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POTENTIAL APPLICATIONS OF DSM PRINCIPLES IN PROJECT RISK MANAGEMENT

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Keywords: Project management, risk identification, risk assessment, risk network, risk structure matrix

1 INTRODUCTION: COMPLEXITY IN PROJECTS

Project management usual techniques include classical principles underlying in scientific management: fragmentation of work and maximisation of visibility and accountability. As noticed by Marle [1], projects are generally managed thanks to the use of single-link trees, with decomposition relations (WBS, OBS, risk lists) or sequential relations (Pert, Gantt), that do not correctly show the networked and interconnected structure of a project. Many factors related to interdependencies have been identified as drivers of project complexity [2, 3]. The same phenomena do exist between risks, which are interrelated by complex and varied interactions.

2 PROJECT RISK MANAGEMENT LIMITS

Risk management process is classically divided into four major steps: risk identification, risk analysis, risk response planning and risk monitoring and control. According to Raz & Hillson, "the origins of operational risk management can be traced to the discipline of safety engineering" [4]. Lots of risk management methodologies and associated tools have been developed, with qualitative and/or quantitative approaches, often based on the two concepts of probability and impact (or gravity). A state of the art was made, notably based on some standard risk management methodologies. It enables us to raise conceptual and practical issues, especially those linked with the complex nature of risk interactions. Namely, current methodologies are focused on only some aspects of risk network complexity, e.g. single cause-effect links identification or acyclic and oriented networks (Bayesian networks). But, some phenomena are still not taken into account by existing risk management methodologies, like loops, chain reactions or non-linear couplings. This is why we have been conducting our research works to improve risk management methodologies thanks to a better integration of complex phenomena. The DSM approach is to help this research as shown hereinafter.

3 DESIGN STRUCTURE MATRIX PRINCIPLES AND APPLICATION TO RISKS

The Design Structure Matrix or Dependence Structure Matrix, called DSM, represents and visualizes relations and dependencies among objects. The DSM was introduced by Steward [5] with tasks and has been initially used essentially for planning issues, but it has been also widely used with other objects, like product components, projects and people. The main authors in our field of interest are Danilovic, Browning, Eppinger and Sosa, with the following non exhaustive references [6, 7]. We decided to use the concept of DSM for another object, which is the risk, in the context of project management. At this stage, we define risk interaction as the existence of a possible precedence relationship between two risks R_i and R_j. We define the binary Risk Structure Matrix (RSM) as the square matrix with $RSM_{ij}=1$ when there is an interaction from R_j.to R_i. It does not address issues about probability or impact assessment of this interaction. The RSM permits to get exhaustive and consistent information about interactions between risks, as we put a sanity check between R_i and R_j. If R_i declared R_j as a cause, but R_j did not declare R_i as a consequence, then there is a mismatch. Each mismatch is studied and solved, like analogous works by Sosa about interactions between actors[7].

4 THE USE OF RISK STRUCTURE MATRIX TO CLUSTER RISKS

The classical partitioning algorithm

Classically, the RSM is re-ordered in a way that enables to show first-level blocks, through the partitioning process [5]. It gives three types of information:

- the dependent risks : they are engaged in a potential precedence relationship,
- the interdependent risks: they are engaged in mutually dependent relation, directly or with a bigger loop,
- the independent risks: the risks are basically non-related.

The aim of this process is basically to obtain a matrix which is low trigonal by blocks. This partition enables to isolate interdependent risks, but our purpose is different. We aim at grouping risks in clusters with maximal internal interactions and minimal inter-clusters interactions. In order to do so, we use an AHP-based assessment of risk interactions to get numerical values, catching the strength of these risk interactions.

Using AHP-based principles to build a risk numerical matrix (RNM)

$RSM_{ij}=1$ implies two different possible ways to address the situation as this can be seen either as a possible risk input of R_i coming from R_j, either as a possible risk output from R_j reaching R_i. Similarly as in [8] for design tasks, we argue that these two visions must be combined, considering both the causes (inputs) and the effects (outputs). That is why we argue for a two-way comparison methodology to achieve the project risks pairwise comparisons. Firstly, the risks are evaluated regarding their contribution to any R_k in terms of risk input (comparison on rows). In other terms, for every pair of risks which are compared, the user should assess which one is more important to risk R_k in terms of probability to be a risk input (i.e., a cause) for risk R_k. Numerical values are obtained thanks to the use of traditional Saaty scales. Then, the same process is used for risk outputs (comparison on columns). The combination of eigenvectors permits to build up two square matrices we name NEM (Numerical Effect Matrix) and NCM (Numerical Cause Matrix). Indeed, for each risk R_i, we calculate the eigenvectors of the two AHP matrices corresponding to this risk, in terms of inputs and outputs. The eigenvectors which are associated to the maximum eigenvalues correspond to the i-th row of the NEM and the i-th column of the NCM. Let us now define the RNM (Risk Numerical Matrix) by the global weighting operation given by equation 1:

$$RNM(i,j) = \sqrt{NCM(i,j) \times NEM(i,j)}, \qquad \forall (i,j), 0 \leq RNM(i,j) \leq 1 \tag{1}$$

This calculation permits an overall estimation of the (i,j)-th term since it aggregates (at the same level of influence) the two approaches of causes and effects.

Clustering by interactions

The first way is to cluster together risks according to their ranking in terms of values in the RNM, i.e. to look for the highest value in the RNM, corresponding to RNM(i,j), and cluster R_i and R_j together. The process is stopped when the cumulated value of clustered risks is 80% of the total value (Pareto principle). This enables to manage far less interactions.

The second way is to maximise the intra-cluster value of the risk configuration. The problem is to obtain the risk clustering alternative, which maximises the intra-cluster interactions value.

The problem formulation and linearisation will be detailed during the oral presentation.

Description of the refinement algorithm

In order to catch an overall interaction level between risks, the RNM must be turned into the RIM (Risk Interaction Matrix). The RIM is a symmetrical matrix which aggregates the possible influence of R_i as a cause of R_j and the possible influence of R_j as a cause of R_i.

The original goal of clustering is to find similarity between objects or groups of objects and group them together [9]. Given the data of the RIM, our aim is to cluster the risks according to their mutual interaction. The proposed algorithm is based on the minimization of the Mahalanobis distance between objects [10]. This process enables to subcluster some risks inside the previously defined clusters.

5 CONCLUSIONS AND PERSPECTIVES

We are developing in this research new application of existing techniques, like DSM, AHP and clustering algorithm. The first innovation is to build and use successive risk matrices in order to model interactions between risks. The second innovation is to cluster risks by interactions and not by one of the classical parameters. There are three levels of depth for this clustering:

- The first level is basically the identification of the interactions thanks to RSM, and the handmade partitioning or using the DSM partitioning algorithm, which isolates interdependent objects.
- The second level is the relative estimation of interactions in the RNM, which enables to refine the groups by taking into account the strength of the interactions and not only their existence
- The third level is the use of an algorithm to cluster the risks with the numerical values in the RNM.
- The fourth level is to refine the clusters by identifying similar risks which constitute subclusters.

A first comparison has been done on a case study for a project in the entertainment industry. The classical decomposition by nature or by value has been studied. It has been compared to the clusters we obtain through the described methods. As a perspective, the DSM approach may also be useful for identifying risks according to analysis of DSM, DMM or combinations of these matrices. We may for instance study the risks involved by the mismatch between potential and actual interactions between projects, or the potential consequences at two levels of a wrong actor choice in a project. Sosa has begun some work on this subject with actor interactions.

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Application of DSM principles to project risk management

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Topics

- Project management
- Risk management
- Risk interactions
- DSM
- AHP
- Clustering

Introduction

- Project management is basically a risky activity:
  - Targets and constraints
  - Uncertainty and change
  - Complex with interrelated parameters

BACCARINI, D. 1996

- Classical project risk management process is:
  - Risk identification
  - Risk analysis
  - Risk response planning
  - Risk monitoring and control
- Project risk management basically considers risks as independent:
  - Risk lists
  - Risk diagrams and graphs (Farmer)

MARLE, F. 2002

- Only some specific methods include interactions:
  - Bayesian networks
  - Monte-Carlo simulation

The problematic of risk classification

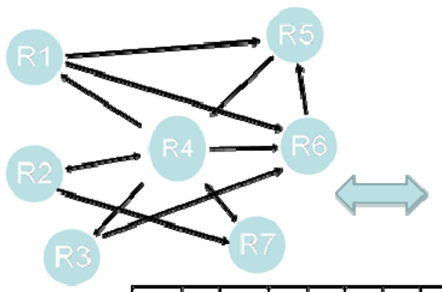
- Risk classification is mandatory:
  - Number of risks (human capacity)
  - Responsibility sharing and coordination
- Risk classification is not a science:
  - Multiple solutions
  - Advantages and drawbacks
  - Return on experience is not enough
- Interaction is an issue of risk classification:
  - Whatever the solution, there are always interactions between clusters
- Classical clustering includes:
  - Clustering by nature (after risk identification)
  - Clustering by value (after risk analysis)

