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SUPPORTING THE DESIGN OF COMPETITIVE ORGANIZATIONS BY A DOMAIN-SPECIFIC APPLICATION FRAMEWORK for the Viable System Model

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ABSTRACT

Industrial companies face the challenge of a rapidly changing environment and struggle to keep up with the pace needed to be competitive. Organizational deficiencies are often reasons for failure. The Viable System Model (VSM) supports organizational diagnosis and design to ensure viability and avoid deficiencies. The objective of this paper is to further support the application of the VSM in industry. Therefore, we conducted a literature review and analyzed twenty-five VSM case studies in order to derive a common application pattern. The results showed that the main assessment criterion was the existence of all VSM subsystems. However, interrelations within the VSM subsystems are often ignored. This paper presents an extended framework for applying the VSM, emphasizing subsystem relations when diagnosing as well as designing organizational systems. The extension is provided in the form of four Domain-Structure-Matrices, which reveal necessary interrelations and connections for a should-be organizational design.

1. Problem Setting and Motivation

Companies are increasingly challenged by the disruptive character of the digital world and further external trends. Kodak for example was not able to respond to the trend of digital photography, which led to a disaster: it suffered an 80% reduction in labor force, over 100,000 employees *(Lucas and Goh, 2009)*. To prevent such disasters, organizations strive for fast responsiveness to external events and fast internal handling of actions stemming from their response.

Cybernetics, especially Management Cybernetics *(MC)* targets the organizational responsiveness issue by providing structural as well as procedural approaches and models to support organizational communication and coordination *(Wiener, 1948)*. Concerning the challenge of coping with increasingly dynamic environments, within MC we put the spotlight on the Viable System Model *(VSM) (Beer, 1972)*. The VSM is a generic model of any viable system at a functional level. Viability means the ability to maintain the outcomes of a situation within a target set of desirable states and to balance out disturbances that could lead the system out of this desired state. The VSM helps to diagnose and design organizational structures and processes *(Espejo, 2003)*. Unfortunately, the VSM is not a "plug-and-play" model due to its abstract and holistic perspective on systems. Therefore, translating the VSM into a target domain is still a challenge for practitioners *(Hildbrand and Bodhanya, 2015)*. Hildbrand and Bodhanya *(2015)* target this issue by providing a guideline for novice VSM users. Nevertheless, there is no support for the translation of the holistic VSM to a domain-specific application.

The paper aims to improve the applicability of the VSM by providing a procedural model for the domain-specific application of the VSM and further extends the model by including four Design Structure Matrices *(DSMs)*. The DSMs enable a quantified analysis of VSM subsystem relations and dependencies to assist with organizational diagnosis and design.

2. Theoretical Background

2.1 Management Cybernetics and the Viable System Model

Cybernetics, the science of communication and control of living and technical systems, forms the theoretical backbone of Management Cybernetics *(MC)* and further for the VSM *(Wiener, 1948)*. MC applies the concept of feedback loops in control theory to empower organizational management with self-organization and self-control *(Schwaninger, 2008)*. Based on MC, Stafford Beer developed the VSM by applying the concepts of self-regulation, learning, adaptation, and evolution of the human nervous system to organizational design *(Beer, 1972; Ríos, 2010)*. The model respects both the structure and the processes of an organization *(Pfiffner, 2010)*. The VSM is used to design a viable organization or to diagnose an existing one concerning deficiencies *(Jackson, 2009)*.

The VSM consists of five subsystems and relation channels linking the subsystems with each other as well as with the surrounding environment. Jackson *(1988)* characterized these channels to be either for communication *(pure information flow)*, coordination *(of actions of one or more subsystems)*, control *(forced actions)*, or interaction *(acting by changing the state of a subsystem)*. **Figure 1** depicts the entire VSM and its subsystems. Important to note is the recursive character of the VSM:

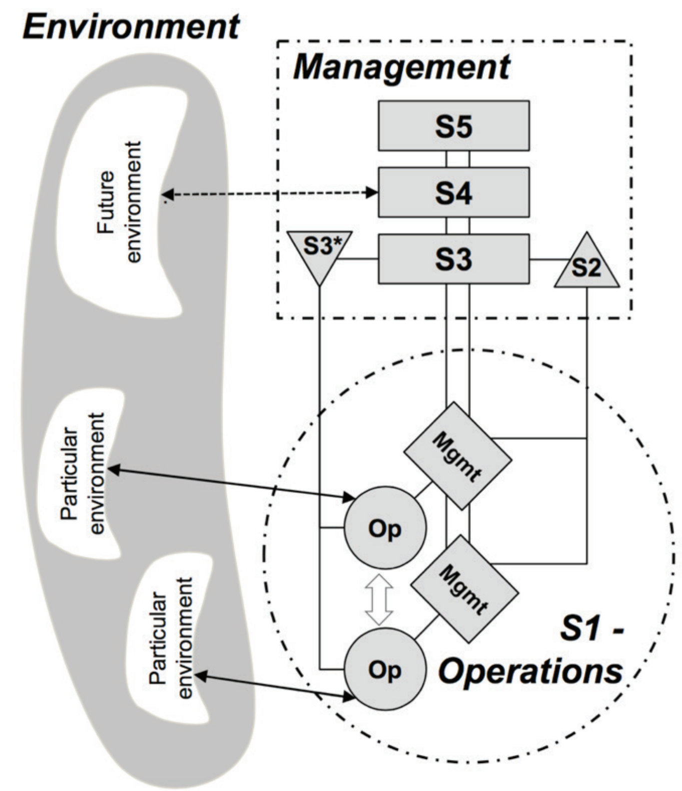

FIGURE 1. *Viable System Model (VSM) adapted from Beer (1972) and Rios (2012)*

	Problem setting		Approach	
Source	Structural	Procedural	Diagnosis	Design
(Britton and Parker, 1993)	x			x
(Herring, 2002)	x		x	x
(Schwaninger, 2006) Case study 1	x		x	x
(Schwaninger, 2006) Case study 2	x		x	x
(Schwaninger, 2006) Case study 3	x		x	
(Schwaninger, 2006) Case study 4		x	x	x
(Leonard, 2007)	x			x
(Laumann et al., 2007)		x	x	x
(Yang and Yen, 2007)		x		x
(Rakers and Rosenkranz, 2008)		x		x
(Wee and Wu, 2009)		x	x	x
(Jun-Feng and Wo-Ye, 2011)		x		x
(Rosenkranz and Holten, 2011)	x		x	x
(Khosrowjerdi, 2013)		x		x
(Tanaka, 2013)		x		x
(Brecher et al., 2013)	x			x
(Elezi et al., 2014a)		x		x
(Elezi et al., 2014b)		x	x	x
(Mugurusi and de Boer, 2014)		x		x
(Rahayu and Zulhamdani, 2014)	x		x	x
(Wilberg et al., 2015b)		x	x	x
(Groten and Schuh, 2014)	x			x
(Preece et al., 2015)	x		x	
(Mayangsari et al., 2015)	x		x	x
(Wilberg et al., 2015a)		x	x	x

TABLE 1. *VSM use cases assigned to their problem setting and solution approach*

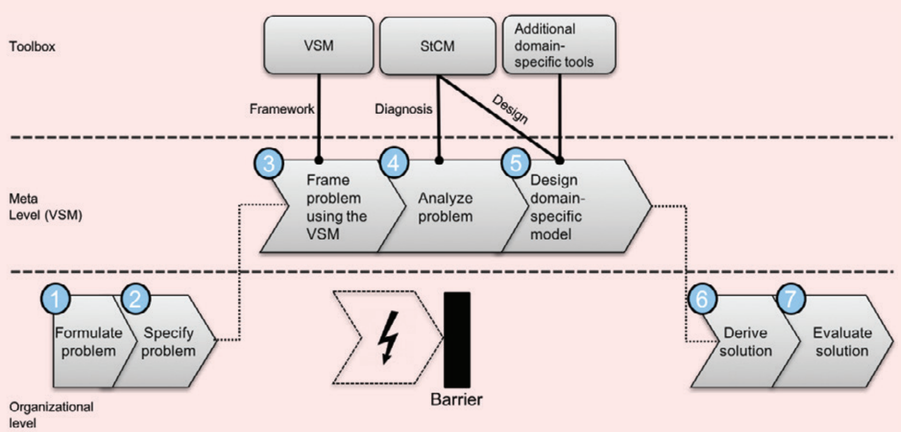

FIGURE 2. *VSM application framework for system diagnosis and design, adapted from Elezi et al. (2014b)*

each subsystem contains and consists of viable systems. Viable systems need to consist of all five VSM subsystems and every subsystem needs to consist of viable systems in a recursive manner *(Ríos, 2010)*. The five subsystems of the VSM are:

- **System 1 (S1):** Operational unit, producing outcome, e.g., goods or services of the organization. It therefore iteratively interacts with the environment and shares information and knowledge with other subsystems.
- **System 2 (S2):** Regulatory center for S1 units. It provides rules and guidelines for smooth operations and damps oscillations between the S1 units.
- **System 3 (S3):** Control unit, engaging in resource negotiations with S1 units and executing strategic instructions by controlling operations. In this manner, S3 acts rather supportive than autocratic (Leonard, 2007).
- **System 3* (S3*):** Auditing unit, supporting S3's control function with periodic audits and additional information on the state of the operational units.
- **System 4 (S4):** Strategic unit, focusing on strategic planning for the organization by constantly monitoring the potential future environment to anticipate changes. It discusses need for action with S3.
- **System 5 (S5):** Policy and normative management, defining mission, goals, objectives, values and culture of an organization (Jackson, 2009). It further decides what S3 and S4 cannot agree on.

2.2 Functional Decomposition of the Viable System Model

Practitioners mainly benefit from model descriptions on a functional level, because this is the abstraction level they work on *(La Rosa et al., 2011)*. In order to provide assistance in this regard, Schmidt et al. *(2014)* propose a function list for all five VSM subsystems, consisting of forty-four functions. Each subsystem includes a set of functions, which are necessary for viability of the entire system. Practitioners can apply this function list to cross-check to find missing functions or in a design setting to implement functions.

2.3 Structural Complexity Management and the Viable System Model

Structural Complexity Management *(StCM)* uses a matrix-based methodology that captures dependencies in complex systems to make them more transparent and manageable *(Lindemann et al., 2008)*. The methodology consists of matrices that can either link elements of the same domain in a Design Structure Matrix *(DSM)* or of different domains in a Domain Mapping Matrix *(DMM)*.

Elezi et al. *(2013)* already tackled the issue of using StCM in combination with the VSM to enhance and support organizational diagnosis and design. The advantage of StCM is that it can help to visualize subsystem relations in structural and procedural problem settings and it allows to deduct insights from it, e.g., related clusters, missing or deficient communications. The matrix approach also supports quantifications of relations, e.g., calculation of passive, active, and critical characteristics *(Elezi et al., 2013)*.

3. Analysis of Case Studies

The purpose of the VSM is to design viable systems or to assess an existing system for structural as well as procedural deficiencies. In order to gain an understanding on how previous literature applied this model to solve various types of problems on an organizational level, we reviewed the literature presenting VSM case studies. The goal was to reveal similarities or implicit patterns in the application of this model, especially concerning the translation of this rather abstract model to an organizational level.

The literature research consisted of a journal, mainly Kybernetes, and paper search on ScienceDirect, IEEE Xplore, and Google Scholar online platforms using search terms "Viable system model *(VSM)* case study, VSM use cases". The result were twenty-five case studies described the time period of 1993 until 2015. Looking at the number and timing of published research, a constant average of two publications per year concerning VSM case studies appeared from 1993 until 2013. Then the number of publications increased significantly up to four in 2014 and five in 2015. This underlines the statement that the VSM still offers support when it comes to solve organizational issues. **Table 1** lists these case studies sorted by purpose of application *(diagnosis and/or design)* and type of system *(structural or procedural)*.

It is important to mention that many structural case studies also had a procedural aspect and vice versa. The focus here is on the primary goal which turned out to be either procedural or structural.

Table 1 shows that most case studies followed a design approach while only a few covered standalone diagnosis of an organizational system. The main purpose of VSM application in real case studies seems targeted towards a new design from scratch or a redesign based on a deficient system. The latter appeared to be the most common case.

4. Model for domain-specific application of the VSM

4.1 Research gap and methodology

All case studies had in common that they did not follow a single guideline in how to translate their domain-specific problem into the VSM domain in order to solve it. All authors interpreted the structure and characteristics of the VSM on their own or proposed a guideline suited to their specific problem or domain. Interestingly, their approaches revealed a common pattern. In addition, many case studies searched for missing subsystems. System diagnosis and design mostly concerned the subsystems and not their interrelations. Inspired by the approaches presented in the case studies, we extracted similarities in the process and formalized them in a framework which is described in the following section. Furthermore, we extended the framework to address the research gap.

