A dynamic methodology and associated tools to assess organizational capabilities

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Abstract

The assessment of organizational capabilities becomes a great challenge in extended and flexible organizations. This assessment is generally independent from the evaluation of operational results and could become isolated from the rest of the global performance system and face validity issues. This paper aims at creating new control loops by proposing a methodology and a toolbox. These help managers to regulate design and transfer discrepancies and to improve the assessment of organizational capabilities.

These propositions are implemented and tested on the industrial case study of Valeo Group, which adopted the Organizational Capability Approach (OCA) in 2006.

1. Introduction

In order to improve their performance, firms look to control their process management and their organizational learning. In this framework the Organizational Capabilities Approach (OCA) emerged in the beginning of the 1990s.

Relying on competency engineering and process-oriented quality “standards”, good practice guidelines were written and modeled by functional experts. These guidelines are used to encapsulate key knowledge and key resources, i.e., the fundamental performance drivers of firms.

These guidelines therefore provide the bases for an “a priori” performance management system (based on the measurement of performance drivers) aside the traditional “a posteriori” system (based on the measurement of operational results).

Nevertheless this implementation of OCA must be done carefully. One must verify if the assessment of organizational capabilities is correlated to the reality of the performance of the firms’ processes. So the questions of the relevance and the validity of practices guidelines must be kept in mind.

This paper aims therefore at rethinking the place of the OCA in the global performance management system, by answering methodologically to these validity issues of the assessment. After a state of the art on the methods for managing and assessing OCA (part 1) a generic assessment model is proposed (part 2). This results in the concrete identification of discrepancies that explain the validity issues. A methodology and a toolbox (with quantitative and qualitative indicators) are then built to refine and improve the assessment of Organizational Capabilities (parts 3 and 4). These elements are applied and tested on the specific case of the Roadmapping method, an OCA method deployed within the Valeo Group since 2006. Finally a discussion is led on this contribution which creates new control loops on the assessment of Organizational Capabilities.

To improve the readability, mathematical formulas are put in the appendix at the end of the paper. They are not essential to the understanding of the methodology, but they can provide indicators to implement the control of discrepancies.

2. Problem data: Organizational Capability Approach methods and limits

After defining the concept of organizational capability and its characteristics, we present assessment methods of the literature, their benefits and their limits.

2.1. Organizational Capability Approach and current methods

Organizational Capability Approach is an emerging theory emanating from management sciences. It is part and parcel of a...
resource based view, which focuses on the internal identification of resources, knowledge and competencies that are considered as strategic, that is to say available for creating a sustainable, competitive advantage for organizations (see [1–3]). Moreover, it is opposed to an “over-elitist” view of resources, which considers only the valuable, rare, inimitable, non-substitutable resources [4,5]. It answered to this criticism through a “managerial” view, and it aims at developing a competitive advantage through the combination of resources that are not strategic when they are taken alone. Proponents of this approach, Saint-Amant, Renard [6] and Fall [7] define organizational capabilities as “the ability to act which results from the combination and the coordination of resources, knowledge and competencies of organization through the value flow, to fulfill strategic objectives”.

This definition points out some pregnant characteristics of the Organizational Capability Approach, as emphasized in Fig. 1:

- Organizational capabilities constitute the key aptitudes that a company must develop and assess to gain a competitive advantage and to determine its strengths and its weaknesses [8] [9,10].
- Organizational capabilities emerged from the synergies of organizational resources, which continuously progress thanks to the acquisition of knowledge, and competencies. They are thus related to organizational learning [11].
- Organizational capabilities can be expressed through the value flow. The use of organizational capabilities should indeed generate a performance improvement in the activities of organization [12]. Trends derived from performance indicators can therefore be clues to their development.
- Finally organizational capabilities align all organizational resources to achieve corporate objectives. At a local level organizational capability is the synergy of human, physical and structural resources of an entity around the defined strategic objectives. At upper levels organizational capability is the synergy of entities.

From this definition we distinguish two kinds of OCA assessment:

- a consequential analysis (what does OCA result in?): organizational capabilities are here considered as black boxes. Firms are aware of the “existence” of organizational capabilities, but they do not manage them operationally. To some extent, they only focus on the visible and resulting part of organizational capabilities, considering that financial performance and customer satisfaction (see Balanced Score Card from Kaplan and Norton [13]) are the expression of organizational capabilities. This monitoring led to reactive, corrective strategies and the solving of apparent issues. The hidden assumption was that if they generated good performances for such an activity, then they should have acquired the capabilities associated to this activity. Organizations therefore focused only on the activities where they had some difficulties, considering that the efficient processes were mastered.

- a causal analysis (what is OCA composed of?): organizational capabilities are here managed and developed pragmatically. Firms focus more on the long term dimensions of the Balanced Score Card [13]. They aim at implementing research works on organizational learning [14,15], competency engineering [16] and process-oriented quality standards. So organizations turned their strategies into a systematic preventive mode. They considered it necessary to document and boost learning around all processes (even the unproblematic ones), to prevent them from a performance decline. So they assumed that if they acquired knowledge corpus, then they should be efficient.

This second standpoint for OCA management (the causal analysis) has been enriched by many scientific and industrial works for this last twenty years [17–20]. Industrial groups constitute different good practice guidelines to make their entities progress on particular concerns (production, information system, purchasing, etc.). They clarify and transmit the knowledge pillars through extended structures, where communication can be complex due to the numerous interactions and the distance between interlocutors (at geographical, semantic or cognitive levels). Same efforts are also found in national institutions, like the Canadian electronic administration [6], or in organizations for the development of emerging countries [21,22].

Among them we can identify two different categories for these methods based on the causal analysis of organizational capabilities:

- maturity-based methods, which decompose organizational capabilities development into progressive steps. For instance,
CMII [20] or the 5 Steps method [23] use 5 or 6 levels. This enables a progressive learning structure of the different involved resources (in process groups or themes) and provides metrics to assess organizational capabilities.

- Coverage-based methods, which focus on the acquisition of best practices. Like ISO [24] or ITIL [25], methods, they assess the quantity of practices acquired, without defining an order or a progressive path to develop organizational capabilities.

2.2 Limits of current methods for assessing organizational capabilities

However, this exclusive causal logic – used by the methods quoted previously – raises limits:

- Limit L. Design and transfer imperfections: the choice of practices for structuring and modeling organizational capabilities development is only a design assumption [28]. It must be refined to correct imperfections at the formal work level – during the design phase – and in the practical application of methods – during the transfer phase [27].

