Faculdade de Engenharia da Universidade do Porto

Development of a multi-criteria collaborative decision model for performance management in networks of organisations

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Abstract

The present work is framed by the research project pmColnet - performance management in Collaborative Networks (project PTDC/GES/71482/2006 funded by Fundação para a Ciência e Tecnologia) developed by a team at INESC Porto - Instituto de Engenharia de Sistemas e Computadores do Porto. pmConNet's main objective is the construction of a generic performance model in collaborative networks. An important part of the project is based on using multi-criteria methodologies potential to maximize the support given to network participant's decision about goals, criteria and performance indicators related to its collaboration.

The focus of this work is to pass in review decision support multi-criteria methodologies that may help designing pmColNet model.

Collaborative networks under consideration are interorganisational and non-vertical, where teams have some form of independence regarding their primitive organisational structure and which already have past collaborative stories, so they are embracing a new collaborative project.

In this context it should be interesting, from the participants point of view, that performance model incorporates aspects from individual organisation performance model and combine them with the general network performance model.

One main characteristic of the model is its flexibility and contextualisation regarding its participants and network typology, so, partners can freely choose and negotiate proper goals, criteria and indicators more suitable for their specific network.

Keywords: collaborative networks, multicriteria performance model

Resumo

O presente trabalho é enquadrado pelo projecto de investigação pmColNet - performance management in Collaborative Networks (projecto PTDC/GES/71482/2006 financiado pela Fundação para a Ciência e Tecnologia) desenvolvido por uma equipa do INESC Porto. O principal objectivo do pmColNet é a construção de um modelo genérico de gestão da performance em redes colaborativas. Uma importante parte do projecto alicerça-se no aproveitamento do potencial das metodologias multicritério para maximizar o apoio aos participantes da rede na decisão de escolha dos objectivos, critérios e indicadores de desempenho da sua colaboração.

O enfoque do presente trabalho passa pela revisão de metodologias multicritério de apoio à decisão que possam contribuir para o desenho do modelo pmColNet.

As redes colaborativas em apreço são redes interorganizacionais não verticais, em que as equipas possuem algum grau de independência face à estrutura organizacional primitiva e que já têm uma história de colaboração anterior, pelo que abraçam um novo projecto colaborativo.

Neste contexto será interessante, do ponto de vista dos participantes, que o modelo de desempenho incorpore aspectos provenientes do modelo de avaliação individual das organizações e os combine com o modelo geral de avaliação da rede.

Uma das características do modelo é a sua flexibilidade e contextualização face aos intervenientes e tipo de rede, pelo que os participantes podem livremente escolher e negociar os objectivos, critérios e indicadores que consideram mais adequados à sua rede.

Palavras-chave: redes colaborativas, modelo multicritério de desempenho

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Abbreviations list

AHP - Analytic Hierarchy Process

CMS – Content Management System

CN – Collaborative Networks

CNO - Collaborative Networked Organisations

DM – Decision-maker

DSS – Decision Support System

ELECTRE - *ELimination Et Choix Traduisant la REalité*

GDSS - Group Decision Support System

HFPA - Hierarchical Framework for Performance Analysis

INESC Porto - Instituto de Engenharia de Sistemas e Computadores do Porto

KPI – Key Performance Indicator

MACBETH - Measuring Attractiveness by a Categorical Based Evaluation Technique

MCDA – Multiple Criteria Decision Analysis

MCDM - Multi-Criteria Decision-Making

MCGSS - Multicriteria Group Support System

pmColNet - performance management in Collaborative Networks

Glossary of terms

Collaborative network (or just network in the scope of this research) – *"A collaborative network (CN) is constituted by a variety of entities (e.g. organizations and people) that are **largely autonomous**, geographically distributed, and **heterogeneous** in terms of their: operating environment, culture, social capital, and goals. Nevertheless these entities **collaborate to better achieve common or compatible goals**, and whose interactions are supported by computer network. Unlike other networks, in CN collaboration is an intentional property that derives from the shared belief that **together the network members can achieve goals that would not be possible or would have a higher cost if attempted by them individually**."* Camarinha-Matos and Afsarmanesh (2005:439)

Commitment level – is a business metric that tries to capture the degree of importance given to the collaborative network by each partner.

Decision overriding – is the privilege of network partners to decide differently from the proposed alternative ranking produced by the multicriteria method. Decision overriding emphasize the constructivist approach of pmColNet.

Facilitators –It's a role that aims to clarify and shape the process of evaluation and/ or negotiation on the decision-making. Its position should be neutral while motivating (Moreira 2007:10). pmColNet should have a facilitator role.

Network partners – participants, players, actors or members of the network.

Primary and secondary stakeholders – We use "primary" stakeholders to refer network participants. Secondary stakeholders are all the other: Government, suppliers, clients, citizens, communities, …

Veto threshold – on the final HFPA's ranking, pmColNet suggests exclusion of alternatives below a pre-defined accumulated preference. The veto threshold is calculated taking into account the vote power of the most and the least powerful members of the network (see 5.6 section).

Vote power - "Usually, all the experts have the same weight, but in certain applications each expert can have a coefficient of importance. (…) [This] may be interpreted as the degree in which that individual is really a decision maker relative to the decision problem, or it can be viewed as the power (degree of importance, competence or ability) of his opinion." Marichal (1999:6)

1. Introduction

Collaborative networks among organisations are more common nowadays to respond to globalisation and competitive economies (Bititci *et al.* 2004; Todeva and Knoke 2005). Participant's specialisation and core competencies focus is seen as a form to maximize efficiency and promote organisational value (Sydow and Windeler 1998).

Parung and Bititci (2006:116) summarize several studies supporting the increase of collaborative networks:

> "*Through collaboration, companies aim to share resources, share and exchange information, reduce risks, reduce cost, reduce time-to-market, reduce delivery-time, increase market-share, increase asset-utilisation, increase skills and knowledge, increase customer-services, and so on.*"

The study of collaborative networks, especially the problem of measuring performance within networks is an up-to-date subject, with observant listeners throughout management science field and organisation leaders. This is why making this thesis was so attractive and one of the main reasons for choosing it.

We are certain that collaborative networks are a valid path to surpass the actual economic and financial crisis and that performance management maximizes the network potential success.

1.1. Problem description and research goals

According to Sydow and Milward (2003:1), network performance evaluation is an increasing need of researchers and practitioners of interorganisational networks to assess the performance of those forms of network governance. This occurs because:

1. there are high failure rates in organisational networking and organisations must have a realistic attitude towards networking;

2. networking announcement has a real effect on participating organisations' value;

3. state agencies are very interested in interorganisational cooperation in order to create value;

4. we have been living in an "age of evaluation" which induces private and public organisations to strongly require performance evaluation.

Collaborative networks are really important nowadays and it is vital to assure that its performance is monitored, but designing a performance model system for collaborative networks is not a trivial task, indeed it is a complex problem because collaborative networked organisations require several dimensional analyses.

Evaluating collaborative networks is a task with common issues related to performance models, such as the choice of appropriate evaluation criteria and indicators. But those issues are more difficult to resolve, because there are multiple stakeholders involved (with possible conflicting interests).

The research question of this work is:

Will collaborative networks benefit from a multi-criteria decision support and collaborative meaning negotiation methods approach, in the construction of their performance model?

Managing collaborative networks clearly involves a set of multi-criteria problems. Therefore, in this work we propose to construct a multi-criteria framework of a performance model for collaborative networks. This multi-criteria framework was developed within pmColNet – performance management in Collaborative Networks' (project PTDC/GES/71482/2006 funded by Fundação para a Ciência e Tecnologia) research project at INESC Porto - Instituto de Engenharia de Sistemas e Computadores do Porto.

The aim of this work won't be the explanation of network formations or why they can promote competitive advantage. This assumption will be considered throughout the thesis.

The initial hypothesis of this work is that collaborative networks do benefit from a multi-criteria performance model that is constructed in a collaborative manner by network partners and that model contributes to maximize the network potential and value creation.

This investigation's primary goals are:

- To develop a multi-criteria decision-making (MCDM) model to support the collaborative design of a network performance management system;

- To develop a method to support the negotiation processes in the collaborative construction of the network performance system.

1.2. Methodology

The chosen approach for this investigation is based in two perspectives: multiple criteria decision analysis and constructivism.

In order to create a coherent and consistent framework for supporting performance management activities, a Multiple Criteria Decision Making (MCDM) framework was developed. The constructed performance system uses concepts from the Relational approach methods (see section 3.4), namely the Analytic Hierarchy Process (AHP), but also from ELECTRE (*ELimination Et Choix Traduisant la REalité)*.

pmColNet is a Group Decision Support System (GDSS) and the Zahir and Dobing (2002) MCGDSS and PROMETHEE GDSS procedure were studied and adapted to fit this work's objectives.

The constructivist paradigm was adopted while conceptualizing pmColNet system:

- The system has a facilitator role: The role of pmColNet is to facilitate the decision-making process, shaping the network performance model. This facilitator position (Moreira 2007:10) should be neutral but motivating;
- Every collaborative network is unique, and therefore needs an unique constructed performance model;
- It must reflect the socio-economic realities of each collaborative network. Focus should be granted to an initial contextualisation phase (see section 5.4) and partner interaction.
- Complementing the context-based approach, the design of a network performance model must not be a sum, or mere adaptation, of each organisation's individual performance model.

1.3. Thesis structure

Chapter 2 will be dedicated to explore relationships between performance evaluation and collaborative networks. The subject will be framed as a multi-criteria decision problem.

Chapter 3 of this investigation will resume the state of the art regarding the Decision Analysis field of study. Major importance will be conceded to Operational Research, especially multi-criteria methods, and Decision Support Systems (DSS).

In chapter 4 we will present an information model proposal according to Neves (2009) for structuring and managing information in the performance evaluation system of collaborative networks.

At chapter 5, a multi-criteria performance model for collaborative networks will be proposed, following pmColNet's objectives. Some scenarios will be explored to understand the model's potential.

Finally, we will present conclusions and leads for future investigation and improvements.

2. Performance measurement for collaborative networks

2.1. Collaborative networks

For the purposes of this paper, an interorganisational collaborative network will be defined considering Camarinha-Matos and Afsarmanesh (2005:439):

> *"A collaborative network (CN) is constituted by a variety of entities (e.g. organizations and people) that are **largely autonomous**, geographically distributed, and **heterogeneous** in terms of their: operating environment, culture, social capital, and goals. Nevertheless these entities **collaborate to better achieve common or compatible goals**, and whose interactions are supported by computer network. Unlike other networks, in CN collaboration is an intentional property that derives from the shared belief that **together the network members can achieve goals that would not be possible or would have a higher cost if attempted by them individually**."*

We will also consider the following features of a collaborative network, regarding Hill's (2002:6) literature review:

- *"Oriented to higher purpose/common vision: Beyond the limited visions and abilities of network members;*[1]

- *Activity affects the whole system (assumption): Network activity has external effects (impact on the community) as well as internal effects (impact within the network);*

- *Horizontal organization: Network structure is not hierarchical; each member is equal within the network;*[2]

[1] This feature does not collide with network participants desire to reach their own objectives.

- *Voluntary participation: Members choose to belong;*
- *Decentralized: No centralized source of power;*
- *Member-controlled: Controlled by member organizations via stakeholders;*
- *Self-regulating: All members determine the network's rules, processes and procedures;*
- *Collaborative: Engaged in an interactive process;*
- *Cognitive: Have self-knowledge; aware of environment and adept at working with it, a learning organization;*
- *Involves a division of labour: Members have specialized tasks and skills;*
- *Autonomous members: Member organizations retain independent decision-making powers;*
- *Deliberative: Deciding/addressing/exploring constructively.*

Collaborative networked organisations (CNO) require several dimensional analyses, namely structural, functional, behavioural and componential dimensions. Camarinha-Matos and Afsarmanesh (2006) proposed a simplified map relating theories/ tools to the modelling dimensions:

[2] Equality between network members can be relaxed and does not compromise network vision. In fact it is not difficult to accept that in most real networks, some partners are more powerful than others, deriving from different resource allocation or socio-political advantages. The pmColNet model will attain equal or unequal membership.

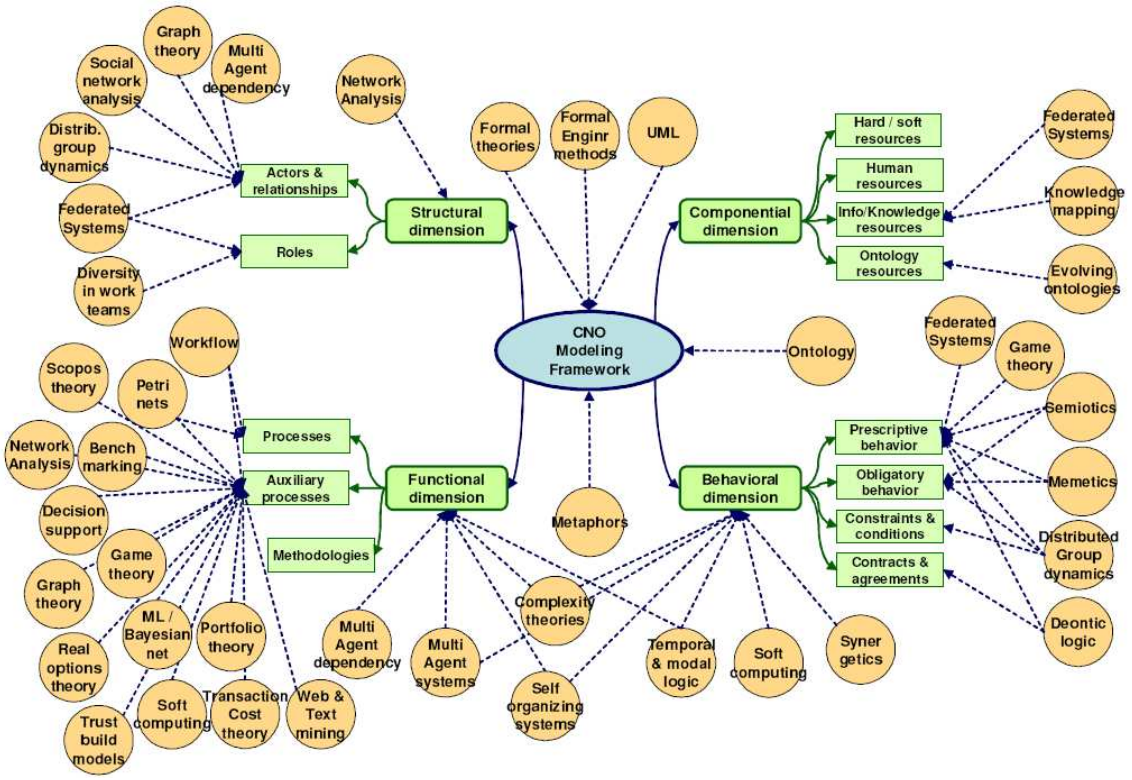


Figure 1 - Map of modeling theories applicable to CNO's, Camarinha-Matos and Afsarmanesh (2006:8)

- Structural dimension addresses the structure or composition of the CNO in terms of its constituting elements, roles and characteristics such as location and time.
- Componential dimension focuses on the individual tangible/ intangible elements in the CNO's network.
- Functional dimension focuses on operations (processes and procedures) of the CNO.
- Behavioural dimension focuses the principles, policies and governance rules of the CNO and its members.

According to Carneiro *et al.* (2007:11), interorganisational networks different dimension analyses are: relationships, actors (network partners in our terminology), resources, activities, motivation and context. These cooperation elements are related with network typology, which is essential to structure a well fitted performance model for each specific case.

Because several classifications are used in the research literature, we will introduce a broad classification in section 5.4.3 using Todeva and Knobe (2005) and Carneiro *et al.* (2007).

2.2. Performance measurement

Performance measurement is a process of assessing the achievement of pre-determined organisational goals and objectives, using collected data and information (such as statistical evidence, qualitative information, quantitative parameters, ...).

According to Busi and Bititci (2006:13-14) and several other authors, during the 1980's, traditional financial measures as the basis for monitoring performance, began to be insufficient. Nowadays, we assist three major transformations in performance measurement:

- "From performance measurement to performance management.
- From individual to collaborative performance measurement.
- From lagging to leading performance management." (*idem*:14*)*

Performance management is defined as:

> "the use of performance measurement information to effect positive change in organizational culture, systems and processes, by helping to set agreed-upon performance goals, allocating and prioritising resources, informing managers to either confirm or change current policy or programme directions to meet those goals, and sharing results of performance in pursuing those goals" (Amaratunga, D. and Baldry, D. (2002). "Moving from performance measurement to performance management", Facilities, Vol. 20 No.5/6, pp.217-23. *in* Busi and Bititci (2006:14))

"The supporting performance management system would include the following key elements:

- a structured methodology to design the performance measurement system;
- a structured management-process for using performance measurement information to help make decisions, set performance goals, allocate resources,

inform management, and report success (see also Amaratunga and Baldry, 2002);

- a set of requirements specifications of the necessary electronic tools for data gathering, processing and analysis (see also Waggoner et al. 1999);
- theoretical guidelines on how to manage through measures (as Adair et al. (2003) points out, performance management systems are used to apply the information and knowledge arising from performance measurement systems); and
- a review process to ensure that measures are constantly updated to reflect changes in strategy and/or market conditions (see also Waggoner et al. 1999)." (*idem*)

Our multi-criteria performance management model for collaborative networks (applied in pmColNet as described in chapter 5 will focus on *a structured methodology to design the performance measurement system*, a *structured management-process for using performance measurement information to help make decisions, set performance goals, allocate resources, inform management, and report success* and in some extent, *the necessary electronic tools for data gathering, processing and analysis*.

The second transformation in performance measurement, from individual to collaborative performance measurement, derives from the identified increase in collaborative networks (chapter 1) and the idea conveyed within managers that "By sharing performance data with partners, firms can identify bottlenecks and "weak links" in the network, and act in accordance to improve the overall performance." [Busi and Bititci (2006:15)]

The third transformation: from lagging to leading performance management, focuses on timely and relevant information, used in a proactive manner, not only to identify poor performance, but to improve present and future operations and processes.

Although the assessment of the need to change and improve performance measurement/ management,

"There has been far too little focus on going beyond this previous work and developing a universal framework for the selection of performance measures for collaborative enterprises and the use of these measures to collaboratively manage the collaborative enterprise through measures. As a result, literature relating to strategic and

performance management of collaborative enterprises is still rather rare (…)". (*idem*:17)

In our research and literature review, we acknowledge the lack of studies regarding performance management within collaborative networks, this was one of the main reasons to conduct this research, but it obviously created some difficulties with literature support.

2.3. A multiple criteria decision analysis problem

The complexity of network evaluation arises from at least four problems mentioned by Sydow and Milward (2003:3-5):

- the choice of appropriate evaluation criteria and indicators;
- network evaluation should be approached on different levels of analysis;
- network structural properties may involve outcomes that are also potential inputs in network processes;
- there are multiple stakeholders involved who will have multiple interests.

Managing collaborative networks clearly involves a set of multi-criteria problems. In particular, understanding what are the objectives of the individual members of the network as well as the global network objectives, for the different types of collaborative structures, is an important research topic. In the field of Operational Research there is a large set of principles and techniques that can tackle this type of multi-criteria problems. In this project, we propose to investigate what are the adequate multi-criteria techniques to be used in this context and will study and propose a MCDM model to support decision making regarding to performance criteria and indicators. Most of this research will be based on previous work in other problems, and it will be strongly driven by practical implementation goals. This will also require work on structuring the criteria (defined in a hierarchical way) and ways to capture their relative importance. Special methods will be developed taking into account the specificity of the context. In particular, given the network aspects of the problem and the existence of various heterogeneous actors, some negotiation and interaction between partners will be considered.

According to Busi and Bititci (2006:11), "the lack of understanding of collaboration structure and dynamics is the major cause of failure of collaborative initiatives." Therefore it is vital to construct a performance management system that can fully organise partner's different points of view and multiple criteria, to contribute to success of the collaborative network.

It is difficult to prove the advantages of dynamic collaborative networks, but according to Camarinha-Matos and Abreu (2007:592), "The ability to measure the performance of a collaborative network as a whole, as well as the individual performance of each of its members, could represent an important boosting element for the wide acceptance of the paradigm."

3. Decision analysis review

According to Smith and Winterfeldt (2004:561),

> *"As part of Management Science, the decision analysis department has focused on papers that consider the use of scientific methods to improve the understanding or practice of managerial decision making."*

Decision-making may involve certainty, uncertainty, competitive, non-competitive situations, individuals, groups, networks, markets and include managerial decisions in any kind of organisation. Thus, it is the appropriate science field to frame the problem of constructing a network performance model within a context of collaborative networking where partners may have compatible or conflicting objectives and it is necessary some form of group negotiation and decision.

Structuring key elements of the network performance model and helping partners to maximize network potential is the objective of the pmColNet support system, which will have a facilitator[3] role.

In this chapter we present a review over the use of decision support systems, especially multi-criteria methods, towards an application in performance management of collaborative networks.

At the end of this chapter we must be able to propose a method to be used in pmColNet's project, respecting its objectives to create and manage a performance system negotiated by network partners.

First focus will be on presenting decision-making main concepts, following the Operational Research field where general methods will be presented; third focus will be on Group Support Systems (GSS) and Negotiation Support Systems (NSS) as defined

[3] The role of pmColNet is to facilitate the decision-making process, shaping the network performance model. This facilitator position (Moreira 2007:10) should be neutral but motivating.

by Arnott and Pervan (2008), where computer-based information systems are studied (Wieserma 2008).

3.1. Perspectives and approaches

Continuing to analyse Smith and Winterfeldt (2004), he refers the distinction between three different perspectives in the study of decision making:

- The **normative perspective** focuses on rational choice. Normative models are built on basic assumptions that provide "logical guidance" for decisions. This perspective uses the expected utility model, probability theory and Bayesian statistics.
- The **descriptive perspective** focuses on how real people think, behave and decide in particular situations. Mathematical models of behaviour may be designed, but only to be confronted to actual decisions people make.
- The **prescriptive perspective** focuses on helping people to achieve better decisions, combining normative and descriptive models of human judgement.

pmColNet's will try to help network partners to build a better performance management model, based on a normative assumption that decision makers should make decisions to maximize their expected utility.

The role of pmColNet is to facilitate the decision-making process, shaping the network performance model. This facilitator position (Moreira 2007:10) should be neutral but motivating.

pmColNet model will be supported on a constructivist epistemology, therefore its objective is to recommend. The preferences model construction is specific to that problem and situational. The network partners do participate in the decision process and in all decision support phases, to achieve the best result, incorporating their subjective values (Moreira 2007:19). Adopting a semi-prescriptive perspective, the

model will focus on two of the three central themes of decision making academia[4]: Utility Modelling and Game Theory and Competitive Decision Making.

