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**Abstract**

**Purpose** – Cognitive maps are used in group decision processes to structure problems. The problem structuring methods helps decision makers to improve the comprehension of the problem, identifying alternative actions and conflicts. However, represents the individual perceptions in a representative group decision into a single structure can be a complex task. The paper aims to discuss these issues.

**Design/methodology/approach** – The objective of this paper is to improve the process of discussion, obtaining the interests and views of the participants and provide parameters to assist the analyst to guide the process. Furthermore, it is possible to analyze how participants are aligned or diverge from the group. The literature review presents some approaches for cognitive maps analysis, but there is a lack of structured methods to analyze them. This paper proposes a structure procedure for the aggregation of cognitive maps in three parts: workshop to generate individual maps, the aggregation of individual maps and the refinement of the global map.

**Findings** – An example illustrates the application of the proposed method and shows the construction of a global map that summarizes the concepts that participants consider important.

**Originality/value** – This paper presents a new procedure that allows reducing the bias of the analyst in the aggregation of individual cognitive maps maintaining the relevant information and allows decision makers know and approve the aggregation procedure.

**Keywords** Cognitive maps, Group decision, Procedure, Aggregation, Crucial path

**Paper type** Research paper

## 1. Introduction

When different persons, groups or entities meet to analyze alternatives, policies, and strategies of action and make a decision to address a problem or try to achieve goals, conflicts can be common.

Mingers and Rosenhead (2004) present and evaluate problem structuring methods (PSM). PSM explore mental models of decision makers and identify cognitive aspects that lead to reflection of future consequences of choices and decisions.

There are various applications of PSM in the literature. Cunha and Morais (2014) show how PSM can help in environmental planning. Levino and Morais (2013) present a PSM in watershed committees. Silva Filho *et al.* (2014) used strategic options development and analysis (SODA) to identify criteria to evaluate segmentation problems of a water distribution network.

Among the methods used, SODA is a general PSM that uses cognitive maps as a modeling device for eliciting and recording individuals' views of the problem situation.

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Cognitive maps are mental representations and are defined as the representation of the thought regarding the problem that follows from the process of mapping (Eden and Ackermann, 2004). Furthermore, they might enable negotiators to determine areas of convergence and the underlying conceptual structure that supports the convergence (Bonham, 1993).

A cognitive map is a collection of nodes that represent events and a set of arcs that connect these events and represent the causal relationship between them. Cognitive maps are usually derived through interviews, so they represent the subjective world of the interviewee (Eden and Ackermann, 2004).

The usefulness and application of cognitive maps has gained space, but in regard to group decisions, procedures for aggregating individual maps deserve special attention, since, in the absence of formal procedures, the good sense of an analyst is the only resource, which, in turn, has its own value judgment, views and experiences.

To fill this gap, this paper presents a procedure whose aggregation of individual cognitive maps contemplates the participants' understanding of the decision problem with minimal loss of information and reduced influence of the value judgment of the analyst in this aggregation.

The aim of this work is to propose a procedure that, through its steps and evaluation criteria, assists the analyst in capturing the relevant information. This follows a defined sequence, starting from the generation of individual cognitive maps until the construction of the cognitive map that represents the group perspective of a decision problem with better communication among group members and respect for individual interests and the perspectives of each participant.

This paper is organized as follows: the following section presents a general review of the aggregation of cognitive maps and the characteristics of existing methods. In Section 3, the model to generate cognitive maps is presented and detailed. In Section 4, a simulation that will illustrate the steps of the procedure is presented. Finally, the concluding remarks on the study and suggestions for future research are provided.

## 2. Cognitive maps aggregation

The construction of cognitive maps in group decisions should follow one of these two approaches. In the first approach, a collective map is generated from individual cognitive maps. In the second approach, a collective map is generated with all the members together.

The generation of a collective map with members working together simultaneously has the advantage of members using common terms to express a specific idea and a better balancing of information among parties. However, there are clear disadvantages, such as possible conflicts in the discussion process, the presence of inhibited participants who avoid expressing their point of view, and the existence of dominant participants that influence and lead the discussion. These problems can cause large losses in the potential map (Almeida *et al.*, 2012).

The aggregation of individual maps may be more suitable to analyze various points that were previously presented. However, the way in which the individual maps are aggregated to generate a collective map can cause dissatisfaction of the decision makers. They may complain about the representation of the map. The most common method for this depends on the analyst, who must use common sense to consider the existing hierarchies between people and ideas.