Actually, this main limit is implicitly hidden by two other barriers: managerial and conceptual:

- Limit La. Organizational Inertia: OCA needs renewal mechanisms to keep practices and assessments reliable. This renewal is described by the triple learning loop (see [28] adapted from [29]) and it often relies on participative innovation. However, this innovation is complex to implement and it is sometimes deficient. Thus Deslè et al. [30] explain that this renewal process is very dependent on enterprise culture. Furthermore a survey at Valeo [31] showed that operational managers are already overwhelmed by operational objectives and they do not have enough time to spend on feedback and on improving Valeo’s practices.

- Limit Lb. Dogmatic standpoint and silo effect: OCA is able to anticipate the organizational behavior (because the diagnosis is based on what induces performance rather than the obtained performance). Nevertheless, this causal knowledge-based assessment generally does not verify the impact of OCA on operational performance. OCA could then become a dangerously “isolated system” within the global performance system. Good practice guidelines could be transformed into irresistible dogma, whereas practices should be updated continuously to keep the assessment reliable [32].

The following paragraphs will focus on the characterization of the discrepancies mentioned in the main limit L, before exploring the leads to face barriers La and Lb and regulate the discrepancies.

2.3 Identification of discrepancies in the phases of design and transfer of OCA’s models

The causal models proposed in the literature ease the deployment of the organizational capabilities. Nevertheless these OCA methods deny the existence of limit L, considering as negligible the discrepancies coming from the phases of design and transfer. Indeed they claim to be standards or proved norms, which should guarantee “a priori” a reliable assessment. This dogmatic standpoint could explain the limits expressed above.

To deal with this issue, the literature on individual competency management [9,19,33–35] could provide interesting clues to get out of the conceptual hole (synthesized in the C-makers model from [36]). They also propose an assessment based on the comparison between required and acquired competencies, represented by a set of good practices.

These concide that at least two strong assumptions [17] must be verified to obtain a reliable assessment:

- Discrepancy D1. Competency/Capability coherence: the link between organizational needs and competencies/capabilities must be correctly and completely described. The coherence between the mission to fulfill and the competency to acquire must be guaranteed.

- Discrepancy D2. Competency/Capability learning efficiency: the link between required and acquired competencies/capabilities must be correctly and completely described. The design is robust enough to take into account the context of use, and the transfer is independent from the learning entity and the local context.

A third source of discrepancy is emphasized by Stata [37]. This author contests the implicit assumptions of OCA models: the implementation of the management of knowledge based models does not always result in a performance improvement within the organization. Sometimes it can even create disorganization.

- Discrepancy D3. Competency/capability effectiveness: there is adequacy between the acquired capabilities (potential performance) and the activity results (real performance).

Coherence, efficiency and effectiveness are terms generally used for characterizing the performance [38]. Their application to the concept of competency, and by extension, to organizational capabilities, enables a better understanding of what causes the design and transfer imperfections (La).

2.4 Approaches and methods for overcoming the OCA limits

To overcome the previous limits and regulate the discrepancies mentioned above, several approaches emerged from the literature:

- For discrepancies D1 and D2:

  The main factor explaining the uncontrolled drift of the capability coherence and the learning efficiency is limit La. The absence of communication and participative innovation prevents: (1) functional experts from improving the design of the knowledge models, and (2) local managers from alerting the issues encountered when knowledge models are implemented.

  Research works attempt to circumvent this limit La, to regulate D1 and D2:

  - There are methods that propose “qualitative” rules to improve the design of the model, such as enterprise modeling approaches IDEF [39] or GRAI [40] approaches. That helps to verify “a priori” that the model reaches an accurate level of homogeneity or granularity.

  - There are other approaches which focus on the study of the learning speed [41]. This temporal indicator could alert if organizational entities stagnate, and provide information on which knowledge elements cause this blockage.

  - For discrepancy D3:

    The dogmatic isolation of OCA in the global performance system (limit Lb) can explain the drift of the effectiveness discrepancy (D3). A causal knowledge model of an organizational capability must be continuously tested and validated (as specified by [26]). It is indeed necessary to verify if the performance drivers (the good practices) proposed and structured by functional experts result in the desired effects.
Different research works continue in this way, to overcome limit \( L_b \) and to regulate D3:

- At a theoretical level, Boucher, Bonjour and Grabort [42] insist on the necessity to make the connection between performance, competency and processes.
- At a practical level, [43–45] studied the impacts of resource and competency management on industrial and operational performance. They crossed statistically performance indicators with competency indicators to evaluate the benefits of the Human Resource System. These authors emphasize the difference of behavior and results according to the context of learning (due to the emergence of a specific culture influenced by the country or the type of product delivered by an organizational unit).
- Collateral benefit: perspectives to overcome limit \( L_a \)

The new information resulting from this permeability between operational results assessment and OCA assessment could provide the means to resuscitate the participative innovation. Research works on communities of practices [12,46] pointed out that passive feedback [47] can be used to automatically identify some groups of organizational entities which share similar properties and the same issues. That enables managers to launch participative innovation around targeted issues in a specific range of the organization.

2.5. Synthesis

Part I highlighted a pregnant limit (L) in the assessment of Organizational Capabilities. This limit is characterized by the existence of three discrepancies (D1, D2 and D3), occurring in the phase of design and transfer of OCA’s causal models. Moreover, the influence of two other barriers on limit L was established, one at a managerial level (La), the other at a conceptual level (Lb).

The main issue addressed in this paper (cf. Fig. 2) is therefore to overcome limit L. It is necessary to remove barriers La and Lb, so as to enable the regulation of the discrepancies.

Relying on the principles emphasized in Section 2.4 and the complementarity of causal and consequential analyses, this paper will propose solutions to solve the problem. First it is necessary to set up and model the problem (i.e. formalizing the assessment of current OCA methods so as to identify discrepancy parameters). Then a methodology and a toolbox will be built and justified, so as to regulate the discrepancies and to avoid an isolation of OCA within the global performance management system.

The following parts of this paper aim at identifying and correcting these discrepancies which emerge in the phases of organizational capabilities design or transfer. First we will list discrepancy parameters then we will propose a methodology and tools to control them.

3. Problem setting: generic assessment models and definition of discrepancy parameters

This part studies the knowledge-based models, in detail, so as to extract generic assessment rules to stress potential discrepancies.