4.2 Formalized application pattern from use case analysis

In this section, we first present a common pattern for VSM application: The formulation and further specification of a problem, the framing by the VSM to make the problem accessible to analysis, the development of a domain-specific solution model, and finally the translation of the theoretic solution approach to a real case study. **Figure 2** visualizes step 1 to 7 of this pattern on two layers of abstraction as well as a tool box layer, which includes additional methodological support.

Figure 2 depicts that a problem on an organizational level cannot be solved on the same abstraction level, as was described in detail by Elezi et al. *(2014b)*. Therefore, the goal is to solve it on the meta-model level, because on this level the VSM can provide assistance in solving the problem. Methodological input from the tool box is displayed by dotted arrows. On this level, the VSM, StCM and additional domain-specific tools offer support. The following explains the developed framework step by step:

1. Formulate a problem on organizational level.
2. Specify the problem through a first interpretation of the problem causes.
3. Use the VSM framework to model the problem setting into its structure. Formulate the problem within the VSM meta-model domain.
4. Analyze the problem on a structural and procedural level by checking for incomplete or missing VSM subsystems and relation channels. To check for completeness, use the function list by Schmidt et al. (2014).
5. Create a domain-specific model to solve the problem. Use familiar tools of your domain as input. Here, StCM can guide channel design, as is described later.
6. Formulate a theoretical solution in the form of a model or approach.
7. Apply of the model on an organizational level by conducting a case study.

This framework provides step-by-step guidance on how to overcome the challenge of fitting the VSM to a problem on an organizational level. The Toolbox Layer provides additional methods and tools to be applied to support various steps of the process. This framework presents a formalized process for VSM application derived from a literature review. Because the analyzed use cases revealed a lack of focus on subsystem relations *(most of their analysis concerned the systems themselves)* in the following we focus on relations and dependencies of VSM subsystems and augment the presented model by an additional tool to diagnose and design them as well.

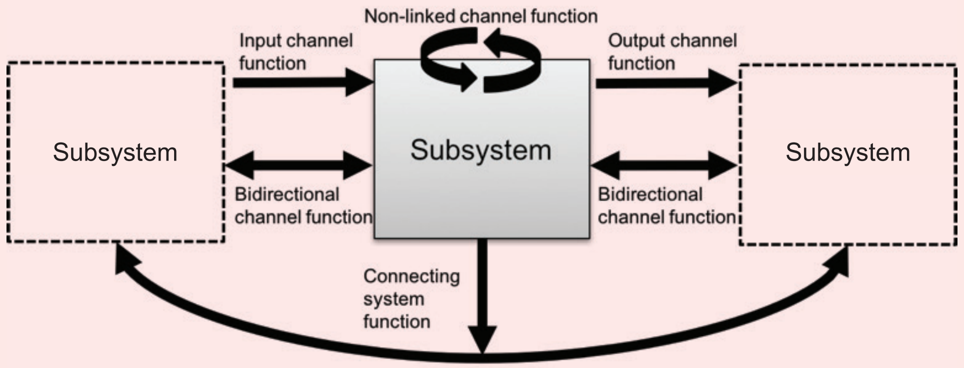

FIGURE 3. *Characterization of different function types within the VSM*

Communication matrix

	S5	S4	S3	S3*	S2	S1	Env	Active Sum
S5			16					1
S4	4, 10							2
S3	4, 19							2
S3*			14					1
S2			13					1
S1	41		12, 40	26				4
Env		6, 8						2
Passive Sum	5	2	5	1				

Coordination matrix

	S5	S4	S3	S3*	S2	S1	Env	Active Sum
S5			21					1
S4			11, 18					2
S3		11, 18				21,23, 27,43		6
S3*						27		1
S2			33, 34					2
S1			23, 43		33, 34			4
Env								
Passive Sum		2	7		2	5		

Control matrix

	S5	S4	S3	S3*	S2	S1	Env	Active Sum
S5		5	5			42		3
S4			15					1
S3						20, 22, 24, 44		4
S3*								
S2								
S1								
Env								
Passive Sum		1	2			5		

Interaction matrix

	S5	S4	S3	S3*	S2	S1	Env	Active Sum
S5								
S4								
S3								
S3*	28	28	28					3
S2								
S1							35, 36	2
Env						36		1
Passive Sum	1	1	1			1	2	