The methods of cognitive map aggregation have emerged with the purpose of filling the gaps of formal methods. Kosko (1988) provides pioneering work in this area. He suggests that each participant receives a weight (0,1) based on his experience. There is a risk that some important connections will disappear. However, this strategy can be useful in cases where a large number of cognitive maps have been collected based on the Kolmogorov strong law of large numbers.

Vanwindekens *et al.* (2013) presents an aggregation method using arithmetic addition of the adjacent matrix. The result is a matrix that is analyzed to generate what is called a social cognitive map. This analysis uses the criterion of the value of the element $a_{im}$ (i.e. the weight of the relationship linking variable i to variable m), which can be greater than 1. This approach can result in the loss of concepts that should result in privileged knowledge of some participant and that could improve the discussion and expand the learning of the problem.

Jetter and Kok (2014) present a mathematical qualitative aggregation as a way to generate a group map. The maps are converted into matrices via qualitative aggregation. The matrixes are added, and the score should be divided by the number of matrices.

Different from the methods of Kosko (1988), Vanwindekens *et al.* (2013) and Jetter and Kok (2014), in which the aggregation criteria are strongly based on quantitative information, the method proposed in this paper attempts to prevent the exclusion of important connections before the participants can reflect on, and learn about the issue and its relevance to the discussion. Decision makers are involved in the definition of decision criteria in the aggregation of individual cognitive maps. Therefore, there is a balance of quantitative and qualitative information in the aggregation process.

Almeida *et al.* (2014) presented a methodology for aggregating opinions based on interviews with stakeholders. The value-focussed thinking methodology was used to identify the values and concepts of the participants individually and then sort "fundamental objectives" and "means objectives." For the aggregation of maps, the information hierarchy of values among the objectives was used. The methodology allows large amounts of information. However, the presented method does not consider the learning and synergy that may occur as a result of the interaction among participants. In addition, the method does not address the representation of dealing with diffused groups or groups with conflicting opinions.

Bilolasvo and Grebenc (2012) presented an interesting alternative to aggregation of knowledge. They use the Delphi method, the analytic hierarchy process, and fuzzy dynamic cognitive maps for development of future scenarios in order to avoid the weaknesses of each separate method while combining their strengths. However, that approach has limitations in regards to the number of factors used since the method uses pair wise comparison. Furthermore, the authors indicated that there is some difficulty in designing measures for all involved factors in a way that the measures properly represent a relationship between cause and effect.

Lee and Lee (2015) highlighted the need for holistic approaches in semantic comparisons of concepts for an appropriate aggregation of fuzzy cognitive maps. For this, the authors presented a proposal for the construction of maps, based on an ontology matching approach in a holistic manner. That seems to be an interesting approach, especially because of its potential to address semantic ambiguity problems and help experts in the construction of cognitive maps.

The qualitative aggregation combines the mentioned concepts for each participant in categories that represents a wide variable. The integration can be based on analytic methods or map comparison and identification of agreement and disagreement areas. A way to perform this analysis is by creating a standard dictionary with the most relevant concepts and their synonyms. Tegarden and Sheetz (2003) state that the process is difficult and slow. Lee and Lee (2015) highlight the need for holistic approaches to semantic comparison of concepts for an appropriate aggregation of fuzzy cognitive maps. For this, the authors present a proposal for the construction of maps, based on ontology matching approach in a holistic way. That seems to be an interesting approach, especially because it is potential to treat semantic ambiguity problems and help experts in the construction of cognitive maps.

## 3. Proposed model

The model has three basic stages: first, workshop and construction of individual maps, second, aggregation of individual maps and third, refinement of the collective map. Each step is described below.

### *3.1 Workshop and construction of individual maps*

This step precedes the elicitation process, which results in the generation of the nodes and presents the role of the analyst in this process. Thus, the goal of this section is to propose a protocol for the construction of cognitive maps aimed at structuring problems in cases of group decision making.

*3.1.1 Define and prepare decision makers and then workshop*. The initial step in the PSM is identifying the decision makers. It must consider the interests and expectations of the parties. In this sense, it can be necessary to have an actor that aids in defining the participants of the decision and in guaranteeing plurality of opinions in all interest areas of the problem.

After that, we recommend a workshop with stakeholders to provide interaction, where information about the problem should be presented by an impartial analyst. It is a moment of exchange for information, knowledge and experiences; it is not the moment to reach agreements, consensus or the resolution of the problem.