3.1.1. Utility modelling

Marichal (1999:5-6) explains that there are two main approaches of multicriteria decision making:

- The **multiattribute utility theory**: each alternative is awarded with an absolute score for each criterion, and then, aggregating all scores, a global score is obtained. This is also called the cardinal approach.
- The **preference modelling approach**: on the contrary, here it is assigned a preference degree to every pair of alternatives for each criterion. The global preference degree is obtained by aggregating all the partial degrees. This is also called the ordinal or relational approach.

The Multiattribute utility theory (MAUT) developed by the American School requires the construction of an abstract utility function, which in the case of collaborative networks would be probably too complex, especially if the network has several partners. On the contrary, the use of expert judgements (network partners) in pairwise comparisons to build utility functions seems to be more adequate.

The preference modelling approach, which is based on judging pairs of alternatives, will be explored at sections: 3.1.3 and 3.4.

This seems to favour pmColNet's interaction purposes and relax (at some extent) the criteria preference independence. The basic assumptions of criteria preference independence and value compensation (between two attributes) are difficult to sustain in pmColNet's real situations.

[4] Smith and Winterfeldt (2004).

3.1.2. Game theory and competitive decision making

Game theory is a very interesting field of study. It analyses decisions from a rational point of view and focuses the choice of cooperation or competition between organisations regarding the best individual expected payoff. Concepts like Nash equilibrium are used to understand decisions:

> *"A Nash equilibrium, named after John Nash, is a set of strategies, one for each player, such that no player has incentive to unilaterally change her action. Players are in equilibrium if a change in strategies by any one of them would lead that player to earn less than if she remained with her current strategy."*
>
> Shor, Mikhael, "Nash equilibrium," Dictionary of Game Theory Terms, Game Theory .net, http://www.gametheory.net/dictionary/NashEquilibrium.html Web accessed: 24-01-2009.

One of the major aspects revealed by investigation in this field, especially using experimental economics[5], is that players are always aware of its social surroundings and tend to be "generous" towards opponents, acting in a somewhat irrational behaviour (unlike the selfish, economic principles):

> "Subjects come to the lab in a social context, a world of repeat interaction in which single transactions are not isolated but part of an ongoing sequence … what is needed … is to reevaluate the experimenter/ theorist's premise that subjects will view such an experiment as a single-trial game … What may be wrong is the very idea that instances of human decision interaction can be construed as without a history or a future. (pp 80-82). *Smith in Bergstrom (2002: 19)*

[5] In experimental economics, scientists tend to validate theory using actual human players confronted in economic games at a controlled environment/ laboratory.

Because of this social context, multicriteria decision making investigators have been trying to capture interaction between players.

According to Marichal (1999:230) the problem of modelling interaction is rather complex and often "overlooked in practical applications". Some of the complexity arises from the lack of a precise definition of interaction, although it is unquestionable that interaction phenomena do exist in real situations, researchers tend to assume that his criteria are independent and exhaustive.

Marichal concludes referring recent approaches using cooperative game theory and multicriteria decision making that propose interaction indices among pairs of criteria. These interaction indices, namely "*the so-called Shapley and Banzhaf interaction indices*" will not be addressed at this work due to their complexity.

pmColnet's model will have a situational and interactional basis, but will try to simplify relationships between players using the model itself. Because the model will ultimately ask network partners its decision (even if aided), interaction will not be modelled, but actually played.

3.1.3. Ordinal/ relational approach vs. cardinal approach

According to Roy, Bernard, "Paradigms and Challenges" in Figueira *et al.* (2005:9-10), there are several types of scales, summarized in Figure 2 - Types of scales. Roy, Bernard, "Paradigms and Challenges" in Figueira *et al.* (2005:9-10)

In ordinal scales, "the gap between two degrees does not have a clear meaning in terms of difference preferences"; on the contrary, in quantitative scales, there is an absolute zero (absence of quantity) and there is a unit that allows interpreting "each degree as the addition of a given number of such units". Therefore, in quantitative scales, "the ratio between two degrees can receive a meaning which does not depend on the two particular degrees considered".

"*A preference degree tells to what extent an alternative a is preferred to an alternative b, and thus is a relative appraisal.* (…) *On an ordinal scale, numbers have no other meaning that defining an order relation on the scale, and distances or differences between values cannot be interpreted. On a cardinal scale, distances between values are not quite arbitrary.*" Marichal (1999:1)

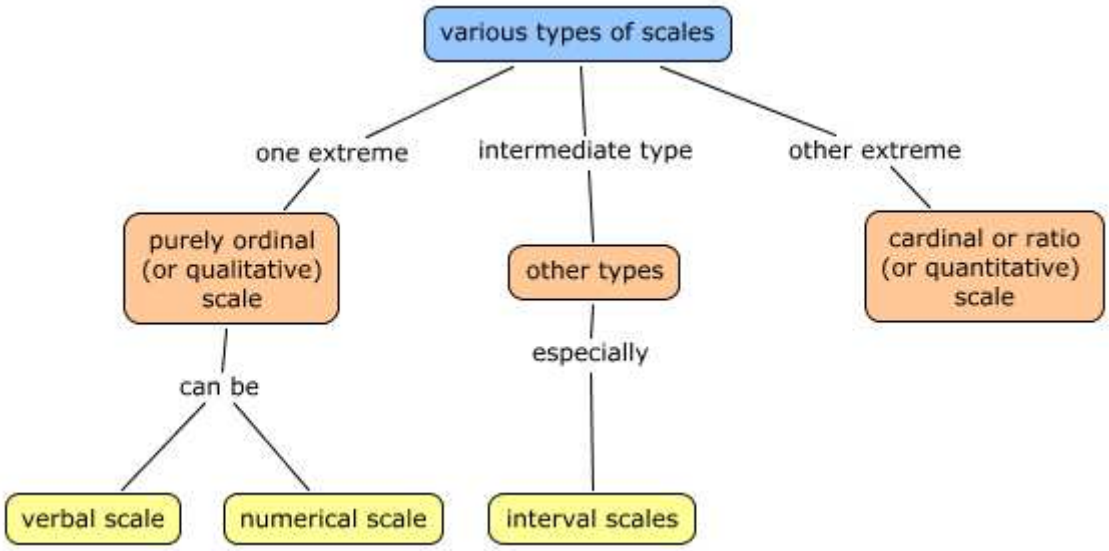


Figure 2 - Types of scales. Roy, Bernard, "Paradigms and Challenges" in Figueira *et al.* (2005:9-10)

3.2. Operational research – multi-criteria methods

"(…) the field is so large and comprises developments so heterogeneous that it is almost hopeless to think that an exhaustive vision of the research and practice of MCDA can be given." Figueira, Greco and Ehrgott (2005:XXIV)

It is impossible within this work to accurately structure this vast field of study. We don't even dare to risk saying this chapter gives a glimpse of the majority of MCDA methods. It is written with focus on supporting the decision of the methodologies used in pmColNet and we must accept all valid critics that further analysis on some particular techniques should be done.

"(…) the basic ingredients of MCDA are very simple: a finite or infinite set of actions (alternatives, solutions, courses of action, …), at least two criteria, and, obviously, at least one decision-maker (DM). Given these basic elements, MCDA is an activity which helps making decisions mainly in terms of choosing, ranking, or sorting the actions." Figueira, Greco and Ehrgott (2005:XXII)

3.2.1. Phases

According to Marichal (1999:7):

"To summarize, multicriteria decision making procedures consist of three main steps (phases) as follows.

a. Modelling phase

In this phase we look for appropriate models for constructing the partial scores x_{ai}

and also for determining the importance of each criterion (i.e., the weights).

b. Aggregation phase

In this step we try to find a unified (global) score for each alternative, on the basis of the partial scores and the weights.

c. Exploitation phase

In this phase we transform the global information about the alternatives either into a complete ranking of the elements in A, or into a global choice of the best alternatives in A."

Modelling phase will be further discussed when we analyse some of the models used to deal with multicriteria problems.

3.2.1.1. Aggregation

"*Aggregation refers to the process of combining several numerical values into a single one, so that the final result of aggregation takes into account in a given manner all the individual values.*" Marichal (1999:1)

Following Marichal (1999:85), he refers several important aspects addressed at this stage:

- The difference in criteria importance, usually modelled recurring to weights.
- Different weights in criteria imply the use of weighted aggregation operators (giving up the symmetry property), namely quasi-linear means and more

specifically the most used weighted arithmetic mean (WAM), which ignores any kind of interaction between criteria.

- Because interaction dealing tools are scarce and complex, researchers tend to construct or assume independent criteria, introducing some bias effect in evaluation.

Expected/ desirable properties for preferences aggregation (Marichal 1999:7-8):

- independence of irrelevant alternatives condition;
- aggregation operator is neutral with respect to alternatives;
- preferential independence (in case of violation of this property, no additive utility function can model the preferences of the decision maker - the concept of fuzzy integral allows to overcome this problem);

3.2.1.2. Exploitation

This is the phase that really matters. When partners of collaborative networks use pmColNet, they will use it to better design the performance model and actually improve/ maximize the network potential.

We will affect several time to exploring results at section 5.9, where some scenarios will be presented.

3.3. Decision support systems

According to Arnott and Pervan (2005),*"Decision support systems (DSS) is the area of the information systems (IS) discipline that is focused on supporting and improving managerial decision-making".*

Managerial decision-making problems are complex so, DSS combines analytical modelling techniques with data manipulation and visualization, helping users to solve problems which, in many cases, are not very well structured (Soeiro 2007). DSS focus is flexibility and user-friendly use, so they can be adapted to diverse situations.

Several categories of DSS can be distinguished (Wieserma 2008:6):

- "Communication-driven DSS, which supplies tools as groupware, video conferencing, bulletin boards, voice and video over IP. These tools are used to lower communicational barriers.

- Data-driven DSS, of which EIS [executive information systems] is an example.

- Document-driven DSS, which is used for document storage and analysis.

- Knowledge-driven DSS, based on a knowledge-base and used for building business-knowledge.

- Model-driven DSS, used to help decision makers by presenting modelling tools (such as financial models and simulations), and problem structuring tools."

3.3.1. Group Support Systems and Negotiation Support Systems

According to Wieserma (2008), GSS are web-based DSS introduced in the 1990's. They have the same objectives of DSS and facilitate discussion by groups.

The tools used by GSS focus on structure group deliberation and may include the following features:

- Member information and preferences;
- Brainstorming;
- Discussion forum;
- Commenting;
- Idea organisation and evaluation;
- Categoriser;
- Consensus formation;
- Meeting management;
- Agenda;
- Voting;

- Aggregation tools (e.g., AHP);
- Analysis and presentation tools.

In Wieserma (2008) survey, we were particularly interested in Zahir and Dobing (2002) paper.

3.3.1.1. Zahir and Dobing MCGDSS

Zahir and Dobing (2002) detail the design of a web-based multicriteria group support system (MCGSS) based on the Analytical Hierarchic Process (see Figure 3 - Zahir and Dobing (2002:53) MCGSS).

The authors sustain that "Multicriteria voting greatly improves the quality of input and helps managers with the more important tasks of analysing alternatives and building consensus around the one chosen" (p.50), so they propose a Web-based multicriteria group support system "that enables users to enter their intensity of preferences using a visual interface" (i*dem)* supported by the AHP decision model.

AHP, extended by Zahir to the Euclidean vector space (VAHP) presents several advantages to the yes/no voting procedure, especially due to the lack of face-to-face communication in a web-based framework.

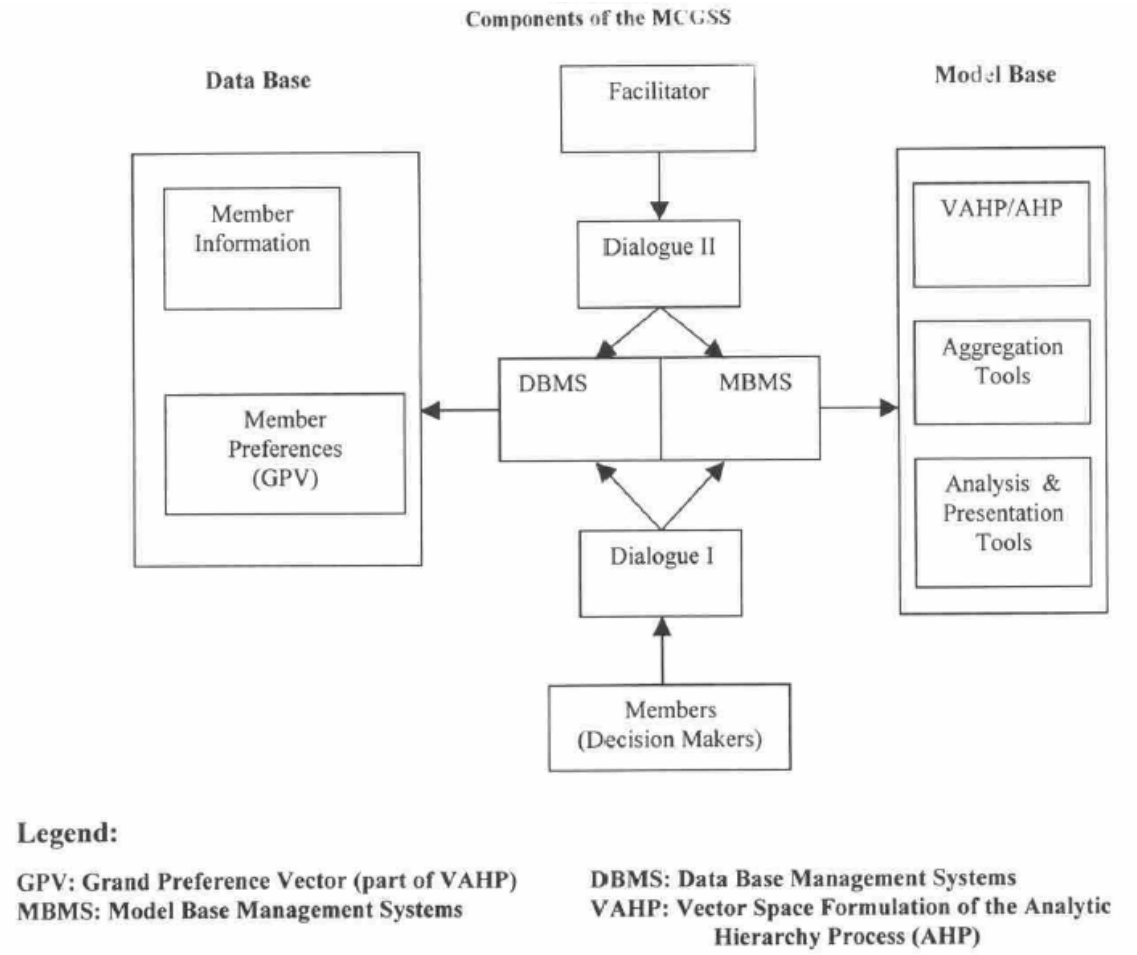


Figure 3 - Zahir and Dobing (2002:53) MCGSS

"The MCGSS databases contain information on preferences and user data, as indicated by the users. The MCGSS model base consists of three different models. The VAHP/AHP model is used to let decision-makers enter their preferences for different criteria. Thereafter, the system calculates each user's grand preference vector (GPV). The GPV is used by the MCGSS to compute the sum of preferences for criteria for a decision-making group. The calculation is made by adding all user vectors to obtain the common preference of the group." Wieserma (2008:7)

Users enter the relative preference for each alternative via a "bar graph" using a slider control and dragging the mouse to any height assigning preferences.

Other interesting aspect of this MCGDSS is inconsistency reporting: "A simple example would be transitive consistency – if alternative A is ranked higher than B and B is ranked higher than C, then A should also rank higher than C. The system can report back to the decision-makers about the consistency of their judgements, giving them an

opportunity to review their preference inputs and also to the facilitator." Zahir and Dobing (2002:54)

This Web-based architecture seems extremely adapted to pmColNet.

3.3.1.2. The PROMETHEE GDSS Procedure

"*The PROMETHEE Group Decision Support System has been developed to provide decision aid to a group of decision-makers (DM_1), (DM_2), ..., (DM_r), ...m (DM_R) (see [54]. It has been designed to be used in a GDSS room including a PC, a printer and a video projector for the facilitator, and R working station for the DM's. Each working station includes room for a DM (and possibly a collaborator), a PC and Tel/Fax so that the DM's can possibly consult their business base. All the PC's are connected to the facilitator through a local network.*

There is no objection to use the procedure in the framework of teleconference or video conference systems. In this case the DM's are not gathering in a GDSS room, they directly talk together through the computer network." Brans, Jean-Pierre, "Promethee Methods" *in* Figueira, Greco and Ehrgott (2005:183)

PROMETHEE GDSS procedure is divided in three phases and several steps:

- PHASE I: generation of alternatives and criteria;
- PHASE II: individual evaluation by each DM;
- PHASE III: global evaluation by the group.

This framework is not far from Zahir and Dobing (2002), but the use of Internet and a Web-based environment maximizes model reach and flexibility.

3.4. Relational approach methods

"The relational approach consists in comparing alternatives two by two, and expressing with a number the degree of preference of one alternative over the other, with respect to a criterion. These numbers are very often expressed by the help of fuzzy (valued) preference relations." Marichal (1999:9)

This approach has been essentially developed by Roy (ELECTRE methods), Blin, Saaty, Fodor and Roubens.

These methods are also called outranking methods. According to Roy (1974) in Figueira, Greco and Ehrgott (2005:XXVII), "*Given what is known about the decision-maker's preferences and given the quality of the performances of the actions and the nature of the problem, an outranking relation is a binary relation S defined on the set os potential actions A such that aSb if there are enough arguments to decide that a is at least as good as b, whereas there is no essential argument to refute that statement."*

Due to the characteristics of network organisations, where interaction and collaboration are essential, methods that are supported in comparing alternatives are more likely to maximize negotiation efforts and "democratic" decisions.

Therefore, fitting ordinal/ relational multicriteria approaches we will compare[6]:

- ELECTRE;
- AHP;
- MACBETH;

[6] The choice of these three methods may be criticised. As said before, there are numerous MCDA methods, but the criterion was that the present ones may represent different perspectives and are widely applied in real decision problems. All have their own software implementations, which is useful due to the practical implementation focus of this work.

3.4.1. ELECTRE

This section is based on Figueira, Mousseau and Roy, "Electre Methods" in Figueira, Greco and Ehrgott (2005:133-162).

ELECTRE (*ELimination Et Choix Traduisant la REalité)* methods are researched mainly in Europe and go back to the 1960's, they are considered outranking methods as defined above (3.4).

3.4.1.1. Relevant context

ELECTRE methods are relevant when facing situations with the following characteristics:

1. "The decision-maker (DM) wants to include in the model at least three criteria. However, aggregation procedures are more adapted in situations when decision models include more than five criteria (up to twelve or thirteen).

And, at least one of the following situations must be verified.

2. Actions are evaluated (for at least one criterion) on an ordinal scale or on a weakly interval scale. These scales are not suitable for the comparison of differences. Hence, it is difficult and/ or artificial to define a coding that makes sense in terms of preference differences of the ratios $\frac{g_j(a)-g_j(b)}{g_j(c)-g_j(d)}$, where $g_i(x)$ is the evaluation of action x on criterion g_j.
3. A strong heterogeneity related with the nature of evaluations exists among criteria (e.g., duration, noise, distance, security, cultural sites, monuments, ...). This makes it difficult to aggregate all the criteria in a unique common scale.
4. Compensation of the loss on a given criterion by a gain on another one may not be acceptable for the DM. Therefore, such situations require the use of noncompensatory aggregation procedures.
5. For at least one criterion the following holds true: small differences of evaluations are not significant in terms of preferences, while the accumulation of several small differences may become significant. This requires the

introduction of discrimination thresholds (indifference and preference) which leads to a preference structure with a comprehensive intransitive indifference binary relation." (*idem*:136-137)

3.4.1.2. Modelling preferences using an outranking relation

Preferences in ELECTRE methods are modelled by using binary outranking relations, *S*, whose meaning is "*at least as good as*".

"Considering two actions *a* and *b*, four situations may occur:

- *aSb* and not *bSa*, i.e., *aPb* (a is *strictly preferred* to b).
- *bSa* and not *aSb*, i.e., *bPa* (b is *strictly preferred* to a).
- *aSb* and *bSa*, i.e., *aIb* (a is *indifferent* to b).
- Not *aSb* and not *bSa*, i.e., *aRb* (a is *incomparable* to b).

The construction of an outranking relation is based on two major concepts:

1. *Concordance*. For an outranking *aSb* to be validated, a *sufficient* majority of criteria should be in favour of this assertion.
2. *Non-discordance*. When the concordance condition holds, none of the criteria in the minority should oppose too strongly to the assertion *aSb*.

These two conditions must be fulfilled for validating the assertion *aSb*." (*idem*:137)

3.4.1.3.Structure of ELECTRE methods and relative importance of criteria

"ELECTRE methods comprise two main procedures: construction of one or several outranking relation(s) followed by an exploitation procedure. (…) The relative role attached to criteria in ELECTRE methods is defined by two distinct sets of parameters: the importance coefficients and the veto thresholds." (*idem:*138)

The importance coefficients in ELECTRE methods refer to intrinsic "weights". For a given criterion the weight, w_j, reflects its voting power towards the contribution that is in favour of an outranking. These weights do not depend of the ranges or scale encoding and cannot be interpreted as substitution rates in compensatory aggregation procedures such as AHP, MACBETH and MAUT.

"Veto thresholds express the power attributed to a given criterion to be against the assertion "*a outranks b*", when the difference of the evaluation between *g*(b) and *g*(a) is greater than this threshold." (*idem:*138)

3.4.1.4. Robustness concerns

In real-world decision problems, decision makers face imperfect knowledge regarding the available data. Imperfect knowledge leads to the assignment of "arbitrary" values to certain parameters: preference parameters (weights, thresholds, categories lower and upper limits, …), and the technical parameters (discordance and concordance indices of ELECTRE methods

> "A conclusion, C^r, is said to be robust with respect to a domain, Ω, of possible values for the preference and technical parameters, if there is not a particular set of parameters, ώ Є Ω, which clearly invalidates the conclusion C^r." (i*dem:*150)

Because variations on each parameter may influence recommendations, it is frequent to proceed to *sensitivity analysis*. Such recommendations should be elaborated from *robust conclusions*. In practice, to surpass robustness concerns, it is frequent to define a "*reference system* built from the assignment of *central values* to these two types of parameters. Then, an exploitation procedure should be applied in order to obtain outputs which are used to elaborate recommendations." (*idem*:149)

3.4.1.5. Elicitation of parameter values

> "A preference elicitation process proceeds through an interaction between DMs and analysts in which DMs express information about their preferences within a specific aggregation procedure." (*idem*:150)

- **Direct elicitation techniques:**

"(…) DMs should provide information directly on the values of the preference parameters. A major drawback of such techniques is that it is difficult to understand the precise meaning of the assertions of the DMs. This is why ELECTRE methods are usually implemented by using indirect elicitation procedures." (*idem:*150)

- **Indirect elicitation techniques:**

"(…) these techniques proceed indirectly by posing questions whose answers can be interpreted through the aggregation procedure." (*idem:*150)

For instance, these techniques may determine the vector of the relative importance coefficients from pairwise comparisons or assignment examples.

