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**Application of DSM in the field Organizational Psychology**

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### **Abstract**

As organizations face many challenges such as globalization or a dynamic and complex environment, new forms of collaboration have emerged like Multiteam Systems (MTS). MTS can be described as complex networks of teams, working together in order to reach an overall goal. The phenomenon of MTS has been studied in the field of Organizational Psychology. The objective of this paper is to exemplarily show that structural analysis criteria can be meaningfully applied in the field Organizational Psychology. We base our analysis on a qualitative study exploring influencing factors of effective collaboration in MTS. The influencing factors were described in a Design Structure Matrix and analyzed by different structural analysis criteria. The results provide valuable insights about the interaction of the influencing factors and help identifying the characteristics of the system and its behavior. The results of the analysis can be used when aiming to improve the collaboration in MTS.

## 1 Introduction

In recent years the work environment has changed and new challenges need to be addressed effectively from organizations and their members (Ilgen & Pulakos, 1999). For example, as communication and information technology has grown extensively, the pace, scope and scale of work have increased (Hesketh & Neal, 1999). Similarly, through globalization, geographic dislocation of organizational work is becoming the norm (Ireland & Hitt, 1999). Because of the increasing immediacy supported by current technology, strategic issues, problems and implications have more interconnectivity across organizational boundaries. In order to meet these challenges new forms of collaboration within organizations as well as across organizational boundaries have emerged. One form can be described as tightly coupled teams (within and across organizations), which have specific core missions, expertise, structures, norms and operating procedures, while collectively striving for an overall common goal. These relatively new network of teams was defined as Multiteam Systems (MTS). (Zaccaro et al., 2012)

Multiteam Systems are a unique form of arrangement within and across organizations (Marks et al., 2005), in which teams of teams work together. A MTS is defined as “two or more teams that interface directly and interdependently in response to environmental contingencies toward the accomplishment of collective goals. MTS boundaries are defined by virtue of the fact that all teams within the system, while pursuing different proximal goals, share at least one common distal goal; and in doing so exhibit input, process and outcome interdependence with at least one other team in the system” (Mathieu et al., 2001, p. 290). Thus, MTS differentiate from traditional organizational structures and depict complex socio-technical systems (DeChurch & Zaccaro, 2010).

A common approach to handle complex systems is the Structural Complexity Management (StCM) methodology (Lindemann et al., 2009). It combines the possibilities of

the Design Structure Matrices (DSM) (Steward, 1981) and the Domain Mapping Matrices (DMM) (Danilovic & Browning, 2004). Both approaches are highly suited for modeling and analyzing system structures of different projects and use cases (for an overview see (Eppinger & Browning, 2012)). In literature lots of successful DSM implementations from various fields, such as automotive (McCord & Eppinger, 1993; Yassine et al., 2000) or aerospace (Browning & Eppinger, 2002), can be found.

Research has started to explore MTS as well as factors that determine its effectiveness (e.g., Marks et al., 2005; Zaccaro et al., 2012) This paper explores how this research can benefit from using the methods of StCM. For that purpose, a DSM, which includes the factors influencing successful collaboration within MTS, is described and analyzed by different structural analysis criteria. The results show that the methods of StCM provide valuable information that can be used to understand, explore and manage MTS.

## **2 Structure analysis**

The data used in the following structure analysis are based on an interview study (see Kugler et al., 2012). In this study 15 expert-interviews with managers working in a MTS in the division for “research and development” in a large German automotive company were conducted. First, the managers were asked to describe the MTS itself in which they and their team were working. Then the interviews focused on factors determining an effective collaboration within the MTS.

The interviews were analyzed according to Mayring (2008; qualitative content analysis) and according to Miles and Huberman (2007): After the text material was read by the coders, small units of content were identified and paraphrased. The information, which was condensed in this way, was then coded deductively with regard to theoretical propositions provided by Okhuysen and Bechky (2009), as well as Marks et al. (2001). In an

iterative process, categories were further defined and refined in order to ensure that the categories really accounted for the information in the data material. In the next step, semantic “causal” relationships between the categories were identified and coded (i.e. “due to x, y happens” or “x makes that y happens”). Based on this analysis Kugler et al. (2012) identify several factors that determine effective collaboration in MTS. These factors form the basis for the analysis described in this paper.

