A global approach to manage the performance of the problem solving process in innovative design

Sébastien Dubois[1] · Nicolas Maranzana[2] · Nathalie Gartiser[1] · Roland De Guio[1]

Abstract This article focuses on the problem solving process in design. Today, enterprises face an important need of innovation, as they have to regularly propose new products or new services. Design is one of the key activities of enterprises in order to be innovative, but it is also one whose performances are hard to assess and activities difficult to manage. Studies on performance of the design process are quite few. Despite there exists many tools to evaluate and manage performance in a variety of fields, few tools are proposed Please check and confirm the author names and initials. Amend if necessary.or customized for the design activity. Some parts of this activity are more or less manageable, but one remains hardly controllable: the problem solving process. Three main topics are tackled in this article. Firstly, the article defines the performance, the enterprise organization, the design activity and the role of problem solving in this activity. Then the focus will be done on the ways to measure and manage the performance of problem solving in design; criteria to evaluate it and a set of indicators that impact it are proposed. In last, the use of this set of indicators will be proposed and a link between the indicators and a strategic choice will be established in order to build the problem solving process in accordance with this strategic position.

Keywords Performance · Problem solving · Design · Indicators

✉ Nicolas Maranzana
nicolas.maranzana@ensam.eu

1 INSA Strasbourg, LGECO, 24 boulevard de la Victoire, 67084 Strasbourg, France

2 Arts et Métiers ParisTech, LCPI, 151 boulevard de l'Hôpital, 75013 Paris, France

1 Introduction

Today's environment imposes to enterprises to be more and more competitive. Due to the decreasing of the products life cycle, the necessity of innovation becomes essential. The enterprises are thus concerned by performance in any of their activities in order to survive and to make benefits. They are then looking for means to evaluate and manage performance at a global level and also in any of their processes. Moreover, the European project CEN/TC389 and the setting of a new standard for the management of innovation [1,2] tends to prove the increasing importance for companies to take into account and to control their innovation process. In [3], the arising of a new age for companies is described, as the age of innovation is describing as succeeding to a dying age of quality.

To increase the performance of their innovation process, enterprises have to design new technical systems faster and faster as the competitive environment is also evolving faster and faster. Thus it is a necessity for enterprises to be able to evaluate their performance, to know how to impact it, so to manage this innovation process. But if there exist several approaches, indicators, tools to measure performance for many processes in the enterprise, the performance of the R&D activities remains hard to manage. Some studies tried to model it in order to manage the engineering design process [4–6], but without linking it to its performance while others evaluate the results in regard of the means but without giving keys to manage it [7,8]. The matter with R&D activities is that they are activities the objectives of which may be hard to define. Is the objective to define a lot of new ideas or one idea that leads to a producible product? Being efficient means proposing directions that lead to innovative products, which are successful on a market. The drawback of this this efficiency definition is that it can only be measured afterwards and sometimes long time after the product design.

Thus the performance of innovative design raises a contradiction. This performance has to be managed in order to be increased, so the performance has to be measured and it can only be measured afterwards. But, on the other hand, the process of innovative design has to be managed to be efficient, so the performance has to be known a priori. The design activity can be considered as a step of activities and decisions [9], but to tackle the formulated contradiction, several resources have to be considered, among them, all the activities linked with the innovative design process: activities linked with the marketing, R&D activities, human resources management activities [10], etc. To increase its performance, an enterprise can increase the performance of the activities of its different services, and of course, also increase the performance of the integration of these services.

This article will boarder the analysis to the activities linked with R&D. Innovative design could be seen as a process which output is a product that will be present on a specific market. And this product has to be differentiated on this market, so it has to propose something new. Let us focus now on the design process and formulate the way the original stated contradiction will be declined for this process.

The design process has to be driven to ensure its performance, but, as it can be described as a creative process, some people argue that this process, to be creative, has to be "free", non driven, non constrained. And this contradiction is particularly sensitive if the design process is compared to an inventive problem solving process. Many researches focus on the performance of this design process [11–13] in terms of result, in regard of the proposed solution, but not in regard of the global performance of the project for the company.

As described in [14], creating a new product, in interactive design, is constrained by 3 factors: the experts' knowledge (and thus their cognitive interaction), the end users' satisfaction and the realization of functions. Thus the challenge is to "supply efficient solutions for leading product engineering".

This article will mainly focus on this specific process of the enterprises activities: the problem solving process. Few tools are proposed to evaluate and manage the performance of the design activity in general, and of the problem solving process in particular.