3.1. Knowledge-based assessment models

The study of knowledge-based methods (cf. Section 2.2) distinguishes some common points, which also comply with the definition of organizational capability (cf. Fig. 1):

- Organizational capability can be decomposed according to three knowledge granularity levels. A capability is generally broken down into requirements (objectives of knowledge corpus acquisition), and then into practices (elementary knowledge, means to achieve the requirement). This decomposition
structure is found for instance in CMMI method, ISO norms, the 5 Steps Roadmapping method, but also in SMEMP, a maturity model for developing the organizational capabilities for project management [48].

- **Organizational capability can be decomposed according to three resource levels:** A capability is broken down into thematic resource groups (the 5 steps method) or aspects, process groups [19,20], functional departments or aspects [17], knowledge areas (SMEMP) etc. and then into elementary human, physical and virtual resources. Organizational capability therefore constitutes a conceptual link between functional knowledge and the resource which has to acquire it.

- **Organizational capability development follows a logic of acquisition**, based on maturity objectives (in CMMI or the 5 Steps Roadmapping method), or coverage level with a conformity trigger (in ISO norms).

These observations result in the definition of the variables used for formalizing both generic maturity- and coverage-based assessment models (cf. Appendix 1).

### 3.1.1. Maturity-based assessment models

The maturity methods look to coordinate, step by step, the progress of all resources composing the capability.

- A requirement is reached if all practices involved in the maturity level are acquired by the resource.
- The maturity level of a resource is given by the sum of the resource maturity level activations, that is to say that all practices of the lower levels must be acquired.
- The maturity level of a capability is given by the sum of the capability maturity level activations, i.e. all practices of the lower levels must be acquired for all resources composing the capability.

### 3.1.2. Coverage-based assessment models

Coverage-based methods look for the progress of resources toward a conformity threshold. There is no more concern about maturity, but about quantity of acquired practices. Different logics can be applied. Capability can be considered globally, or each resource can be studied to verify if it reaches a sufficient local coverage of practices. An example is given in Fig. 3.

- The coverage of a resource is given in percentage by the amount of requirements reached on the number of existing requirements for this resource. The number of existing requirements corresponds to the number of maturity levels of capability, since the maturity structure is kept for comparing maturity to a coverage model.

The coverage of a capability is given in percentage by the amount of requirements reached on the number of all the requirements composing the capability model.

### 3.1.3. Comparison of maturity- and coverage-based assessments

The maturity assessment introduces the notions of order, of learning paths. It insists therefore on gradual progress, and rewards coordinated and synchronized knowledge acquisition. On the contrary, coverage assessment takes all practice acquisitions into account (or at least the requirements reached) to assess capability and resource states. The two assessments can be thus used independently, to express two different ways to acquire knowledge. However the choice of the assessment impacts the way of learning of the entities. With the maturity methods, learners focus on homogeneously mastering their resources, whereas the coverage methods incite people to explore all the practices they can acquire. Moreover only maturity assessments provide meaningful metrics for organizational capabilities. Maturity levels are given according to a structure established for developing capabilities, whereas coverage percentages are difficult to analyze, except from showing how organization and its entities are from the complete acquisition of the capabilities. The first one can therefore be considered as an indicator for organizational diagnosis, and the second one is more adapted to inform learners and encourage them. To illustrate this difference, let us consider an example. An organizational capability Cox and its resources are assessed (Fig. 3) with the maturity-based and coverage-based assessments.

The gray requirements ($E_{ij}$) mean that all their elementary knowledge ($K_{ij}$) has been acquired (All or nothing logic).

### 3.2. Potential discrepancies in knowledge-based models

The assumed ideality of the used knowledge-based models sometimes does not fit reality. It is therefore necessary to consider the existence of discrepancy parameters. This section analyzes the potential discrepancies:

- in the design phase, when organization model organizational capabilities by structuring good practices guidelines
- in the transfer phase, when these modeled organizational capabilities are transferred to entities to develop their skills on strategic subjects.

#### 3.2.1. Design discrepancy parameters

$\varepsilon_{Rm}$ – discrepancy in the structure of resources

The parameter $\varepsilon_{Rm}$ represents a design discrepancy which comes from a too complicated structure (there are too many
resources, some resources could be combined into one) or too simplistic a structure (the resources composing organizational capability are insufficient).

\(\varepsilon Kn\) – discrepancy in the structure of knowledge

The parameter \(\varepsilon Kn\) can only be present in a maturity model since it focuses on the learning path. It represents a design discrepancy which can occur if:
- the practices \(Kijz\) are insufficient or not structured enough to reach the requirement \(Eij\);
- the practices \(Kijz\) (or at an upper level the requirements \(Eij\)) are not well ordered: assessment.

- if two practices are too far from each other, in time or in structure, the memory effect of the learning path can be dissipated
- if the learning path is suboptimal for the learning context. For instance, teaching theory before practice can work for some people who favor abstract concepts, but practice before theory is sometimes more understandable for operational people
- if there is a permutation between two conditional practices or requirements (e.g. if the first one is modeled in the structure after the second), the organizational capability development is at a standstill.

3.2.2. Transfer discrepancies parameters

\(\varepsilon Rm'\) – discrepancy of contextualization in the structure of resources

\(\varepsilon Rm'\) represents the discrepancy when the context of the application is in discord with the practices modeled. Some resources can be absent from the operational ground, or be broken down in a different way than in theory. The users then find it difficult to assess their progress, or to use the assessment to diagnose their status. If a discrepancy appears for all entities, then it becomes a design discrepancy.

\(\varepsilon Kn\) – discrepancy of contextualization in the structure of knowledge

The practices or requirements, which must be acquired, are irrelevant for such an entity. The entity can notify that by declaring the knowledge inapplicable. If this discrepancy exists for all entities, it also becomes a design discrepancy.

\(\varepsilon A\) – discrepancy in assessment

This represents the discrepancies which can occur in the assessment (human discrepancy for instance) and can cause interference on the obtained maturity level or coverage.

This part precisely formalizes the parameters explaining the design and transfer discrepancies introduced in Section 2.4. The following sections will justify some propositions for estimating and detecting these discrepancies in the framework of a methodology.

4. Problem solving strategy: a methodology for controlling discrepancies

In order to overcome the identified barriers, we propose a methodology and then use it to build tools.