In this stage, all important processes in the construction of the map should be presented, and participants should be instructed about the operation. In addition, the analyst should discuss and present the definition of the criteria used for the aggregation of maps, including the acceptance limits and cutting of the nodes and arrows. This value is not inflexible, but it can be used as a benchmark for future evaluations and gives more clarity and confidence to participants. It is necessary that the participants should be free to consider all concepts related to the problem that they judge relevant, following their personal interpretation.

*3.1.2 Generation of nodes*. At this stage, the analyst asks participants to make a list of factors they consider important in the topic discussed. Some ways to perform this procedure are: open list (participants freely describe aspects they consider important) or individual listing (participants write the import aspects. After, all aspects are condensed into a single document).

It is possible also to consider a hybrid option using a prior discussion in the individual list or a step where people suggest individually before the conference discussion.

Another suggestion to use the best of both methods is the use of communication systems to instantly receive the points suggested by each participant. The system should gather and classify the information, and it should be shared by the analyst to avoid inhibition of any participant. The number of aspects considered should not be a restriction on this time.

*3.1.3 Create a node library*. Due to the encouragement of free suggestion of relevant aspects, the amount of information can be extensive, and many aspects can be expressed as duplicates or synonyms. Thus, the role of the analyst in this phase is to group the aspects mentioned by the participants, filter synonyms or terms with the same meaning, attempt to regroup them in concepts and generate a library of nodes, based on these aspects raised.

With this, we try to homogenize the participants' understanding of the meaning of each node, which will be chosen to form the map. Markóczy and Goldberg (1995) also suggested a review of the relevant literature as a means of supplementing the set of nodes.

*3.1.4 Build individual maps*. The construction of individual maps is through the choices of the nodes within the group formed and the relations among these nodes. The non-existence of an upper limit on the quantity of nodes can result in the generation of a large number of nodes and can enhance the complexity of the analysis. It is a possible problem, but it is recommended that it not be limited, based on the belief that the construction of individual maps should be as free as possible because that is one of the advantages of the method of structuring the learning problem.

Bilolasvo and Grebenc (2012) present the main difference between crisp cognitive maps and fuzzy cognitive maps: in fuzzy cognitive maps the relation values are also defined, i.e. can capture values within the interval and casual connections or relations between nodes.

Choosing nodes individually, participants should indicate the influence of each node on the other, if any. This is done by specifying arcs. The numbers associated with the arcs can express a specific causality between concepts by using a (−1, +1) or may also add information on the strength of that relationship with (−3, +3).

A strong positive or negative perception should be represented by +3 or −3. A moderate relationship is represented by +2 or −2 (positive or negative), and a weak relationship is denoted by +1 or −1.

### *3.2 Aggregation of individual maps*

Individual cognitive maps express the perceptions of stakeholders. The construction of a collective cognitive map allows these perceptions to be gathered and expressed broadly, concisely and in a visual manner. Thus, the challenge is to define what relationships among nodes should be maintained and removed in the aggregation of the individual maps. The qualitative methods presented in the literature highlight the high responsibility of the judgment of the analyst. Moreover, quantitative aggregation has the risk of rejecting of a node that would be important in broadening the discussion and learning about the problem.

Thus, this study proposes a sequence of processes to assist the analyst in defining what nodes and arcs should be eliminated or retained. It includes border regions that allow the participation of decision makers in this process.

*3.2.1 Definition of criteria for accepting nodes*. The following describes a protocol of actions to aid the analyst in the aggregation of individual cognitive maps to build the collective cognitive map. A previous step ensures the standardization of nodes, the comprehension of participants about the meaning of the concepts used and the definition of the intensity of the relationship among concepts.

3.2.1.1 Distance ratio (DR). The analyst should calculate the DR between cognitive maps of all participants. The objective is to obtain a reference for the evaluation of improvements. The individual cognitive maps are transformed in matrices. Langfield-Smith and Wirth (1992) presented a revision on distance measurements between cognitive maps and proposed Equation (1), which can be used to identify the divergence of opinions. The equation for DR is presented below:

$$DR = \frac{\sum_{i=1}^{p} \sum_{j=1}^{p} \left| a_{ij}^{*} - b_{ij}^{*} \right|}{6pc^2 + 2pc(pu_1 + pu_2) + pu_1^2 + pu_2^2 - (6pc + pu_1 + pu_2)} \quad (1)$$

