

MULTI-DOMAIN MATRICES: ANOTHER PERSPECTIVE

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1 INTRODUCTION

One way of approaching an MDM is to view the entire MDM as one big DSM. Yet there is a problem with such an approach. Important interactions which cut across more than 2 domains become less visible, especially, due to the size of the MDM [1]. However, there is another perspective from which an MDM can be approached. An MDM can be approached as several DSMs and DMMs which interact within the MDM. Such an approach can enable one gain insights into issues of managerial importance such as *supercircuits*.

2 EXTRACTING DENSE MDM INTERACTIONS

In an MDM system composed of n-domains, a Matrix which shows the mutual dependency of b-domains within the n-domains is called a *b-domain reduced MDM* in the formulation in this paper. The approach for extracting dense MDM interactions is illustrated in the diagram below.

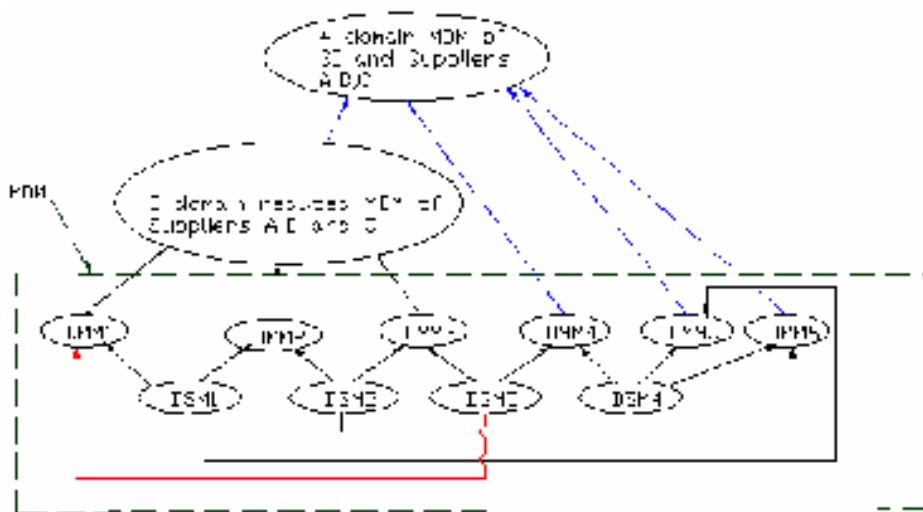


Figure 1. Simple diagram to illustrate the approach

Key:

DSM 1 refers to the DSM of Supplier A within the MDM

DSM 2 refers to the DSM of Supplier B within the MDM

DSM 3 refers to the DSM of Supplier C within the MDM

DSM 4 refers to the DSM of SI (Systems Integrator) within the MDM

DMM 1 refers to the DMM capturing coupled relations between Suppliers A and C in the MDM

DMM 2 refers to the DMM capturing coupled relations between Suppliers A and B in the MDM

DMM 3 refers to the DMM capturing coupled relations between Suppliers B and C in the MDM

DMM 4 refers to the DMM capturing coupled relations between SI and Supplier C in the MDM

DMM 5 refers to the DMM capturing coupled relations between SI and Supplier A in the MDM

DMM 6 refers to the DMM capturing coupled relations between SI and Supplier B in the MDM

The use of such an approach to an MDM leads to an output such as that below in Figure 2:

SUPPLIER C

	PROPERTIES		EVALUATION CRITERIA											
			1. A.1.1.001.001.001.001	1. A.1.1.001.001.001.002	1. A.1.1.001.001.001.003	1. A.1.1.001.001.001.004	1. A.1.1.001.001.001.005	1. A.1.1.001.001.001.006	1. A.1.1.001.001.001.007	1. A.1.1.001.001.001.008	1. A.1.1.001.001.001.009	1. A.1.1.001.001.001.010	1. A.1.1.001.001.001.011	1. A.1.1.001.001.001.012
SUPPLIER A														
SUPPLIER B														