4.1. Assumptions

- Knowledge-based assessment: The modeling structure of literature methods enables an evaluation of organizational capabilities. The measure of knowledge/competency acquisition can therefore assess a capability. Section 3.1 develops and formalizes this point.
- Causality: Capabilities (what an organization is able to do) cause performances (what organization achieves). This assumption is time-dependent: there can be a delay, a ramp-up phase between knowledge acquisition and the expression of the capability.
- Equivalence: A capacity level (maturity-based methods) or quantity (coverage-based methods) must fit a performance level. So there is equivalence between a potential performance and an expressed performance.
- Design and transfer discrepancies existence: Modeling or applying a knowledge model at operational level can generate discrepancies: e.g. the model does not induce the desired performance, or the model is unfit for such contexts.

4.2. Proposed methodology

The current proposition improves the reliability of organizational capability assessment, by using the previous assumptions. Fig. 4 illustrates the methodology.

4.2.1. Step A. Impact analysis of organizational capabilities on performance

Causal links (between “potential” and “expressed” performances) are determined, by crossing organizational capabilities assessment with performance indicators. This first step enables us to find the performance criteria necessary to study the behavior of each capability.

4.2.2. Step B. Discrepancy identification for one organizational capability

The discrepancies are analyzed according to two different processes:

- B.1. Internal discrepancy estimation, by analyzing “coherence and learning efficacy discrepancies”: The discrepancies are identified by studying only the complexity of the structure or the knowledge acquisition speed of an organizational capability (cf. Section 5.1).
- B.2. Discrepancy detection by analyzing “effectiveness discrepancy” (cf. Fig. 2) between knowledge-based assessment and performance results: Discrepancies are detected by comparing statistically the capability evaluation to the associated performance indicators (obtained in step 1).

4.2.3. Step C. Discrepancy correction for one organizational capability

Discrepancy identification generates actions on how one organizational capability is assessed:

- C.1. Indicative assessment improvement: The feedback given by the phase of discrepancy identification informs managers of any problems.
- C.2. Corrective model improvement: If identified discrepancies concern the organizational capability design, the model is improved.

4.2.4. Step D. Aggregation/consolidation of assessment

The assessments and performance indicators (given by each organizational entity) are aggregated and consolidated. It helps managers to diagnose their organizational capabilities more reliably, whatever organizational level is studied. Some adapted organizational capability indicators can be built from local assessment (cf. IV).
5. Problem solutions: tools for identifying discrepancies

In this section we explain and justify the tools we developed for improving organizational capability assessment. It focuses especially on step A (impact analysis) and B (discrepancy identification) of the proposed methodology (as illustrated in Fig. 5).

This figure emphasizes the information used for each step of the methodology, which helps the estimation and the detection of discrepancy parameters:

- Step A. Impact analysis data source
  - The values of performance indicators.
  - Step B.1. Discrepancy estimation data source
    - information about the structure of the model,
    - information about the learning behavior of the model, given by active feedback (in natural language) or passive feedback (analysis of the assessment of Organizational Capabilities),
    - the self-evaluation of organizational capabilities by each entity and its behavior
    - the declaration by some entities that a practice, a requirement or a resource is inapplicable, audit reports, which enable the detection of inaccurate assessments.
  - Step B.2. Discrepancy detection data source
    - the comparison criteria for each capability resulting from the impact analysis.
  - Step C. Discrepancy correction data source
    - The discrepancy indicators (resulting from B.1 and B.2) and organizational levels where the discrepancies are identified (local or global).

5.1. Tools for impact analysis (Step A)

Let us assume that the major part of organizational capability and performance indicators is shared by all the entities. A statistical analysis can be carried out to determine the impact of organizational capabilities on real performance. By stressing the statistical dependency between organizational capabilities and performance indicators, the impact of potential performance on real performance will be determined (as described in Appendix 3). This tool will provide criteria to compare the behavior of each entity on organizational capability learning (cf. Section 8).

5.2. Tools for internal discrepancy estimation (Step B.1)

Estimation of discrepancies uses information:

- about the structure of the model, in a static and off-line way,
- about the learning behavior, in a dynamic and on-line way, when entities acquire knowledge and give feedback, either by their assessment or by their recommendations.

6. Analysis of the model's structure for estimating εRm and εKn

The parameter εRm can be estimated by studying the complexity of the structure of the resources involved (as emphasized in Section 2.4 with the existing rules to model enterprise with IDEF and GRAI approaches).

6.1. Design rules for εRm and εKn

Organizational capability methods recommend rules for designing with a good granularity level and with all the necessary...
resources. If a model does not match the “normative” recommendations of the methods, a discrepancy in the structure of resources exists.

For instance, in the domain of enterprise process modeling, IDEF0 considers that a process is decomposed with a good granularity level if the number of activity diagrams is between 3 or 6 at each level.

In the same way, organizational capability methods provide modeling principles. For instance, the 5 steps method decomposes organizational capabilities from 5 to 10 resources. The parameter \( \varepsilon_{Rm} \) can therefore be determined by the distance to this interval. Likewise, design rules could be proposed to recommend a good granularity level of requirement. The parameter \( \varepsilon_{Kn} \) could be therefore determined by the distance to the suggested “right” number of practices.

6.2. Structuring groups of resources for \( \varepsilon_{Rm} \)

Methods (like CMMI, project maturity models based on PMBoK, or the 5 steps method) propose lists of process domains,
knowledge areas or themes to guarantee a multidisciplinary capability.

For instance, if a company wants to develop a capability for the effective adoption of a new software by all the employees, it will of course require:

- technical resources (people, methods and tools for purchasing, installing on computers, administrating etc.)
- but also other resources (people, methods and tools for communicating about the new implemented software, for training the employees, and for collecting feedback and helping people who have difficulties).

7. Analysis of the model's behavior for estimating \( \varepsilon_{Kn} \), \( \varepsilon_{Kn'} \), \( \varepsilon_{Rm} \) and \( \varepsilon_A \)

Because the coverage models lack the notion of a learning path, practices can be acquired without following a structure. On the contrary, the maturity methods impose an order to acquire knowledge, so a discrepancy in the structure of knowledge can occur in this case.

7.1. Use of the “learning speed” for \( \varepsilon_{Kn} \), \( \varepsilon_{Rm} \), \( \varepsilon_{Kn'} \), \( \varepsilon_{Rm'} \) (cf. Appendix 2).

- To estimate the parameters \( \varepsilon_{Kn} \) and \( \varepsilon_{Rm} \), the behavior of organizational capability in time can be studied (as mentioned in Section 2.4 regarding the works of de Pablos [41]). If the maturity level stagnates at a global level of the organization there could be a sticking point (at least in practice) which cannot be acquired and blocks the progression of the capability.