This article will point out two problems linked with the management of performance of problem solving process, in a context of innovative design:

- To increase the performance, it is necessary to be able to evaluate it, so to measure it. A first part of this article will be dedicated to the definitions of the performance and its measurement.
- To increase the performance, it is necessary to be able to manage it. A second part of the article will propose a set of indicators for the performance of problem solving process in design. These indicators will be defined in order to link the defined indicators to the global performance, thus an approach to manage this performance will be proposed.

2 Definitions and performance measurement

The objective of this first part is to identify, first, how companies organize themselves to seek the maximal performance. In a second step it is to identify and locate the design activities in the company before ending at a definition of design performance on one particular phase of the design process, namely: problem solving in design.

Organization of the companies to reach maximal performance

Purpose and organization of the company

A company is an economical and social structure, legally autonomous, operating in an organized way in order to supply goods or services to customers. To exist, the company has to generate benefits (i.e. achieve a turnover superior to the sum of its costs); one of the best ways to reach this objective is to satisfy the needs of his customers, a goal which is even more difficult to satisfy in a competitive environment.

The performance of a company, and thus its demarcation with the competitors (competitive advantage), results from numerous realized activities; indeed, every activity is going to impact on the company in terms of costs and is going to create a basis for differentiation. Michael Porter proposes to use a fundamental instrument to examine all the activities which are realized by a company as well as their interactions: the value chain [15].

For Porter, the value chain of any company consists of nine categories of core activities which are related to each other, and two kind of activities are defined: the primary activities, which imply the physical creation, the sale of the product, its transportation and the after-sales service; and the support activities, which are support for the main activities.

Having defined the various activities in a company, and having for objective to increase the performance, two questions arise: What is performance? How to evaluate the performance?

2.1 Companies performance, activities performance

The first question is related with the definition of performance. Managers, like Lorino, qualify the performance as everything that contribute, for the company, to reach the strategic objectives [16]. The company being essentially an economics purposes institution, one can assume that his performance could be mainly financial. However, other considerations must be taken into account to calculate his global performance; such as its ends, its ecological considerations, its social issues, its jurisdiction. It is thus obvious that the company performance is multidimensional. In Fig. 2, performance is positioned by Gibert at the centre of a triangle combining the notions of efficacy, efficiency and relevance [17]. These concepts can be defined in the triptych: objectives, means, results:

- Objectives-results axis: defines efficacy as relative to the use of means to obtain given results within the framework of fixed objectives; i.e. the objectives achievement.
- Results-means axis: defines efficiency as the ratio between outputs and total resources deployed in an activity; i.e. objectives achievement with minimal cost.
- Means-objectives axis: defines relevance as the ratio between the means deployed and the objectives to be achieved; i.e. the good resources allocation.

The company including various activities, it is necessary to evaluate all of them to obtain the global performance of the system. In Fig. 1, Gartiser et al. propose to expand the Gibert triangle's to all the organization activities to build a global coherence (triptych: ends, culture, structure) [18].

Indeed,

- objectives and results depend of the set of shared values (corporate culture)
- resources allocation and results of the activities depend on the structure of the organization
- objectives and means must be decided in coherence with the ends

Thus, any activities of the company evolve in such a system.

The second question is related to the evaluation of the performance. Performance is considered as a latent variable. A latent variable can be defined as a variable which

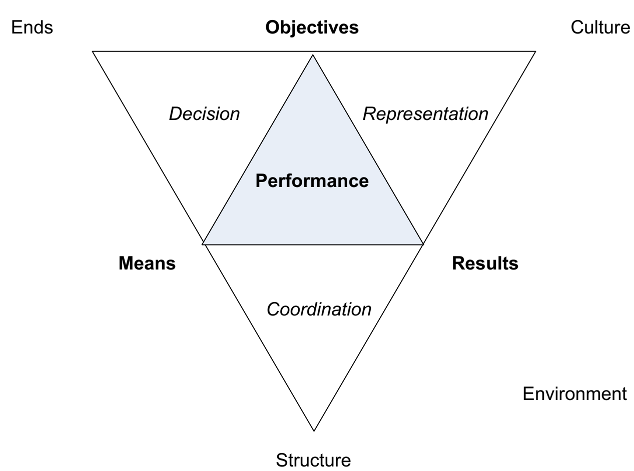

Fig. 1 Company general politics [18]

is not directly observable but not deducted from one or several variables (indicators) belonging to the field of empirical investigation. It seems thus necessary to define these measure variables allowing characterizing the performance: the performance indicators.