where p is the number of elements in the distance matrix; pc the quantity of common elements in both maps; $pu_1$ the quantity of unique elements in map A; $pu_2$ the quantity of unique elements in map B; $a_{ij}$ and $b_{ij}$ represent the intensities that the participants a and b provided to the connection from node i to node j. However, these values should be adjusted before use in the formula via the expression below ($b_{ij}^{*}$ follows a similar pattern):

$$a_{ij}^{*} = \begin{cases} 1 \text{ if } a_{ij} > 0 \text{ and } i \text{ or } j \notin Pc \\ -1 \text{ if } a_{ij} < 0 \text{ and } i \text{ or } j \notin Pc \\ a_{ij} \quad \text{otherwise} \end{cases}$$

The denominator represents the maximum distance between a pair of cognitive maps. The value of the strength of the relationship is considered only for elements that are common to both maps. Thus, the greatest difference between two maps that have common elements is +6, and the maximum distance when they have unique elements is +1.

3.2.1.2 Clustering. The number of views in the evaluation can be very large. León *et al.* (2014), for example, evaluated more than 100 opinions in his analysis. This type of analysis is not useful for deeper analysis. Therefore, in cases of a very wide range of opinions, or when groups of people have clear similarities in their points of view, it can be useful for analyzing the formation of clusters of opinion and for reducing the absolute number of possible results.

There are various options to propose a cluster. Some fundamental options can be observed in León *et al.* (2014). This paper suggests two options based on previous concepts.

Clusters based on proximity: the cluster can be based in previous information from the participants.

Clusters based on DR: this relation uses a mathematical basis for suggesting clusters. The reference for the construction of clusters is a referential value of DR. For this, it is necessary to find a subset C of actors whose distance among them is less than a specified threshold.

The mathematical clustering methods always run the risk of making mistakes (León *et al.*, 2014). Therefore, it is recommended that they be used cautiously.

The cluster can be replaced by a cognitive map that represents the general opinion of members of the cluster. This map can be formed by averaging (weighted or not) the evaluations of decision makers in a set C. It is also possible to use statistical tools, such as the t-student, to assist in this process and evaluate if the distance between elements of the set of values of the cluster are within a reasonable limit.

3.2.1.3 Classification of nodes. There are three types of classifications presented in Cunha *et al.* (2013):

(1) global consensus node: those elements considered by all actors;

(2) relative consensus node: elements considered important by some actors; and

(3) restrict importance node: elements only considered important for a decision maker.

The inclusion of different nodes in individual maps is expected in group decision. Individual decision makers may present different preference values. Therefore, it is hard for a group of decision makers to attain consensus (Gong *et al.*, 2013).

The latter deserve special attention in the evaluation. Your consideration or not depends on several factors; according to Cunha *et al.* (2013), "antagonistic causes can justify the presence of such nodes in cognitive maps. On the one hand may be the result of knowledge, experience or information that other players do not. On the other hand, it can be due to an immature reflection on the real importance of the element."

The nodes of the global consensus can be added directly to the collective map, as they are agreed upon by all involved concepts. However, other nodes should undergo more analysis to avoid deleting previous nodes that have the potential to enrich our understanding about the problem.

3.2.1.4 Force ratio. This step tries to reduce the size of the global map. The force ratio suggests some notes with little influence that should be eliminated from the process. The relationship is defined in the following equation:

$$\frac{f_{im} = \sum |a_{il}| + \sum |a_{ki}|}{l + k} \tag{2}$$

The term $f_{im}$ is the force of node i in an individual cognitive map. The first term of the numerator is the sum of the intensities of the relationships that go from node *i* to node l, and the second term of the numerator refers to the arcs from node *k* to node *i*. *m* is the cognitive map being analyzed, and $1 \leqslant m \leqslant N$, where N is the total number of cognitive maps.

The values l and *k* in the denominator represents the number of arcs leaving and arriving at *i*.

Equation (3) defines the average force of node *i*, considering all individual cognitive maps:

$$F_i = \sum_{m=1}^{N} \frac{f_{im}}{N} \tag{3}$$

A criterion suggested to support the decision on the inclusion or exclusion of nodes:

$$F_i < 1, \quad \text{node i should be excluded}$$
$$F_i > 2, \quad \text{node i should be included}$$
$$1 \leqslant F_i \leqslant 2, \quad \text{node i should be discussed about its inclusion}$$

This formulation determines the intensity of causal relationships exerted by a node. The force ratio suggests exclusion of the cognitive map if a node has few and weak relationships. The group interest can adjust the criterion presented to decrease or increase the autonomy of the analyst.

