A FREQUENCY ANALYSIS APPROACH TO ENSURE THE ROBUSTNESS OF INTERACTIONS-BASED CLUSTERING OF PROJECT RISKS

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ABSTRACT
Projects are dealing with bigger stakes and facing an ever-growing complexity. Project risks have then increased in number and criticality. Lists of identified project risks thus need to be decomposed, for smaller clusters are more manageable. Project interdependent risks are indeed often managed as if they were independent. An interactions-based clustering method which permitted to group risks, so that the interaction rate is maximal inside clusters and minimal outside, was presented with its associated tools and algorithms at ICED'09 conference with a case study in the entertainment industry. This article goes further into these approaches in order to obtain more robust results in order to facilitate the coordination of complex projects by reducing interfaces when dealing with risks. After some pages which introduce the problem and these approaches, we present an approach based on a frequency analysis, based on the variation of parameters of the quadratic integer clustering problem. A case study in the construction industry is finally presented (tramway design and construction project in a city). It permits to conclude on practical recommendations, conclusions and perspectives.

Keywords: Project management, Risk, Clustering, Frequency analysis, Robustness, Complexity.

1 INTRODUCTION
A project is a temporary and unique endeavour undertaken to deliver a result, which generally corresponds to the creation of a unique product or service which brings about beneficial change or added value [1]. They coexist with permanent organizations which exist within the firm. This coexistence (involving interfaces and dependencies) makes project and project management all the more complex. This intrinsic complexity of project management makes it impossible to visualize and manage projects as a whole, notably because of the existence of project complexity induced risks.
Propagation effects throughout the project structure are likely to notably reduce the performance of the risk management process [2]. Particular attention should be paid to this performance since poor or delayed risk mitigation decisions may have great potential consequences in terms of crisis, underachievement of objectives and avoidable waste [3].
As a whole, project management appears to be a complex and risky activity, which underlines the need for efficient and effective project risk management. As a consequence, this paper proposes an innovative method and its associated tools to assist project risk management under complex contexts by focusing on project risk interdependencies. It exposes works which were carried out after the ICED'09 conference at Stanford University, when first interactions-based approaches to cluster design project risks had been presented [4].
Our goal is still to group risks into clusters in order to catch inside of them most of project interactions, which is notably to facilitate the coordination of the project risk management process. These new works present how a frequency analysis can be performed to improve the robustness of the initial clustering results, by making several parameters of the quadratic integer problem vary. The research hypothesis is that the optimal solution is sensitive to the problem configuration, and that this configuration is not easy to decide. Then, we propose to make some variations on problem configuration in order to test the robustness of the proposed solution. A case study in the field of the construction industry (design and installation of a tramway infrastructure in a city) is presented at the end of the paper to illustrate the practical application of these methodologies in fieldwork for large complex projects.

2 BACKGROUND : THE PROJECT RISK CLUSTERING PROBLEM

2.1 Why clustering project risks?

Project risk management is classically decomposed into four successive major steps: risk identification, risk analysis, risk response planning and risk monitoring [1].Risk identification is the process of determining events which, may they occur, could impact positively or negatively project objectives. Risk identification methods are classified according two different families: direct or indirect risk identification [5]. This step in the end generates a list of risks. The number of risks in this list may vary from some decades to some hundreds of risks. It is then mandatory to decompose this list into subgroups in order to have more manageable items. In other terms, project risks need to be clustered.

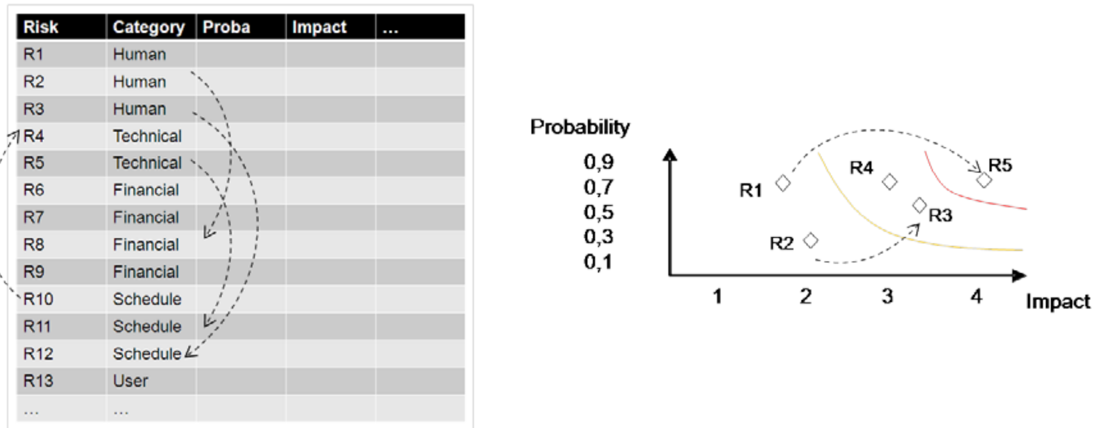
2.2 Why developing interactions-based risk clustering?