In this paper we conduct a structure analysis about the interaction of the different factors determining effective teamwork in MTS. First the DSM in Figure 1 was developed. It contains the influencing factors which determine the success of MTS and the relations between them. Within the matrix crosses indicate that one factor leads to another factor, e. g. “Structure: Plans & rules” leads to “Resources, Team composition”. All these factors were mentioned by the interviewees with regard to effective cooperation in MTS. In the following, the matrix is analyzed by different structural analysis criteria in terms of triangularization, calculation of system characteristics and graphical analyses. The results of the structure analysis are presented below, indicating possibilities and advantages of structural analysis of influencing factors of MTS.

	leads to													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Resources, Team composition	1	X	X	X		X	X					X	X	X
Structure: Plans & rules	2	X	X	X		X			X	X		X	X	X
Structure: Proximity & Contact	3			X		X			X	X		X		X
Structure: Roles & responsibility	4		X		X	X			X				X	X
Structure: Goals & mission	5				X	X							X	
Team processes: Action	6					X			X		X	X	X	X
Team processes: Transition	7			X		X	X				X		X	X
Team processes: Interpersonal	8						X	X		X				
Shared states: Structure & processes	9					X	X	X	X				X	
Emergent states: Climate	10					X	X	X	X	X		X	X	X
Emergent states: Awareness of complexity	11						X	X	X	X				
Coordination: Entrainment	12		X			X	X				X	X		
Coordination: Alignment	13					X	X			X			X	
Common understanding: Accountability	14					X							X	

Figure 1. DSM influencing factors of MTS

In Figure 2 the matrix is visualized in a graph: The graph shows which factors are strongly connected. For example, it can clearly be seen that most factors, except “Team processes: Interpersonal”, are strongly connected to the other elements of the system.

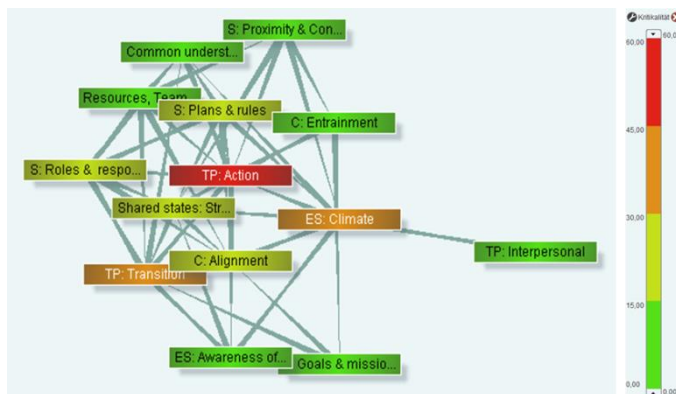


Figure 2. Graph influencing factors of MTS

Furthermore, the active and passive sum, the activity, passivity and criticality is calculated for each factor of the system. Table 1 shows the results, indicating the highest values by a grey background. For example, the influencing factor “Team processes: Interpersonal” is identified as a leaf and transit node.

Table 1. Analysis criteria based on active and passive sum

	Resources, Team composition	Structure: Plans & rules	Structure: Proximity & Contact	Structure: Roles & responsibility	Structure: Goals & mission	Team processes: Action	Team processes: Transition	Team processes: Interpersonal	Shared states: Structure & processes	Emergent states: Climate	Emergent states: Awareness of complexity	Coordination: Entrainment	Coordination: Alignment	Common understanding: Accountability
Active sum	8	8	5	6	2	6	5	1	3	6	3	3	3	1
Passive sum	1	3	1	3	1	10	7	1	6	5	3	4	8	7
Activity	8	2,67	5	2	2	0,6	0,71	1	0,5	1,2	1	0,75	0,38	0,14
Passivity	0,13	0,38	0,2	0,5	0,5	1,67	1,4	1	2	0,83	1	1,33	2,67	7
Criticality	8	24	5	18	2	60	35	1	18	30	9	12	24	7

In Table 2 the amount of indirect dependencies and feedback loops of the lengths 2 and 3 is illustrated. The matrix of indirect dependencies of the length 2 is shown in Figure 3. The numbers circled in red present the highest values of the matrix. The feedback loops of the length 2 are visualized in Figure 4.

Table 2. Indirect dependencies and feedback loops

Indirect dependencies	Length 2	253
	Length 3	1022
Feedback loops	Length 2	28
	Length 3	51