Research methodology

- Defining the issue:
  - Defining risk interactions
  - Identifying inter-clusters links with existing solutions
  - Quantifying the potential issues (management, coordination)
- Using DSM principles:
  - Putting risk interactions into RSM (Risk Structure Matrix)
- Using AHP principles:
  - Putting numerical values into RSM thanks to AHP
  - Elimination of the 20% lowest values (Pareto principle)
- Using clustering methodologies:
  - By interaction values
  - By maximizing the global Intra-cluster value
- Comparing solutions and algorithms
- Refining solutions thanks to distance calculations

The Risk Structure Matrix

STEWARD 1981
DANILOVIC, M. and T. BROWNING 2007



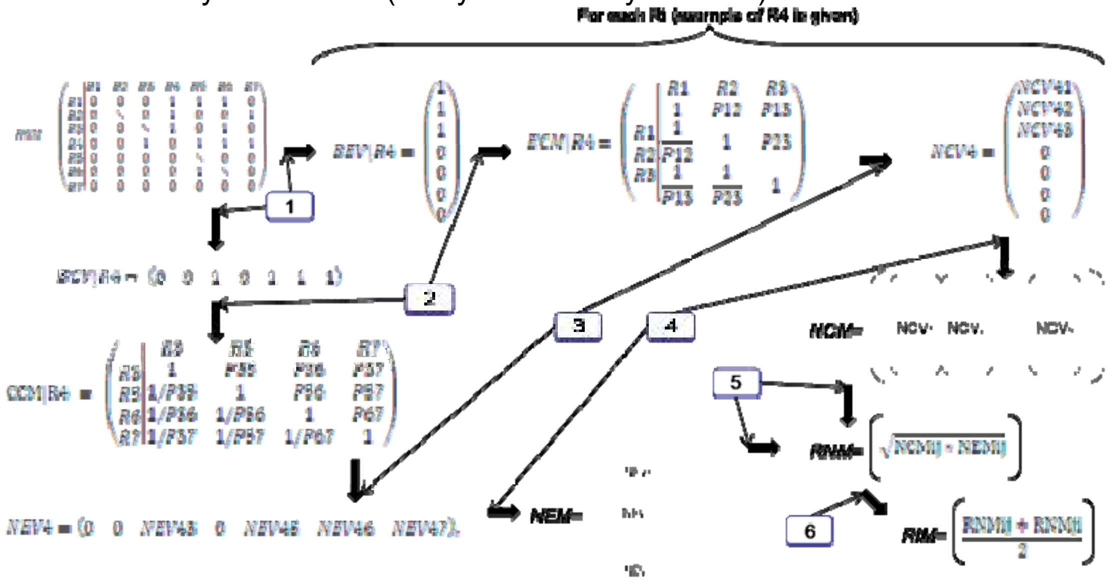
	R1	R2	R3	R4	R5	R6	R7
R1	1	0	0	0	1	1	0
R2	0	⋱	0	1	0	0	1
R3	0	0	⋱	0	0	1	0
R4	1	1	1	1	0	1	1
R5	0	0	0	1	⋱	0	0
R6	0	0	0	0	1	⋱	0
R7	0	0	0	1	0	0	1

	R4	R12	R6	R7	R1	R2	R3	R5	R10	R8	R9	R11
R4	4											
R12		12										
R6	1		6	1								
R7	1		1	7								
R1	1				1	1			1			
R2						2	1					
R3					1	1	3	1				
R5						1	1	5				
R10				1		1			10			
R8		1						1		8		1
R9										1	9	
R11											1	11

The Risk Numerical Matrix

CHEN, S.-J. and L. LIN 2003

- Obtained by use of AHP (Analytic Hierarchy Process)



Clustering by value of risks interactions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0,066	0	0	0	0	0,042	0	0	0	0	0	0	0,0799	0	0,099	0	0,04503	0,041
8	0,070597	0	0	0,09387	0	0	0	0	0	0,0604	0,033	0,033	0	0	0	0,09	0,081	0	0,0275	0,041
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0,025884	0	0	0	0,10632	0	0	0,039	0	0	0	0	0,085118	0	0	0	0	0	0,04082	0,022
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0,042048	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,077
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0,095	0	0,0817	0	0,1019	0	0,08251	0	0,046	0,071	0	0	0	0,0585	0,065	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0,076	0	0	0,10084	0,04535	0,1049	0	0,1	0	0	0,062	0,038	0	0	0,0578	0,0556	0	0	0,09594	0,031
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Pareto cut

Keep only the values in the RNM corresponding to 80% of interactions.