During these steps, several ways to cluster risks together are commonly proposed according to their project risk attributes:

1. A first approach is to group them according to their nature (e.g. financial risks or technical risks).
2. A second approach is to group them according to one of their numerical attributes such as probability, impact or more frequently criticality (low, average, high).
3. A third approach is to group them according to their risk owner.

Initially, the aim of risk clustering processes is to facilitate the coordination and management of risks. But with existing approaches, fieldwork proves us this is not always the case in complex projects. For example, project complexity, such as that described in [6], [7], [8] involves specific issues in decision-making under complex situations [9], [10]. Indeed, the complexity of a project makes it impossible to have complete information about the project in question and thus to simultaneously visualize all the elements and interactions of a given project [11]. This is underlined when looking at projects through systems thinking [12], [13]. In the end, this may lead to failure and dramatic propagation effects because of the interrelated nature of the project elements.

The problem with current methodologies is that project risk interactions are not explicitly incorporated. For instance, Figure 1 shows a project where some links exist between risks (dotted lines), although they are not modelled and thus not managed. Risks are indeed interrelated with complex links.



Risk	Category	Proba	Impact	...
R1	Human			
R2	Human			
R3	Human			
R4	Technical			
R5	Technical			
R6	Financial			
R7	Financial			
R8	Financial			
R9	Financial			
R10	Schedule			
R11	Schedule			
R12	Schedule			
R13	User			
...	...			

Figure 1.Classification of projects risks by nature and/or by value

There is thus crucial need for better awareness, consideration and management of project risks, knowing they are intertwined. Clustering risks according to their interaction level is then all the more interesting to constitute subgroups, the management of which would permit to cope better with possible propagation effects.

2.3 History of the interactions-based risk clustering methodology

A methodology to cluster risks according to their interactions level was presented at ICED'09 conference, the aim of which was to facilitate coordination between decision-makers in the risk management process [4]. Basically, the approach is constituted of five steps.

2.3.1. Catching project risk interactions through binary matrix representation

As tasks, projects and people, an hypothesis in this methodology is that project risks are (or can at least be supposed as):

1. in a finite number (since a project is in essence temporary, with finite resources, objectives, means, etc., i.e. a finite number of elements),
2. managed during the project management process,
3. interrelated, which justifies the use of a methodology for complex interactions management.

Similarly as with Design Structure Matrices (DSM) approaches [14], [15], binary matrices are built to catch risk interactions. Risk interaction in defined here as the existence of a possible precedence relationship between two risks R_i and R_j. We then define the binary Risk Structure Matrix (RSM). It corresponds to the square matrix with $RSM_{ij}=1$ (else 0) when there is an interaction from R_j to R_i. Main advantages of this approach are to overcome the display issue of complex network and to permit easier calculations which are inherent to the matrix format (eigenvalues, matrices product, matrix transposition, etc…).

2.3.2. Transforming the binary RSM into a Risk Numerical Matrix (RNM)

In order to catch the strength of risk interactions, different possibilities do exist, although all based on expertise and experience. A first one is to evaluate directly the level of interactions using 10-level Likert scales. A second approach is to use Analytic Hierarchy Process [16] (AHP)-based pairwise comparison evaluation to obtain a numerical assessment of the strength of interactions as seen in [17].Indeed, fieldwork proves us that such assessment of interactions is hard to do directly. On the contrary, it can be observed that people find it easier to say that a cause C_1 is more likely to produce an effect E (first level neighbor) than another cause C_2, or similarly, that an effect E_1 is more likely to be the consequence of a cause C than another effect E_2. That is why we mostly claim for the use of the second evaluation whenever possible. Details of calculations are given in [4].