FIGURE 4. *DSMs mapping function types to channel characteristic*

4.3 Extending the framework to enable diagnosis and design of interlinking channels

StCM enables the reduction of complexity by providing approaches to map structural and procedural relations; doing so proves to be highly compatible with the VSM. In this case, the relations are derived from the function list by Schmidt et al. *(2014)*, because they implicitly formulate the role of each subsystem and its relations to other subsystems. Within the function list, five types of functional relations appear: *(1)* non-linked channel functions *(fulfilled by only one subsystem with no connections to other subsystems)*, *(2)* input channel functions, *(3)* output channel function, *(4)* bidirectional channel functions, and *(5)* connecting system functions *(connecting the inputs and outputs of two subsystems)*. **Figure 3** depicts these five function types and how they interlink VSM subsystems.

An abstract description of subsystem functions is still not very useful for practitioners who are intent on analyzing problems on an organizational level. Jackson *(1988)* revealed the four channel types, which we further interpreted: *(1)* communication *(pure information exchange)*, *(2)* coordination *(managing the relations of other subsystems)*, *(3)* interaction *(exchanging more than information and leading to state changes of subsystems)*, and *(4)* control *(directed forced actions)*. Having characterized all functions, we mapped them into a DSM, using their assigned number instead of their name. Non-linked channel functions do not appear in the matrix, as they do not form a relation channel.

The DSMs show the functional relations and dependencies between all VSM subsystems concerning the four domains *(communication, coordination, interaction, and control)*. Items in the column on the left influence those in the upper row of the matrix, e.g., function 16 in the Communication matrix *("receive goals, values, instructions from S5 and higher recursion levels")* indicates how S5 is active in communicating goals, values, and instructions to a passive *(receiving)* S3. This relation consists only of pure and directed information flow; this is why function 16 was inserted into the Communication matrix. After this description of how these four DSMs have been created, the following section details the quantified analysis which is one major feature of a DSM.

Quantified analysis of the DSMs: The sum of functions *(inserted by their listing number in the function list, see VSM function list in Schmidt et al. 2014)* in columns is calculated and displayed in the bottom row as passive sum, meaning how other functions influence this particular function. The sum of functions in rows is accordingly calculated in the right column as active sum, meaning the influence this function has on other functions. Highlighted are active and passive sums showing a value over 3 *(with 7 as the maximum value, this is considered to be a significant high score)*. For example, within the Coordination matrix S3 is highly involved in coordinating activities among higher and lower order subsystems. S1 units are involved in coordination activities. The Communication matrix clearly shows S5 passive in receiving and S1 highly active in providing information. Coming back to the framework in **Figure 2**, these DSMs and their implicit insights aim to assist in diagnosing existing relations between identified VSM subsystems during Step 4, the analysis. In Step 5, the domain-specific model design, the matrices aim to support the detailed understanding of necessary channel relations between specific subsystems in order to create a viable system. This now allows for a quantified analysis of subsystem relations using active and passive sum calculation. This matrix visualization further enhances a general overview over the VSM and its implicit functional relations. Practitioners can use these matrices to gain an understanding of critical relations between VSM subsystems.

5. Summary and Outlook

The Viable System Model *(VSM)* is a tool to reveal deficiencies in organizations by providing a description a should-be state for viability. Although useful, there is still no structured approach guiding the general translation of the model to solve a problem on an organizational level. Existing literature shows how the VSM can be used to solve domain-specific problems. The analysis of twenty-five VSM cases studies from literature revealed a common application pattern. All these case studies implicitly used a similar approach from which we derived a model for the domain-specific application of the VSM. Looking deeper into the case studies revealed not only a common application pattern but also a missing consideration of the relations between VSM subsystems. Therefore, we extended the derived framework to target this issue. This extension is derived from an analysis of the VSM function list by Schmidt et al. *(2014)*. We derived four DSMs *(communication, coordination, interaction, and control)* that enabled a quantified analysis of VSM relation channels. These DSMs can also be used to design an organizational model by offering a should-be perspective for relations in viable systems.

Further research could concern System 3 and its role in the VSM in terms of relations with other subsystems. Its tight visible in the DSMs how System 3 is highly involved *(active and passive)* in all four channel types. of its tight interrelation with other subsystems makes it vulnerable for deficiencies. Further work could concern case studies on implementing strategic changes derived from monitoring the external environment based on technology road mapping. Such research may lead to an increased understanding of how to achieve requisite variety in a dynamic environment.

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