The discrepancy can be therefore estimated by the rate of change. This rate of change (or learning speed) can be defined as the difference of the assessment grade of an organizational capability between two different instants. If this rate is close to zero, the learning stagnates. If the rate becomes negative, it means that entities lose some practices.

- The parameters \( \varepsilon_{Kn'} \) and \( \varepsilon_{Rm'} \) mean the model design is accurate but some practices, requirements, or resources of the model are irrelevant for a specific context. There is therefore a discrepancy at a local level. The previous solution can be adapted to estimate the parameters \( \varepsilon_{Kn'} \) and \( \varepsilon_{Rm'} \). Entities that meet some sticking points are found by observing the stagnation for each entity, by comparing the rate of change of one learner from the others.

7.2. Use of “user feedback” for \( \varepsilon_{Kn} \), \( \varepsilon_{Rm} \), \( \varepsilon_{Kn'} \), and \( \varepsilon_{Rm'} \)

Another means is to rely on user feedback. In the 5 steps method, people who assess organizational capabilities can declare if a practice, a requirement or a resource is applicable or not to their context.

The NA declarations (“not applicable”) can mean a design or a transfer discrepancy, depending on the number of entities which declare it. The more numerous the NA on a practice, the more the discrepancy is due to the design. Moreover, some NA feedback can be aggregated to deduce some undeclared NA. For instance, if a resource presents too many requirements of practices which are not applicable, then the resource should be considered as not applicable too.

7.3. Use of a “double check” assessment for \( \varepsilon_A \)

Finally the discrepancy due to an inaccurate assessment can be estimated by audit campaigns. These actions correct the discrepancies of an assessment, and could also give feedback for designers. Practices or resources may not be acquired correctly because they are misunderstood by entities.

8. Tools for discrepancy detection (Step B.2)

The previous tools for discrepancy estimation only study the internal structure or behavior of the organizational capability model. So as to check if knowledge-based assessment models are reliable, it is also necessary to evaluate organizational capabilities in another way. This other means is to compare the value given by the acquisition of knowledge (what induces the organizational capability) with the value given by organizational performance indicators (what is expressed by the organizational capability). The following propositions are based on the works of Becker et al. [43] and Ahmad et al. [44] studying the link between competency management and operational performance (mentioned in Section 2.4).

8.1. Use of impact analysis for detecting global design discrepancies and finding comparison criteria

First, it is necessary to find the performance indicators associated to the implemented organizational capabilities. They can be known or chosen, a priori, by the experts or calculated by studying the statistical dependency between organizational capabilities and performance indicators.

This impact analysis has a threefold role:

- to identify some unknown primary effects or some secondary effects of the capabilities which could be positive or negative for the organization,
- to enable the detection of some design discrepancies (\( \varepsilon_{Rm} \) and \( \varepsilon_{Kn} \)) in the models, and
- to analyze independently each organizational capability, compare entities and detect local transfer discrepancies.

8.2. Statistical comparison for detecting local transfer discrepancies

Once the impact analysis is done, this statistical study aims at emphasizing the potential singularities. These singularities can mean some discrepancy in the assessment (\( \varepsilon_A \)) or some contextual discrepancies (\( \varepsilon_{Rm'} \) and \( \varepsilon_{Kn'} \)).

To achieve this statistical analysis, the assumptions on the equivalence and the causality (expressed in Section 4.1) have to be used. Fig. 6 represents an instantaneous \((t = T)\) picture of the values of the considered Organizational Capability and its associated Performance Indicator.

The equivalence between a level of organizational capability \( gCOX \) and a level of performance indicator \( IPy \) indicates that at least the intervals are in bijection (as illustrated in Fig. 6 by the three rectangles, cf. Appendix 4 for formulas)

With this assumption of equivalence (time-independent and applied globally to the organization), the points outside the boxes are singularities resulting from transfer discrepancies. The parameters \( \varepsilon_{Rm'} \), \( \varepsilon_{Kn'} \) and \( \varepsilon_A \) can thus be calculated by the distance to this boxes. Nevertheless, this approach raises some difficulties, especially to determine the triggers between two consecutive levels (for performance and capability).

The causality assumption (time-dependent and applied locally on each entity) can be used to solve this issue. The causality
between organizational capabilities and performance induces that if \( gCOx(t) \) increases over a period \([t1; t1 + DT]\), then \( IPy(t) \) increases (or decreases) over a period \([t2; t2 + DT']\). The periods \( DT \) and \( DT' \) differ because there can be a delay between the acquisition and the effective emergence of an organizational capability (cf. Fig. 7).

An “interval of tolerance” integrates this local, time-dependent, delay effect on the instantaneous graph (as illustrated in Fig. 6 by arrows on each point). This enables the problem of trigger identification raised by the equivalence approach to be bypassed. This interval of tolerance can be extrapolated to a regression channel (cf. dotted channel of Fig. 6).

The analysis cannot be completely automated. Experts must check if the analysis parameters (performance criterion, size of the “interval of tolerance”) are relevant. Moreover experts must bring their experience and their knowledge to select singular entities. Only human experts are able to take into account some contextual information, which is difficult to inject into a computer. For instance an expert knows that a singular newcomer could be less alarming than an older entity which has had problems for several months). In Fig. 6, the points in the red shapes are considered as singular, and the points in the orange shapes require attention.

9. Identification of the discrepancies (Steps B1 and B.2) for assessment improvement (Step C)

Once the discrepancies are estimated or detected with the previous tools, it is necessary to understand why the discrepancies occur. First of all, as mentioned above, the number of concerned entities must be studied. If it is a global discrepancy (given by the estimation tools or the impact analysis) the model design can be called into question. If it is a local discrepancy, the context of transfer or the assessment by learners can be pointed out and environmental causes must be analyzed.

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**Fig. 6.** Detection by using equivalence and causality assumptions.

**Fig. 7.** Time-dependency of causality assumption: a delay effect explaining some discrepancies between entities.
9.1. Research of model factors (based on the learning speed estimation for maturity tools)

In maturity methods, the study of the organizational behavior in time (learning speed) stresses the existence of a discrepancy. How can we identify this model discrepancy from the estimation of the learning speed of a singular performance of the capability?

- If there is a practice which is put in the wrong place, a major part of the entities could be stuck at a given level.
- After finding the sticking level, the discrepancy must be localized according to the resources. The focus must be on the resources where a major part of the entities are stuck. By repeating the same process for each practice, the problematic practice can be identified.
- The prior discrepancy can be identified by comparing the successful entities with the failing entities, and by studying the difference of practices acquired at the following maturity levels.
- If the study of consecutive levels is not significant, the study must be carried out at the upper level. The same study could be made at an upper level of knowledge granularity, by analyzing the requirements instead of the elementary knowledge.