2.3.3. Overall interactions-based risk clustering problem definition

We want to cluster risks to maximize intra-cluster interactions thanks to the use of the RNM.
Let us consider a set of interrelated project risks (R_1, R_2, …,R_N). Let us suppose we know the RNM of this set of risks (the former steps to build the RNM should have been followed by the user).Let us define K as the number of clusters of the optimal clustering solution, which maximises intra-cluster global interactions value. INTRA value is defined by the sum of the values of all interactions between risks which belong to a same cluster. INTER (Inter-cluster global interactions) value is defined by the sum of the values of all interactions between risks which are not paired inside a same cluster. The sum of INTRA and INTER values corresponds to the sum of all risk interactions values, which is constant. As a consequence, maximizing INTRA is equivalent to minimizing INTER. The reader should note that we do not know K in advance.
Namely, the goal is to assign project members to clusters in order to manage more properly the risks which belong to a same cluster, i.e. which are strongly interdependent. The problem is then formulated mathematically (it is known as the K-graph partitioning problem [18] , [19]).

2.3.4. Formulation of the quadratic integer problem

Here is the corresponding integer programming problem formulation. This problem is to be solved for each value of K which is superior to K_{min}. We first introduce the following decision variables:
$\forall i, 1 \le i \le N, \forall k, 1 \le k \le K, x_{ik} = 1$ if risk R_i belongs to cluster C_k.

The objective function, which is to be maximized, is as following in equation 1

$$INTRA = \sum_{k=1}^{K} \sum_{i=1}^{N} \sum_{j=1}^{N} x_{ik} x_{jk} RNM(i, j) \qquad (1)$$

Problem constraints are the following (equations 2 and 3).

$$\forall i, 1 \le i \le N, \sum_{k=1}^{K} x_{ik} = 1 \qquad (2)$$

as we argue for clusters disjunction in order to permit easier management in practice.

$$\forall k, 1 \le k \le K, \sum_{i=1}^{N} x_{ik} \le S_{\max} \qquad (3)$$

since we want a maximum size for the clusters (one of the parameters of the problem).

2.3.5. Solving the problem

We first used OPL (Optimization Programming Language) to solve this problem. However, its complexity is high (2^{N-1}), and problems over 20-21 risks appeared to be critical when testing them. Some heuristics were presented in [4] to address larger problems. Other approaches are presently developed to reduce processing time by avoiding trivial alternatives.

2.4 Problem setting

As a whole, the approach proved to propose good results which were interesting and complementary with traditional approaches. The approach was notably tested on a project in the entertainment industry and coordination was facilitated thanks to interactions-based clustering [4]. However, a question about the stability of the results arose when discussing with industrial practitioners. How can we ensure the robustness of the obtained results? How are the results sensitive to a change in the parameters of the quadratic integer problem?

This paper proposes first insights about this issue by proposing a frequency analysis to study the stability of clusters regarding a variation for the S_{max} size of clusters which is chosen by management teams when carrying out the process. Other insights are given regarding other objectives or parameters (the size of the clusters for a given S_{max}). The whole frequency analysis approach is tested on a new case study.

3 BUILDING UP A FREQUENCY ANALYSIS APPROACH

The aim of this approach is to screen out some alternatives of assignment of couples of risks inside the same cluster. This means that for some couples (Ri,Rj), the possibility that they are assigned to the same cluster will be declared as "never" or "always". This will enable to fix some of the variables of the optimization problem and then to reduce the size of the problem. The principle of the approach is thus to define the experiments plan to make some parameters of the problem vary, to define some frequency indicators, and then to make decisions knowing the percentage of times when each couple (Ri,Rj) are assigned together. These decisions are pre-assignment decisions and enable to reduce the size of the optimization problem by fixing some variables.

3.1 Design of experiments for the configuration parameters of the optimization problem

The main test will be done on S_{max}. As we are talking of human groups who are supposed to work together in order to be creative, an interval of [6,10] will be tested for S_{max}. There is no scientific proof for this interval, just a pragmatic upper bound for a good teamwork. Secondly, different configurations will be tested for a given S_{max}, with full clusters configurations (clusters of size S_{max}) or smaller clusters configurations (more clusters, but smaller than the allowed S_{max}). We define $\bar{S}$ as the average size of clusters for a configuration:

$$\bar{S} = \frac{\sum_{k=1}^{NC} S_k}{NC} \text{ (as } S_k \le S_{max}\text{, then } \bar{S} \le S_{max}\text{)}$$

The configurations will be tested with $\bar{S}$ more or less close to S_{max} (which means that clusters are filled at the maximum possible size). The last analysis will be done on the calculation time variation due to variations in the problem configuration. It is an important practical issue in our context, in order to be sure to converge quickly to a good enough solution (optimal or close enough from optimal).