A performance indicator is, as Fortuin defined it, "a variable indicating the effectiveness and/or the efficiency of a part or whole of the process or system against a given norm/target or plan" [19,20]. It must be measurable, observable and controllable all being simple, clear and easy to understand. "Performance indicators provide management with a tool to compare actual results with a preset target and to measure the extent of any deviation" [19]. For Lorino [16], the performance indicator can have two roles; help an actor, individual or more generally collective, to drive the course of an action towards the achievement of an objective or to enable it to assess the result.

To have a global vision with the help of indicators, it is common to group them together in a system: a Performance Measurement System. All indicators are defined using multiple criteria, at many levels, and having interactions between them.

2.2 Towards a performance measurement system

The development of a Performance Measurement System may conceptually be separated into three phases: design, implementation and use. The implementation of such a system is not a unique effort; it is moreover necessary to install processes that ensure continuous review of the system.

Different methods for designing indicators system emerge from the literature: Lohman proposes a nine steps process Lohman [20].

The comparison of these various models, leads to the identification of five important steps:

- the definition of a strategy and of a set of objectives
- the definition of performance inductors
- the definition of performance indicators
- the synthesis of the indicators in a dashboard
- the periodic re-evaluation of the indicators system

We have seen that performance indicators can have two roles: either drive the course of action towards achieving a goal (monitor) or allow to assess the results (measure). In addition, the triangle Gibert has shown us that to be successful it must be effective, efficient and relevant. We notice that some activities have advanced evaluation repository to monitor and measure the activity in all its forms (i.e. production activities), while much less in others (i.e. design activities).

The next part will be focused on the design activity; one supplementary step towards the definition of the design performance.

2.3 Design activities and design performance

Porter's value chain will allow us to locate the design activity among the various activities of the company. Relying on this model, the design activity is a part of the support activities which come in support of the primary activities; as well as the basic research, design product or equipment of transformation is more particularly situated in the category *"technology development"* of Porter's model.

What is design?

"Design is an interplay between what we want to achieve and how we want to achieve it" [21]. Two dimensions emerge: design, i.e. the product, the object; and the activities sequence which allow to obtain it [22], i.e. the design process.

Various stages compose the design process, among the different approaches, it is proposed to focus on the following two:

On the one hand the systematic approach of design proposed by Pahl and Beitz [23] represents the design process as a hierarchical succession of stages enabling to converge to the best solution. The decomposition of the process is based on four main stages: clarification of the task, conceptual design, embodiment design and detail design.

On the other hand, the axiomatic approach, resulting from the work of Suh [21,24] establishes fundamental principles and methods to drive the decision-making during the design process. Suh identifies four domains, differentiating four types of design activities, namely the customer domain, the functional domain, the physical domain and the process domain. He also identifies five relations connecting these domains to each other and forming the design process: know or understand their customer's needs, define the problem they must solve to satisfy the needs, conceptualize the solution through synthesis, perform analysis to optimize the proposed solution and check the resulting design solution to see if it meets the original customer needs.

The objective of the design activity consists on the proposal of an artefact, a product or a process, satisfying determined objectives, in accordance with fixed means.

Now, one question remains: what is design performance? Design performance subject has received some considerable attention over recent years. But there remain particular challenges to be able to define measure and manage performance. It is important to propose a solution for these points to be able to deal with the complexity, the short-time resources, the increasing degree of required novelty, the high competitive environment, ... of design activities [25].

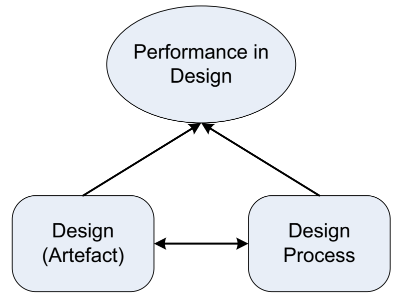

Fig. 2 Performance relationships in design [26]

Quite as there are two design dimensions, two areas of design performance appears (Fig. 2), namely:

- the product performance, which can be characterized by the product value according to the customer expectations, and
- the design process performance which can be defined in consideration of the triptych cost, time and quality

With regard to the objective of the design activity, to be successful, it is necessary to maximize the adequacy between the objectives and the results by minimizing the means. Of course, one can consider that the recognition of a satisfying solution is not as obvious, especially if considering creative solutions, which can be rejected in regard of their feasibility [27].