3.4.2. AHP

This section is based on Saaty, "The Analytic Hierarchy and Analytic Network Processes for the measurement of intangible criteria and for decision-making" in Figueira, Greco and Ehrgott (2005:345-407).

"The Analytic Hierarchy Process (AHP) and its generalization to dependence and feedback, the Amalytic Network Process (ANP), are theories of relative measurement of intangible criteria. With this approach to relative measurement, a scale of priorities is derived from pairwise comparison measurements only after the elements to be measured are known. (…) In the AHP paired comparisons are made with judgements using numerical values taken from the AHP absolute fundamental scale of 1-9. (…) The AHP/ ANP is useful for making multicriteria decisions involving benefits, opportunities, costs and risks." (*idem*:345)

AHP is the original theory of prioritisation that derives relative scales of absolute fundamental scale. AHP is a descriptive approach to decision-making based on four axioms:

- reciprocal judgements;
- homogeneous elements;
- hierarchic or feedback dependent structure;

- rank order expectations.

AHP is a theory of relative measurement on absolute scales for both tangible and intangible criteria, based on the judgement of knowledgeable and expert people (a panel of experts) and statistics needed to make a decision.

"Paired comparisons deal with comparative judgement. However, (…) the AHP also provides a way to rate alternatives one at a time to deal with absolute judgement. In absolute judgement the criteria are first prioritized through comparisons and then for each criterion one creates a scale of relative intensities possibly of widely ranging orders of magnitude. The priorities of these intensities are again appropriately derived through paired comparisons with respect to their criterion, and in the end the alternatives are rated one at a time by assigning each one an intensity level for each criterion, then weighting by the priorities of the criteria and adding to obtain their overall rating priority." (*idem*:348-349)

According to Smith and Winterfeldt (2004:568), "The appeal of the AHP as a prescriptive methodology remains matter of disagreement. While many in the decision analysis community (ourselves included) follow Dyer in believing the AHP to be fundamentally unsound, others (including Saaty, Harker, and Vargas) disagree and the AHP is still widely used in practice today".

3.4.3. Macbeth

MACBETH stands for Measuring Attractiveness by a Categorical Based Evaluation Technique and is a multicriteria decision aid approach developed in the early 1990's by Bana e Costa and Vansnick. It follows the concept of an humanistic, interactive and constructive approach (Bana e Costa *et al.* 2003?:1):

- Humanistic in the sense that it should be used to help decision-makers ponder, communicate, and discuss their value systems and preferences;
- Interactive because the learning process can best spread through socio-technical facilitation sustained by straightforward questioning-answering protocols. From a practical viewpoint, such interaction would greatly benefit from an extremely efficient and user-friendly decision support system (the case of the M-MACBETH software);

- "Constructive because MACBETH rests on the idea that full-bodied convictions about the kind of decision to make do not (pre-)exist in the mind of the decision maker, nor in the mind of each of the members of a decision advising group, but that we can provide them with help to form such convictions and to build robust (shared) preferences concerning the different possible options to solve the problem." (*idem*:1)

MACBETH builds a "quantitative model of values based on qualitative (verbal) difference judgments, that facilitates the path from ordinal to cardinal preference modeling" (*idem*). This characteristic "requires the availability of very rich information, concerning the decision makers' preferences" because the chosen additive value model implies the production of mathematically significant results.

On the one hand, MACBETH is clearly in the line pmColNet main objectives, including a path of interaction and constructivist orientation; on the other hand, "the long way between ordinal and cardinal information" (Bana e Costa *et al.* 2003?:4) is a disadvantage, especially if there are several network partners and different alternatives.

The amount of information regarding attractiveness of the elements means many questioning procedures.

3.4.4. Comparative analysis

Method	Advantages	Disadvantages
ELECTRE	Vote power and veto thresholds are available. Indifference intervals are much more adequate to real world: uses the concept of weak preference and incomparability; Robustness evaluation; Sensibility studies.	Binary relations/ dominance qualification are complex concepts to implement and explain (although very powerful).

AHP	Very easy to implement; The decision-maker judges through linguistic comparisons; Robustness and consistency check; May incorporate some small inconsistencies.	Rank reversal problems: - fails independence of irrelevant alternatives condition; - aggregation operator is not neutral with respect to alternatives; The user has to perform a huge number of comparisons, for every pair of alternatives and every used criterion and to remain coherent by establishing the relations of dominance; It uses reason comparisons and not value differences (does not have an absolute zero).
MACBETH	Uses qualitative differences in comparisons, but achieves value differences.	The amount of information regarding attractiveness of the elements means many questioning procedures; Much more complex path in terms of application.

Table 1 - Relational approaches comparative table

In the next chapter we will study the information model which will be used at pmColNet's framework. At chapter 5, the chosen method will be used and further explanations will be addressed.

4. Structuring and managing information in the performance evaluation system – Information model

Throughout this chapter we will mainly use the work of Neves, Jorge (2009), "Gestão de informação de desempenho em redes de organizações", wich as also developed along the pmColnet research project at INESC Porto.

Performance management within networks of organisations is very complex and involves several aspects that influence metrics choice, such as:

- Performance objectives;
- Evaluation level;
- Criteria choice;
- Network typology;
- Data source and data access;
- Network governance;
- Power relationships between network partners;
- Evaluation timeframe;
- Data gathering timing;
- Data gathering frequency.

Because of several influencing elements, a generic and satisfactory model is very hard to achieve, and therefore, a situational and constructivist approach is a valid option. This situational approach should be used in the specific network and its specific timeframe and constructed in a collaborative manner.

Although in this situational model, criteria and indicators should be attained regarding individual and network objectives, that choice must be supported by a pre-defined information model that allows a quick network setup.

4.1. Perspectives and framework

Neves' (2009:90) proposes an information model that includes the following key perspectives:

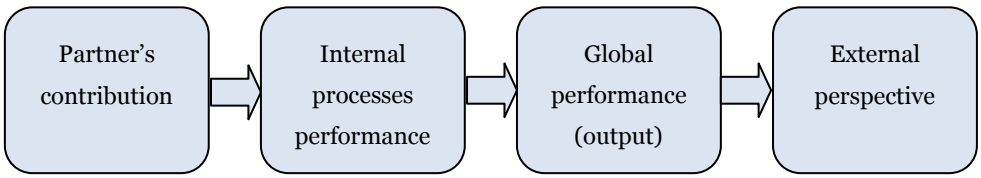


Figure 4 - Key perspectives within network performance evaluation. Neves (2009:90)

Partner's contribution refers to the level of allocated resources by each partner to the network. Internal perspective is an adapted vision of Balanced Scorecard inside the network; output refers to global network performance regarding its established objectives; and external perspective tries to capture network impact in the community.

Neves' (2009) presents a framework for performance management that includes several different contextualisation layers that allow selecting appropriate indicators for performance evaluation:

- Collaborative network typology;
- Stakeholders;
- Evaluation framework;
    - Evaluation levels;
    - Evaluation perspectives;
    - Evaluation criteria;
- Types of performance evaluation indicators.

4.2. Collaborative network typology

Network typology is a very important contextualisation aspect when defining the performance model. Network typology is defined regarding (not only, but also) objectives and influences criteria and indicators choice. At section 5.4.3 we will define specific network typologies regarding the type of interorganisational governance and network objectives.

4.3. Stakeholders

There are numerous stakeholders gravitating around a collaborative network: network partners (members), clients, suppliers, banks, investors, workers, general community (local or regional). Each of them has specific information needs and may have contradictory objectives. Therefore, a multicriteria performance model is needed to attend conflicting objectives and to maximize the network success and stakeholders satisfaction.

4.4. Evaluation framework

Neves' (2009) identifies three dimensions within networks of organisations performance evaluation:

- Evaluation level (or evaluation object): may be individual, organisation, network and community. Criteria may refer to different evaluation levels.
- Evaluation perspective;
- Criteria.

4.4.1. Evaluation perspective: facets vs. hierarchy classification

Neves' (2009) identifies several **facets**, different mutual exclusive dimensions, of network performance management:

- Evaluation perspective: partner's contribution (input), internal network processes, results (output) and external perspective (clients and other stakeholders).
- Evaluation criteria:
    - Collaboration: commitment, coordination, trust, sharing and conflict resolution;
    - Network growth;
    - Processes coordination;
    - Efficiency in using resources;
    - Finance: sales, profitability and costs;
    - Flexibility: mix, production, delivery and volume;
    - Network image;
    - Innovation: learning and produced knowledge;
    - Productivity;
    - Quality: client response, perceived quality and requirements compliance;
    - Market share;
    - Time: process cycle, lead time and client response;
    - Client's satisfaction;
    - Partner's satisfaction;
    - Relational capital;
    - Human capital.
- Measure type: objective or subjective.
- Management level: strategic, tactical, operational or not defined.

Assuming an **hierarchic** classification, we have:

- Perspectives,
- Criteria,
- Subcriteria,
- Indicators, and
- Properties,

In a top-down categorisation.

4.4.2. Criteria

Neves (2009:71-85) network performance evaluation criteria:

Collaboration (social interaction): it's fundamental within network's context and implies a constructivist approach. Some of the attributes required by this criterion are: mutual trust, commitment, coordination, communication, interaction, interindependence, sharing, reciprocity, conflict resolution, flexibility, mutual objectives and partner's satisfaction.

Partner's contribution: measuring members input is vital for network success. There are several types of resources involved – physical, financial, organisational, relational and human. Equity is also an important attribute to guarantee network success.

Other generic criteria: costs, flexibility, quality, time (fastness), innovation, productivity, profitability, client satisfaction and market share.

4.5. Performance indicators

Performance indicators within the presented information model should have attributes that are independent from the specific network:

- Indicator title;
- Reason: why measuring this;

- Goal;
- Desirable direction of indicator results (maximization/ minimization).
- Measure type (objective/ subjective);
- Unit of measure and calculating formula (if applicable);
- Measuring frequency;
- Measurement responsible;
- Data source.

Network partners will have to manage organisational indicators, internal network indicators and external network indicators.

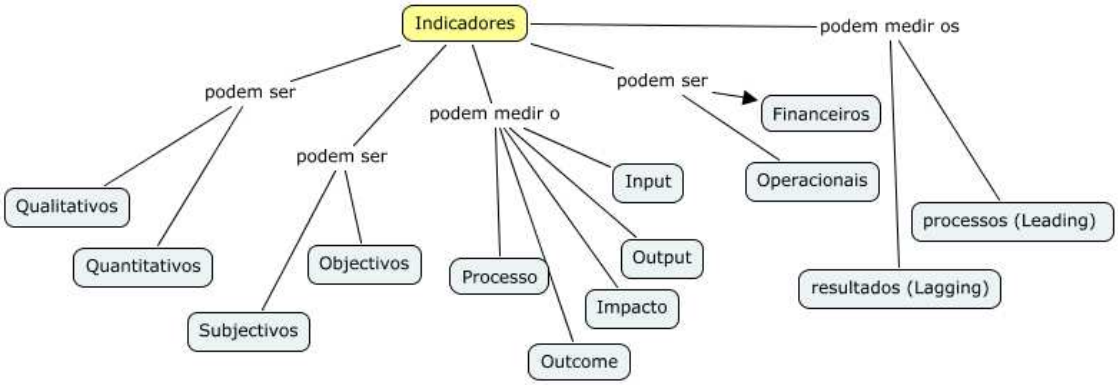


Figure 5 - Types of performance indicators. Neves (2009:44)

4.6. Other conceptual metrics for managing collaborative networks

Neve's work is much more broaden and flexible, but because of its similarity regarding the chosen methodology of pmColNet, we will briefly present Parung and Bititci's (2006) conceptual metric for managing collaborative networks.

4.6.1. Parung and Bititci

According to Parung and Bititci (2006:117) a collaborative network should be observed as a system. A conceptual metric for managing collaborative networks must include three kinds of measurements:

- Measuring input: "an atempt to confirm what resources participants contribute into a collaborative network" (*idem*);
- Measuring process: "an effort to distinguish healthy collaborative networks from unhealthy ones" (*idem*)*;*
- Measuring output: "an attempt to determine values gained by stakeholders through collaborative networks" (*idem*).

Parung and Bititci presented a model with three kinds of measurement that influence the success of collaborative networks: contribution, health and outcome. AHP is used to measure partners' contribution on five value generators: financial, physical, human capital, relational capital and organisational capital.

"Each value generator has its own factors and weights that are generated and selected within a particular meeting among partners. Further, the health of the relationships based on key performance indicators of five relationships attributes (i.e. commitment, coordination, trust, communication and conflict resolution) is measured using Likert scale. Key performance indicators are identified and selected by partners before formalising the collaboration. The overall outcome of collaborative network is measured using mathematical approach. These outcomes comprise of internal and external values and they are measured aggregately in order to have one single measurement." (*idem*)

Using the information model structured by Neves (2009) at pmColNet's research project, we are now ready to present in the next chapter the multicriteria performance management model for collaborative networks.

5. Multicriteria performance management model for collaborative networks

The objective of this chapter is to propose a multicriteria performance management model for collaborative networks suitable to use at pmColNet – performance management in collaborative networks research project.

pmColNet' goal is the design of a performance evaluation system for collaborative networks, supported in a multi-criteria decision method and collaborative meaning negotiation within a constructivist context.

Through this approach, we believe that network participants and the network itself can maximize the performance and potentiate the collaborative value.

The role of the pmColNet approach is to facilitate the design of the evaluation by supporting decision-making. This facilitator position (Moreira 2007:10) should be neutral but motivating.

pmColNet model is supported on a constructivist perspective, therefore its objective is to recommend, not to prescribe. The construction of the preferences model is specific to that problem and situational. The network participants do participate in the decision process and in all decision support phases, to achieve the best result, incorporating their subjective values (Moreira 2007:19).

5.1. Method proposal

We will use AHP within the pmColNet project. We are aware of the method limitations, but we will try to justify the choice and refute the indicated disadvantages.

Rank reversal problems can be minimized, because in a real network analysis, partners will include only the relevant alternatives. Each alternative will be at least relevant for one particular network partner.

Reducing the amplitude of the scale, for instance by using 1 to 5, over 1 to 9, we are reducing inconsistency problems. Because all the network partners are experts in the particular situation, 1 to 5 scale is perfectly adapted.

Despite of the proposed pairwise verbal judgements, which are common to AHP, Macbeth or even Electre methods, and the prescriptive results, pmColNet should definitely focus on interaction and commitment agreement, following its main constructivist approach.

In other words, the prescriptive results regarding objectives, criteria and indicators should never be taken as final, but as a starting point for discussion.

As follows from previous literature review, every preference modelling technique and aggregation functions has flaws and academia is not unanimous regarding specific model virtualities.

Therefore, pmColNet should provide the tools to maximize partners' contributions and a primary factors ranking, helping networks to correctly and efficiently structure the problem of designing a satisfying performance model for collaborative networks.

This specific task of designing a performance model recurring to partners' proposals is extremely flexible with respect to basic multicriteria decision making traditional premises (Matos 2005):

- Alternatives and criteria should be independent: Because all the primary stakeholders[7] are represented in pmColNet and because the model is presented as an interaction tool, relations between criteria (each partner point of view) and between alternatives are not completely independent.
- Exhaustive: all points of view are expressed. This is, all (primary) stakeholders are represented.
- Consistent: if two alternatives are equivalent except in one criteria *k,* where a_k is better then b_k, then A should be considered globally at least as good as B. This is, if two alternatives have similar partner's voting except for one partner, who prefers one over another, the preferred alternative by the latter is preferred by the network (at least equally preferred).
- Non-redundancy: if one criteria is eliminated, the preceding two properties are compromised. This is true at a network context, because removing a partner point of view will compromise representation.

[7] We use "primary" stakeholders to refer to network participants. Secondary stakeholders are all the other: Government, suppliers, clients, citizens, communities, …

- Readability: number of criteria should be relatively low. This is completely dependent of the number of network participants. pmColNet should help "big" networks to efficiently and effectively structure its performance model.
- Operability: decision makers and (primary) stakeholders should accept the selected family of criteria.

This work's focus is network performance evaluation and multicriteria methods are tools to achieve a better model framework. Therefore, pmColNet may be used with any multicriteria method that satisfies the interaction and constructivist approach.

AHP will mainly be used, but some concepts from other methods, like vote power and veto thresholds, from ELECTRE will also be helpful.

5.2. pmColNet fundamentals

5.2.1. Hierarchical Framework for Performance Analysis – HFPA

pmColnet will be structured regarding a very simple Hierarchical Framework for Performance Analysis (HFPA). There are different systems for business performance management, most of them derived from Balanced Scorecard techniques[8] and Key Performance Indicators (KPI). Nevertheless, many business performance management systems, especially those supported by technological means, focus on the relationship management of the following hierarchical elements (see 4.4.1), applying different perspectives according to the specific context of analysis:

[8] Initially proposed by Norton and Kaplan.

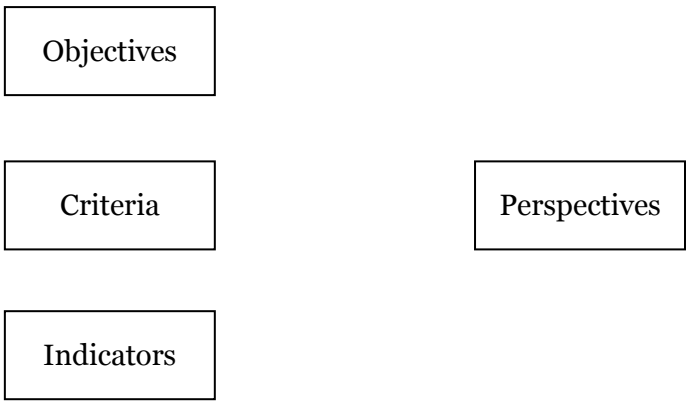


Figure 6 - HFPA elements

Objectives are the entities goals, the reason of their existence or the reason of their actions. Objectives are the expected results.

Criteria are forms of aggregation; they represent a common feature within different indicators. This concept must not be confused with "perspective".

Indicators are business metrics.

Perspectives are:

1) Different ways to categorise the hierarchical performance elements;
2) Different angles of viewing the performance relationships.

Let's exemplify the concept:

1)

- Objectives may be strategic, tactical or operational [Grabot, B. (1998) in Berrah and Clivillé (2007:709)], …
- Criteria may be financial, economic, process, customers, learning, collaboration, …
- Indicators may be leading or lagging, financial, operational, input, output, process, quantitative or qualitative, … (see 4.5)

We may find endless adjectives to classify the hierarchical performance elements.

2)

- Network partners different views;
- Level of analysis: individual, organisational, network, community, …

And many other examples.

Within a specific perspective, a performance element is an indicator or a criterion or an objective. It cannot be different things at a time. But, within two different perspectives, an element can be an objective for perspective A and an indicator for perspective B. In real life applications, hierarchical performance elements classification is sometimes subjective, that's why it follows a specific perspective.

A perspective is just a specific materialisation, for a given situation, of the hierarchical performance elements.

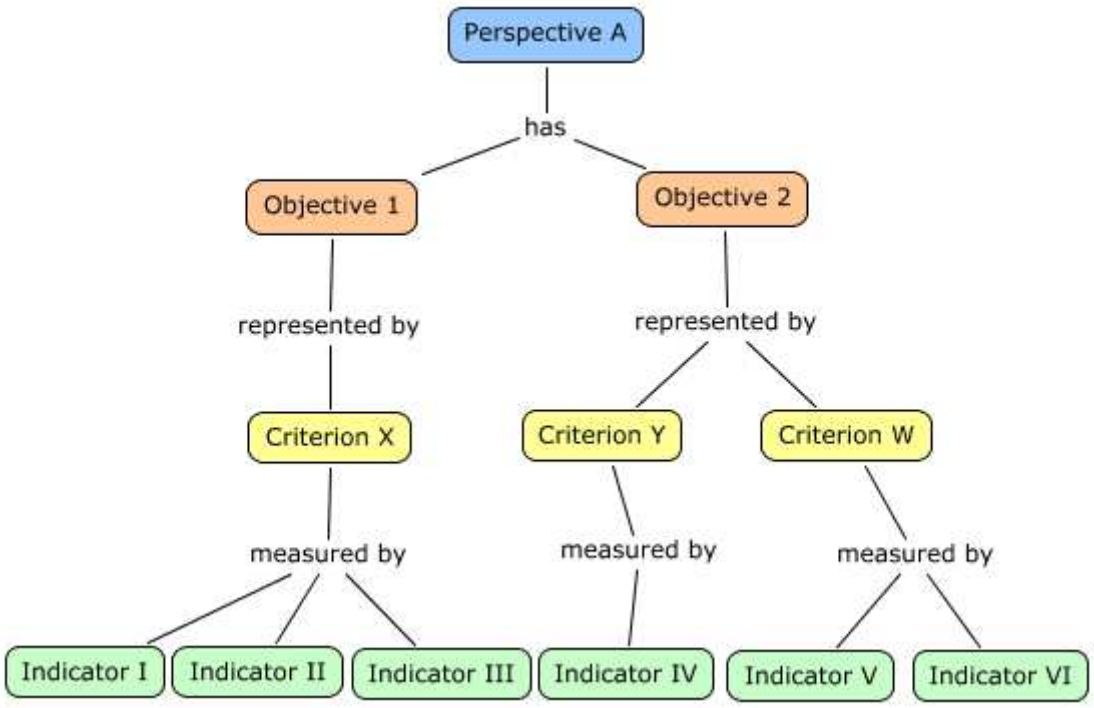


Figure 7 - HFPA

pmColNet framework will use this HFPA.