Clustering algorithm

Cluster together risks according to their ranking in term of values in the RNM, i.e.

Look for the highest value in the RNM, corresponding to RNM(i,j).

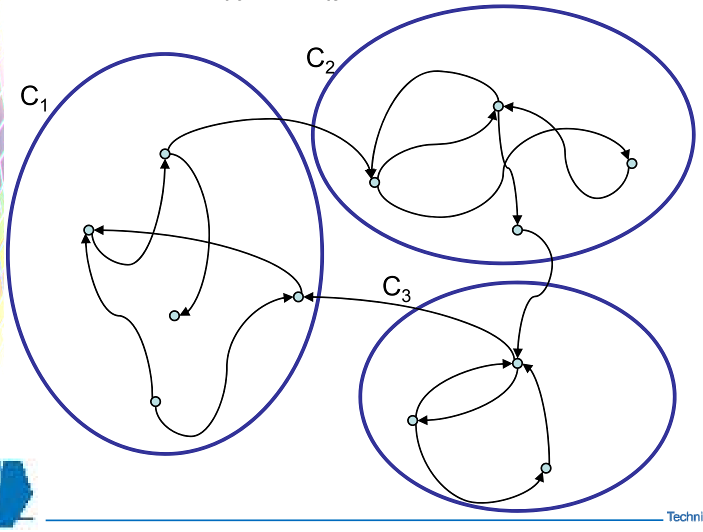
Cluster R_i and R_j together. And so on…

HARTIGAN, J.A. 1975

Clustering by global optimization

Let R be the number of risks. Let R_j, $1 \le j \le R$ be the set of risks to be studied.

The problem is to obtain the risk clustering alternative, which maximises the intra-cluster interactions value (or minimises the inter-cluster interactions value since $IV_{intra} + IV_{inter} = C$ fixed).



K_{opt}, the optimal number of clusters is unknown.

However, we do not want more than 7 risks in the same cluster.

Therefore,

$$Int\left(\frac{R-1}{7}\right) + 1 \le K_{opt} \le R$$

Clustering by global optimization

<u>Problem formulation</u>

For each K = number of clusters $Int\left(\frac{R-1}{7}\right) + 1 \le K \le R$

Objective function : $\max\left(\sum_{i=1}^{K}\sum_{j=1}^{R}\sum_{k=1}^{R} x_{ij} x_{ik} RIM(j,k)\right) = \max(IV_{intra})$

Constraints : $\forall j, \sum_{i=1}^{K} x_{ij} = 1$

$\forall i, \sum_{j=1}^{R} x_{ij} \le 7$

Variables : $\forall i, \forall j, x_{ij} = 1$ if $R_j \in C_i$

$\forall i, \forall j, x_{ij} = 0$ if $R_j \notin C_i$

<u>Problem linearisation</u>

New constraint :

$\forall i, \forall j, \forall k, y_{ijk} \le x_{ij} + x_{ik} - 1$

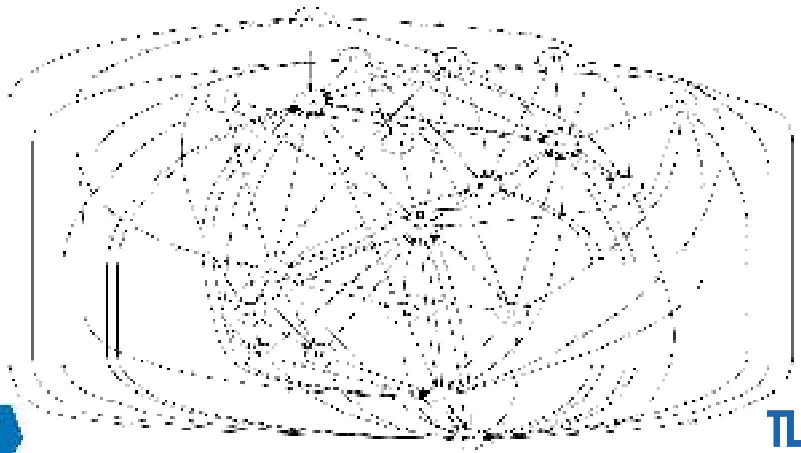
New variables :

