-Hill

von Foerster H (1974) Cybernetics of cybernetics. University of Illinois, Urbana, Ill

Yolles M (2004) Implications for Beer's ontological system/metasystem dichotomy. Kybernetes 33(3/4):726–764