3.2 Frequency indicators

We define N_{Config} as the number of different tested problem configurations. We introduce a new index which calculates the percentage of times where two risks are put in the same cluster (Common Cluster Frequency Index). An associated complementary index gives the percentage of times where a risk is included in a cluster (Clustered Frequency Index). For different configurations C_l, we have different Clustered Organization matrices CO_l, and we define the Frequency Matrix as the sum of the CO_l matrices. The non-diagonal terms of the Frequency Matrix give the Common Cluster Frequency Index for a couple of actors, and the diagonal terms give the Clustered Frequency Index for an actor :

$$CCFI(i,j) = \frac{\sum_l^{NConfig} CO(i,j)}{NConfig}, \; CFI(i) = \frac{\sum_l^{NConfig} CO(i,i)}{NConfig}$$

For each configuration C_l, the matrix CO_l is binary. That means that both indexes are between 0 and 1 (or 0% and 100%). The interesting values are 0% and 100%.
CCFI = 0 means that the risks are never clustered together and 100% means that they are always in the same cluster. Similarly, if a risk is always included in a cluster, even if with different risks, then it can give an indication that this risk should preferably appear in the chosen clusters. This can give an indication on the robustness of the decision to put together two risks (if their CCFI = 1), or to keep isolated one risk (if its CFI = 0). It is a refinement of the previously tested algorithms, as it considers the robustness of the decision. The procedure is as following:

1. Step 1 is a screening step for CFI(i) equal to 0. The risks are reordered in the bottom-right part of the matrix.
2. Step 2 is an aggregating step for CCFI(i,j) equal to 1. It gives some clusters, which are or not full, and are reordered on the top-left part of the matrix.
3. Step 3 is a decision-making process on the middle part of the matrix for inclusion or not of remaining risks in existing clusters.

Several situations may occur at step 3. The more the index is close to 1, the more the decision is almost to put them together. But, with an index of 0.8 or 0.7, this is not a safe decision. The worst case is when a risk has an index of 0.5 with risks in two different clusters. It is a kind of dilemma, since half the time this risk has been clustered with the risks of cluster 1 and half the time with risks of another cluster.

3.3 Analysis and pre-assignment decision-making

From the analysis of frequency of clustering for actors and couples of actors (CFI_i and $CCFI_{ij}$), it is possible to display the results on the matrix (figure 4). It represents approximately the percentage in a 5-level scale (0, 25%, 50%, 75%, 100%), in order to be easier to read. The rows and columns are reordered in such a way that very dense areas are visible (like kernels), with intermediary areas where percentage is between 50 and 75%. That means that some risks are somewhere between two clusters, and that we have to decide whether we put them in one or in the other. The decisions of steps 1 and 2 make the problem smaller, since less variables remain at step 3. Step 3 can be conducted with the heuristics already used in [4], with an optimization software if the size is reduced enough, or with manual heuristics for decision-making using the frequency index.

4 CASE STUDY

4.1 Description of the project

The industrial background of this study is a large infrastructure project, which consists in building the infrastructure and associated systems of the future tramway of a city with a population of 750 000 inhabitants. We shall designate the country as C. The lead company is French and is historically a designer/developer of trains, which recently extended its scope by proposing turnkey projects, including not only the trains, but also the complete infrastructure around the trains.

This civil engineering project thus comprises:

1. The construction of a depot to stock trains and execute their control and maintenance,
2. The installation of tracks throughout the city, over land with many steep slopes,
3. The construction delivery of the corresponding trains, including redesign activities if the current version does not fit with city's specific requirements,
4. The establishment of a traffic signalling operating system, which gives priority to the tramway so as to guarantee travel time performance levels.

A local industrial partner is undertaking the civil work which is required for the installation of the tramway. This project is a public-private partnership, due to the implication of the local government and its services. The project was put out to tender by the government of country C in 1995, with designation of a number of key players in 1999. The project contract was signed in 2002. After negotiations with banks, the government and the future operator (of which the French company is a major share-holder), the final concession contract was signed in 2004.

The project was launched in February 2005, and concrete execution in 2006. A project risk management process was implemented and led to the existence of 8 lists of risks which contributed to the successive risk reviews. Our focus here is on one particular product line known as "System" which, as it integrates all the aspects of the project, is one of the most complex. The 42 risks indicated in the list are diverse and are classified according to six risk classes (risk nature): contractual, financial, technical, project management, stakeholder management and country. Risk ownership in terms of responsibility is shared by 12 actors in the project.