$\forall i, \forall j, \forall k, y_{ijk}$ is binary

Objective function : $\max\left(\sum_{i=1}^{K}\sum_{j=1}^{R}\sum_{k=1}^{R} y_{ijk} RIM(j,k)\right) = \max(IV_{intra})$

Case study: introduction

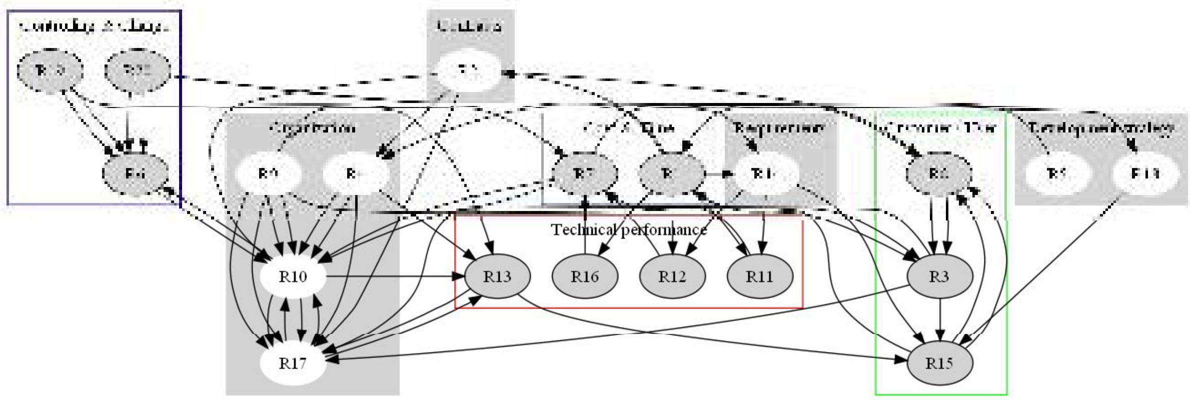
- Project : Production of a musical in a theatre in Paris.
- Project duration: 6 months before staging. Staging for 9 months at least.
- Production team: 6 persons (production)+3 creators (composition) + 18 persons (technical)
- Budget: 60 000€ - without salaries



Complex structure of the risks

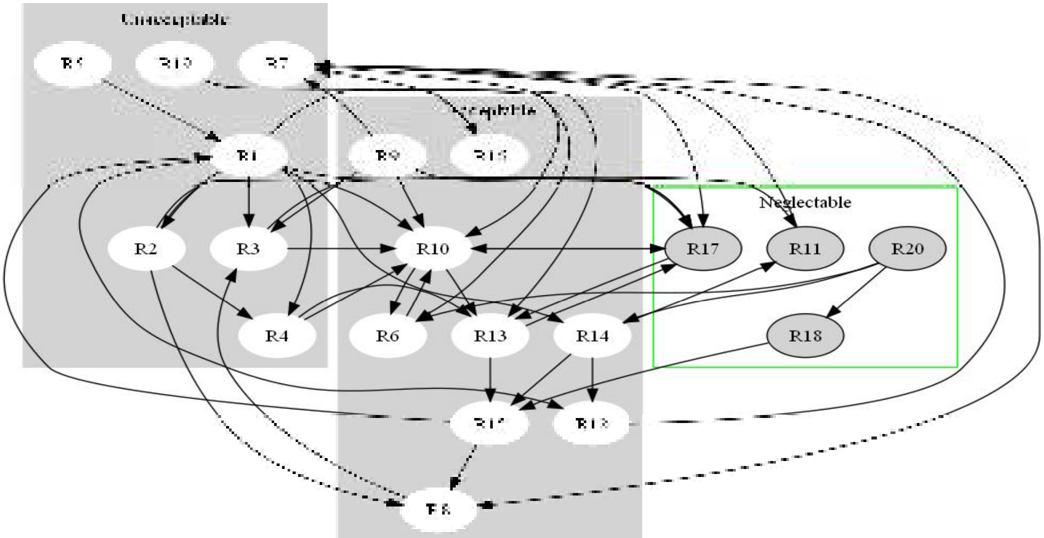
Case study: clustering by risk nature

- 8 clusters
- Small clusters with many inter-clusters interactions
- Except „Organization“ and „Controlling & Change“, intra-cluster interactions are minimal.