9.2. Research of environmental factors

When singular entities are detected, it is necessary to understand the origins of these singularities. One possibility is to cross the lists of all these singular entities to find the shared properties of the sites with respectively outperformance and under-performance. This step enables us to identify some issues due to:

- Cultural context (under-performance in specific geographical zones).
- Misunderstanding (an inadequate knowledge of English language can avoid a good self-assessment of capabilities for instance).
- Entity seniority in the organization (the entity is not mature enough on the practices to implement).
- Functional or product context (the practices are not adapted to all the products delivered by an entity).
- Self-assessment mistakes (a single singularity which has no commonalities with other singular sites is sometimes the result of a human discrepancy).

Nevertheless the causes of singular organizational capability performance can also be positive and generate a source of innovation for the organization. Thus outperformance can be seen as occasions to identify new good practices. Indeed an entity with a good value of the performance criterion and a weak grade on the capability model can use practices which have not yet been modeled.

9.3. Improvement

All the tools for estimation and detection are proposed to help experts, but they cannot replace the expertise of managers. These tools could also support innovative participation around organizational capability models [46].

The detection of singular entities enables the experts to focus the support for organizational capabilities development. Indeed, global actions are more difficult to deal with than those at a local level [36]. Vectors of collaboration can be drawn up either between the sites in difficulty and the sites which succeed, or between the similar entities.

Moreover, it can be a means to realize that some deliverables or some requirements must be rewritten in order to be adapted to a local context. This single loop will not change the global assessment of the transferred capability. In addition, the estimation or the detection of generic discrepancy, can express a need for globally changing the content of roadmaps in a double-loop way.

Finally, knowledge-based assessment provides a more finely-shaded analysis to diagnose the capabilities and the state of the organization.

10. Problem instantiation: development of a demonstrator and case study

The previous tools sometimes use a large amount of data, and their implementation needs for automation. This automation would enable the crossing and mining of data, or the visualization of the analysis results which would help managers. This last part shows how tools can be implemented (in a demonstrator) and used in the context of a distributed organization.

10.1. Development choices and overview

To achieve the automation of some tools previously described, we elaborated a demonstrator:

- A part of it was developed in VBA (Visual Basic for Applications).
- The framework because it is easily implementable in an industrial organization. This part focuses on the study of statistical dependency between performance and capabilities, as well as the learning speed.
- Moreover, another part of the tool uses Google’s API. We chose it for its ease of portability (it only needs a web browser and an internet connection). This part implements multi-criteria graphical and geographical views. These views help experts to stress the results of analysis, to identify the singular entities, and to look for the environmental origins of these singularities. In addition, it provides functionalities which gather entities into communities of practices. CoPs represent collaboration vectors between similar entities (to progress by neighborhood and to support entities in difficulties). CoPs also facilitate actions of participative innovation.

10.2. Use of the demonstrator

The 5 steps Roadmapping method [23] is an organizational capability maturity method, designed by MNM Consulting. Supported by a formalism (the roadmap) and a software tool, it has been implemented across the whole Valeo Group since 2008. It is used:

- to codify and transfer good practices with knowledge models called roadmaps, - to integrate new sites on some corporate standards, and
- to assess locally and globally the organizational capabilities.

The research works on this method are in the project Pilot2.0, supported by the French National Agency for Research since December 2007 (ANR, 2007).

For illustrating the use of the developed tool, we take the framework of this industrial and academic project. The data on organizational capability and performance indicators are fictive so as to be able to present a simplified case and to respect industrial confidentiality.

Let us look at an organization V which is composed of one hundred production plants. These plants are specialized in many different products (compressors, lights, air conditioning, etc.) and are located worldwide. They are heterogeneous on their seniority within the organization and its industrial culture.
Step A. Impact Analysis
First of all, we study the impact of their production on the performance of the organization. Our aim was to verify the accurate behavior of these models and to detect some potential global design discrepancies.

We perform a multiple linear regression-based impact analysis (cf. Appendix 3) between Performance Indicators and the production roadmaps. In Fig. 8, the implementation of the roadmap Total Quality/6 sigma has a significant impact on machine capability and Overall Equipment Effectiveness.
Fig. 11. Positions of the proposed tools.
Interviews of experts could also lead to this impact analysis. The automation is only here to confirm their intuition or to indicate some unplanned effects (for instance, the security seems to have a negative effect on machine capability). Moreover, this analysis provides the associated performance criteria for studying each organizational capability (here modeled by roadmaps) and compares plants according to these criteria.

Step B.2. Discrepancy detection

Thanks to a graphical visualization, the expert can select all the plants that seem to be singular (i.e., with a performance not adequate to their maturity level). Entities with under-performance must be distinguished from entities with out-performance. The tool enables us to filter entities according to knowledge on the seniority and some other contextual properties.

For the example, we studied the maturity levels. However, coverage could be also used in the same way. Furthermore, the roadmap could be implemented with some a priori objectives on performance. In this case, the graphic view can also indicate if the cloud of points and the regression channel are coherent with the expected performance.

Once we detect the singular plants, the expert tries to understand what causes these discrepancies. He/she also analyzes if the problem are endemic to a single entity or shared by plants with common characteristics. Thanks to a set of filters and a pivot table, the expert can identify the environmental factors.

As emphasized in the list of singularities of Fig. 9, many plants from Eastern Europe are singular, and most of them present under-performance.

Step C. Discrepancy correction

Finally the expert and the learners can use the output to visualize, graphically or geographically (to take the cultural and neighborhood aspects into account, cf. Fig. 10) collaboration vectors and to gather similar entities into communities of practices [46].

Experts can use these lists of communities of practices to launch focused brainstorming sessions around roadmap adaptation in particular contexts. Moreover this visualization helps entities to find the “good” neighbor to imitate (in terms of roadmap behavior and similarity of properties). Thus, in addition to the path drawn by the maturity level, an alternative progression can be proposed by successful neighbors.

Finally, Fig. 11 stresses how the demonstrator supports the methodology (cf. steps A, B, and C of Fig. 4) and it covers the different tools explained in Section 5 (cf. Fig. 5).