5.2.2. Visual pairwise judgment

Multi-criteria decision making is based on comparing different alternatives. pmColNet will use a visual rule to attain preference intensity, based on Zahir and Dobing MCGDSS referred at 3.3.1.1 :

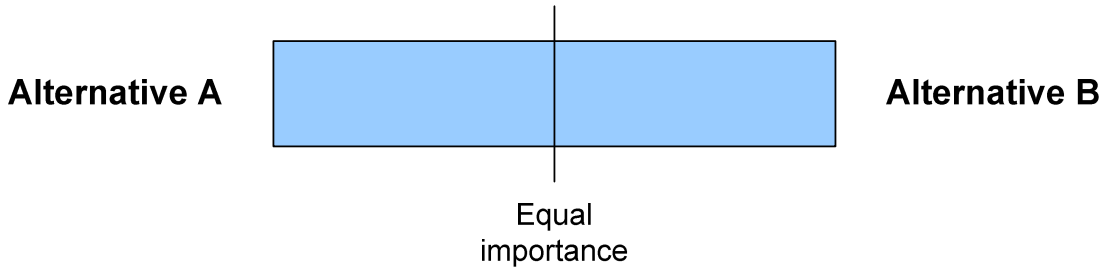


Figure 8 - Visual judgment

pmColNet users will simply click and drag a bar, starting at "Equal importance", dropping it at the exact point they feel the visual relation correctly manifests their importance judgement.

To maximize system consistency and minimize the number of judgments, when comparing Alternative A to Alternative B, users will be automatically comparing (with the inverse punctuation) Alternative B to Alternative A.

Behind the visual system, there is a five degree scale, which is derived from AHP fundamental scale[9] (Saaty 1990:15):

[9] See 5.1.

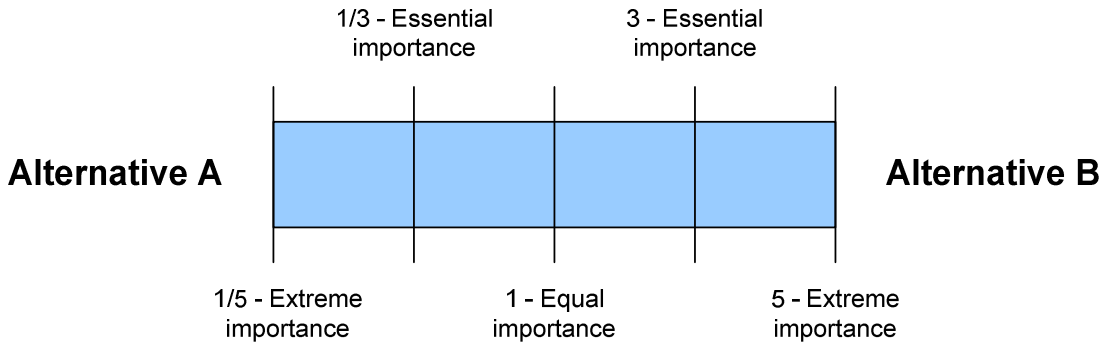


Figure 9 - Quantitative visual judgment

This numeric scale will be used to calculate and order partner's intensity of preferences at the aggregation stage. Note that the system will use a continuous numeric scale to compute the pairwise judgment. The left side of the scale is the inverse of the right side of the scale, wich means the middle point between "1/5 – Extreme importance" and "1/3 – Essential importance" corresponds to the inverse of 4 (middle point between "3 – Essential importance" and "5 – Extreme importance"), which is 1/4.

5.2.3. Aggregating preferences

5.2.3.1. Method

Network partners are considered a panel of experts, rating each alternative regarding the objective of building the best performance model, using AHP (see 3.4.2 and 5.1).

As explained before, partners will rank HFPA alternatives using a 5 degree visual judgment.

Using eigenvectors of the reciprocal matrices obtained, alternatives will be ranked. Nevertheless, final decision will ultimately be delivered with a final partners' meeting, where interaction and negotiation will prevail over AHP. Partner's "final meeting" will have preponderance over the pmColNet decision advice.

5.2.3.2. Vote power

"Usually[10], all the experts have the same weight, but in certain applications each expert can have a coefficient of importance. (...) [This] may be interpreted as the degree in which that individual is really a decision maker relative to the decision problem, or it can be viewed as the power (degree of importance, competence or ability) of his opinion." Marichal (1999:6).

This particular parameter is very adequate to real situations; nevertheless it is difficult to negotiate it in a transparent and open way.

pmColNet will promote vote power definition and negotiation. If this feature is not used, partners will be considered as having equal vote power.

Vp_i – vote power of network member i;

$$\sum_{i=1,\ldots,n}^{n} Vp_i = 1$$

Partners will conduct an anonymous voting procedure to define vote power distribution.

Each partner will have 2 votes. First vote may be attributed to himself or any other network partner. Second vote may only be addressed to other network partners (he/ she cannot vote for himself).

pmColnet will count the votes and attribute vote power:

$vote_i$ – a vote in network member i;

$$Vp_i = \frac{\sum vote_i}{\sum votes}$$

[10] The term "usually" refers to models analysed by Marichal. In real life networks, it is easier to accept the idea that partners do not have the same vote power within network organisations.

5.3. Resuming pmColNet Phases

pmColNet decision support model will have several sequential phases. The model is designed with a special emphasis in partner interaction and "decision overriding". This means that pmColNet results, as indicating in a certain way, or using certain performance elements may be contradicted by network members applying any different method at any phase. pmColNet should have the ability to incorporate this "manual" network decision and carry on to the next phase. In fact, every network decision will be supported by the structured pmColNet suggestion and by an un-structured partners' meeting, where the partners can freely discuss and achieve a different path of the structured proposal.

Other aspect of the model resides in its flexibility towards the chosen method to measure partner preferences. We will purpose and defend a particular multi-criteria method, but pmColNet will be flexible enough to incorporate a different approach without losing its main objective: to facilitate the performance model design.

Description	Method/ characteristics
Phase A – Contextualisation I. Initial setup II. Partner's individual performance model III. Network typology IV. Defining vote power	Web form/ PROMETHEE GDSS framework Tree structure Private folder HFPA Commitment level
Phase B – Partner's proposals	HFPA
Phase C – Measuring preference intensity	Visual pairwise judgment AHP Veto threshold

Phase D – Negotiating and achieving a commitment package I. Network global commitment level II. Defining failure and success III. Levels of analysis IV. Performance relationships V. Index construction	Weighted Arithmetic Mean Index construction
Phase E – Monitoring performance I. Normalising indicators and achieving a dashboard/ *tableau de bord* II. Ideal performance – TOPSIS III. Relationship between individual and network performance model	Normalisation TOPSIS

Table 2 - pmColNet phases

The MCDM performance model should be distributed in a Web form page using PROMETHEE GDSS framework (see 3.3.1.2). This means it can be used directly by network players, without any kind of consultant help, which maximizes the model reach and its usability. A user-friendly graphical interface and the use of Internet "permits a wider range of users, (…) asynchronous communication (…) and a larger number of participants (…)." Zahir and Dobing (2002:50)

5.4. Phase A – Contextualisation

As seen in previous chapters, performance management and especially network performance management is a highly contextualised task. In spite of pmColNet's flexibility it is vital to correctly describe the network and its partners, so that the performance model is suitable for that situation and maximizes the constructivist approach.

5.4.1. (I) Initial setup

Each network partner has a folder with private information about the organisation type. A tree structured assistant interface should present the questions so that standard data from organisation typology can be collected and stored:

- Profit or non-profit organization
- Number of employers
- Industry
- Assets value
- Revenue value
- (…)

This information should be private and only accessed by the organisation.

5.4.2. (II) Partner's individual performance model

Information regarding each of the partners' individual performance models will also be collected. Such information should include performance data and metrics that are used in the organisation's business performance management system.

Information must be entered according to the HFPA described in section 3.1, capturing each organisation's objectives, criteria and indicators[11]. Multiple perspectives are welcome.

At this stage, the organisation must choose a metric that represent the level of commitment with the network.

The commitment level will be an important element to perform the connection between the individual and the network performance model. Such indicator should represent the resource allocation effort towards the network, for instance:

[11] See Scenario #1 at section 5.9.1 for some examples.

- Human resources hours, within the organisation, allocated to the network project / total human resource hours within the organisation;
- Network investment value by the organisation / total investment by the organisation;
- (...)

It is recommended that the commitment level should be measured by a ratio using an individual performance model indicator in the denominator. This guarantees that the commitment level is being measured by a really important indicator.

If the organisation wants to use a composed indicator to measure the commitment level, it is necessary to use visual pairwise judgments and aggregation, as previously defined.

5.4.3. (III) Network typology

Network typology is related with two particular characteristics:

- Type of interorganisational governance, according to Todeva and Knoke (2005:124-125):
    - Strategic cooperative agreements
    - Hierarchical relations
    - R&D consortia
    - Joint ventures
    - Equity investments
    - Cooperatives
    - Licensing
    - Franchising
    - Cartels
    - Action sets
    - Subcontractor networks
    - Industry standards groups
    - Market relations

- Type of network regarding its objective, according to Carneiro *et al.* (2007:16):
    - Operational synergies network
    - Technological/ functional synergies network
    - Strategic synergies network

These characteristics should be listed to each network partner for individual selection within the private contextualisation folder. If there are discrepancies between partner responses, visual pairwise judgment and preference aggregation will be used. Only the preferred will be used.

At this stage, network main objective will also be defined. Supposedly, in real life situations, partners already have discussed the network main objectives. So, partners define the objective at this stage. If there are discrepancies between partner responses, visual pairwise judgment and preference aggregation will be used. Several objectives can be selected.

In future projects the decision support platform may advise partners according to network typology and individual characteristics or even retain some constructivist learning capability. This predictive feature is excluded from this work.

5.4.4. (IV) Defining vote power

Vote power, as described at section 5.2.3.2 will be determined in this phase.

5.5. Phase B – Partner's proposals

At this phase each of the network partners proposes alternatives regarding the HFPA elements:

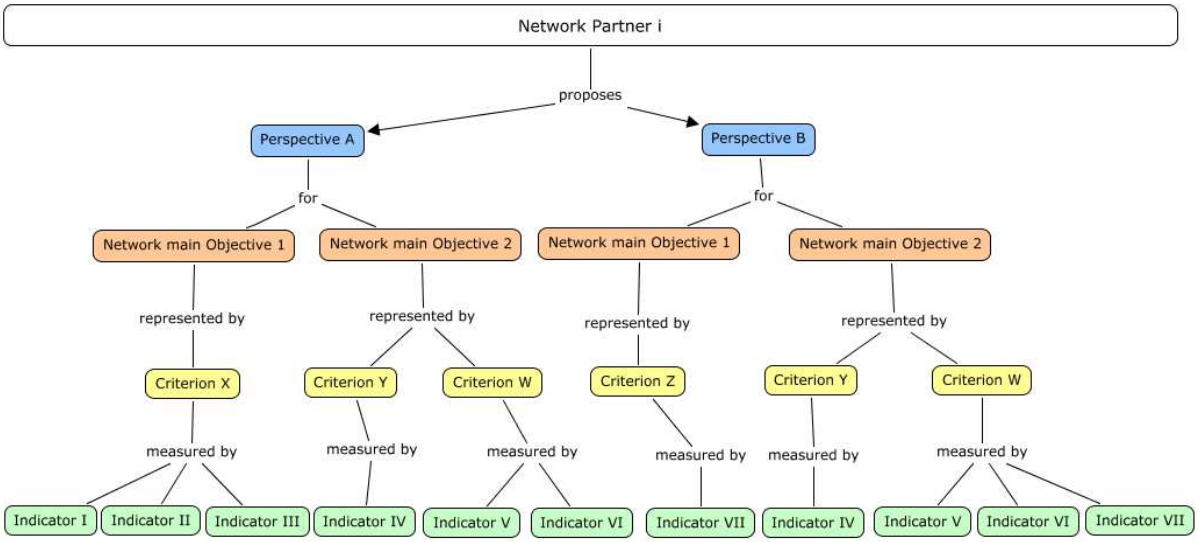


Figure 10 - HFPA partner's proposals

These alternatives should generally manifest the partner perspective of the network main objective and the best way to measure its performance.

A partner can propose several different alternatives for each of the network main objectives. If he does so, he must evaluate the several alternatives obtaining an ordered list according to its preferences and using the visual pairwise judgments and aggregation methods previously explained.

Each HFPA's element may have a description field and indicators must have additional scaling description, so that every partner correctly understands the proposal.

It is desirable that pmColNet system presents some standard alternatives regarding each of the HFPA elements. At this point, Neves's (2009) work will be used.

An example:

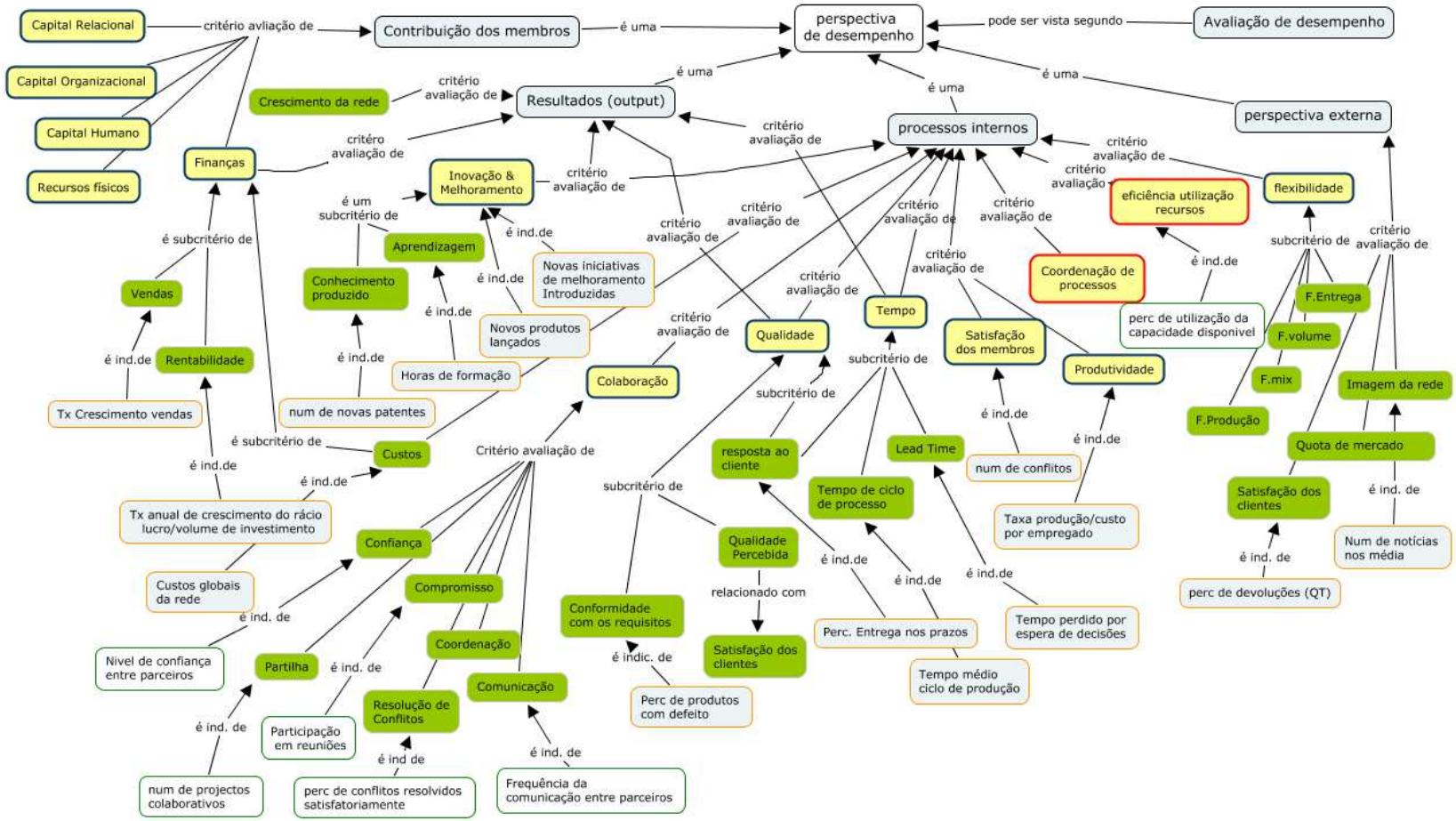


Figure 11 – Neves' (2009:119) performance information conceptual map example

5.6. Phase C – Measuring preference intensity

This phase can only begin when there are at least two partners that have already completed phase B.

Resulting from visual pairwise judgments (as defined in 5.2.2) and preference aggregation, an ordered list of perspectives will be obtained, representing partner's vision towards the network performance model.

Example:

Perspectives order	Global priorities	Accumulated preference	Veto threshold
D	0,45	0,45	
F	0,30	0,75	Accumulated preference reaches 75%. Possible excluded alternatives:
A	0,15	0,90	Possibly excluded
B	0,10	1	

Table 3 - Example of perspectives order and veto threshold

pmColNet will present the ordered list and identify the veto threshold. Indifferent perspectives will not be ordered, having equal global priorities will result in inclusion or exclusion based on the others global priorities.

For the purposes of this work, veto threshold is the level of accumulated preference (resulting from the preferences aggregation ranking) from which all alternatives below are suggested, by pmColNet, to be excluded from the performance model[12].

[12] This concept is based on the ELECTRE methods discrimination thresholds, in spite of the differences between the two. In ELECTRE methods, discrimination thresholds (including veto thresholds) are used to outrank alternatives. In pmColNet, veto threshold is only applied after the alternatives ranking is done.

The veto threshold is calculated taking into account the vote power of the most and the least powerful members of the network:

Vp_M – vote power of the most powerful network member (resulting from 5.2.3.2 election procedure);

Vp_l – vote power of the least powerful network member;

VT – veto threshold.

$$VT = 1 - (\frac{Vp_M + Vp_l}{2})$$

Using the extreme vote power values and achieving its medium point to calculate the veto threshold we promote a sense of an "inclusive decision":

- When all partners have the same vote power, the veto threshold will "exclude" the alternatives that only have the support of one member. Because,

  $VT = 1 - Vp_i$.

- When the extreme vote power levels are very distant, veto threshold tends to be smaller, with the minimum level of 0,50 (when $Vp_m \approx 0{,}99$ and $Vp_l \approx 0{,}01$).

These situations will be further addressed at the 5.9 Scenarios section.

To complete this stage, the system will promote a partners meeting to conclude the perspectives selection.

Note that at this meeting, partners can decide to rollback the process and start over again contextualisation phase or just initiate new partner's proposals phase. For instance, partners may want to elaborate a new perspective that combines elements from different proposals.

Again, importance of interaction is greater than rigid method application.

After the perspectives choice, each of the winning perspective criterion is compared in the same pairwise procedure, respecting vote power and obtaining its relative importance in the final network performance model.

5.7. Phase D – Negotiating and achieving a commitment package

Arriving at this phase, network partners have already decided which HFPA best represents the network performance model, note that can be one, two, or several different perspectives and criteria relative importance within the performance model.

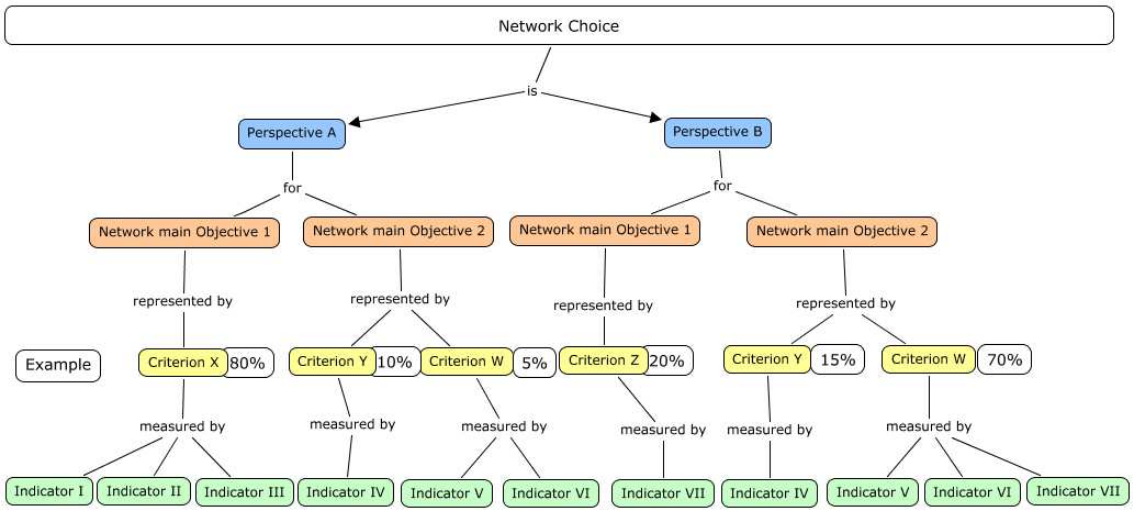


Figure 12 - Network HFPA example

Resuming, the network main objectives are defined; criteria and indicators are chosen.

It is now important, within the business performance model, to organise several metrics to help monitoring network performance.

Key elements at this phase are:

I. Network global commitment level

II. Defining failure and success

III. Perspectives as levels of analysis

IV. Performance relationships and expected evolution

V. Index construction

5.7.1. (I) Network global commitment level

Commitment level concept was introduced at 5.4.2; it measures the degree of investment of partners in the network.

Cl_i – commitment level of partner i;

CL – network global commitment level.

Being Cl_i a ratio, we can simply define CL as the arithmetic mean of Cl_i. This data is only informational, thus partners that have a higher commitment level than the average may want to push other members relative investment.

Other argument to maintain this data with information only purpose, is that partners have little control over the veracity of commitment level declared by their colleagues[13].

Nevertheless, network members will know the global commitment level and if performance is under their objectives, this may indicate that higher commitment levels are necessary. In fact, at long term relationships, correlation between commitment level and performance level can be analysed.

5.7.2. (II) Defining failure and success

Members will define failure and success limits for each chosen indicator.

As will be further explained below, defining failure and success limits for HFPA will bring several advantages:

- direct comparison between different indicators;

- aggregation procedures used in index construction;

[13] Note that each organisation's commitment level is private (at the contextualisation folder) and it influences the relationship between individual and network performance model, thus partners have some advantage to reveal the real investment effort.

- dashboard/ *tableau de bord* construction.

An indicator will be at successful level when it permits to attain network main objectives. On the contrary, failure level indicates that network main objectives won´t be attained.

Using the pmcolNet's Web interface, all partners propose failure and success limits for all HFPA chosen indicators. Then, pmColNet will submit for a partners meeting the lowest value proposed to be the failure limit and the highest proposed value to be the success limit.

As usual, partner's decision is sovereign.