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Resources, Team composition	1	1	2	0	2	1	7	3	0	4	3	2	3	4	5
Structure: Plans & rules	2	0	3	1	1	1	7	5	1	3	1	2	2	5	4
Structure: Proximity & Contact	3	0	1	0	0	1	4	2	1	2	0	2	1	3	2
Structure: Roles & responsibility	4	1	0	0	2	0	5	3	0	2	2	2	2	4	3
Structure:Goals & mission	5	0	0	0	1	0	2	1	0	0	1	1	0	1	1
Team processes: Action	6	0	1	0	1	1	5	3	0	1	2	1	0	2	1
Team processes: Transition	7	0	1	0	0	0	3	4	0	3	2	1	1	2	2
Team processes: Interpersonal	8	0	0	0	0	0	1	0	1	1	0	1	0	1	1
Shared states: Structure & processes	9	0	0	0	1	0	2	2	0	1	1	2	1	2	2
Emergent states: Climate	10	0	0	0	0	0	3	4	0	2	3	1	1	2	1
Emergent states: Awareness of complexity	11	0	0	0	1	0	3	1	1	1	0	2	0	3	2
Coordination: Entrainment	12	1	0	0	1	0	1	2	0	2	1	1	2	3	2
Coordination: Alignment	13	0	0	0	1	0	2	1	1	2	0	3	1	3	3
Common understanding: Accountability	14	0	0	0	0	0	0	1	0	1	0	1	1	1	1

Figure 3. Indirect dependencies of the length 2

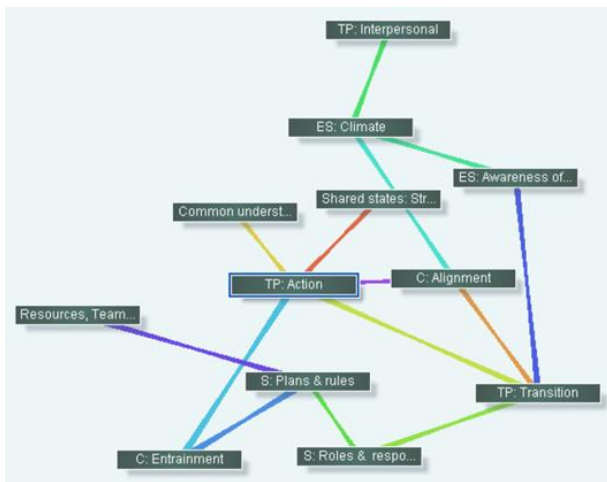


Figure 4. Feedback loops of the length 2

In addition, the whole system is identified as strongly connected. To get an overview of the direct dependencies of an element, the locality can be examined. Thereby just the incoming or outgoing edges can be considered. The edges can also be arranged hierarchically. Figure 5 shows the locality of the critical factor “Team processes: Action”. To visualize possible chains of change impact that originate from the adaptation of one node, a feed-forward analysis can be depicted. In Figure 6 a feed-forward analysis for the critical element “Team processes: Transition” is illustrated.

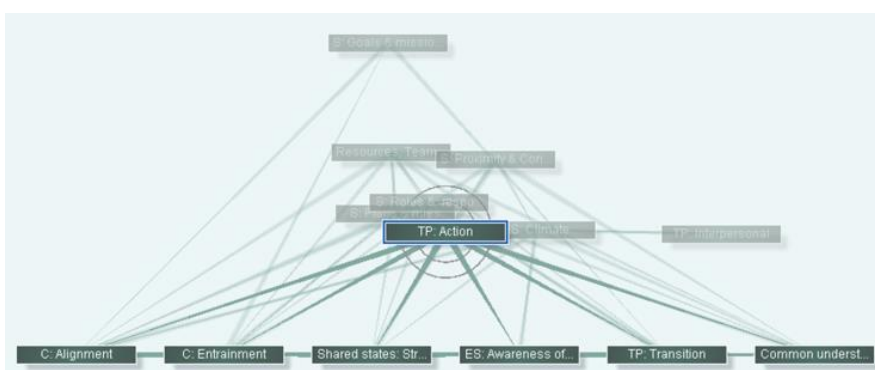


Figure 5. Locality



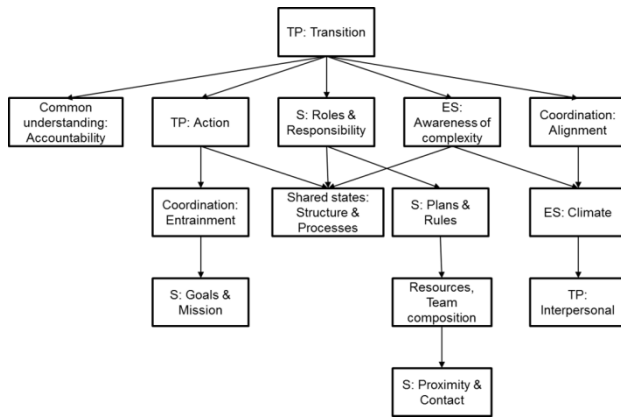


Figure 6. Feed-forward analysis

The degree of connectivity of this system is 33%. Figure 7 presents the triangularization and clustering of the DSM. Three clusters are identified.