4.2 Analysis of the existing organization

Currently, risk management receives moderate attention within the firm and the following issues need to be underlined.

First, risk lists are elaborated since they must be done, but no real attention is paid to them and they are not sufficiently exploited. Secondly, risk management is still too often considered as an academic pursuit which is not necessary applicable to day-to-day project management. Thirdly, some risk owners (in terms of responsibility) have been assigned too quickly and without an in-depth analysis of the required skills and experience. Indeed, risk owners belong to varied hierarchical levels in the company structure, and some risk owners are responsible for one risk, while other ones are responsible for more than ten.

When performing the risk interaction identification process, new risks appeared during our intervention, for two reasons. Some were a consequence or cause of other risks already present in the initial list; others were seen as intermediary risks which were useful to explain the link between two or more existing risks which were present in the initial list. Identification is done on direct cause or effect relationship.

But, we ask interviewees whether they think this is a direct link or if new intermediary elements deserve to be created. In the end, the aggregation of local cause-effect relationship identifications enables to display the global risk network. This permits to organize a final meeting when interviewees can possibly propose new nodes and connections in the risk graph.

As a whole, when performing this risk interaction identification process, 14 new risks were identified (see Table 1), which represents an increase of nearly 32% in the number of identified risks. This is a first significant result. Six of the risks which were present in the initial list (R1, R8, R11, R15, R23 and R34) were considered as poorly interrelated with others and possibly negligible for this study. Finally, this step raises the issue of risk formulation as they were not initially formulated in a standard way, which made it more difficult to identify some interactions.

In the end, a global Risk Numerical Matrix (RNM) for the studied risk network was obtained. Its density is quite low (3% of non-null values) and no feedback loops are present in it. When considering the existing natural communication and coordination paths (natures of risks, values of risks, risk ownerships), approximately 44% of interactions take place within groups. Due to the number of interactions which are outside these structures, there is a danger that some propagation may occur without the organisational capacity to cope with it. "Organisational capacity" means the relationship between two or more different risk owners for making decisions about two or more interrelated risks.

Table 1. Global list of risks updated after the risk interaction identification process

Risk Id	Risk name	Risk owner	Risk Class
1	Safety studies	1	Technical
2	Liquidated damages on intermadiate milestone and delay of Progress Payment Threshold	2	Contractual
3	Vehicle storage in another city	1	Contractual
4	Vandalism on site	3	Contractual
5	Traction/braking function : behaviour in degraded mode on slope	1	Technical
6	New local laws and regulations	1	Contractual
7	Traffic signalling, priority at intersections	4	Contractual
8	Unclear Interface with the Client, for Infrastructure equipment	5	Contractual
9	Delays due to client late decisions	5	Contractual
10	Travel Time performance	4	Technical
11	Limited Force majeure definition	2	Contractual
12	Operating certificate delay	2	Contractual
13	Reliability & availability targets	4	Technical
14	Permits &authorisations	2	Contractual
15	Insurance deductibles	6	Financial
16	Archeological findings	2	Contractual
17	Discrepancies Client / Operator / Concessionaire	7	Contractual
18	Civil Work delay & continuity	8	Contractual
19	Responsibility of client on Civil Work delay	2	Contractual
20	On board CCTV scope	9	Technical
21	Noise & vibration attenuation	4	Technical
22	Potential risks of claim from Civil Work subcontractor	2	Contractual
23	Harmonics level	5	Technical
24	Non compliance contractual Rolling Stock	1	Technical
25	Non compliance technical specifications Rolling Stock	1	Contractual
26	Exchange risk on suppliers	6	Financial
27	Track installation machine performance	10	Client/Partner/Subcontractor
28	Tax risk on onshore	6	Financial
29	Additional poles overcost for Tramway Company	5	Contractual
30	Overcost due to Security requirements for trains	4	Technical
31	Track insulation	9	Technical
32	Delay for energizing	5	Project management, Construction site
33	Fare collection requirements	7	Contractual
34	Construction safety interfaces	3	Technical
35	Electromagnetic interferences	4	Technical
36	Exchange risk	6	Financial
37	Risk of partial rejection of our request for EOT (Extension Of Time)	2	Contractual
38	Interface rail / wheel	4	Technical
39	Risk on Certification of our equipement	11	Country
40	OCS installation	3	Project management, Construction site
41	Banks stop financing the project	2	Contractual
42	Costs of modifications not covered by EOT agreement	2	Contractual
43	Return profit decrease	2	Financial
44	Extra trains	4	Contractual
45	Pedestrian zones	4	Technical
46	Train performance	1	Technical
47	Waiting time at stations	4	Contractual
48	Depot delay	3	Technical
49	Error in the Survey (topography)	4	Technical
50	Ticketing design delays	7	Contractual
51	Track installation delay	3	Technical
52	Reengineering / Redesign	4	Technical
53	Slabs pouring delay	3	Technical
54	Initial specifications of CW (Civil Work)	3	Technical
55	Available cash flow decrease	2	Financial
56	Rolling stock delivery delay	1	Technical