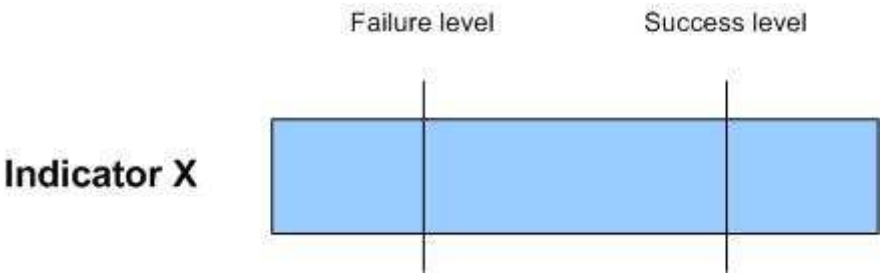


Figure 13 - Defining each indicator's failure/ success limits

5.7.3. (III) Levels of analysis

As referred at chapter 4, in Neves's (2009) information model, we can have different levels of analysis towards the collaborative network performance system:

- Evaluation level (or evaluation object): may be individual, organisation, network and community. Criteria may refer to different evaluation levels.
- Evaluation perspective;
- Criteria.

The evaluation perspective may be addressed in several **facets**, different mutual exclusive dimensions, of network performance management:

- Evaluation perspective: partner's contribution (input), internal network processes, results (output) and external perspective (clients and other stakeholders).

- Evaluation criteria:
    - Collaboration: commitment, coordination, trust, sharing and conflict resolution;
    - Network growth;
    - Processes coordination;
    - Efficiency in using resources;
    - Finance: sales, profitability and costs;
    - Flexibility: mix, production, delivery and volume;
    - Network image;
    - Innovation: learning and produced knowledge;
    - Productivity;
    - Quality: client response, perceived quality and requirements compliance;
    - Market share;
    - Time: process cycle, lead time and client response;
    - Client's satisfaction;
    - Partner's satisfaction;
    - Relational capital;
    - Human capital.
- Management level: strategic, tactical, operational.

As an example of input, process, output, facets perspective we may refer Parung and Bititci (2006) model:

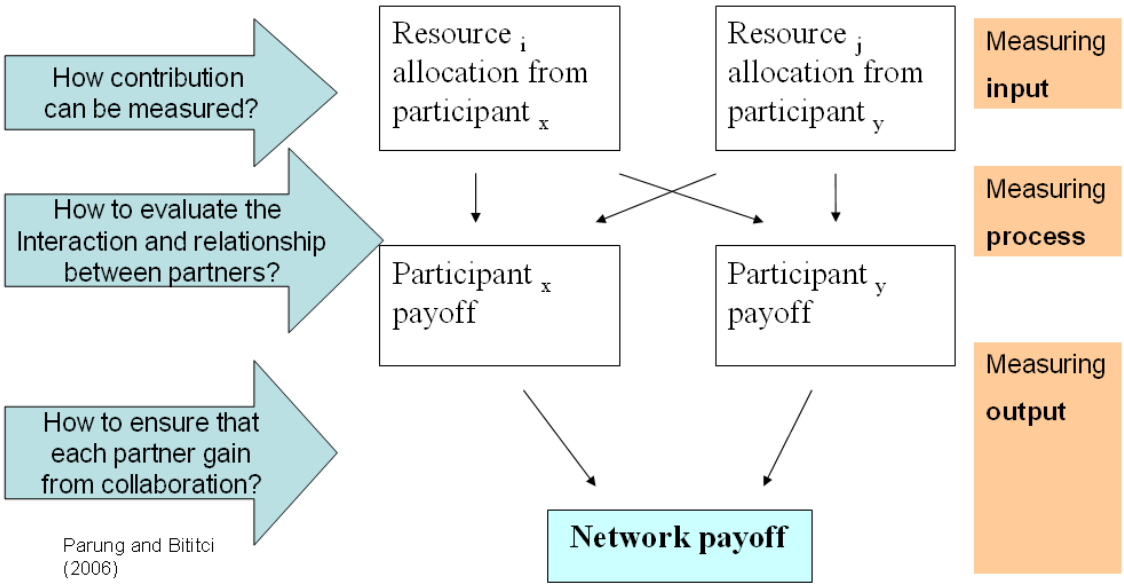


Figure 14 - Parung and Bititci (2006) adapted performance model

These levels of analysis may be constructed relating certain HFPA perspectives. As we will see at the next section, pmColNet will help network partners to construct performance relationships with different HFPA perspectives.

5.7.4. (IV) Performance relationships

Performance relationships are like puzzling different HFPA perspectives and levels of analysis.

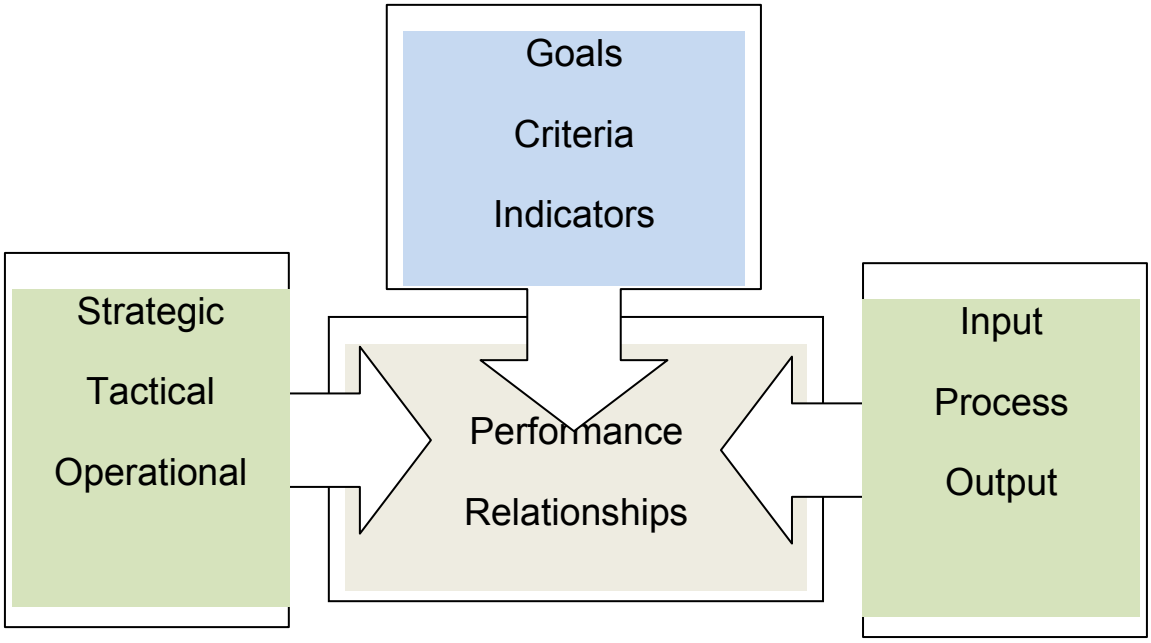


Figure 15 - Puzzling Performance relationships

At this phase, partners are encouraged to associated the chosen HFPA perspectives with several levels of analysis (some examples will be available, but partners can create different ones).

The objective is to create a sequential path with the perspectives. For example:

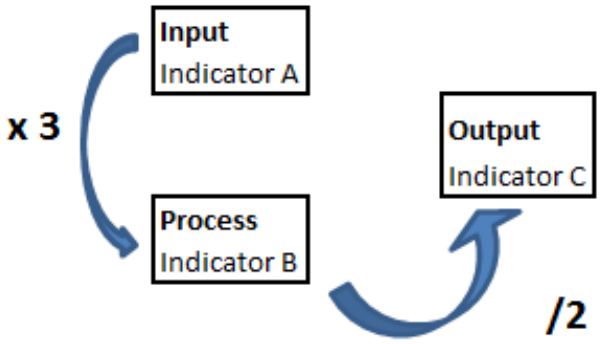
Input perspective → Process perspective → Output perspective

pmColNet will try to establish relationships between input indicators and process indicators, producing data that can improve network efficiency. The performance model should also relate indicators according to its expected evolution and correlation with other indicators.

> "the established links between overall and elementary performance expressions allow explanation and diagnosis of the objective's satisfaction according to the different reached performances, leading thus to choose or launch improvement actions. More precisely, it is well known that one challenge of control is to identify "coalitions" of improvement between different areas in as efficient as possible way." Berrah and Clivillé (2007:709)

These "productivity ratios" (Berrah and Clivillé 2007:710) between indicators, other indicators and objectives should be entered by the network partners and then confronted with periodically gathered performance data.

Example:



These relations may also be seen as substitution rates, especially when we are analysing indicators from conflicting criteria.

5.7.5. (V) Index construction

Using relative weighting and normalised indicators, various performance indices can be constructed and presented in a dashboard/ *tableau de bord* display.

For this purpose several techniques can be used, for instance the weighted arithmetic mean. For relative weights one can use an objective weighting process[14] (Deng *et al.* 2000) or subjective weighting, using partners meetings.

Indices can relate to different HFPA perspectives, represent levels of analysis or even a combination of them.

A particular case of the index construction is the combination of individual/ network performance, described in the next section, using commitment level for relative weighting.

[14] At the next section we will see an application for this method.

5.8. Phase E – Monitoring performance

5.8.1. Normalising indicators and achieving a dashboard/ *tableau de bord*

Suppose network participants want to monitor, regarding an innovation criteria perspective, "new brainstormed ideas per week".

Once negotiating the commitment package, partners have decided that an average of 10 new ideas per week would mean success. Otherwise, 3 ideas per week would mean network failure.

If the number of monitored ideas in a given week is 9, the indicator would be:

$$\frac{9-3}{10-3} = 86\%$$

Therefore, with every indicator (regardless whether the objective is to maximize or minimize the indicator), we should use:

$$\frac{failure - x}{failure - success} = normalised\ indicator$$

Where, x represents the observed value of the indicator in a certain period and success/ failure represent the negotiated objectives to the specific indicator.

Applying the normalising expression, participants will obtain all their performance indicators in an equal scale, which present several advantages, for instance direct comparison and index construction.

If the normalised indicator is greater than 1, the network is surpassing the success objective. Otherwise if the normalised indicator is lesser then 0, the network is performing below failure level. When the normalised indicator is between 0 and 1, network is performing within failure and success limits.

We can then use the previously determined criteria relative importance, to construct indices, using the weighted arithmetic average (see the scenario section for more details).

The dashboard/ *tableau de bord* is a very useful information management tool. It is very popular in real world businesses because a simple glimpse can rapidly show a

business performance. In collaborative networks and particularly in pmColNet, a dashboard is essential to monitor the network performance.

Dashboard potential can be maximized if the performance relationships previously referred are constructed.

5.8.2. Ideal performance - TOPSIS

Suppose network performance was at success limit for all the chosen indicators of the HFPA – this is the ideal situation. Now, suppose network performance was at the failure limit for all the chosen indicators – this is the anti-ideal situation.

TOPSIS stands for Technique for Order Preference by Similarity to Ideal Solution and it is a multi-attribute utility theory method whose concept "is that the most preferred alternative should not only have the shortest distance from the positive ideal solution, but also have the longest distance from the negative ideal solution" (Deng *et al.* 2000:964).

We are interested in the concept to build a benchmark for monitoring the network performance. The objective is similar to the explained use of the normalised indicators and indices, but the calculus are more complex, because weighted Euclidean distances need to be obtained, to capture the distance between each indicator real performance and its ideal/ anti-ideal point.

At the ideal point, when all indicators are at the top (success limit), pmColNet may calculate the ideal productivity ratios/ substitution rates for indicators relations which will set a benchmark for performance relationships. This procedure should however be dealt with care, because scaling affects results and in some situations, results may be absurd or meaningless for some pairs of indicators. It is safer to calculate substitution rates (by definition) for two observed performance measures:

Being x_i the measurement of indicator x for period i and y_i the measurement of indicator y for period i, substitution rate (SR) will be:

$$SR = \frac{x_{i+1} - x_i}{y_{i+1} - y_i}$$

5.8.3. Relationship between Individual and Network performance model

It is expected that the pmColNet performance model can manage and integrate a partner's individual performance model, which means some form of relationship between the organisation individual performance model and the network performance model.

The commitment level, as said before, will be an important indicator to perform the connection between the individual and network performance model. Such indicator should represent the resource allocation effort towards the network.

It is also important that network partners negotiate the desirable network commitment level for everyone, which supposedly maximizes the network potential.

Commitment level can be determined by only one indicator or more complexly, by several indicators, using the previously explained procedures at section 5.4.2.

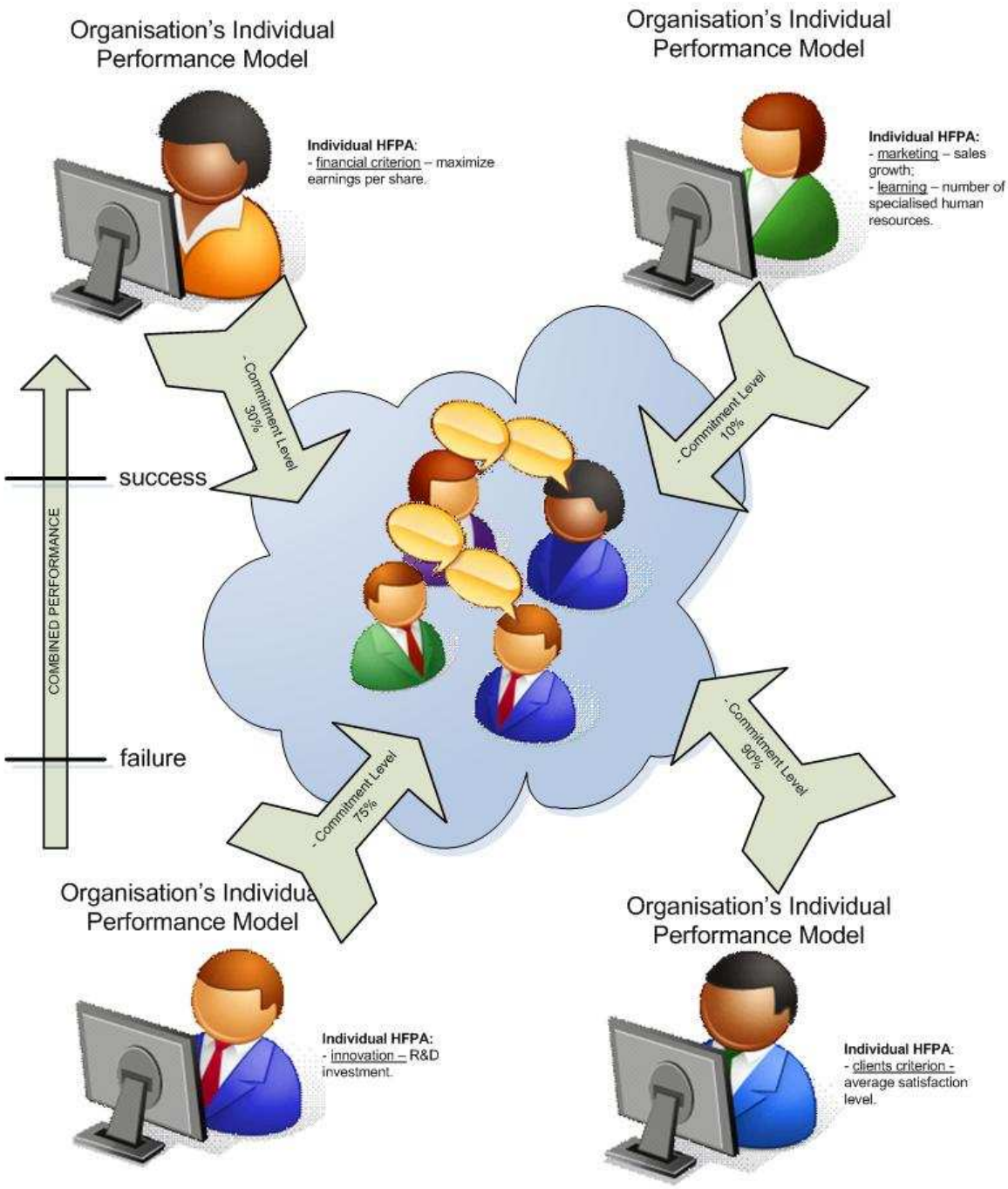


Figure 16 - The link between organisation and network performance model

Ahead we will detail an example of this relationship, but the objective is to aggregate the normalised organisational performance indicators, with the normalised network performance indicators. The aggregator will be the weighted arithmetic mean, recurring to commitment level and obtaining a final index:

I_o – individual normalised performance index;

C_l – organisation commitment level to the network;

I_n – network normalised performance index;

CPI_i – combined performance index for network partner i.

$$CPI_i = (1 - C_i) \times I_o + C_i \times I_n$$

5.9. Scenarios

5.9.1. Scenario #1

Three organisations will start this year a new collaborative project:

- Scenario Business School (BS);
- Technology SME (SME);
- Industry Scenario Association (Assoc).

These three organisations are used to collaborate in past projects and have achieved their objectives in a satisfactory way. Nevertheless, in spite of the institutional trust they deposit in each other, they wish to improve their collaborative network efficiency, starting to monitor their performance through the prototype pmColNet model.

The project

The project final objective is to build a logistic planning information system adapted to the scenario industry.

A I – Initial setup

The Scenario Business Scholl is a business school with non-profit purposes. It has 100 employees.

BS is estimating a 100.000 euros / 2.500 investigation hours investment in the project.

Total investment in concurrent areas is 600.000 euros / 10.000 investigation hours.

Technology SME is a privately held company with profit objectives. It employs 10 workers.

SME is estimating a 30.000 euros / 3.000 hours investment in the project.

Total investment in concurrent areas is 50.000 euros / 6.000 hours.

Industry Scenario Association is a privately held business association with non-profit purposes. It has 40 employees.

Assoc is estimating a 60.000 euros / 4.000 hours investment in the project.

Total investment in concurrent areas is 90.000 euros / 6.000 hours.

A II –Partners' individual performance models

BS – individual HFPA

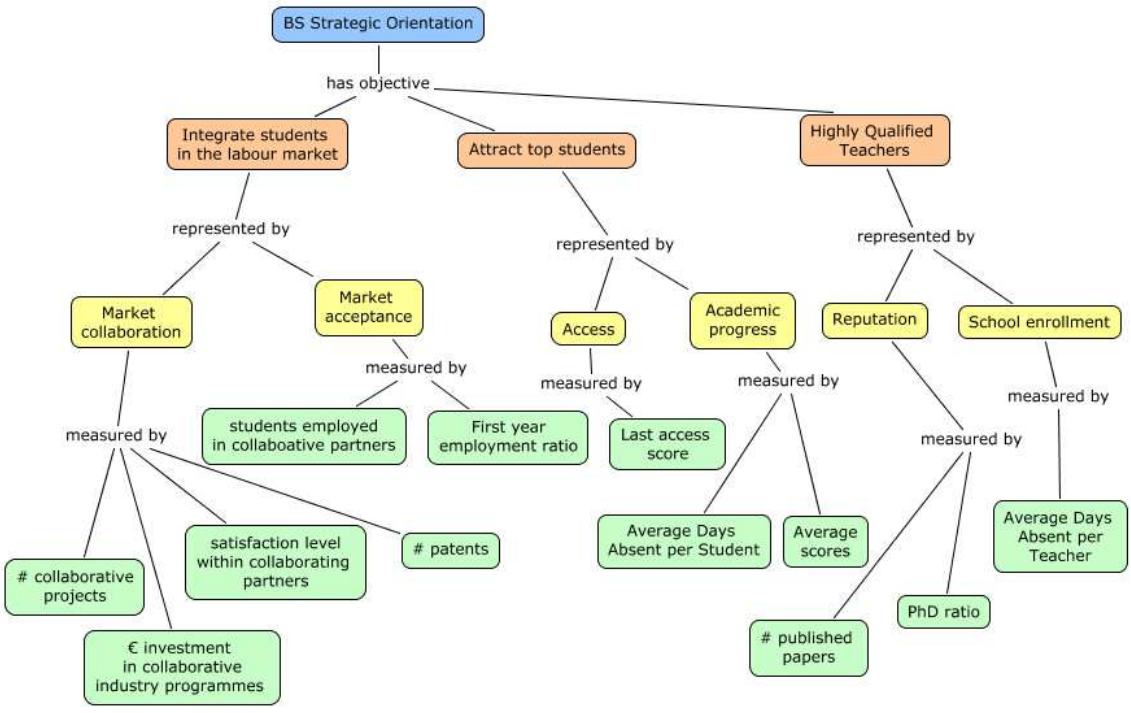


Figure 17 - Scenario #1: BS individual HFPA

Inspiration from Chicago Public Schools (2005?).