Figure 2. A b-domain reduced MDM (A 3-domain reduced MDM of the network involving the 4 companies namely the: System Integrator, Supplier A, Supplier B and Supplier C)

3 DISCUSSIONS

The usefulness of the output data shown in Figure 2 above generated by the formulation lies in its power to reveal new MDM phenomena of managerial importance such as supercircuits. Supercircuits are circuits in different DSMs within an MDM which interact together. A supercircuit revealed by the output in Figure 2 is shown below in Figure 3:

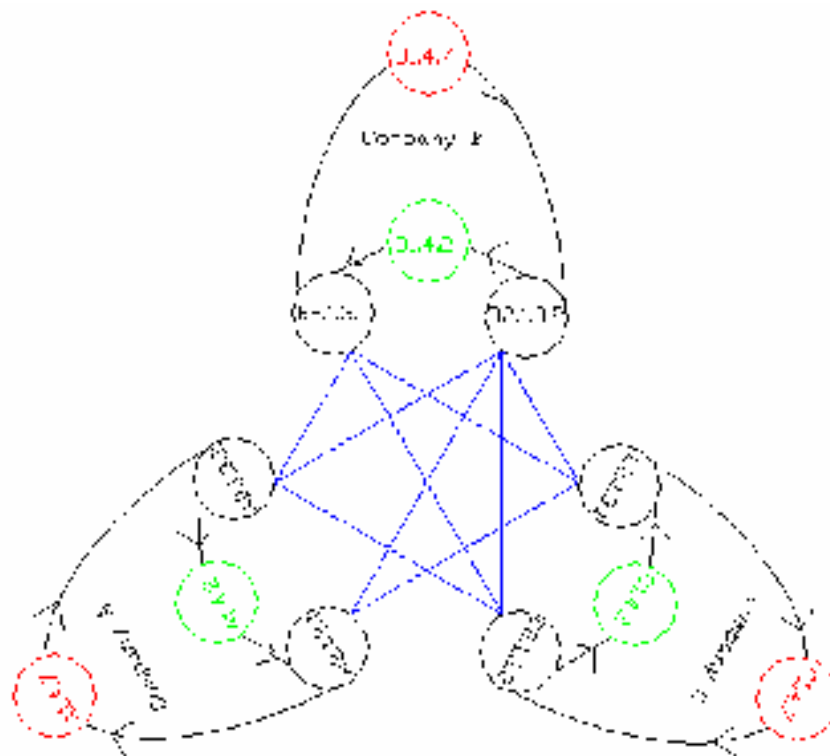


Figure 3: A Simple Supercircuit in the Network

Key:

- 2.1.3.1 refers to Equipment
- 1.4.7 refers to Product Mix Flexibility
- 2.1.3.2 refers to Automation
- 1.4.2 refers to Number of Variants

In Figure 3 above, A2.1.3.1 refers to Equipment in Company A. Figure 3 is a visual representation of a supercircuit found in the network. Supplier companies A, B and C are the domains and each has its own DSM within the MDM which gives rise to circuits. The blue lines, the red regions as well as the green regions show inter-circuit interdependency linkages between the DSM circuits as revealed by the output shown in Figure 2. This supercircuit reveals an area of iteration within the network which needs to be strategically planned for. However, the managerial implications of such supercircuits in a network are the subject of another paper by Asamoah-Barnieh and Danilovic.

REFERENCES

[1] Browning Tyson R. Matrix-Based Systems Architecting, Schedule Management and Organization Planning. *M.I.T Lean Aircraft Initiative*, 1997

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Abstract

- With ever increasing competition, companies are collaborating in networks with projects increasingly spanning across different teams in companies with divisions in different geographical locations and with partner companies with different specializations. This creates the situation in which different companies must interact effectively to achieve a common goal in a multi-domain network environment. In this paper, a new approach for Multi-Domain Matrix (MDM) analysis based on empirical research on 4 companies in a network is presented. The approach builds on the perspective that the MDM consists of several matrices whose interrelationships can be explored. The perspective leads to the formulation of an aggregation of novel concepts for Multi-Domain Analysis which in turn leads us to a novel MDM phenomenon of managerial importance which has been named supercircuit in this paper.