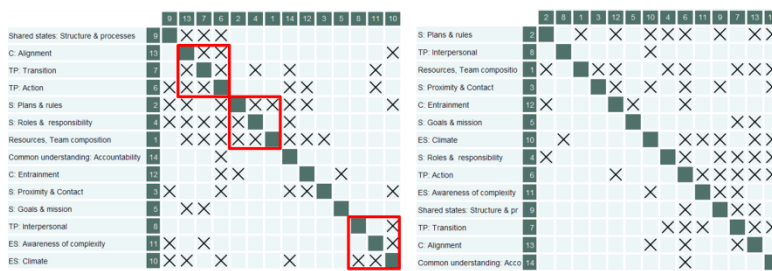


Figure 7. Triangularization (right) and Clustering (left)

### 3 Practical application of results

The graph of the system in Figure 2 provides a basic overview of the dependencies. The degree of connectivity is very high, whereby it is difficult to recognize the relations between the elements in detail. Nevertheless, factors which are in the center or at the edge of the system can easily be identified. “Team processes: Action” e. g. is a central element and “Team processes: Interpersonal” is located at the edge of the system.

Nodes with a high activity value predominantly impact other nodes in the structure, whereas elements with a high passivity value are affected by other nodes. “Structure: Proximity & Contact” and “Resources, Team composition” are detected as the influencing

factors with the highest activity of the system. The active sum of “Resources, Team composition” is 8 and the passive sum is 1. Hence, “Resources, Team composition” leads to more than half of the factors in the system. As the influencing factors with a high active sum lead to many other factors in the system and all elements lead to effective cooperation in MTS, these factors with a high active sum or activity can be seen as a type of basic requirement. “Common understanding: Accountability” is identified as the element with the highest passivity, whereby the active sum is 1 and the passive sum is 7. Therefore, this factor is affected by half of the elements in the system or half of the factors in the system lead to this element. Thus, “Common understanding: Accountability” can be considered as a type of outcome of the system. There are many critical nodes in this system, which often occurs in strongly connected systems. “Team processes: Action”, “Team processes: Transition” and “Emergent states: Climate” are detected as the nodes with the highest criticality of the system. As can be seen in Figure 2, “Team processes: Action” is strongly involved in the system. The critical factors influence many other nodes and are influenced by lots of other nodes of the system. These elements have a high relevance within this system and further analysis should be focused on these influencing factors. “Team processes: Interpersonal” is identified as a leaf or transit node. This factor can only affect and is only affected by “Emergent states: Climate”. Leafs can often be combined with the node directly connected to them to facilitate structural considerations.

The relatively high degree of connectivity indicates that the influencing factors are strongly connected and interdependent, which makes it complex to handle the system. The complete system is identified as a strongly connected part, which also supports the prior idea. Furthermore, three clusters can be developed, but there are also lots of relations which can't be combined. The amount of indirect dependencies and feedback loops of the lengths 2 and 3 is very high in this system. The interaction of many feedback loops can result in uncertainties

in the system and it is difficult to foresee consequences. The influencing factor “Team processes: Action” is involved in many feedback loops of the lengths 2 and 3, which underlines the relevance of this factor for the system. To get an overview of the feedback loops, it is possible to visualize them in a graph, as Figure 8 shows. The graph illustrates the feedback loops of the length 3, in which “Team processes: Action” is involved. Thus, self-energizing feedback loops can be detected, such as the feedback loop which includes the factors “Team processes: Action”, “Team processes: Transition” and “Structure: Roles & responsibility”. The elements of self-energizing feedback loops mutually reinforce each other.

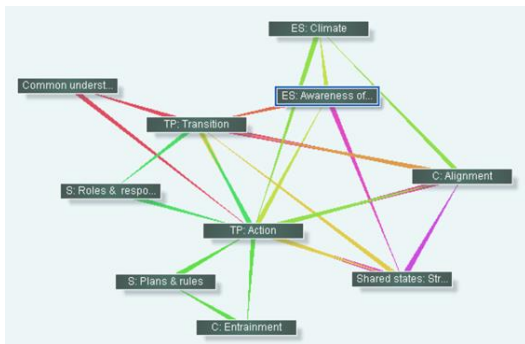


Figure 8. Feedback loops of the length 3 (“Team processes: Action”)

Elements which are connected by many indirect dependencies influence each other in case of a change. There are seven indirect dependencies of the length 2 between the factors “Resources, Team composition” or “Structure: Plans & rules” and “Team processes: Action”. This can be explained by the fact that “Team processes: Action” is the most critical element of the system and “Resources, Team composition” as well as “Structure: Plans & rules” have an active sum of eight. Therefore, the recognition of indirect dependencies offers an opportunity to predict multiple, indirect and complex consequences within the system when changing one factor.