SME – individual HFPA

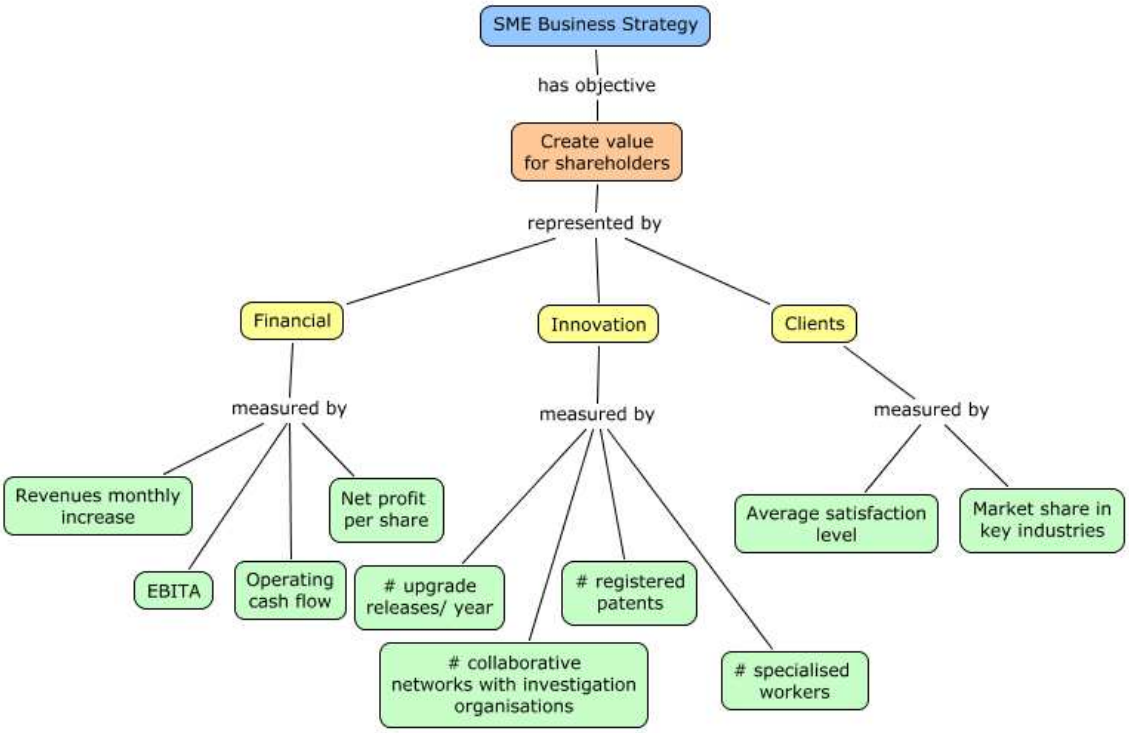


Figure 18 - Scenario #1: SME individual HFPA

Assoc – individual HFPA

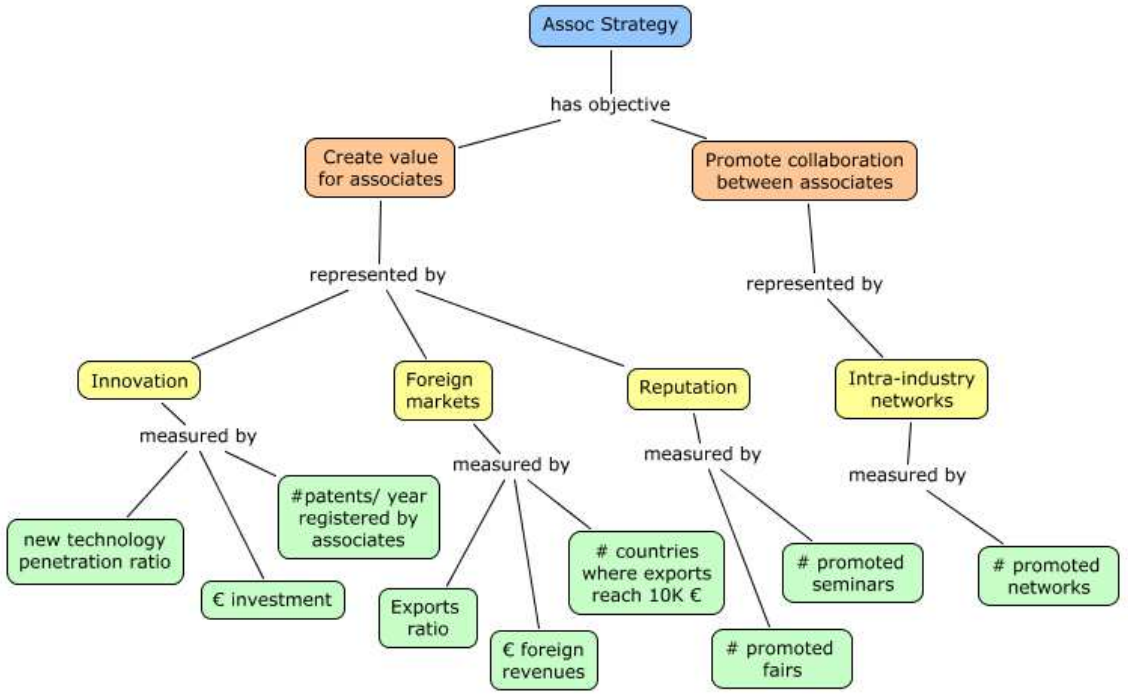


Figure 19 – Scenario #1: Assoc individual HFPA

To define commitment level, the three organisations choose simple indicators that are present in some individual performance models: investigation hours and money invested.

Commitment level	BS	SME	Assoc
% allocated investigation hours	2.500 / 10.000 = **25%**		
% allocated investment		30.000 / 50.000 = **60%**	60.000 / 90.000 = **67%**

Table 4 - Scenario #1 Commitment level

A III –Network typology

Type of interorganisational governance:

strategic cooperative agreements – "contractual business networks based on joint multi-party strategic control, with the partners collaborating over key strategic decisions and sharing responsibilities for performance outcomes." (Todeva and Knobe 2005:125)

Type of network regarding its objective:

Technological/functional synergies network – a network of organisations that collaborate to obtain functional synergies in support chain value areas: such as R&D, marketing and logistics (Carneiro *et al.* 2007:16).

Network main objective:

As said before, the project final objective is to build a logistic planning information system adapted to the scenario industry. All partners agree on that.

A IV –Vote power

Partners	First vote	Second vote	Vote power
BS	BS	Assoc	50%
SME	SME	BS	16,67%
Assoc	Assoc	BS	33,33%

Table 5 - Scenario #1: Vote power

Veto threshold will be: VT = 1 – [(50% + 16,67%) / 2)] = 66,67%

B – Partner's proposals

<u>BS – network HFPA</u>

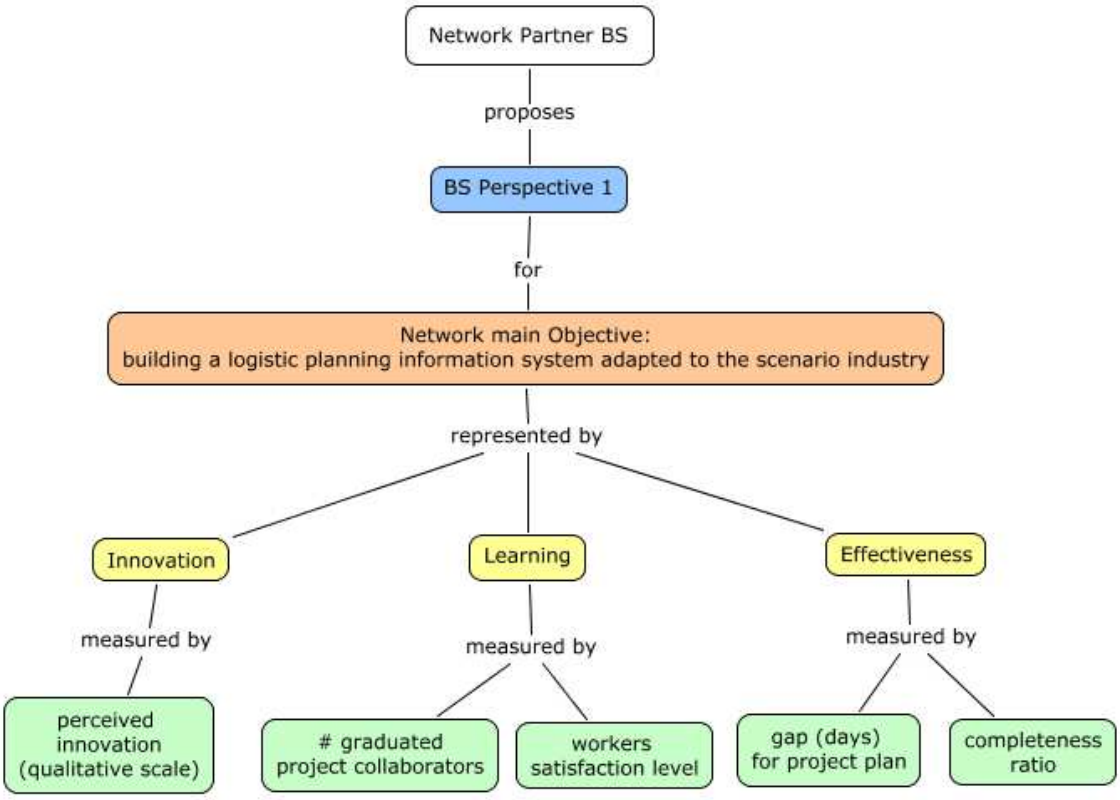


Figure 20 - Scenario #1: BS network HFPA proposal

SME – network HFPA

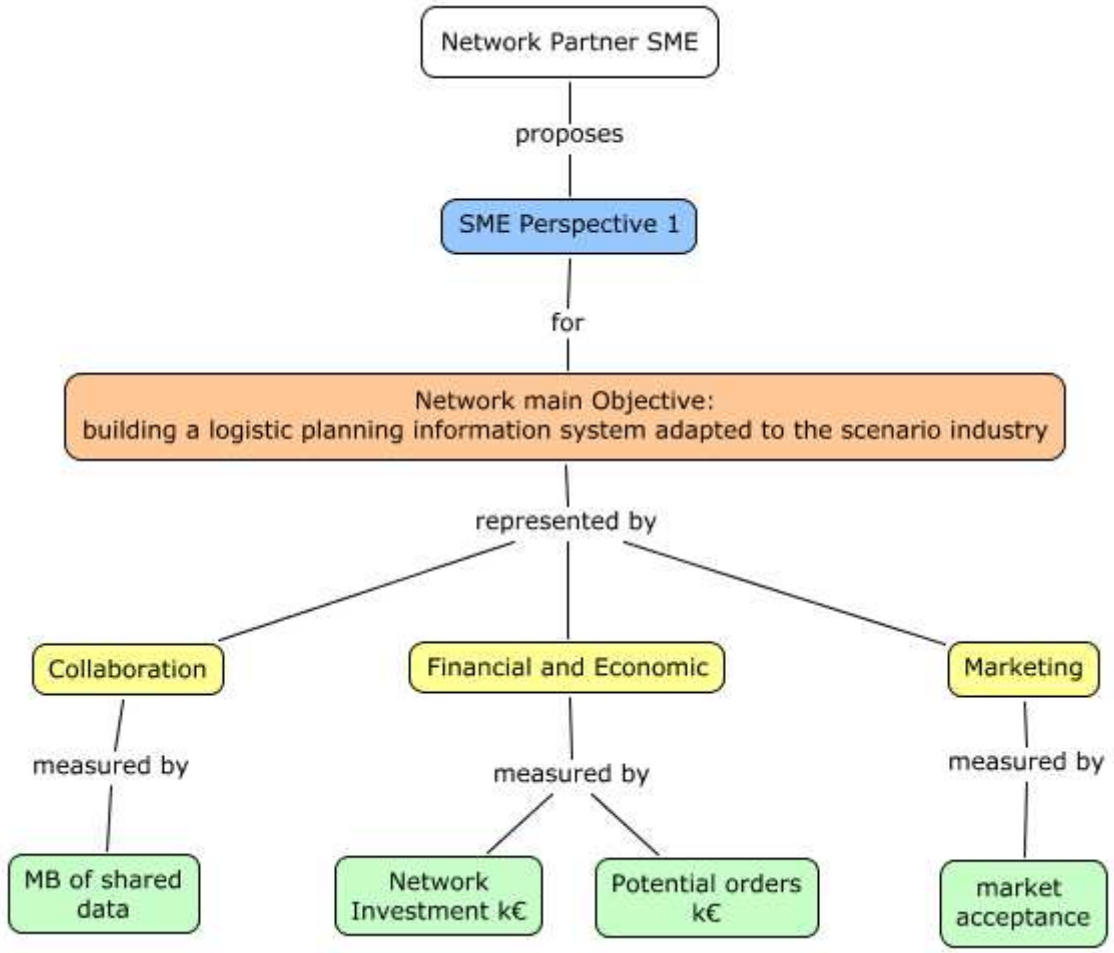


Figure 21 - Scenario #1: SME network HFPA proposal

Assoc – network HFPA

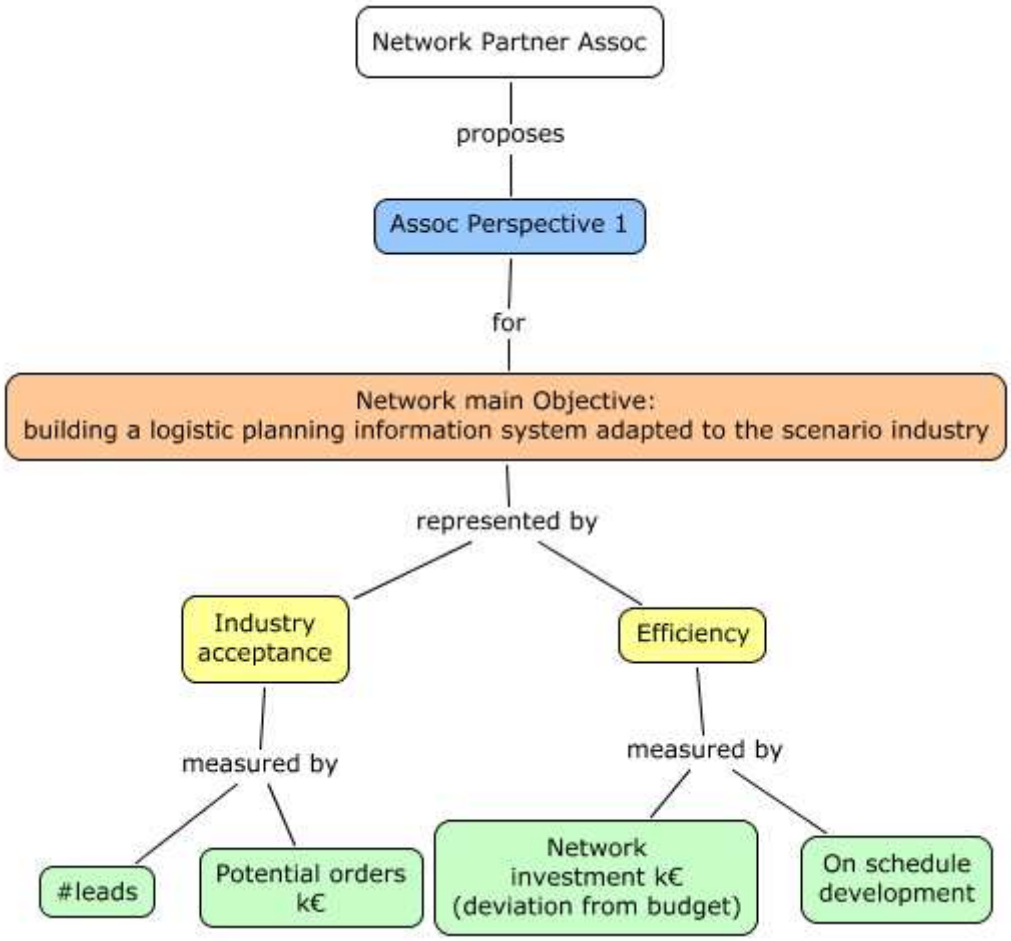


Figure 22 - Scenario #1: Assoc network HFPA proposal

Each HFPA's element may have a description field and indicators must have additional scaling description.

C – Measuring preference intensity

Each partner evaluates the different HFPA on a pairwise visual judgement as defined in section 5.2.2.

The following figures represent the measuring preferences:

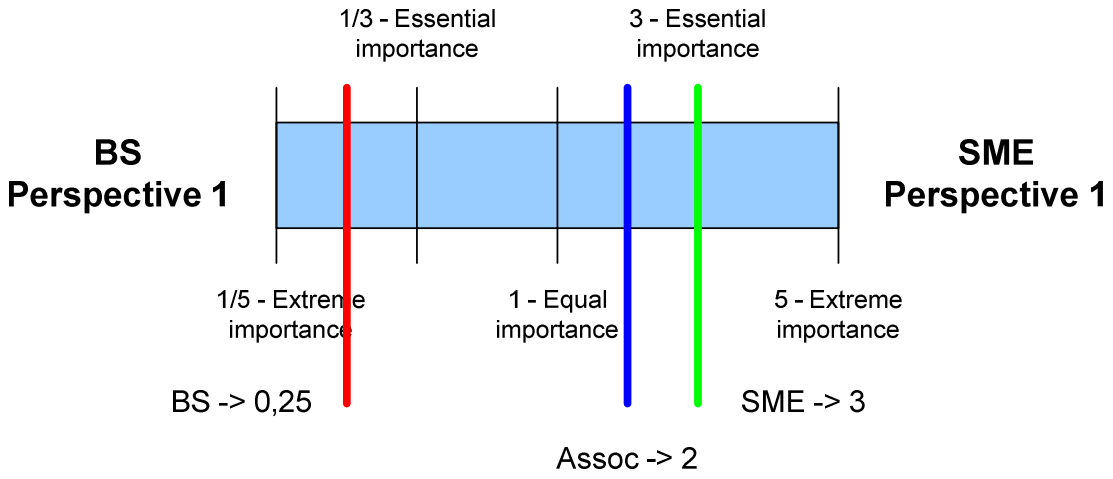


Figure 23 - Scenario #1: BS/SME perspectives pairwise judgement

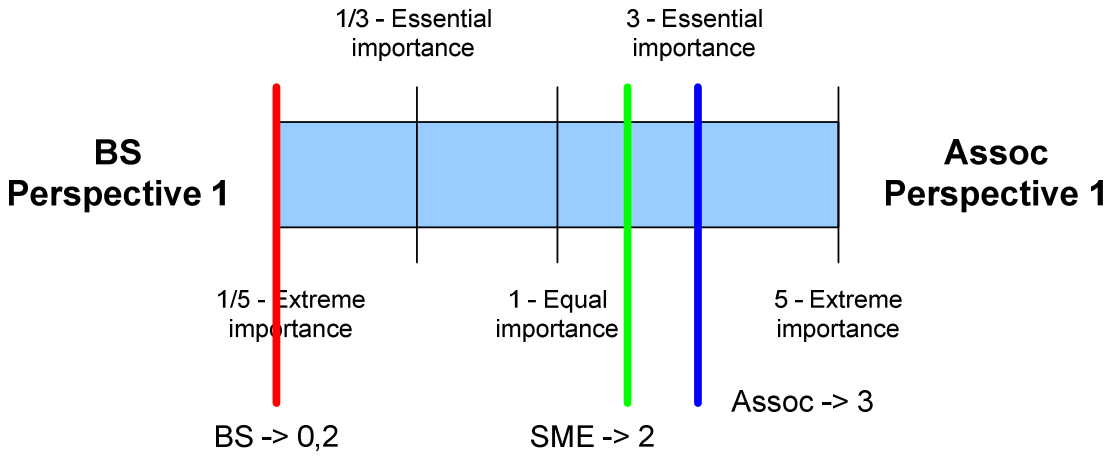


Figure 24 - Scenario #1: BS/Assoc perspectives pairwise judgement

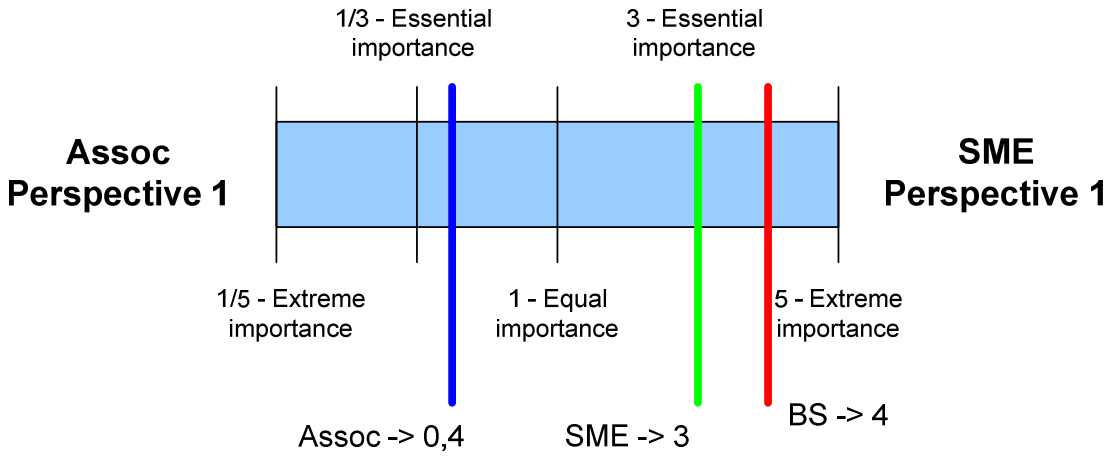


Figure 25 - Scenario #1: Assoc/SME perspectives pairwise judgement

Applying AHP methodology and defined vote power:

BS	BS HFPA 1	SME HFPA 1	Assoc HFPA 1	Priority Vector
BS HFPA 1	1,00	4,00	5,00	0,65
SME HFPA 1	0,25	1,00	4,00	0,25
Assoc HFPA 1	0,20	0,25	1,00	0,10
	1,45	5,25	10,00	1,00

Table 6 - Scenario #1: BS pairwise comparisons

Note that we can calculate consistency tests for each network partner, and if consistency is not acceptable, propose repetition of pairwise comparison. In this case:

Priority Vector (P)	Weighted Sum Vector (W)	W / P
0,65	2,14	3,30
0,25	0,80	3,14
0,10	0,29	3,03
1,00	**Average**	**3,16**

Table 7 - Consistency index auxiliary calculus

n= 3

Consistency index (CI) = (3,16 – 3) / (3 – 1) = 0,08

Random index (RI) is Saaty's random judgments control index, used to compare with CI. For n = 3, RI = 0,58.

Thus Consistency ratio (CR) = 0,08 / 0,58 = 0,134, which is bigger than 0,10 Saaty's limit for consistency, meaning that this partner has some inconsistency in its judgments.

At this point, pmColNet may advise the Business School to repeat its pairwise comparisons.

SME	BS HFPA 1	SME HFPA 1	Assoc HFPA 1	Priority Vector
BS HFPA 1	1,00	0,33	0,50	0,16
SME HFPA 1	3,00	1,00	3,00	0,59
Assoc HFPA 1	2,00	0,33	1,00	0,25
	6,00	1,67	4,50	1,00

Table 8 - Scenario #1: SME pairwise comparisons

SME's consistency ratio is 0,04 (below 0,10) which means its comparisons have been consistent.

Assoc	BS HFPA 1	SME HFPA 1	Assoc HFPA 1	Priority Vector
BS HFPA 1	1,00	0,50	0,33	0,16
SME HFPA 1	2,00	1,00	0,40	0,27
Assoc HFPA 1	3,00	2,50	1,00	0,57
	6,00	4,00	1,73	1,00

Table 9 - Scenario #1: Assoc pairwise comparisons

Assoc consistency ratio is 0,04 (below 0,02) which means its comparisons have been very consistent.

The last matrix before final global priorities:

Perspectives	BS	SME	Assoc
BS HFPA 1	0,65	0,16	0,16
SME HFPA 1	0,25	0,59	0,27
Assoc HFPA 1	0,10	0,25	0,57
	1,00	1,00	1,00

Table 10 - Scenario #1: priority vectors

Defined partner's vote power and veto threshold:

Vote power		**Veto threshold**
BS	0,50	0,67
SME	0,17	
Assoc	0,33	
	1,00	

Table 11 - Scenario #1: vote power matrix

Final global priorities:

Perspectives	Score	Accumulated preference	**Veto threshold**
BS HFPA 1	0,41	0,41	
SME HFPA 1	0,32	0,72	0,67
Assoc HFPA 1	0,28	1,00	
	1,00		

Table 12 - Scenario #1: final global priorities matrix

To simplify the scenario, partners accept the decision (not deciding to rollback the process proposing new perspectives). The Assoc HFPA 1 was out of the veto threshold and therefore was excluded from the final network performance model.