4.3 Results

4.3.1 Variation of the initial configuration

The first result is the analysis of the influence of S_{max} on both the process and the result, which means the calculation time and the performance of the clustered organisation. The second result is the analysis of the influence of the size of clusters S_k for a given S_{max}. Is it better to get more but smaller clusters, or to fill clusters to the maximum allowed size S_{max} ?

Then, the frequency indicators are calculated and put in the frequency matrix (figure 4). A discussion is introduced about the final choice of the decision-maker and the complementary robustness analysis given by the frequency matrix.

We ran different calculations with S_{max} varying between 6 and 10, and with different configurations for a given S_{max}. For instance, for S_{max}=10, it is possible to test a five cluster configuration with each size of 10, or to test an eight cluster configuration with two clusters of 10, two clusters of 9, and so on. For each configuration, the calculation time has been recorded. The conclusions are :

- The highest values are obtained for the biggest S_{max}. This is essentially due to the presence of positive values only, and to the presence of enough non-null values in the original matrix (no saturation).
- For a given S_{max}, the best configuration is the one where each cluster is fulfilled (Sk=Smax, except the last one and the non clustered risks)

  $CO(S_{max}) = \{CO_{1,Smax}; CO_{2,Smax}; \ldots; CO_{NC-1,Smax}; CO_{NC,SNC}; NCR\}$, where NCR are the Non Clustered Risks

  But, it has to be noticed that in some cases, we found clusters with two or more independent sub-clusters. This means that in terms of clustering value, it does not bring anything, although in terms of human group coordination, it brings together people who do not have interactions. It can then be counterproductive to "artificially" group people with not enough reasons to do it.
- The speed of convergence is quite similar for different S_{max}, which means that the value is increased by relaxing the constraint without creating problems for the clustering process speed (figure 3).

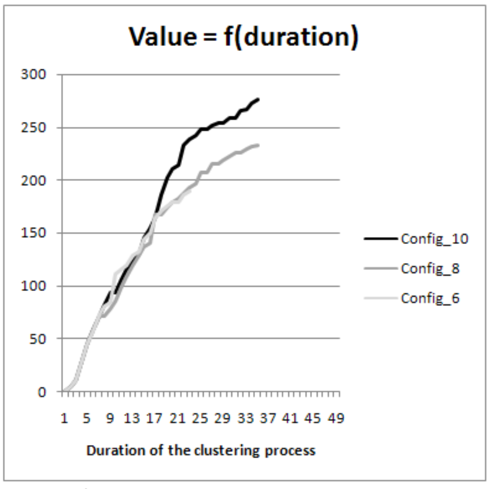


Figure 2. Influence of the variation of S_{max} on the maximum attained value and the calculation time

4.3.2 Application of the frequency analysis to the real case study

The organisation finally chosen by the decision-maker is given below in figure 3. It has to be noted that the cluster size is not equal to S_{max}, except for one cluster. As seen previously, it is better in terms of practical implementation of the group to get smaller clusters than to group independent clusters into a bigger one. The second reason is that it more efficient for the cluster coordinator to manage smaller clusters. Clusters filled at S_{max} must then be justified by a high enough density in terms of number and strength of interactions within them. The shape of the matrix in this particular case (the tramway project) influenced the final clustered organisation, since many small clusters are independent or quasi-independent, which means that their merging would be only artificial.