2.4 Problem solving in design and how to evaluate performance of problem solving in design?

The next part of our study is going to concern one of the phases of the design process (*"conceptual design"* phase in the model of Pahl and Beitz, and the relationship *"define the problem they must solve to satisfy the needs"* of the Axiomatic Design Suh): namely the problem solving in design.

What is exactly problem solving in design?

Various dimensions characterize problem solving in design. Bonardel [28] presents design problems as being open-ended and ill-defined. Design problems are open-ended as they do not imply one single solution, but a set of solutions satisfying problem constraints. The synthesis of a solution to a given problem is the result of the choice of one satisfying solution among many of possible ones. In addition a problem, in design, is considered ill-defined as the initial formulation of a problem is incomplete and insufficient to synthesize a solution. Information about the problem to solve is collected during the trials to solve the problem. This notion of open-ended problem can be attached to the one of structurized problem, as defined in [29]. Problem formulation and problem solving are two concomitant processes.

Simon [30] describes the designer activities as a problem forming, finding and solving activity. Designing a new system means building a representation of a concept that could be recognised and validated as a solution. Problem solving can thus be described as the building of a specific representation of the world; it also implies parallel thinking process at different level of abstractions [31].

The role of the problem solving process is to change one situation which is qualified as not satisfying. The problem solving can be model as a process transforming one initial state of the situation, where inconvenience exists, into a final state of the situation, in which the inconvenience does not exist anymore.

The resolution of a problem, in design, is generally a group, a team, work, as many actors act on it, even sometimes including suppliers [32]. It could have been possible to categorize the roles of actors as precisely as in [33], but authors preferred to define large categorization. Depending of the company strategy, the methodology used to solve problems will imply only internal actors (actors from the company) or resort to external ones. This decision depends both on the availability of competences in the company and on different strategic decisions (external feedback, crisis resolution …).

One can consider at least three main roles in the problem solving process: the project leader, the animator, and the decision-maker, which are three main actors, but these roles do not necessarily refer to three different persons:

- The project leader is the person in charge of the project, which is responsible of the good advancement of the project
- The animator is the person responsible of the good application of one specific method to identify, formulate and solve the problem.
- The decision-maker is the person (or group of person) in charge of the validation of the strategic orientation for solution research and of the development of defined solutions.

The project will also require other resources, knowledge and competences that will be found either internally either externally. Moreover, all the actors of the life-cycle of the future products have to be implicated, in order to share information about the environmental impact of the product [34].

It is now possible to tackle the evaluation of the performance of problem solving in design.

In the frame of inventive design, problem resolution is the research of unknown solutions. Due to the open-ended and ill-defined characteristics of inventive problems, processes of resolution are still difficult to manage. To build robust process, it is necessary to understand which criteria make a process competitive. However the different criteria able to influence the process are various and seem to operate systemic way, as they do not seem to be independent.

The definition of the performance of problem solving process in design being proposed, the next part will be dedicated to the proposal of a set of indicators to manage this performance. In the next part, the method to define the set of indicators will be presented. Then, in Sect. 4, the indicators will be given, and also a criteria to measure the performance will be defined. Then the interrelations between the indicators and the way the indicators influence the performance will be proposed,.

3 A system of indicators for problems resolution in design

To build a performance measurement system for problem resolution in design, the five steps methodology described in Sect. 2 will be deployed.

3.1 Definition of strategy and set of objectives

The aim is to be able to measure from a certain point of view the result of problem solving process. According to the Fig. 1, it has to be done in accordance with ends, culture, structure and environment of the company. So, our system of measurement has to involve at least those four dimensions. Below is listed, and classified in regard of the four dimensions, the elements of problem resolution in design which influence performance:

- Culture: animator, project actor
- Structure: process, decision maker
- Ends: result
- Environment: all external resources

The next step is to identify the list of inductors based on these elements.

3.2 Definition of a system of inductors

From the defined strategy and objectives, inherent inductors could be identified; i.e. elements influent on the problem solving process. It is important to notice that the performance inductors work as a system. This system is based on different elements which can have, all together, an impact on performance. But it is different to consider separately these elements and to reduce the evaluation of performance to only one or a few inductors. On the other hand, it is difficult to manage the process by one criteria, changing the value of one of the inductors, as the impact of one value can be totally different (and perhaps opposite) because of the interactions with others inductors in the system and all of these inductors act on the performance of the companies.