Next, partners evaluate criteria of the two winning perspectives, once again applying visual pairwise judgements and AHP. For convenience purposes, we will skip visual judgements and show only AHP matrixes.

Vote power is considered for final aggregation procedure:

BS	BS Innovation	BS Learning	BS Effectiveness	SME Collaboration	SME Financial and Economic	SME Marketing	
BS Innovation	1,00	1,00	1,50	3,00	4,00	3,50	0,27
BS Learning	1,00	1,00	2,00	1,50	5,00	4,50	0,27
BS Effectiveness	0,67	0,50	1,00	1,00	3,50	4,00	0,17
SME Collaboration	0,33	0,67	1,00	1,00	5,00	4,00	0,18
SME Financial and Economic	0,25	0,20	0,29	0,20	1,00	0,33	0,04
SME Marketing	0,29	0,25	0,25	0,25	3,00	1,00	0,07
	3,54	3,62	6,04	6,95	21,50	17,33	1,00

Table 13 - Scenario #1: BS criteria pairwise comparison

Again, pmColNet may check each partner consistency ratio. This time BS consistency ratio is below 0,10: 0,04.

SME	BS Innovation	BS Learning	BS Effectiveness	SME Collaboration	SME Financial and Economic	SME Marketing	
BS Innovation	1,00	2,00	1,00	0,50	0,33	0,50	0,12
BS Learning	0,50	1,00	2,00	0,67	0,50	0,33	0,11
BS Effectiveness	1,00	0,50	1,00	0,50	0,50	0,50	0,10
SME Collaboration	2,00	1,50	2,00	1,00	1,00	1,00	0,21
SME Financial and Economic	3,00	2,00	2,00	1,00	1,00	1,50	0,25
SME Marketing	2,00	3,00	2,00	1,00	0,67	1,00	0,22
	9,50	10,00	10,00	4,67	4,00	4,83	1,00

Table 14 - Scenario #1: SME criteria pairwise comparison

CR = 0,03.

Assoc	BS Innovation	BS Learning	BS Effectiveness	SME Collaboration	SME Financial and Economic	SME Marketing	
BS Innovation	1,00	3,00	0,50	3,50	2,00	0,33	0,17
BS Learning	0,33	1,00	0,25	1,00	0,33	0,25	0,06
BS Effectiveness	2,00	4,00	1,00	4,00	2,00	1,00	0,27
SME Collaboration	0,29	1,00	0,25	1,00	2,00	0,25	0,08
SME Financial and Economic	0,50	3,00	0,50	0,50	1,00	0,25	0,10
SME Marketing	3,00	4,00	1,00	4,00	4,00	1,00	0,32
	7,12	16,00	3,50	14,00	11,33	3,08	1,00

Table 15 - Scenario #1: Assoc criteria pairwise comparison

CR = 0,05.

The last matrix before final global priorities:

Criterion	BS	SME	Assoc
BS Innovation	0,27	0,12	0,17
BS Learning	0,27	0,11	0,06
BS Effectiveness	0,17	0,10	0,27
SME Collaboration	0,18	0,21	0,08
SME Financial and Economic	0,04	0,25	0,10
SME Marketing	0,07	0,22	0,32
	1,00	1,00	1,00

Table 16 - Scenario #1: priority vectors for criteria

Defined partner's vote power:

Vote power	
BS	0,50
SME	0,17
Assoc	0,33
	1,00

Table 17 - Scenario #1: vote power

Final score is used has relative preference (wheight) of each criterion:

Criterion	Score
BS Innovation	0,21
BS Learning	0,17
BS Effectiveness	0,19
SME Collaboration	0,15
SME Financial and Economic	0,10
SME Marketing	0,18
	1,00

Table 18 - Scenario #1: criteria's final global priorities

Veto threshold should note be used at this level for two reasons:

1) It has already been used for "excluding" some HFPA. Using it again may arise in excluding too much information;
2) Having a sum of 1 for all criteria relative importance is useful for constructing performance indices.

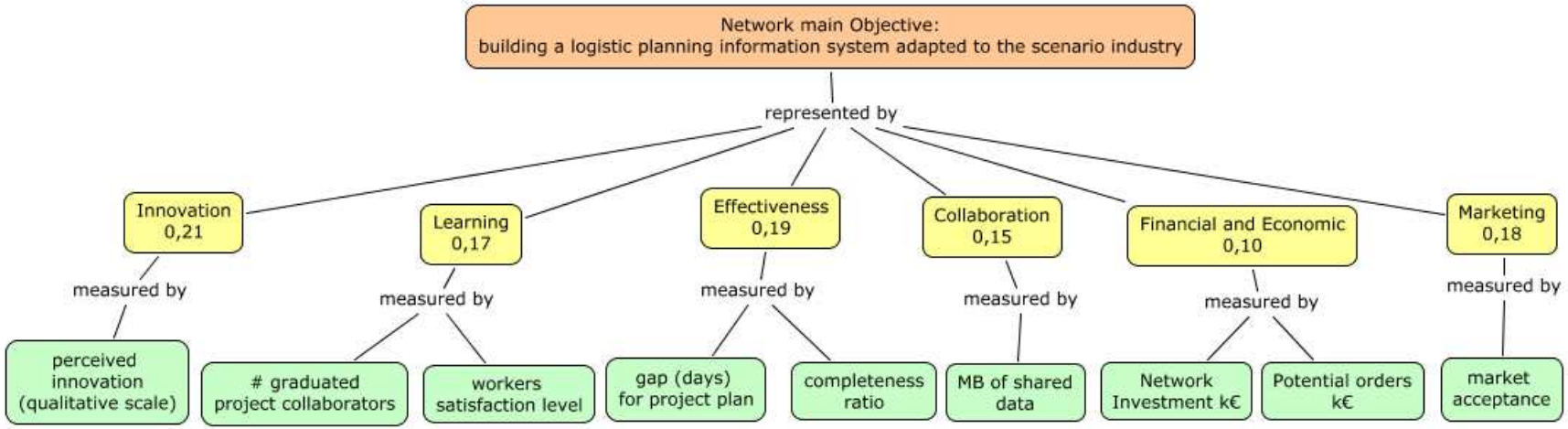


Figure 26 - Scenario#1 network HFPA

D – Negotiating and achieving a commitment package

D I –Network global commitment level

Applying average metric of individual commitment level we obtain the network global commitment level: **50,6(6)%**. Although individual commitment level is private, SME understands it is putting more effort in the network because it's commitment level (60%) is higher than the average. The same is valid for Assoc. These two network participants may force BS to allocate more resources to the project.

At this phase, pmColNet should promote a meeting to discuss commitment level. Partners may decide more (or less) resources should be applied in the project.

D II –Defining failure and success

		BS		SME		Assoc		Network	
		Failure	Success	Failure	Success	Failure	Success	Anti-ideal (failure)	Ideal (success)
Innovation	Perceived innovation (qualitative scale)	8	17	10	15	11	18	**8**	**18**
Learning	# graduated project collaborators	5	20	5	7	5	9	**5**	**20**
	workers satisfaction level	0,40	0,80	0,50	0,70	0,35	0,70	**0,35**	**0,80**
Effectiveness	gap (days) for project plan	15	5	20	8	25	7	**25**	**5**
	completeness ratio	0,60	0,90	0,65	0,95	0,55	0,85	**0,55**	**0,95**
Collaboration	MB of shared data	1.000	5.000	3.000	5.000	2.000	4.000	**1.000**	**5.000**
Financial and Economic	Network investment k€	150	300	150	200	100	150	**100**	**300**
	Potential orders k€	500	2.500	300	1.500	200	2.000	**200**	**2.500**
SME Marketing	market acceptance	0,10	0,20	0,20	0,33	0,33	0,65	**0,10**	**0,65**

Table 19 - Scenario#1: Defining failure and success for each indicator

D III –Level of analysis

At this stage, partners associate chosen indicators to specific levels of analysis. For instance:

- SME Collaboration measured by MB of shared information is a network, process, operational level of analysis.

		Levels of analysis									
		input	process	output	operational	tactical	strategic	individual	organisation	network	community
BS Innovation	Perceived innovation (qualitative scale)			X			X				X
BS Learning	# graduated project collaborators	X				X				X	
	workers satisfaction level		X			X		X			
BS Effectiveness	gap (days) for project plan		X		X					X	
	completeness ratio		X		X					X	
SME Collaboration	MB of shared data		X		X					X	
SME Financial and Economic	Network investment k€	X				X				X	
	Potential orders k€			X			X			X	
SME Marketing	market acceptance			X			X			X	

Table 20 - Scenario#1 levels of analysis

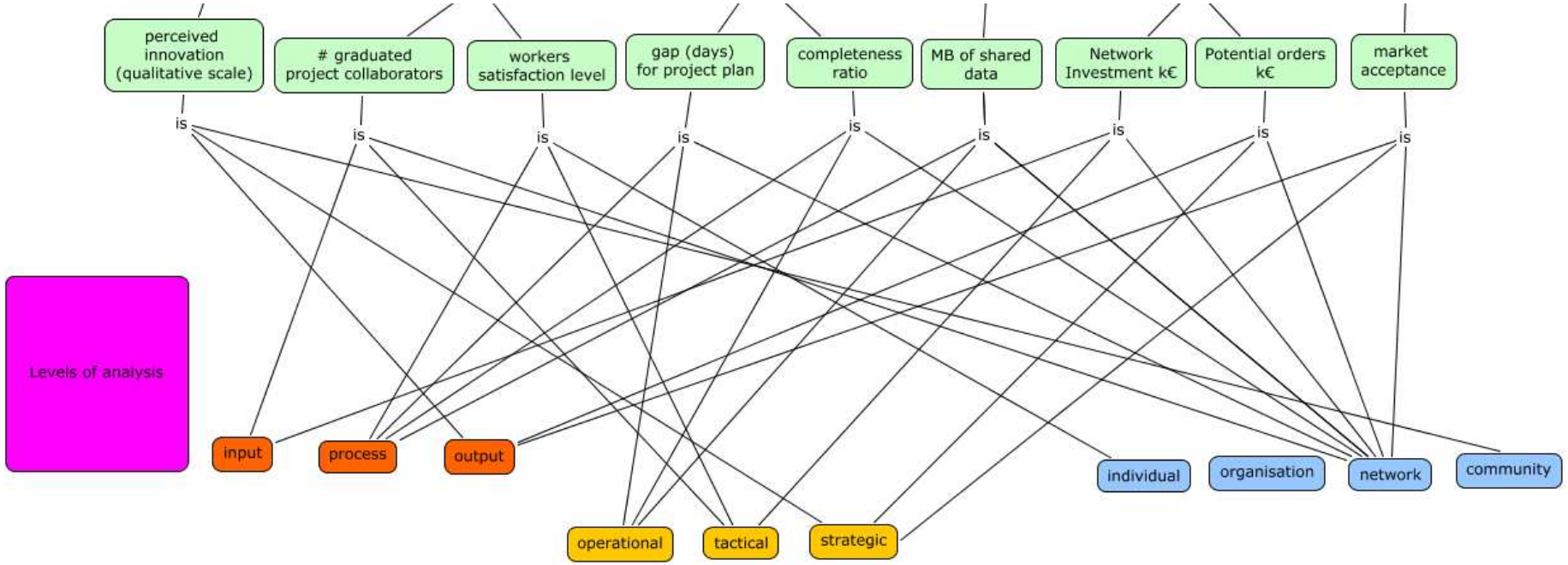


Figure 27 - Scenario#1: Puzzling levels of analysis and indicators

To associate each indicator to a specific level of analysis, pmColNet should promote a partner's meeting. If consensus is not achieved, a voting procedure is taken for each indicator[15].

D IV –Performance relationships

Using previous associations between indicators and levels of analysis, partners may construct performance paths.

These performance relationships should be approached with some caution. In spite of their potential importance to performance management, causality relations are not easy to measure or demonstrate.

Nevertheless, measuring productivity ratios at ideal point:

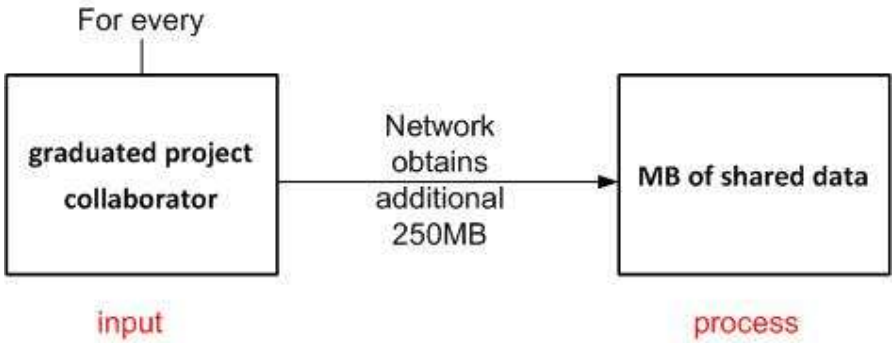


Figure 28 – Example of productivity ratio between input and process indicators

[15] Vote power is taken into account.

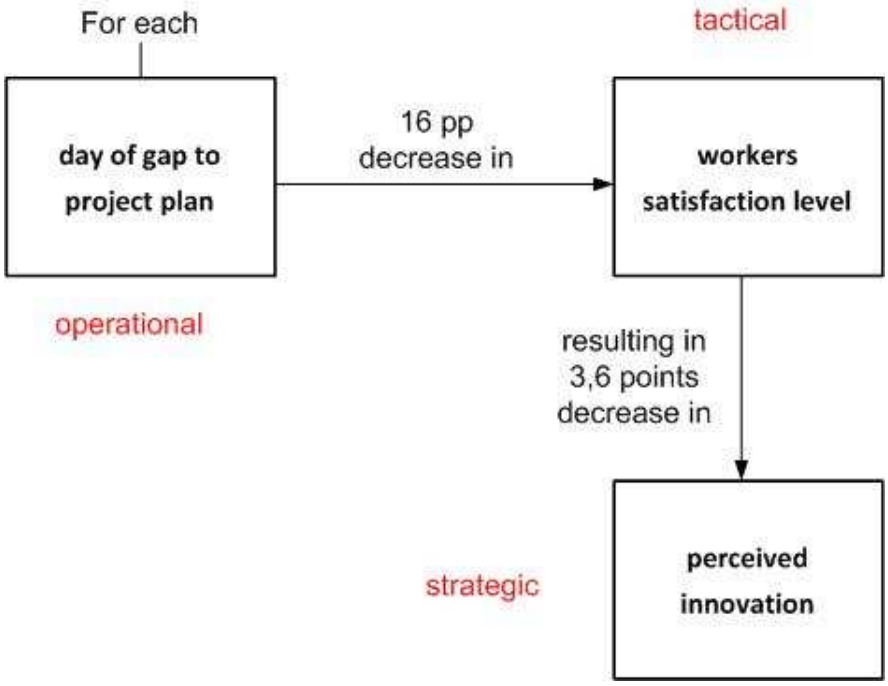


Figure 29 - Example of productivity ratios and path from operational to strategic indicators

It is now possible to monitor productivity ratios performance using the data collected from indicators measurement. These comparisons are important managing tools because they can show to the network partners, the areas that can be improved and that are below expected behaviour.

For instance, if one more graduated project collaborator is only bringing additional 83MB of shared information, it means something is not working as expected:

Indicator	Period 1	Period 2	Period 3	Period 4	Period 5	(...)	Anti-ideal	Ideal
# graduated project collaborators	3	5	8	9	15		5	20
MB of shared data	100	500	1.000	1.500	2.000		1.000	5.000
Productivity ratio	33	100	125	167	133		200	250
Substitution rate		200	167	500	83			

Table 21 - Scenario #1: substitution rate

In period 5, partners may understand that more than 9 project collaborators will result in decreasing marginal returns, or that new collaborators need more training time, before developing its maximum potential.

Note that for this analysis to make sense, we are admitting that it's possible to isolate the two effects, *ceteris paribus*.

D V –Index construction

We can imagine several indices to be developed, for instance one that combines performance for Financial and Economic criteria.

Network partners periodically (daily, weekly, monthly, …) introduce performance data regarding each indicator:

	Indicator	Period 1	Period 2	Period 3	Period 4	Period 5	(…)	Anti-ideal	Ideal
Financial and Economic	Network investment k€	20	50	100	150	200		100	300
	Potential orders k€	50	100	150	125	250		200	2.500
	Productivity ratio	2,500	2,000	1,500	0,833	1,250		2,000	8,333

Table 22 - Data gathering for indicators

Let's assume that both the indicators have the same importance. Then, the index is constructed following the described procedure at section 5.8.1:

	Period 1	Period 2	Period 3	Period 4	Period 5
Network investment k€	20	50	100	150	200
Network investment index	-40	-25	0	25	50
Potential orders k€	50	100	150	125	250
Potential orders index	-7	-4	-2	-3	2
Financial and Economic Index (50/50 importance)	-23	-15	-1	11	26

Table 23 - Index construction

We observe that potential orders are really below the network success limit, which pulls down the financial and economic index, although network investment is having a relatively good performance. Graphically we obtain a visual analysis that helps to achieve a dynamic perspective of the indices evolution.

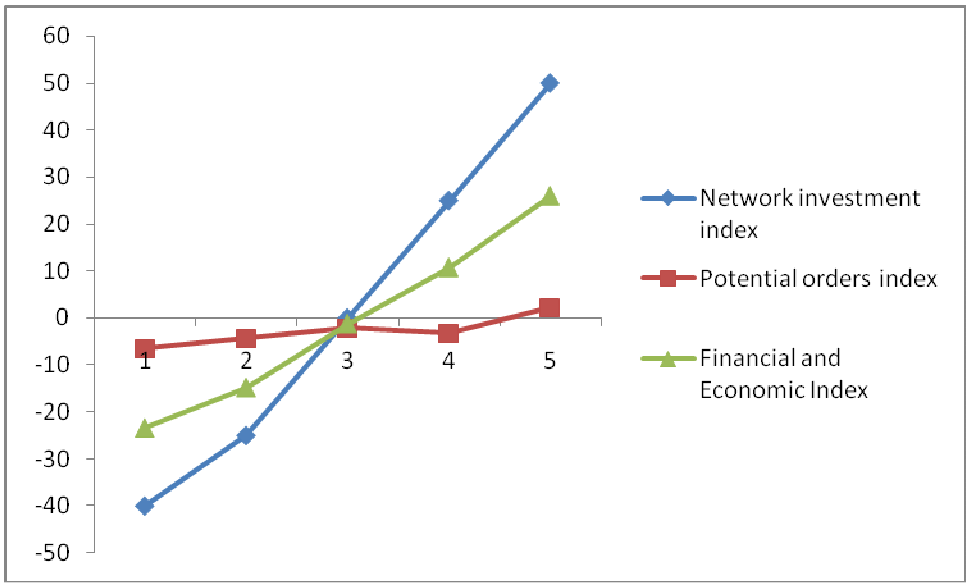


Figure 30 - Graphical view of the indices' performance

E – Monitoring performance

E I – Normalising indicators and achieving a dashboard/ tableau de bord

We have seen some interesting index construction and graphical analysis that can be done with indicators, criteria and levels of analysis. Dashboards are extremely popular among business performance analysts and every management software has a few tools to provide numerical and graphical data, whose objective is to give the whole business picture with just a glimpse.

pmColNet should provide such tools. The following figures show examples of dashboards:

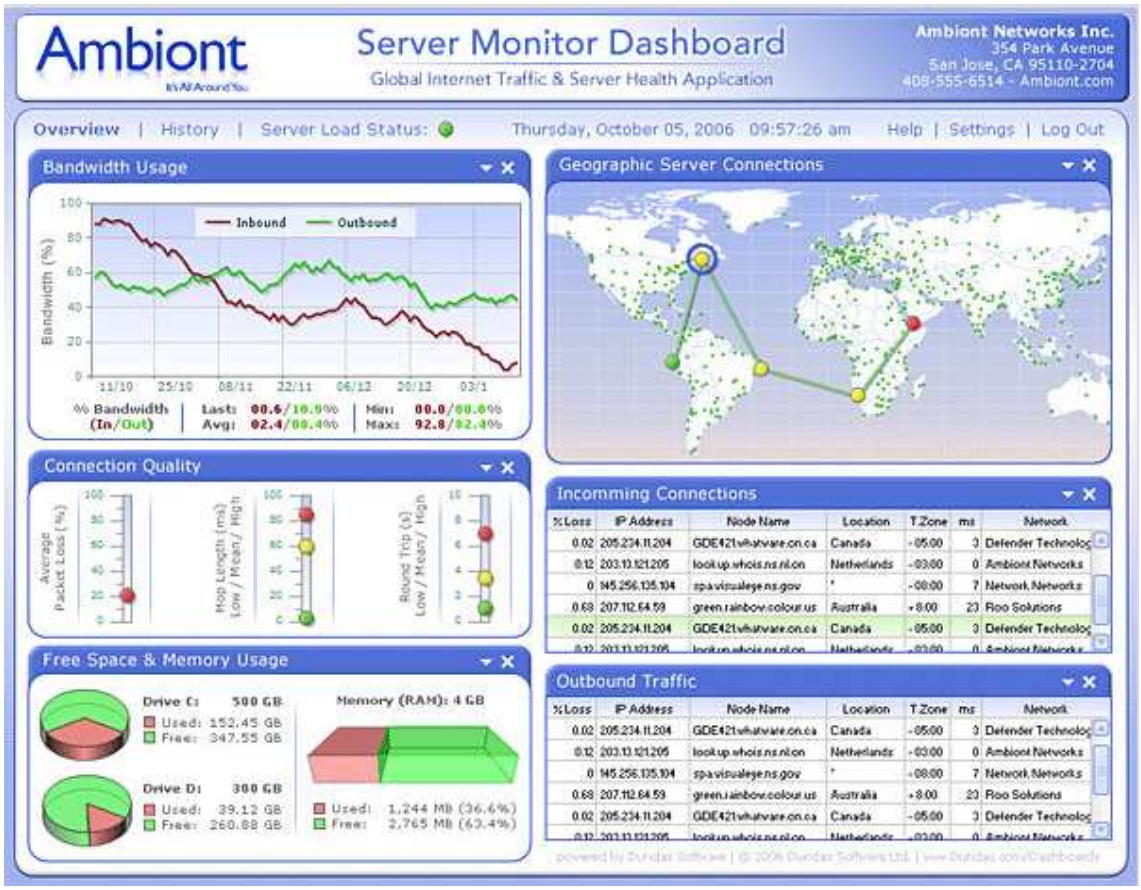


Figure 31 - Dashboard example #1

Source: http://www.dundas.com/Gallery/Flash/Dashboards/index.aspx (20-03-2009)

Figure 32 - Dashboard example #2

Source: http://www.dundas.com/Gallery/Flash/Dashboards/index.aspx?filename=sp_levronDash.jpg (20-03-2009)

5.9.2. Scenario #2

At this scenario we will try to further explore business information from pmColNet data gathering.