The first feedback from Valeo is positive:

- From a managerial viewpoint, François Blanc, Valeo’s Director of Information Systems, explained the use of a roadmap and the works presented in this paper as a means to give functional objectives in addition to the operational objectives, and to monitor them accurately [47]. “This enables us to have a long-term view of the strengths and weaknesses of an entity, in addition to the short-term performance view. An entity could have, for instance, good financial indicators over a short-term period, if a manager reduces investments, training and resources for process and product innovation. However, this reduction can trigger bad performance, because there are not enough resources. Roadmaps are therefore a means of controlling the sustainable good health of entities and not only their apparent fitness”.
- Moreover, the regulation of effectiveness (step B2, emphasized in the case study), using the comparison of organizational capability indicators with operational result indicators, seems to produce satisfaction. The Valeo survey led in 2008 shows than more than 60% of operational managers considered the roadmap system as a

Fig. 12. synthesis of the proposed solutions to solve the problem.
reporting tool. 65% of them use the system once a month or less, and did not use (or even do not know) the feedback functions. One of them explained this deficient renewal process by a lack of time and the distance between functional managers (“We do not speak with God!” he joked). The first implementation of this complementary module on scenarios showed the advantages for users to detect and to correct the problems in organizational capability management more rapidly, and more locally, in adapted communities of practices (even if participative innovation is still globally weak). To illustrate this point, we mention the following and real “good story”. For more than one year, Valeo’s middle management did not understand why Eastern Europe was not “capable” of security, and they had no local feedback on this issue. A targeted discussion on plants in difficulty was able to explain that the practice of “armbands” actually had a negative connotation in this geographical zone (because of a historical and political past) and prevented the plants from progressing in their learning.

11. Concluding discussion

This paper points out an obvious paradigm which is sometimes forgotten in the implementation of the Organizational Capability Approach. Knowledge-based models must be verified in terms of validity and effect on performance, to avoid a drift of OCA toward a dogmatic and useless management system. On the contrary, OCA should be an open system, linked and integrated in the global performance management system (cf. Fig. 12).

The different propositions of the paper tend toward this point of view. Especially the permeability between OCA and the operational results assessment is created to overcome limit Lb (by using steps A and B2). This opening of OCA enables us also to face the weak participative innovation expressed in La (by using passive feedback and communities of practices explained in step C).

Moreover these propositions for improving the reliability of organizational capabilities assessment open new perspectives for using OCA as a method of organizational diagnosis, by using the last fourth step D, called “aggregation/consolidation”. The assessment and the discrepancies must be indeed aggregated and consolidated, so as to help experts and managers at all organizational levels to give an accurate idea of their strengths and their weaknesses. Thus they understand: (1) what grades really mean, (2) how potential discrepancies can interfere with the signal they receive from the knowledge models evaluation, (3) how they can trust figures when they cross many measurements.

The knowledge of the reliability of the OCA indicators would therefore enable an accurate organizational diagnosis. Thus a relevant strategy could be articulated and implemented, transforming the power of organization (knowledge acquisition, resource synergy, and finally the emergence of organizational capabilities as described in Fig. 1) into efficient activities. This could for instance:

- control the progress of entities on the organizational capabilities (by studying the dispersion of maturity of the resources composing an organizational capability);
- manage multi-objectives, multi-disciplinary and therefore “multi-capability” subjects;
- deduce the degree of interoperability [12] for launching collaboration or reorganizing the organizational structure (for instance by developing joint sourcing between several plants, according to their maturity degree on their product reference and their relationship with suppliers).

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Appendix 1. Maturity and coverage evaluation

Let us take the following variables:

COx be an organizational capability, Ri a resource involved in COx, M the number of COx’s resources, N the number of maturity levels of COx, Gj a resource group of COx, and Ej a requirement (a set of knowledge) that Ri has to achieve at the maturity level j.

Kijz an elementary knowledge (a good practice) which is a part of Ej, with Oj the number of Kijz composing Ej. Following the “All or Nothing” logic, the acquisition of elementary knowledge is expressed by:

\[ K_{ijz} = \begin{cases} 1 & \text{if Kijz is acquired} \\ 0 & \text{else} \end{cases} \quad (1.1) \]

A requirement Ej is fulfilled if all practices Kijz are acquired.

\[ E_{ij} = \begin{cases} 1 & \forall z \leq O_j, K_{ijz} = 1 \quad \Leftrightarrow \quad E_{ij} = \prod_{z=1}^{O_j} K_{ijz}. \quad (1.2) \end{cases} \]

A.1. Maturity evaluation

The maturity level of a resource Ri and an organizational capability COx can be expressed with the following formulas (an illustration is given in Fig. 3 with N = 5):

Let us take the following variables:

- nk be a maturity level, with nk ≤ N
- a(nk,Z) the function that evaluates if a maturity level nk is activated for each object Z (resource or capability).

\[ a(nk, R_i) = \begin{cases} 1 & \text{if } \forall j \leq k \leq N, E_{ij} = 1 \quad \Leftrightarrow \quad a(nk, R_i) \\ 0 & \text{if not} \end{cases} \]

\[ = \prod_{j=1}^{k} E_{ij} = \prod_{j=1}^{k} \prod_{z=1}^{O_j} K_{ijz}. \quad (1.3) \]

\[ a(nk, COx) = \begin{cases} 1 & \forall z \leq M, a(nk, R_i) = 1 \quad \Leftrightarrow \quad a(nk, COx) \\ 0 & \text{if not} \end{cases} \]

\[ = \prod_{i=1}^{M} a(nk, R_i) = \prod_{i=1}^{M} \prod_{j=1}^{k} \prod_{z=1}^{O_j} K_{ijz}. \quad (1.4) \]

The maturity level nRi that a resource Ri reaches is given by the sum of the resource maturity level activations, that is to say that all practices Kijz of the levels nk ≤ nRi must be acquired.

\[ n_{Ri} = \sum_{k=1}^{N} a(nk, R_i) = \left( \sum_{k=1}^{N} \prod_{j=1}^{k} \prod_{z=1}^{O_j} K_{ijz} \right). \quad (1.5) \]

The maturity level nx of a capability COx that an entity reaches is given by the sum of capability maturity level activations, i.e. that all practices Kijz of the level nk ≤ nx must be acquired for all resources Ri.
composing the capability.

\[ n_{COX} = \sum_{k=1}^{N} a_{nk} a_{nk} = \sum_{k=1}^{N} \left( \sum_{i=1}^{M} \sum_{j=1}^{O_{i}} \prod_{l=1}^{O_{j}} K_{i,l} \right). \]  

(1.6)

A.2. Coverage evaluation

The coverage of a resource \( R_i \) and an organizational capability \( COX \) can be expressed with the following formulas (an illustration is given in Fig. 3 with \( N = 5 \)):

Let us take the following variables:

- \( c_{COX} \) be the coverage of an organizational capability \( COX \),
- \( c_{RI} \) the coverage of a resource \( R_i \).