Thus, this method retains its characteristic group decision. It includes involvement of participants in the crucial stages of the aggregation process, thus reducing the bias of the analyst's judgment.

*3.2.2 Aggregation procedure*. At this stage, the facilitator should use the parameters from the previous step and perform the necessary computations in the process to build a first version of the collective cognitive map. In the case of divergence of meaning, the causality relationship should be discussed with the participants. The calculation of the DR can be repeated whenever necessary to identify where agreements are needed most.

To reference this stage, some decisions must be made:

- Decisions about priorities in node definitions: in the previous section, it was possible to analyze two perspectives of the decision. The distance relations take into account the relation between the quantity of relations and their forces. Their priority or the balance between them will depend on what is expected of the decision.
- Definition of parameter values: the values of acceptance and rejection of the previous parameters must be defined, depending on the characteristics of the problem.
- Decisions on border regions: the cluster formation, definition of force and distance relationship are procedures that have regions where the decision may require special treatment. It is necessary to define what type of action should be taken in border regions when the score obtained is very close to the frontier.

The first version of the cognitive map should be discussed and presented to the participants, guiding them to a discussion of the final definition of the map. The quantitative features should be used to aid the revelation of opinions and perceptions of the participants. The acceptance of the collective cognitive map of the group by the participants is essential.

*3.2.3 Building the collective map*. In this step, the analyst should build the cognitive map. The map should consider the representativeness of the community without becoming lost in minor details. The final group map should be presented to the participants and shown as results are found.

The rules for the aggregation were presented at the workshop, and the presentation that was made to the group about how their input was used helps foster feelings of justice and representation for the decision makers. Thus, the expectation is that the collective map can be accepted by all with minimal problem.

### *3.3 Refinement of the collective map*

The final step of the model is the identification of crucial paths in the collective map, considering personal evaluations. Septer *et al.* (2012) proposed the equations presented in this section to identify the crucial path that will be useful in refining the decision.

The crucial path is defined as a connection or a small group of connections whose alignment of views contributes largely to the consensus (Septer *et al.*, 2012).

It considers two nodes, $v_1$ and $v_2$, and P, a path that goes from $v_1$ to $v_2$; the concepts of partial effect and full effect can be defined as described below.

Partial Effect [$PE(P_{ij}^{q})$] represents the intensity of path q among possible paths that go from $v_i$ to $v_j$. PE can be presented via the formula below:

$$PE\left(P_{ij}^{[q]}\right) = \frac{1}{3^{l_1-1}} \prod_{kl \in P_{ij}^{q}} a_{ij} \tag{4}$$

where $a_{ij}$ is the weight intensity between $v_i$ and $v_j$.

Total effect [$ET(P_{ij})$] is defined as the weight of all paths between $v_i$ and $v_j$.

The total effect is important for evaluating the crucial path. It can be defined as the weighted average of the partial effects. However, to provide a comparison using total effects, it is necessary to add the weighted sum of all paths, including those with no importance at any given map. Thus, the formula of the total effect can be presented as:

$$TE\left(P_{ij}\right) = \frac{\left[\sum_{t=2}^{n-1} \frac{W^t}{3^{t-1}}\right]_{ij}}{R_{ij}} \tag{5}$$

W is the weight set between nodes $v_i$ and $v_j$, and $R_{ij}$ is the number of possible nodes between $v_i$ and $v_j$.

It is possible to calculate the effects of each path in the cognitive map, but the crucial path is not clear. To find it, the concept of total result is presented:

$$TR(v) = \frac{\sum_{i=1}^{n_g} s_{g_i}.ET\left(P_{m,g_i}\right)}{\sum_{i=1}^{n_g} s_{g_i}} \tag{6}$$

In this formula, $s_{gi}$ is the importance of objective $g_i$ to a cognitive map, and the index m represents the average weight for each path. This measure represents the satisfaction of the case where all the possible consequences of reaching the objective happen simultaneously.

With the definition of TR, it is possible to define a formula for the crucial path. The objective is to find the causal relationships among the estimates of cognitive maps that contribute most to the diversity of opinions.