The project

Several SME organisations are working together in textile industry in a small Portuguese region. They know that individually, cannot compete at this extremely competitive market, nor can compete with lower labour costs from emerging economies.

As a result, they formed an industry cluster with several strategic cooperative agreements, to collectively design, produce and distribute their textile goods. They have built a technological/ functional synergies network.

Network partners are very similar organisations. There are about 10 different organisations that contribute for building specialised teams is three different key areas: design, production and marketing.

This network as achieved a HFPA throughout the use of pmColNet's performance management system:

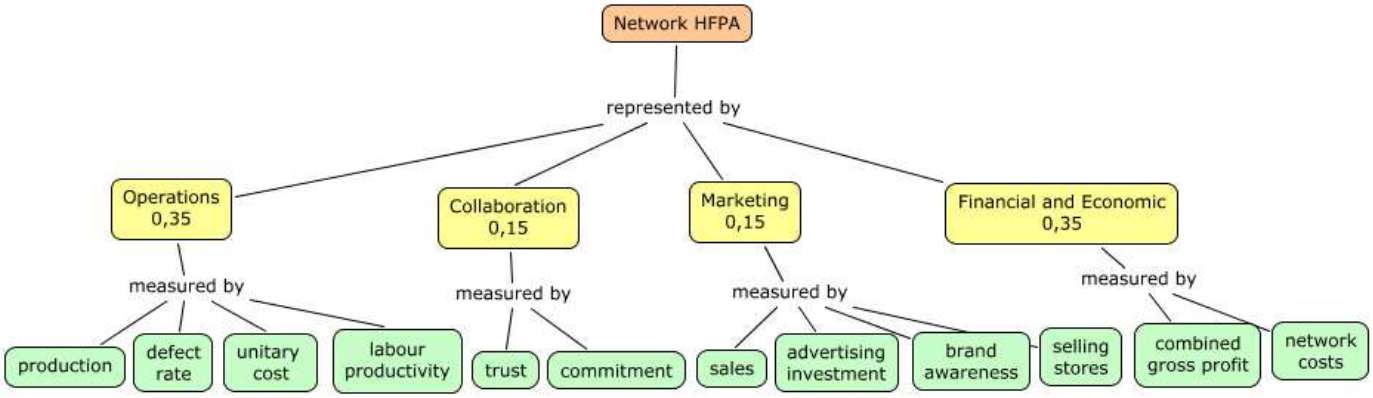


Figure 33 - Scenario #2: network HFPA

For the following analysis, we will use this table of recorded performance for 3 periods (assume monthly periods, so that every indicator as registered values):

Indicators (indices)	Period 1	Period 2	Period 3
production	60	75	95
defect rate	50	80	85
unitary cost	30	50	60
labour productivity	40	45	55
trust	55	60	60
commitment	65	55	60
sales	80	85	90
advertising investment	75	70	65
brand awareness	50	55	55
selling stores	80	80	85
combined gross profit	25	20	30
network costs	15	20	25

Table 24 - Scenario #2: indicators data

Indicators have already been normalised with ideal/ anti-ideal performance values, so that comparisons and index construction may be possible.

This is a very simple dashboard composed of indicators indices and 3 period's observations:

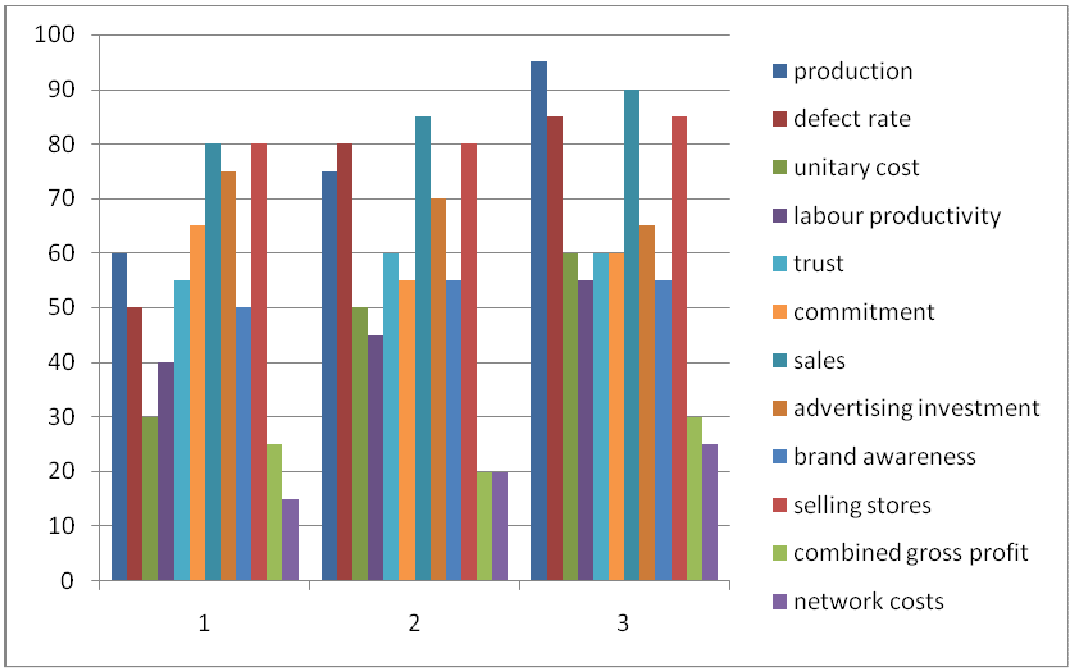


Figure 34 - Scenario #2: dashboard

Indicator	Description	Measure type	Desirable direction	Unit	Formula	Measuring frequency	Ideal	Anti-ideal
production	number of produced textile pieces	objective	maximize	number of pieces	sum of produced pieces	daily	10.000	1.000
defect rate	measures the ratio of defective pieces	objective	minimize	percentage	ratio between the number of defects and total production	daily	2%	5%
unitary cost	measures the production overhead cost	objective	minimize	euros	ratio between total costs and production	daily	0,8	1,2
labour productivity	measures the production of one labour resource	objective	maximize	number of pieces	ratio between production and total labour resources	daily	250	100
trust	trust level between network partners	subjective	maximize	1 to 20 scale	network members questionnaire	monthly	18	12
commitment	perceived level of commitment towards the network project	subjective	maximize	1 to 20 scale	network members questionnaire	monthly	17	13
sales	volume of sales	objective	maximize	euros	volume of sales	monthly	50.000	10.000
advertising investment	euros invested in advertising	objective	minimize	euros	volume of investment in advertising campaigns	monthly	15.000	30.000
brand awareness	percentage of people who voluntary associate our brand to textile products	objective	maximize	percentage	using questionnaires	monthly	80%	20%
selling stores	number of worldwide stores that sell our products	objective	maximize	number of stores	sum of worldwide stores	monthly	2.000	500
combined gross profit	sum of gross profit of every network partner	objective	maximize	euros	sales shares minus production costs	monthly	15.000	-5.000
network costs	network expenditure	objective	minimize	euros	sum of network expenses	daily	8.000	15.000

Table 25 - Scenario #2: Indicator's attributes

Figure 34 shows some network problems regarding costs and productivity. In spite of very good production and sales performance, combined gross profit, costs and productivity are not performing so well. This indicates that performance relationships behaviour is not as expected.

We can build a overall performance index, constructing criteria indices (assuming indicators have the same relative importance within each criterion):

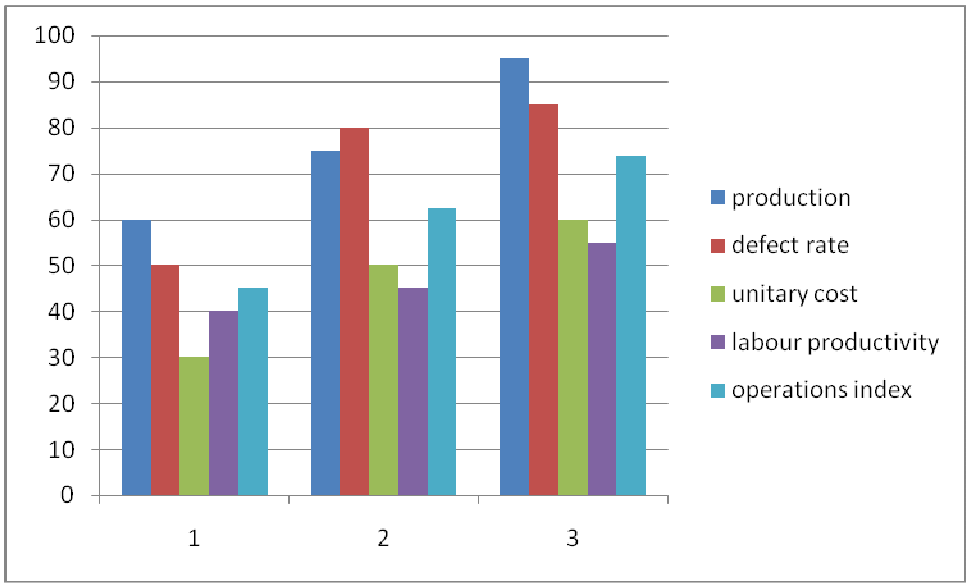


Figure 35 - Scenario #2: operations index

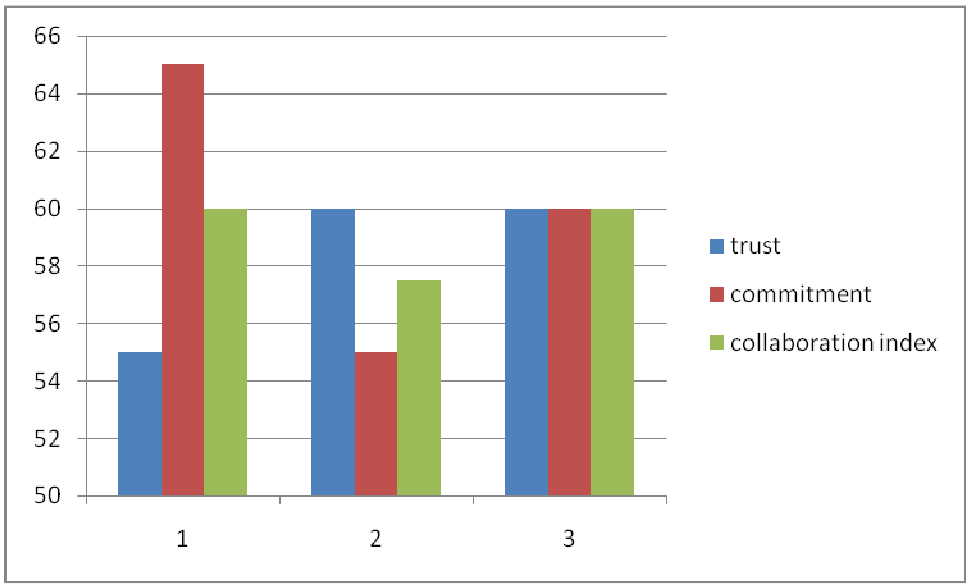


Figure 36 - Scenario #2: collaboration index

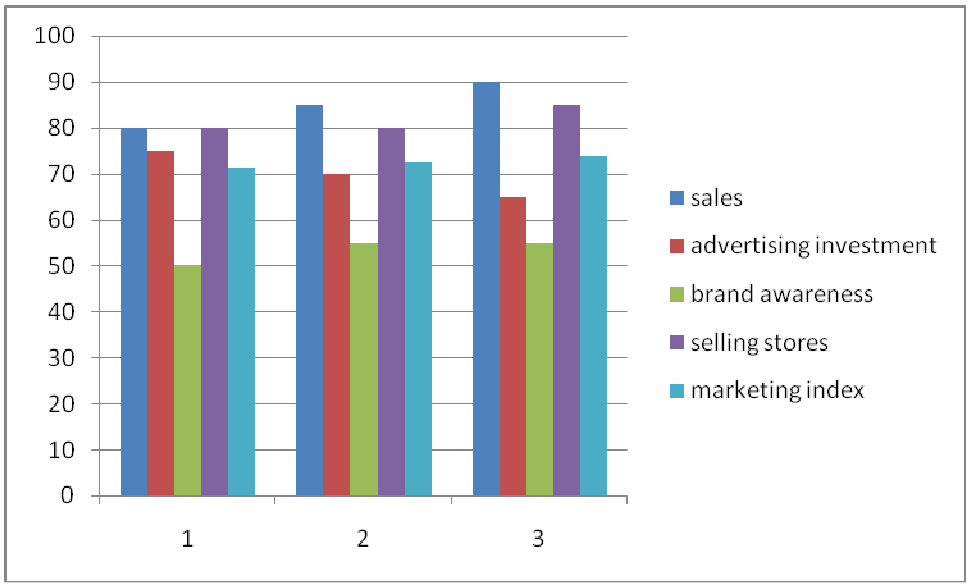


Figure 37 - Scenario #2: marketing index

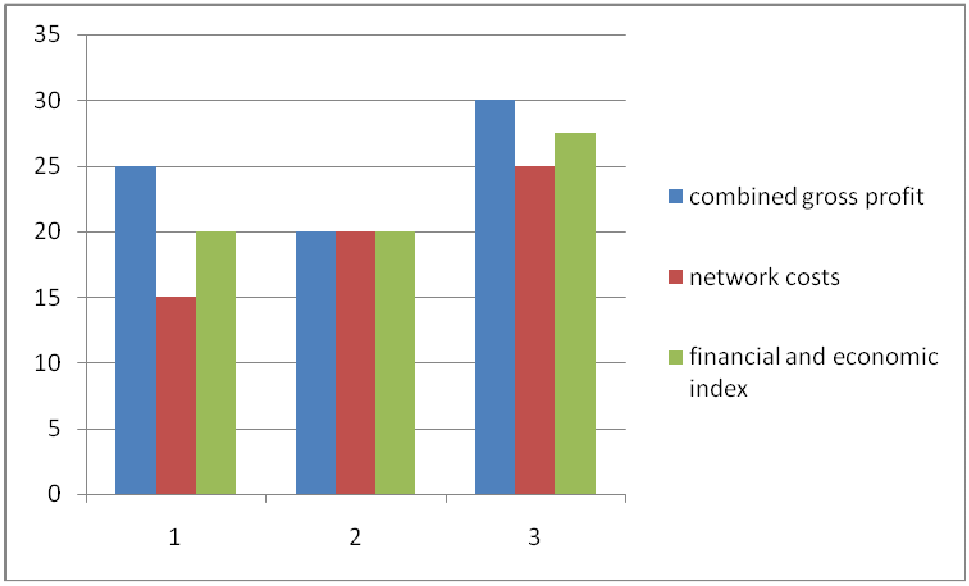


Figure 38 - Scenario #2: financial and economic index

Using criteria relative importance (from the HFPA) we obtain the overall index:

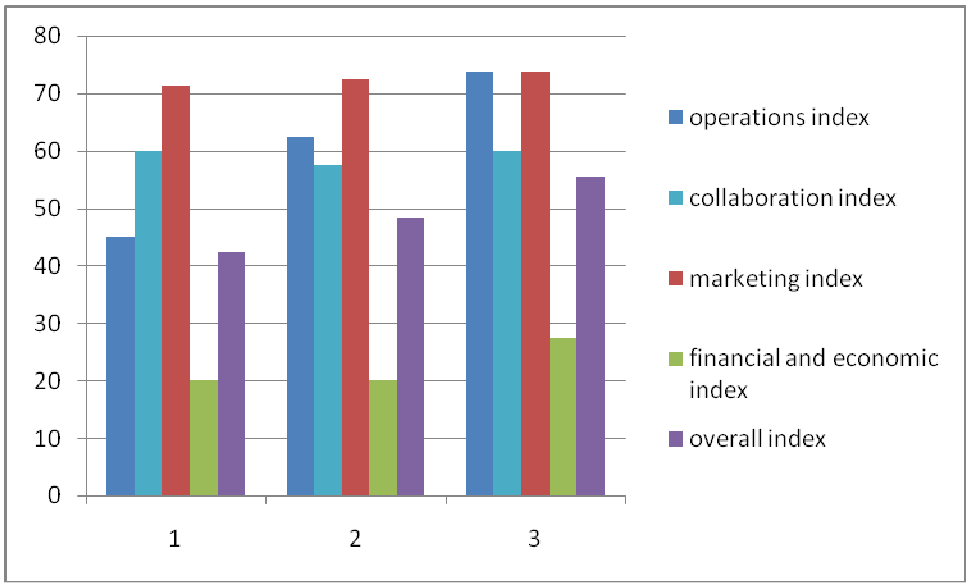


Figure 39 - Scenario#2: overall index

We have a clear picture that financial end economic criterion is performing very badly, comparing with good performance from operations, collaboration and especially marketing.

This graphical analysis may be extended to other facets, for instance management level: operational, tactical and strategic. Remember that network partners associate each criterion to certain levels of analysis (see scenario #1, D III for an example).

Operational level is composed of production, defect rate, unitary cost and sales indicators. Tactical level is composed of labour productivity, advertising investment, selling stores, combined gross profit and network costs. Strategic level is measured by trust, commitment and brand awareness. We will assume equal relative importance for the indices construction:

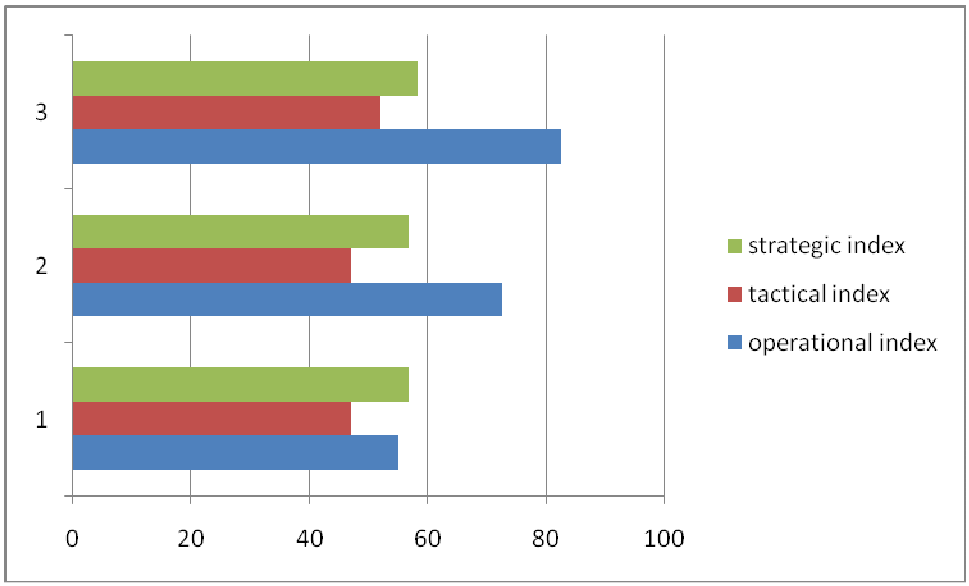


Figure 40 - Scenario #2: mangement level indices

pmColNet's performance system may show this type of leads so that partners may improve network performance. It can not actually solve the problems, but may be vital in detecting flaws.

6. Conclusions

This work was developed within the pmColNet – performance management in Collaborative Networks – research project at INESC Porto. Its main objective is the design of a framework for collaborative networks performance management.

This dissertation premise was that collaborative networks performance management is a complex and multicriteria problem that benefits from a situational approach whereas all participants propose criteria and indicators to monitor objective completeness.

There are still few investigation regarding performance evaluation models within collaborative networks, but it is vital to assure its success (Busi and Bititci 2006). The few existing studies point the importance of using multicriteria tools (Parung and Bititci 2006) and different levels of analysis (Hill 2002, Sydow and Milward 2003, Neves 2009). Camarinha-Matos and Abreu (2007) argue that understanding of collaborative benefits is the key for a wide adoption of the collaborative networks paradigm.

There are at least four problems related to network evaluation pointed out by Sydow and Milaward (2003): the choice of appropriate evaluation criteria and indicators; network evaluation should be approached on different levels of analysis; network structural properties may involve outcomes that are also potential inputs in network processes; there are multiple stakeholders involved who will have multiple (sometimes conflicting) interests.

Therefore, we propose a performance model that fosters the combination of MCDA methods and negotiation between network partners. Although in this work we could not cover the entire existing multiple criteria methods, we were particularly interested in relational ones.

Relational approach methods focuses in comparing alternatives two by two, by expressing a degree of preference (Marichal 1999), which favours our goals of interaction and collaborative construction. We have chosen AHP for using at pmColNet's performance model system. This can be one of the major criticism of the work, but, in our perspective, it is not a relevant drawback: pmColNet's framework can be constructed using MACBETH or ELECTRE or other relational method.

AHP is the easiest to implement and it's very simple to understand for every involved organisation. Moreover, its specific disadvantages are minimized within this framework:

- We want a situational approach. Results are specific and valid at that particular network and time frame;
- There won't be irrelevant alternatives within a specific network. All partners are experts, which reduces rank reversal problems.

But the most important aspect is that we are not interested in technically perfect results and are willing to "ignore" MCDA advices, giving network partners the opportunity to really build the model itself on a collaborative manner.

The increase of collaborative networks is a fact (Parung and Bititci 2006). Within the actual economic and financial global crisis, they are really going to have a burst. Sharing resources is one (if not the only) response to the actual economic situation and we believe "the age of the collaborative networks" has arrived definitely

6.1. Future steps

pmColNet's potential will only be accessed in real cases application. The use of scenarios at this work was important, but cannot substitute real life interaction. The lack of time and interested networks sentenced this drawback, but that will certainly be exceeded in pmColNet's next phase.

Integrated in pmColnet's research project, a prototype of the performance model will be constructed. Empirical validation will be attained using real networks for testing and evaluation. This phase will be extremely important due to the practical objectives of pmColNet' project.

Neves (2009) has already proposed an implementation for the collaborative management system using *plone* (http://plone.org), a open source CMS.

An ambitious lead is conceding pmColNet's system the ability to store past network context, HFPA and maybe results (this last will be extremely difficult due to confidentiality business issues). This function, combined with a global access web-based service, would provide massive data storage and enable for new networks to be advised for similar HFPA regarding its contextualisation: "similar networks have chosen this criteria: …".

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