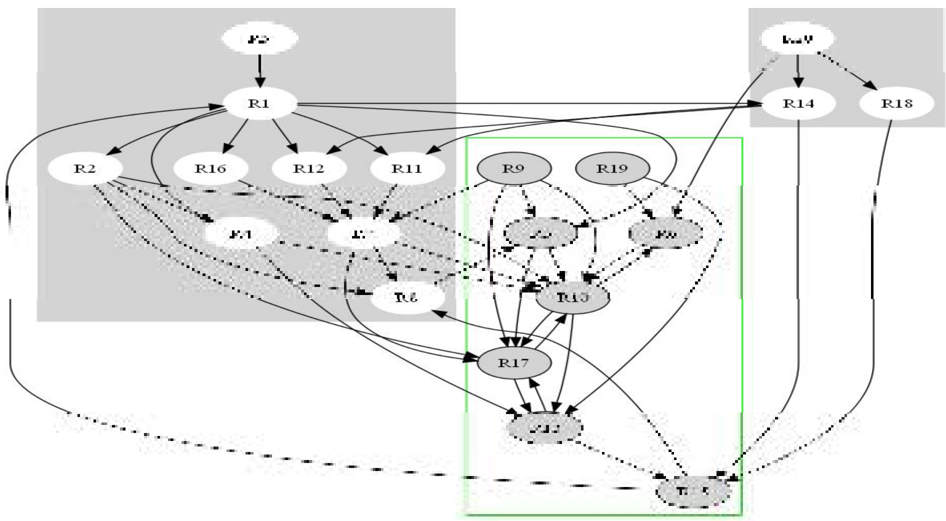
Case study: clustering by risk value

- Less clusters, but lots of inter-cluster interactions
- Intra-cluster interactions are many in the cluster „Acceptable“



Case study: Clustering by value of risks interactions

- 3 clusters
- Far more intra-clusters links than inter-clusters => easier coordination



Comparison of solutions and algorithms

- With the goal of minimization of inter-clusters links:
  - Clustering by nature and value are far less performant
  - Clustering by interaction strength seems to be easier for further coordination of risks clusters
    - The solution by interaction value is longer to implement as linear programming (solution by optimization)

- Consequences on project management:
  - Risks are in more interrelated clusters
  - Risks are of several types (nature and value)
  - Time of calculation is not a key parameter, as calculation time is far faster than identification & analysis time

Refining results: the distance calculation

- From RNM to RIM

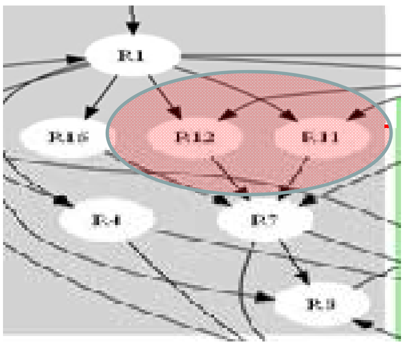
$$RIM(i,j) = \frac{RNM(i,j) + RNM(j,i)}{2}$$

Note that $RIM(i,j) = 0 \Leftrightarrow (RNM(i,j) = 0 \;\&\; RNM(j,i) = 0)$

- Use of a distance:
  - Euclidian
  - Mahalanobis

$$\Delta_{ij}^2 = \Delta_{ji}^2 = \sum_{k=1}^{n} (RIM(i,k) - RIM(j,k))^2$$

$$D_{ij}^2 = D_{ji}^2 = \Re_{ij}.S^{-1}.^t\Re_{ij}$$



MAHALANOBIS, P.C 1936

Refining the clusters by similarity (of Interactions) => some subclusters

Summary of actual work

- The first results are promising:
  - Processes of clustering by interactions or by nature or by value are similar in difficulty and time
  - The difference is significant in terms of coordination and interfaces issues
- The main difficulties are:
  - The time of interactions estimation
  - The management of a group of risks with great diversity
- A difficulty which is not related to our research, but to the main topic:
  - The use in real-life projects of risk management concepts

Perspectives for future works

- Test robustness of the model on several cases:
  - Size
  - Variety of risks
  - Types of projects (development, event, construction)
- Develop second application of DSM to project risk management:
  - Detection of mismatches between potential and actual data in DSM/DMM
  - Anticipation of propagation of a risk in the project structure via matrices
  - Identification and analysis of risks due to complexity thanks to matrices

SOSA, M., S. EPPINGER, and C. ROWLES 2004
DANILOVIC, M. and T. BROWNING 2007

- Initiate some collaborations
  - PhD students
  - Professors