The extent of divergence is assumed to be the variance of TR:

$$\sigma^2(TR) = \frac{1}{n}\sum_{\alpha=1}^{n}\left(RT^{\alpha} - \frac{1}{n}\sum_{k=1}^{n} RT^{[k]}\right)^2 \tag{7}$$

where $TR^{[\alpha]}$ is the TR of decision maker α. When $w_{ij}^{[\alpha]}$ is defined, it is assumed that the collective weight between $v_i$ and $v_j$ should be the mean weight among the weights provided by the decision makers. This value is defined as $\overline{w}_{ij}$. The variance of all TR should be calculated, using $\overline{w}_{ij}$ as a reference:

$$\sigma^2\left(TR \middle| a_{ij}^{[\alpha]} = \overline{a}_{ij}\right) \tag{8}$$

The smaller the variance is, the more important that way is. There is a fundamental difference of interpretation between the variance of TR and the crucial path. It can be calculated more than one way simultaneously.

Both formulations presented here are distinct. When calculating specific values of $v_i$ and $v_j$, Septer *et al.* (2012) define Equation (7) as a measure of divergence in attitudes. This equation shows the intensity of the difference of opinion between connections.

Alternately, Equation (8) defines the crucial path. This equation creates the replacement of one of the paths for consensus values (defined as the weighted average of the intensities of the paths) and recalculates TRs. If, after this move, the variance presents a very low value, the path can be considered critical.

*3.3.1 Analysis of the crucial path.* After presenting the concepts of the crucial path, it is important to discuss how it can help the process to obtain a consensus:

- Calculation of the crucial links and variances.

All nodes and their direct and indirect paths must have their variance calculated. The results should be entered in a table with all the values of the critical links, and the analyst should use this table as a reference:

- Calculate the TE of the most important paths.

The total effects of the paths of each cognitive map must be calculated to highlight the differences of opinion. The interpretation of the TE should be careful, and various mistakes are to be avoided:

- Final adjustments in cognitive maps.

The maps can be adjusted. The calculations are done again, and it is expected that a consensus has been reached. Otherwise, this step must be repeated.

## 4. Application of the proposed model

Langfield-Smith and Wirth (1992) proposed a method for calculating the difference between cognitive maps and showed an example to illustrate. The objective of this work is different, but the maps used allow for illustrating aspects of the model proposed in this paper. The information from the example is described below.

Three managers represent their beliefs about the consequences of the release of a new alcoholic product.

The managers are named X, Y and Z. The numbers associated with the concepts are used to represent them in the construction of maps. Some of these concepts were shared. Others were used by only one of the managers. The cognitive maps that expresses the presented below beliefs of Manager X, Y and Z on the problem are presented in Figure 1.

The numbers on top of the arches represent the force of the causal relationship between nodes. This force varies in the range [−3, +3]. A strong positive perception of a relationship or a strong negative perception is represented by +3 or −3; a moderate positive perception of a relationship or moderate negative perception is indicated by +2 or −2; a weak relationship by +1 or −1.

Manager Y expressed two concepts as generators nodes: nodes 9 and 10. Similarly, manager X considered node 14 to be a receiving node.

Finally, manager Z's cognitive map contained four generators nodes, 8, 20, 27 and 28, and two receiver nodes, 14 and 18.

The individual cognitive maps of managers express the personal reflections that they have about the factors involved in the launch of a new alcoholic drink. Every manager used a different amount. This emphasizes the differences between what they believe.

When comparing two cognitive maps, differences of opinion can be classified according to their type as follows:

- Existence of elements (r0): an individual considers as important a concept, represented by a node. Another individual does not consider this same node and therefore does not add it to the map. Comparing the maps of managers X and Y, this divergence can be observed in node 2, which is only considered by manager X.