Introduction

- In the paper, we explore a perspective of interactions within networks. The basis of this exploration is an empirical research involving a network of 4 companies. The network of 4 companies is made up of 3 suppliers and a systems integrator. The interactions are visualized with the help of a matrix.
- The 3 Suppliers are referred to as Supplier A, Supplier B and Supplier C
- The System Integrator is sometimes referred to as SI
- In this presentation, all figures retain their figure numbers in the paper covered by this presentation. This is to make it easy for later follow up in the paper.



The MDM

- The MDM (Multi-Domain Matrix) is a tool for visualizing interactions in networks. It reveals interdependent elements within the network.
- An MDM for a network basically consists of several DSMs which map interactions among elements within individual domains in the network and also DMMs which map interactions across elements of two different domains within the network.
- The DSM (Design Structure Matrix, Design System Matrix or Dependency Structure Matrix) (Steward, 1981) is a square matrix which reveals how an element depends on another within a given domain.
- The DMM (Domain Mapping Matrix) is a rectangular matrix which reveals how an element in one domain depends on another element in a different domain. (Danilovic and Browning, 2007).



Introduction to Approach

- One way of approaching an MDM is to view the entire MDM as one big DSM. Yet there is a problem with such an approach. Important interactions which cut across more than 2 domains become less visible, especially, due to the size of the MDM (Browning, 1997). However, there is another perspective from which an MDM can be approached. **An MDM can be approached as several DSMs and DMMs which interact within the MDM.** Such an approach can enable one gain insights into **issues of managerial importance such as *supercircuits*.**