As the degree of connectivity is very high in this system, the complexity can be reduced and the visibility can be increased by the locality of an element or by a feed-forward-analysis. By considering the locality of an influencing factor the direct dependencies can easily be determined. A feed-forward-analysis shows to which other factors the considered factor gradually leads.

By triangularization of the matrix a sequence of elements can be identified which starts with the active and critical elements and ends with passive elements, such as “Common understanding: Accountability”. The sequence is a kind of chain beginning with the influencing factors which lead to many other factors and ending with the elements which are the results of lots of other factors. Thus, a causal chain from the triggers to the consequences of the system can be illustrated.

#### **4 Discussion**

For the results of the analysis and the practical application of these results, it can be noted that many of the considered structural analysis criteria provide relevant information when exploring complex systems like for example the MTS. For example, by determining the elements with the highest activity, passivity and criticality the factors which should be especially considered in further analyses can be identified. Using methods, such as the feed-forward-analysis, the complexity of the strongly connected system can be reduced. Thus, it is easier to handle the system and predict consequences within the system. Nevertheless, there are some criteria which were applicable only to a limited degree. As in this case the factors of the system are highly cross-linked, the relations of the system cannot be seen exactly in the graph. The graph can only give a basic overview of the arrangement of the elements in the system. Furthermore, the most active, passive and critical influencing factors can be identified, but there are not many other criteria, such as start and end nodes or articulation

nodes, due to the high degree of connectivity. The only detected leaf or transit node of the system, “Team processes: Interpersonal”, does not provide too much additional information. The connection could not be supported by any other context of the system. In addition, the amount of indirect dependencies and feedback loops is very high due to the strongly connected system. This makes it very difficult to foresee any consequences. To get an overview of the indirect dependencies and feedback loops, graphic illustrations need to be made. The clustering of the matrix just shows that there are many relations which cannot be combined, but it does not provide any further relevant information about the system.

Overall, it can be determined that the methods of StCM support the analysis of complex systems in the field of Organizational Psychology. By conducting a structure analysis the characteristics of the entire structure and its behavior can be identified, as well as the structural embedding of single elements and dependencies. The structural analysis criteria are well established and many of the criteria can be evaluated by mathematical methods. For example, the influencing factors of MTS with the highest activity or passivity could be detected and thereby a type of basic requirements or outcome of the system. Furthermore, the elements which are very important within the system and therefore should be considered in further analysis could be identified by calculating the criticality of the single factors. It was also possible to detect self-energizing feedback loops which could be visualized by graphic illustrations. As the system of the influencing factors of MTS is strongly connected, the visibility could be increased by different methods such as the feed-forward-analysis. Altogether, the application of structure analyses provides the basis for further system optimization.

## 5 Conclusion and outlook

This study investigated the applicability of structural analysis criteria in the field of Organizational Psychology. Based on an interview study (cf. Kugler et al., 2012) the factors influencing effective collaboration within MTS were determined and afterwards presented and connected in a DSM. This matrix was analyzed by different structural analysis criteria and the results were interpreted.

To summarize, it can be stated that a sound scientific basis is provided by using the methods of StCM. The clearly structured approach makes it possible to identify the characteristics of the system and its behavior. The results of the structure analysis can be used to understand, explore and manage the system. Many of the analyzed criteria provided important information about the interaction of the factors influencing effective collaboration within MTS. The factors with the highest activity or passivity of the system were detected, as well as the most critical elements. Therefore, further analysis can be focused on these influencing factors. The system has a very high degree of connectivity, many critical elements and feedback loops, which makes it difficult to handle it and to track any consequences. Hence, methods, such as considering the locality of an element or a feed-forward-analysis, are of great significance to reduce complexity and provide an overview of the dependencies. Furthermore, self-energizing feedback loops can be detected using graphic illustrations. By triangularization of the matrix a causal chain from the triggers to the consequences of the system can be demonstrated.

Overall, the methods of StCM provide helpful insights into the general interaction patterns within data structure; however, it cannot fully deal with the complexity of psychological, qualitative data. The main work of gaining useful insights for psychological theory and practice lies within the mindful interpretation of the data.

These results create a basis for further research regarding structural modeling of systems in the field of Economic and Organizational Psychology. Other systems of this field could be analyzed with different structural analysis criteria and graphic illustrations. The results could provide additional information within the process of qualitative data analysis and could be used to support the handling of these systems. A set of criteria may be identified which is particularly suitable for this kind of systems.

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