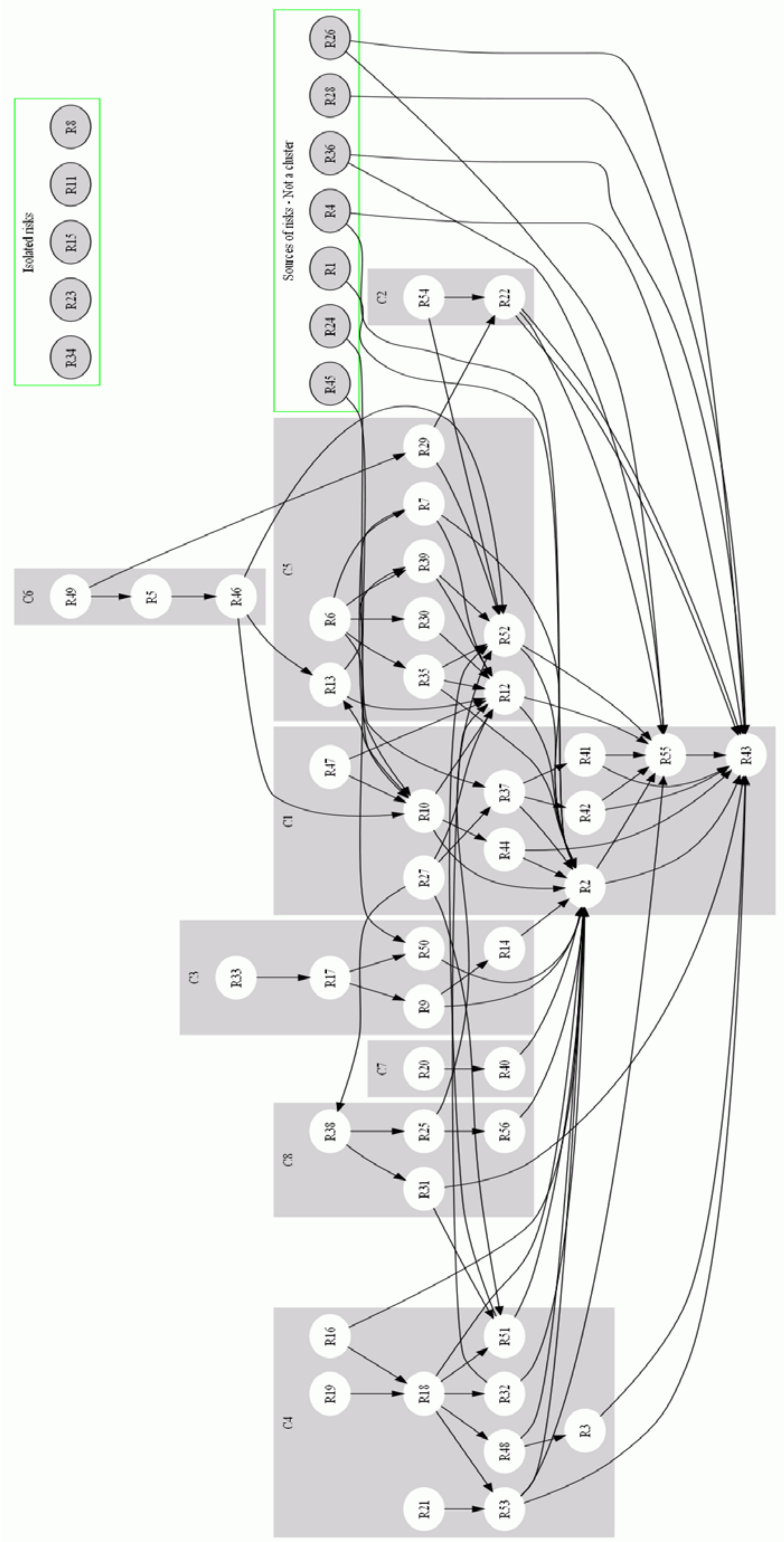


Figure 3.Clustering of projects risks while maximizing the intra-cluster interactions

The analysis of the Frequency Matrix shown in figure 4 gives information about the robustness of this decision (the different frequency values are transformed into partially or totally filled circles).