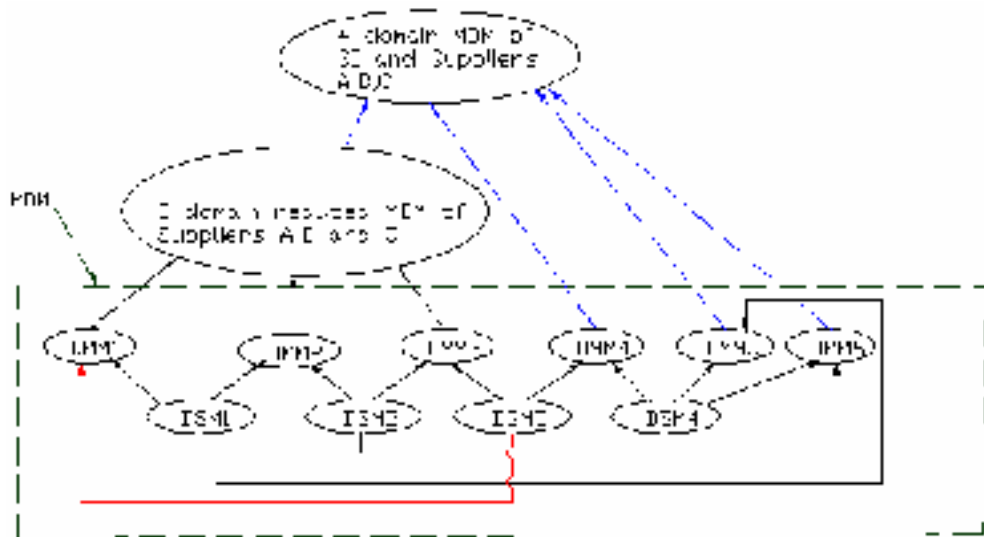


Extracting Dense MDM interactions

- In an MDM system composed of n-domains, a Matrix which shows the mutual dependency of b-domains within the n-domains is called a *b-domain reduced MDM* in this formulation. Thus in the network MDM made up of the 4 domains (System Integrator, Supplier A, Supplier B and Supplier C), a matrix capturing interactions involving 3 of the 4 domains is a *3-domain reduced MDM*. A Matrix which shows the mutual dependency of all n-domains is called an *n-domain MDM*. The word “reduced” in “b-domain reduced MDM” is used to show that all domains in the MDM system have not been considered.
- The various *b-domain reduced MDMs* are formed by using a *Transformation Algorithm* to combine individual DMMs within the bigger MDM to form a *b-domain MDM* and further combining this b-domain MDM with other DMMs or b-domain MDMs as needed in a recursive manner to form higher level b-domain MDMs and eventually the *n-domain MDM*.
- After using a *Transformation Algorithm* to form the b-domain MDMs or the n-domain MDM, the resulting matrices can be treated with usual matrix methods such as clustering depending on the focus of the analysis.



Fig.6: Simple diagram to illustrate the approach



Key to Fig. 6 (Fig.6 notes)

- DSM 1 refers to DSM of Supplier A within the MDM
- DSM 2 refers to DSM of Supplier B within the MDM
- DSM 3 refers to DSM of Supplier C within the MDM
- DSM4 refers to DSM of SI (Systems Integrator) within the MDM
- DMM 1 refers to DMM capturing coupled relations between Suppliers A and C in the MDM
- DMM 2 refers to DMM capturing coupled relations between Suppliers A and B in the MDM
- DMM 3 refers to DMM capturing coupled relations between Suppliers B and C in the MDM
- DMM 4 refers to DMM capturing coupled relations between SI and Supplier C in the MDM
- DMM 5 refers to DMM capturing coupled relations between SI and Supplier A in the MDM
- DMM 6 refers to DMM capturing coupled relations between SI and Supplier B in the MDM



Explanation of Critical Terminologies

- **Transformation algorithm:** An algorithm which aggregates data from a typical MDM to form a denser MDM such as a 7-domain MDM.
- **Interdependency link chain:** A group of interacting elements or units which can be lumped up as a single interaction unit.
- **Interdependency strength:** A representation of the degree of interaction between two or more elements. It is often numerical.
- **Link chain strength function: Interdependency link chain strength function:** A function, formula or program which determines the interdependency strength of an interdependency link chain.
- **Single to coupled relations transformer function:** This is a function which computes a coupled dependency strength when non-coupled dependency strengths are fed into it as inputs. This is essentially an Index computation (Malmqvist, 2002) function.



Generic Transformation Algorithm for Forming a coupled b-domain reduced MDM from non-coupled DMMs in an MDM

- Extract coupled dependencies so as to form a coupled dependence matrix
- Assign interdependency strengths for the extracted coupled dependencies by using a “single to coupled relations transformer function”
- Extract “Interdependency link chains” by using the MDM and the output in step. 2
- Assign Interdependency strengths to the link chains using a “link chain strength function”
- Repeat until the Matrix is Complete



Application to Network: Structure of the MDM of the Network

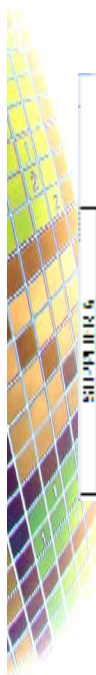
- The MDM of the network used in this research is very large and would probably be illegible if displayed here. However the structure of the MDM is basically that given in Fig. 1. In Fig. 1 below, DMM of A →B means the DMM showing the dependence of Supplier B on Supplier A. There are about 54 elements under each company and these elements are grouped into 3 major categories namely: layout, decision criteria and competitive analysis factors.

	Systems Integrator (SI)	Supplier A	Supplier B	Supplier C
Systems Integrator (SI)	DSM of SI	DMM of A→SI	DMM of B→SI	DMM of C→SI
Supplier A	DMM of SI →A	DSM of A	DMM of B →A	DMM of C →A
Supplier B	DMM of SI →B	DMM of A →B	DSM of B	DMM of C →B
Supplier C	DMM of SI →C	DMM of A →C	DMM of B →C	DSM of C

Fig. 1



Application to Network: Snapshot of Empirical Data



		SUPPLIER A									
		1	2	3	4	5	6	7	8	9	10
SUPPLIER A	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										