To determine how a requirement \( E_{ij} \) is reached, the All or Nothing logic of (Eq. (1.1)) can be applied, but the coverage logic can also be further applied by removing the requirement granularity level, and expressing the coverage levels by counting only the number of acquired practices on the number of existing practices (\( E_{ij} \) becomes therefore a percentage). In this case, the coverage model becomes a simple addition of checklists of the different resources composing the capability.

\[ E_{ij} = \frac{O_{i}}{\prod_{l=1}^{O_{j}} K_{i,l}} \quad \text{or} \quad E_{ij} = \prod_{l=1}^{O_{j}} K_{i,l}. \]  

(1.7)

The coverage \( c_{RI} \) of a resource \( R_i \) is given by the amount of reached \( E_{ij} \) on the number of existing requirements for this resource (that corresponds to the number of maturity level of capability, since the maturity structure is kept for comparing maturity and coverage models)

\[ c_{RI} = \frac{\sum_{i=1}^{N} E_{ij}}{N} \quad \text{(local coverage)}. \]  

(1.8)

The coverage \( c_{COX} \) of a capability \( COX \) is given by the total of reached \( E_{ij} \) on all existing requirements of the capability.

\[ c_{COX} = \sum_{i=1}^{M} \sum_{j=1}^{N} \frac{E_{ij}}{M \times N} \quad \text{(global coverage)}. \]  

(1.9)

Appendix 2. Definitions of discrepancy

Let us take the following variables:

- \( t \) be the instant of the first assessment,
- \( T \) a period of time,
- \( n_{sites} \) the number of sites developing the considered organizational capability.

The discrepancy in the structure (of resources or of knowledge) corresponds to the learning speed of organizational capabilities. If this value is negative that means practices are lost by learners.

B.1. Design discrepancies

\[ \varepsilon_{RM} = \sum_{n_{sites}} \frac{n_{Ri}(t + T) - n_{Ri}(t)}{n_{sites} \times T} \quad \text{(global discrepancy)}. \]  

(2.1)

\[ \varepsilon_{KX} = \sum_{n_{sites}} \frac{n_{COX}(t + T) - n_{COX}(t)}{n_{sites} \times T} \quad \text{(global discrepancy)}. \]  

(2.2)

B.2. Transfer discrepancies

\[ \varepsilon_{RM}' = \frac{n_{Ri}(t + T) - n_{Ri}(t)}{T} \quad \text{(local discrepancy)}, \]  

(2.3)

\[ \varepsilon_{KX}' = \frac{n_{COX}(t + T) - n_{COX}(t)}{T} \quad \text{(local discrepancy)}. \]  

(2.4)

Appendix 3. Step A – impact analysis

Let us take the following variables:

- \{CO\} be the list of \( x \) shared capabilities \( COX \), with a grade \( g_{COX} \) (maturity level \( n_{COX} \) or coverage \( c_{COX} \)),
- \{IP\} be the list of \( y \) performance indicators \( IP_y \).

The goal in this first stage is to find, in a natural and causal way, the relation which links the performance indicator to the organizational capabilities such as:

\[ IP_k = \sum_{i=1}^{x} a_{ki} \times g_{COX_i} \quad \text{with} \quad \sum_{i=1}^{x} |a_{ki}| = 1. \]

The coefficients \( a_{ki} \) are normalized (so as to measure the impact of a capability on \( IP_k \) in comparison with the other capabilities): they can vary between \(-1\) and \(1\) (in order to take into account their positive or negative effect on the performance).

1. To find the \( a_{ki} \), many tools exist such as the multiple linear regression, or some statistical methods which test the statistical dependence between two variables (Mutual information, coefficient of Pearson, covariance, etc.). In assuming that the multiple linear regression method is chosen, the following formula can be written:

\[ IP_k = \sum_{i=1}^{x} A_{ki} \times g_{COX_i} + B + e, \]

with \( A_{ki} \) the multiple linear regression coefficients, \( B \) a constant and \( e \) the regression discrepancy.

If \( e \) is acceptable, the \( a_{ki} \) can be deduced from the \( A_{ki} \) by normalizing them:

\[ a_{ki} = \frac{A_{ki}}{\sum_{i=1}^{x} |A_{ki}|}. \]

2. Once this transformation is done for the \( m \) performance indicators, the linear system is:

\[ \begin{bmatrix} IP_1 \\ IP_2 \\ \vdots \\ IP_y \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{1x} \\ \cdots & \cdots & \cdots \\ a_{y1} & \cdots & a_{yx} \end{bmatrix} \begin{bmatrix} g_{COX_1} \\ \vdots \\ g_{COX_x} \end{bmatrix}. \]

This system enables a global understanding of the impact of capabilities on group performance.

3. In studying the matrix of this linear system, the list of significant performance indicators which represent the importance of each \( COX \) from \( COX \) can be extracted. The user has firstly to pose a threshold \( T \) from which he considers one capability plays a significant role on the performance indicators, for instance \( T = 25\% \). Then the list of significant performance indicators associated to \( COX \) is:

\[ \text{(Signif } IP(COX)) = \{IP_y \text{ such as } |a_{y}x| \geq T\}. \]
Appendix 4. Step B.2. Intervals bijection for discrepancies detection

Let us take the following variables:
- \( (g_{COx_i}) \) a subdivision of \( [g_{COx_{\min}}, g_{COx_{\max}}] \).
- \( (IP_y) \) a subdivision of \( [IP_y_{\min}; IP_y_{\max}] \).
- \( \text{IntCO} \) and \( \text{IntUP} \) the spaces of intervals given by these subdivisions then there is a bijection function \( f \) from \( \text{IntCO} \) to \( \text{IntUP} \) if and only if \( \forall [\text{IntCO}]; [IP_y_{\min}; IP_y_{\max}] \ni g_{COx_i} 
[1] \] and \( \exists ! [\text{IntCO}]; [IP_y_{\min}; IP_y_{\max}] \ni g_{COx_i} + t \in \text{IntCO} \). \( t \in [IP_y; IP_y_{\infty}] = f(\{g_{COx_i}; g_{COx_{\infty}}\}) \).

References


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