List of inductors to define the context of the problem and human resources:

- The animator: his implication, his role among the group, does he train people to method or does he only animate to solve the problem?
- The project actors: the cognitive and language gap; the group composition, its variety; the inhibitions inside the group; the mobilized resources; the enterprise culture; the project importance from actors point of view.
- The decision-maker: the project strategic horizon; the project importance from strategic point of view; the implication of the decision-maker into the project.
- External resources: the mobilized resources.
  List of inductors to evaluate efficiency of the process
- Duration of the project; mobilized internal resources; information availability; project actor's implication; individual and groups dynamics.
  List of inductors to evaluate efficacy of the process
- Solution relevance; resolution impact; generated knowledge outside project; other inputs than resolution; innovative degree, area of the solution.

3.3 Definition of performance indicators

Table 1 presents the proposal of indicators to measure the role of inductors previously defined. Based on this system of indicators, a dashboard to capitalize information about problem resolution cases can be built. The role of the dashboard is to collect information, as an experiment, and by combining all the dashboards to be able to use Design of Experiments tools.

4 Results

4.1 Presentation of the indicators

As described in previous part, the performance of the problem solving process in design could be qualified by the relevance, the efficiency and the efficacy of this process. In [35] a set of indicators was proposed in order to evaluate the performance for problem solving in design context. It was proposed as a set of elements representative of the performance for problem solving. These indicators have been classified into two sets: indicators to measure the performance and indicators that impact the performance, i.e. indicators that are not directly representative of the performance but which are influent on the performance.

Based on different processes to build a system of indicators, a five step process has been proposed:

- the definition of a strategy and of a set of objectives: the aim is to be able to measure from a certain point of view the result of problem solving process. In an industrial context, it has to be done in accordance with ends, culture, structure and environment of the company. So, the proposed system of measurement has to involve at least those four dimensions.
- the definition of performance inductors is the definition of the set of elements influent on the problem solving process. It is important to notice that the performance inductors work as a system. This system is based on different elements which can have, all together, an impact on performance. The inductors are categorized according to the fact that they refer the definition of the context of the problem and human resources (the animator, the actors of the project, the decision maker and the external resources); the problem resolution process, or the result.
- the definition of performance indicators which are defined to measure the role of the previously defined inductors.
- the synthesis of the indicators in a dashboard, this dashboard is presented in Table 1.
- the periodic re-evaluation of the indicators system has to be done to check the exhaustivity and relevancy of the system of indicators.

4.2 Criteria to measure the performance of problem solving activities

The performance has to be representative of the relevance, the efficiency and the efficacy of the process. As defined in part 1:

- the relevance is the ratio between the dedicated means and the objectives,
- the efficacy is the ratio between the results and the objectives,
- the efficiency is the ratio between the results and the dedicated means.

Increasing the performance could be described by the increasing of at least one of the three previous criteria. It means that increasing the performance could be done, either by decreasing the means dedicated the satisfaction of the objectives, either by increasing the adequacy of the results according to the objectives, or by decreasing the dedicated means to obtain the results. The formula (1) defines the performance according to these ratios and the formula (2) defines the performance by the two criteria efficiency and efficacy.

$$Performance = \frac{results \Big/ objectives}{dedicated\_means}$$

Table 1 Proposal of a system of indicators

	Object	Inductor	Indicator	Measure
Context of the problem Human resources	Animator	Evaluate the implication, the relationship towards the group	Origin	Internal
				External
		Objective of the study	Goal	Training
				Resolution
	Project actors	Evaluate the language gap, the cognitive distance	Trained to the method	Average number of services
		Group composition, representativeness	System life cycle experts	Yes
				No
		Group inhibitions	Hierarchical links	Same level, different levels gap
		Mobilized resources	Number	Number
		Enterprise culture	Age, seniority	Age average from the group standard deviation
		Project priority in the point of view of actors	Implication degree	% Time allocated to the project/number of projects
	Decision maker	Strategic horizon	Term	Short-term
				Medium-term
				Long-term
		Importance on strategic point of view	Importance	blocant, priority, secondary
		Implication of the decidor	Presence in the group	Yes
				No
	External resources	Mobilized networks	Number	Internal number
				External number (group)
Efficiency	Process	Group dynamics	Exchanges between actors	Low, medium, elevated (animator point of view)
		Individual dynamics	Activity between sessions	Low, medium, elevated (animator point of view)
Efficacity	Result	Solution relevance	Goals adequacy	% of satisfied specifications
		Resolution impact	Number of solutions	Number (short term, medium term)
		Generated knowledge outside project	Changing directions	Number
		Other inputs than resolution	Generated knowledge	Concepts, patents, projets kept to be initiated
		Innovative degree, area of the solution	Firm appropriation	immediately, technology transfer, research

$$= \frac{\%\_of\_satisfied\_objectives}{dedicated\_means} \tag{1}$$

$$Performance = \frac{efficiency}{dedicated\_means} = \frac{efficiency}{objectives} \tag{2}$$