DSM of Supplier A (represented as “DSM of A” in Fig.1)



Application to Network: Snapshot of Empirical Data

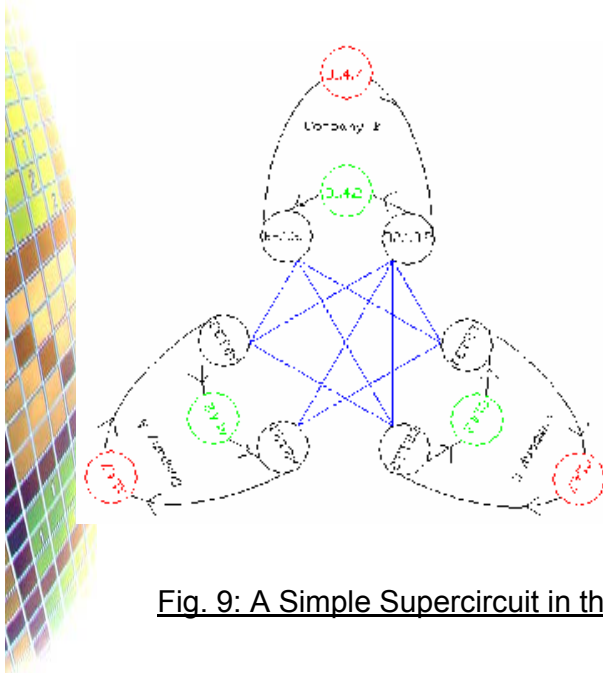


		SUPPLIER B									
		1	2	3	4	5	6	7	8	9	10
SUPPLIER A	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										

DMM showing Supplier A’s dependence on Supplier B (represented as DMM of B →A in Fig. 1)



Application to Network: Discussions: Network Supercircuit



Key:

- 2.1.3.1 refers to Equipment
- 1.4.7 refers to Product Mix Flexibility
- 2.1.3.2 refers to Automation
- 1.4.2 refers to Number of Variants

Fig. 9: A Simple Supercircuit in the Network



Application to Network: Discussions: Network Supercircuit

- In Fig. 9 above, A2.1.3.1 refers to Equipment in Company A. Fig. 9 is a visual representation of a supercircuit found in the network. Supplier companies A, B and C are the domains and each has its own DSM within the MDM which gives rise to circuits. For instance, the DSM of Supplier A in the MDM gives rise to the circuit $A1.4.7 \rightarrow A2.1.3.2 \rightarrow A1.4.2 \rightarrow A2.1.3.1 \rightarrow A1.4.7$ above. All dependencies within the circuits are actually coupled dependencies but the circuit has been drawn the way it is to enhance clarity. The blue lines show inter-circuit linkages between the DSM circuits as revealed by the blue shaded region in the output shown in Fig. 7. The blue lines depict regions of coupled dependence between the circuits in the different domains. All the red regions in the different circuits within the supercircuit in Fig. 9 are also coupled. This is revealed by the red shaded cell in the *3-domain reduced MDM* in Fig. 7. Moreover, all the green regions in the circuits forming the supercircuit in Fig. 9 are also coupled. This is revealed by the green shaded cell in the *3-domain reduced MDM* in Fig. 7. This supercircuit reveals an area of iteration within the network which needs to be strategically planned for. **However, the managerial implications of such supercircuits in a network are the subject of another paper by Asamoah-Barnieh and Danilovic.**



Conclusion

- DSM techniques increase in value with organization complexity (Browning, 1997). However, matrices can grow in size to the point that they are either too large for conventional publication formats or are too small to read. In the research covered by this paper, an approach to MDMs has been presented and the approach has been applied to a network of 4 companies to arrive at a new MDM phenomenon of managerial importance which we have named the *supercircuit*. The approach is to consider an MDM as several matrices which interact with each other. This approach enables relevant data in an MDM to be extracted from the MDM and represented in a simple format to make it easy to display in a conventional publication and make it easy for use in MDM analysis.



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