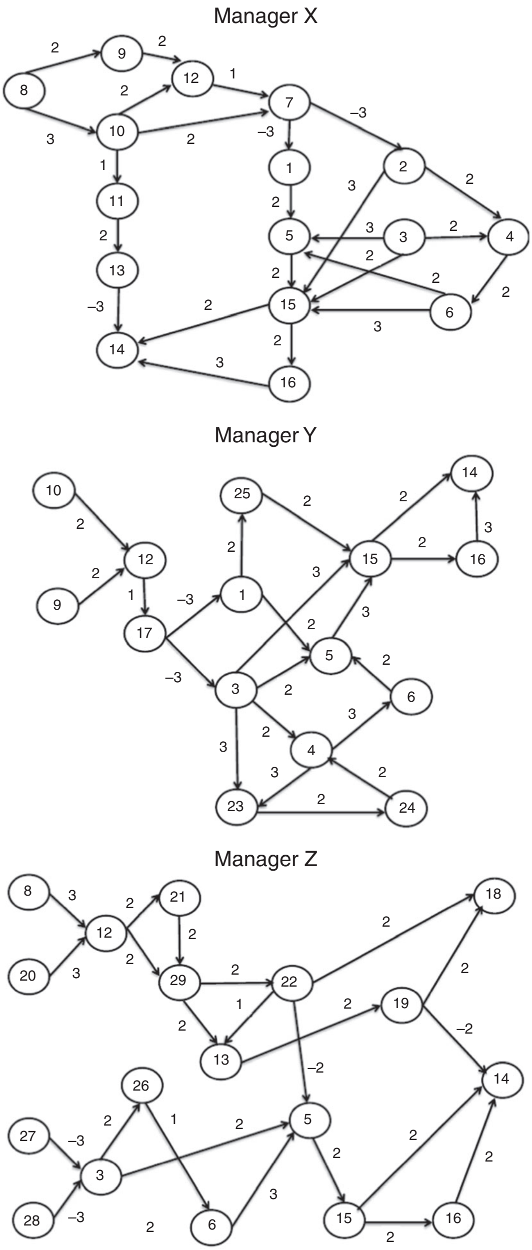


**Figure 1.**
Individual cognitive maps

- Existence of a relationship (r1): maps may differ on whether a causal relationship exists between two nodes. Comparing the maps of managers X and Y, this divergence is noticed with respect to nodes 1 and 5. The managers consider these two nodes in their maps, but only manager X defines a relationship between them.

- Direction (r2): evaluation of a relationship between two nodes may differ according to the causal relationship among them. For example, a cognitive map can evaluate a certain relationship as a positive effect, while the other can evaluate it as a negative effect.
- Intensity (r3): decision makers can agree on the direction but differ on the intensity of this relationship. For example, the relationship between two nodes can be judged as "strong," and another decision maker can consider this relationship as "weak." This divergence is observed when comparing the maps of managers Y and Z. In the assessment of the causal relationship between nodes 6 and 5, manager Y rated the force of this relationship as moderate (+2), while manager Z considered the relationship as strong (+3).

*4.1 Aggregation of individual maps*

After construction of the individual cognitive maps, the next step is the aggregation of these maps. The information that can be used to complete this step and reach a collective map that represents the group's vision of the problem is described below, as are the steps of the proposed model.

*4.1.1 DR*. Langfield-Smith and Wirth (1992) calculate the distance between each pair of maps. The results were:

$DR_{XZ} = 0.0678$

$DR_{YZ} = 0.0640$

$DR_{XY} = 0.0489$

This result indicates that the maps of managers X and Y are closest. This information can be useful in the search for agreements.

*4.1.2 Cluster*. The reduced amount of maps and nodes make this step unnecessary for this application.

*4.1.3 Classification of nodes*. All concepts chosen and depicted as nodes must be classified according to their presence in the individual maps.

In the example used, there are 29 nodes, which can receive the following classification:

- global consensus node: 3, 5, 6, 12, 14, 15 and 16;
- relative consensus node: 1, 4, 8, 9, 10 and 13; and
- restrict importance node: 2, 7, 11, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 and 29.

Thus, of the 29 concepts submitted by managers, seven are shared by all, six are shared by two managers and 16 concepts are used by only one manager.

The nodes of global consensus can be added directly to the collective map, and the other nodes should undergo further analysis.

*4.1.4 Calculation of force ratio*. The Force Ratio allows for identifying the importance of a node in the existing relationships in an individual map and when considering all stakeholders, thereby providing a parameter for the elimination of those nodes with little influence in the process.

Thus, applying Equation (3) defines the force ratio, as shown in Table I.