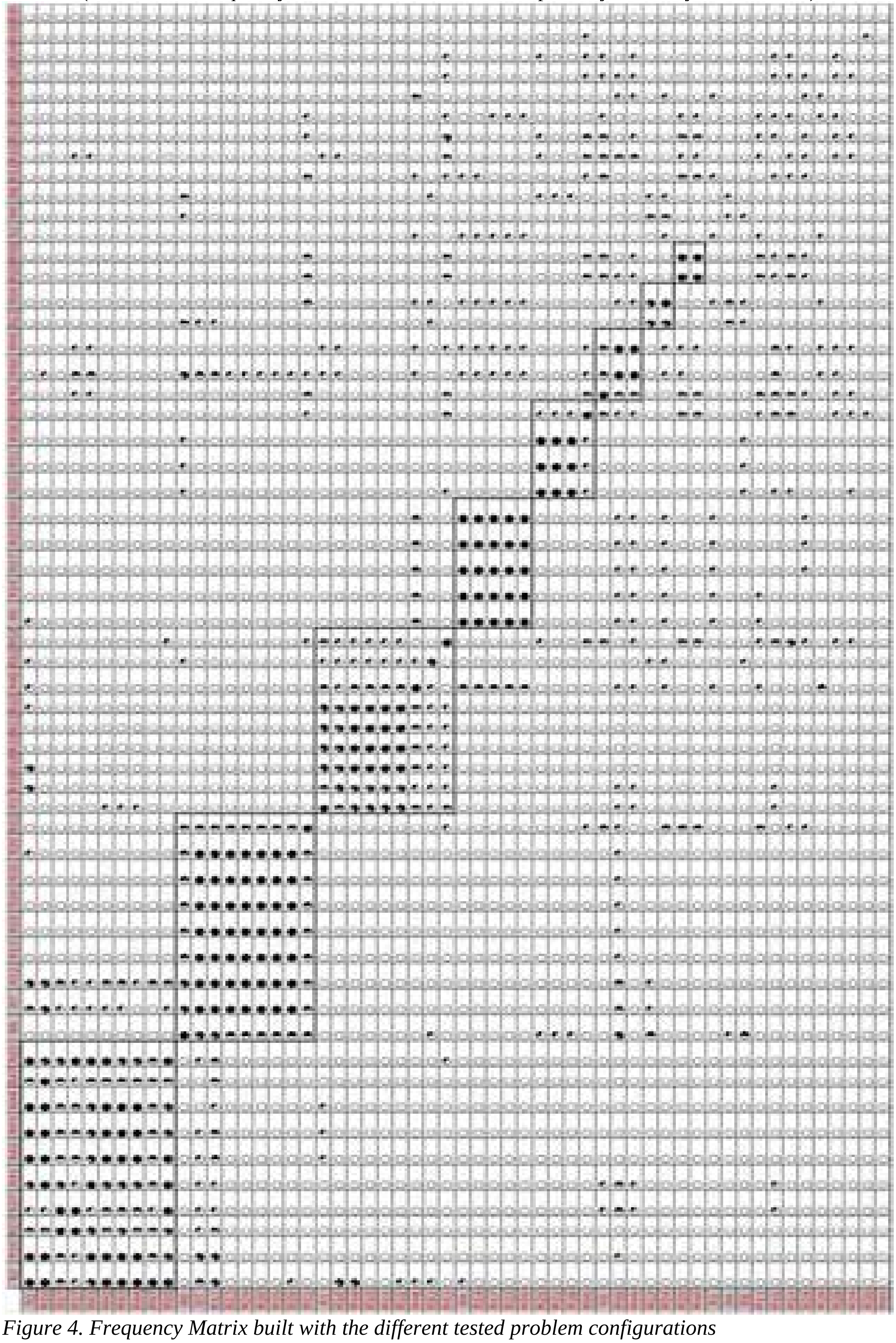


Figure 4. Frequency Matrix built with the different tested problem configurations

Except for some risks, the frequency of the chosen clusters is good enough to validate this solution. Some risks inside a cluster do not have a strong frequency index. Some risks outside a cluster have a strong frequency index with that cluster. But, the majority of proposals are validated by the frequency index. This means that it seems to be useful for future works as a pre-assignment technique in order to run more sophisticated optimization algorithms and software on a reduced problem. The clusters are partially sensitive to initial configuration parameters, but the majority of the solution is stable. This enables to be more confident with the solution.

5 CONCLUSIONS AND PERSPECTIVES

Clustering by interactions is all the more important today than projects are becoming more and more complex. In the example of risk clustering, the configuration of the optimisation problem may vary and may have an influence on the final result. This is why we introduce a frequency matrix which indicates, for its non-diagonal elements the percentage of times where two risks Ri and Rj are assigned to the same cluster, and for its diagonal elements the percentage of times where one risk is assigned to a cluster. These information give an indication for pre-assigning some variables to 0 or 1, expressing that two risks can not be together or must be together. Moreover, it gives an idea of the robustness of the final clustering decision, since we are more confident with an index of 1 (or close to 1) than an index of 0.5. Further works will test other possibilities to make the problem configuration vary, by introducing new constraints like the number of different risk owners in a cluster (and not only the number of risks in a cluster). The pre-assignment decisions will also be validated by several cases in order to illustrate the cases where the frequency matrix can be used with confidence or with caution. It mainly depends on the decision-making problem and on the problem configuration, but also on the risk numerical matrix, since the density and the (repartition) of the risk interactions may influence the clustering problem solving.

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