The highlighted nodes are the nodes of global consensus, which have been included in the collective map. It is noteworthy that node 12, although considered by all participants, has connections with weak intensities. This justifies the force below 2. When the force is less than 1, the nodes can be excluded from the collective map.

| Node | Force (*F*) | Node | Force (*F*) | Node | Force (*F*) |
|---|---|---|---|---|---|
| 1 | 1.44 | 11 | 0.50 | 21 | 0.67 |
| 2 | 0.83 | 12 | 1.94 | 22 | 0.58 |
| 3 | 2.42 | 13 | 0.83 | 23 | 0.67 |
| 4 | 1.50 | 14 | 2.39 | 24 | 0.67 |
| 5 | 2.25 | 15 | 2.19 | 25 | 0.67 |
| 6 | 2.28 | 16 | 2.33 | 26 | 0.50 |
| 7 | 0.67 | 17 | 0.78 | 27 | 1.00 |
| 8 | 1.50 | 18 | 0.67 | 28 | 1.00 |
| 9 | 1.33 | 19 | 0.67 | 29 | 0.67 |
| 10 | 1.25 | 20 | 1.00 | | |

**Table I.** Force ratio for the nodes

This criterion is based on the lower amount and intensity of connections. However, the connections must be checked for consistency after the removal of nodes.

When the force is between 1 and 2, nodes should undergo analysis. To set about adding or excluding nodes between $1 < F < 2$, further discussions can be had among the group. Another option is to define a new level of acceptance/rejection.
This stage ends when it forms a collective map that represents the group's view of the issue at hand.

Thus, using the criteria presented in the example of the launch of a new alcoholic beverage, the map shown in Figure 2 may represent the thinking of three managers.

*4.2 Refinement of information*
Finally, an analysis of the cognitive map is suggested to identify points that need special attention in the discussion. This is done by identifying crucial paths. The identification of crucial paths allows for finding what the impact of the alignment of opinions is. That can direct the focus to the connections that can contribute to the consensus.

The paths were drawn from four different nodes generators, 8, 20, 27 and 28, but node 20 has been removed in the previous step. All paths have the receiving node 14. When performing the calculations for the 36 possible paths, there was a tie between four paths, (27-3-5-15-14), (27-3-6-5-15-14), (28-3-5-15-14) and (28-3-6-5-15-14) with $\sigma = 0.513$.

This result provides some information about the problem. First, nodes 27 and 28 are originally present only in the decider map Z. This isolation of Z-maker had already shown signs in calculating the DR. The facilitator, therefore, must act in these cases to approximate the cognitive maps.

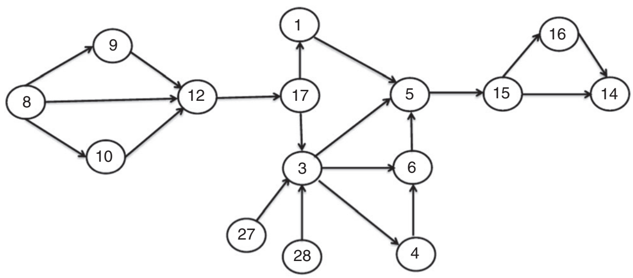


**Figure 2.** Collective map

The crucial path from node 8 was also calculated, which would include information from managers X and Y. The paths (8-10-12-17-3-5-15-16-14) and (8-10-12-17-3-5-15-14) reached $\sigma = 0.171$.

In this specific example, it makes no difference to calculate the ETs because, as X and Y did not consider nodes 27 and 28 and the Z-maker did not consider node 8, the calculations of individual ETs show no discriminatory values.

After the calculations, modifications are suggested in the crucial paths to decrease the discrepancy between the views. With this, it is expected that the collective cognitive map can adequately represent the parties involved.

## 5. Concluding remarks

The paper presents a procedure to transform personal cognitive maps into a representative global cognitive map. To this end, various tools that generate information and facilitate the process are used. The information generated by the method assists the analyst in interpreting and organizing the data collected and in the analysis of the global cognitive map, where greater efforts and discussions are needed in the search for consensus.

The example given illustrates how the proposed method can be applied. The collective map used almost half of the union of the nodes individually, without thereby losing the representation of the decision makers. By identifying and acting on crucial paths, the distances between the maps tend to decrease and become closer.

It is important to highlight some weaknesses of the proposed method. First of all, for a set up that will yield proper results, it is important that participants have knowledge on the functioning of the method. Although this condition may result in greater stakeholder confidence in the process, the decision making process can lose part of its efficiency. Furthermore, the amount of required workshops and interviews can require extra costs and be time consuming for the participants. To address this weakness, it is suggested that future studies focus on finding alternatives to improve the usability of the method for stakeholders.

The insertion of new techniques to aid the decision regarding the aggregation of cognitive maps is a suggestion for continued research. This can reduce the bias of the analyst. Another suggestion is to apply the method in different contexts and group sizes to test the limits of the method.

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