The dedicated means could be calculated at micro or at macro level:

- on a micro level, the specific indicator for an enterprise could be evaluated either in Euros, or in man-hours;
- on a macro level, to compare different enterprises, it is necessary to evaluate the value of dedicated means in accordance with the possibilities of the enterprise, thus the dedicated means will be measured as a ratio between real dedicated means and the amount of available means.

Table 2 List of the contradictions that impact performance

The parameter	Has to be	To increase the parameter
Activity between sessions	High	Quantity of generated knowledge
	Low	Efficiency
Cognitive distance between actors	High	Efficacy
	Low	Efficiency
Exchanges between actors	High	Efficacy
		Exchanges between actors
		Quantity of generated knowledge
	Low	Efficiency
Firm appropriation of the results	Immediate	Efficiency
	Long	Efficacy
Hierarchical links between actors	no	Exchanges between actors
		Exchanges between actors
	Yes	Number of solutions
		Presence of the decision-maker in the group
Implication degree of actors	High	Exchanges between actors
		Relevancy
	Low	Efficiency
Level of training of actors to the method	High	Cognitive distance between actors
	Low	Efficiency
		Relevancy
Meetings frequency	High	Efficiency
		Implication degree of actors
	Low	Relevancy
Number of actors	High	Number of solutions
	Low	Efficiency
		Exchanges between actors
Number of external resources	High	Cognitive distance between actors
		Hierarchical links between actors
		Quantity of generated knowledge
	Low	Cognitive distance between actors
		Efficiency
Number of solutions	High	Efficacy
	Low	Efficiency
Objective of the study in terms of methodological transfer	Resolution	Efficiency
	Training	Cognitive distance between actors
		Level of training of actors to the method
Origin of the animator	External	Cognitive distance between actors
		Exchanges between actors
		Hierarchical links between actors
	Internal	Cognitive distance between actors
		Seniority of the actors in enterprise
Presence of the decision-maker in the group	Not present	Exchanges between actors
	Present	Cognitive distance between actors
		Efficacy

Table 2 continued

The parameter	Has to be	To increase the parameter
Process duration	Long	Efficacy
		Quantity of generated knowledge
		Relevancy
	Short	Efficiency
		Implication degree of actors
Quantity of generated knowledge	High	Efficiency
	Low	Relevancy
Seniority of the actors in enterprise	High	Relevancy
	Low	Cognitive distance between actors
System life cycle experts representativeness	No	Efficiency
		Number of actors
	Yes	Efficacy
		Relevancy
Term of the project	Long	Firm appropriation of the results
		Quantity of generated knowledge
	Short term	Efficiency
		Implication degree of actors

4.3 Criteria influencing the performance of problem solving activities

In the Table 1, a list of considered parameters has been proposed. But from this list of indicators, which can be used as a dashboard for innovation process, to move forward a management tool for this process, it is necessary to understand the role of these indicators. To do so, the way these indicators influence the performance has been studied. Thus it has been established that all those indicators could have influence on the performance, either by influencing directly the efficiency, the efficacy or the relevancy; or by influencing another indicator which one influences one of the three main criteria. A constraint that has been considered in the identification of this list is to consider only indicators for which there is no obvious value to be considered. For example, in [35] the indicator priority of the project in regard of strategic point of view was considered, but the authors suppose that a prior project will imply a better allocation of the resources and will enable increasing performance of the process, it has no real interest to consider low priority projects. Then, it means that the considered indicators could lead to contradictions when changing a value of one parameter could imply either increasing the performance or decreasing it, in consideration of the systemic relationships between the indicators.

In the Table 2, these contradictions have been listed, by the identification of the impact the evolution of an indicator could have. One can consider two possibilities: an indicator can either impact directly one of the three criteria that influence the performance (efficacy, efficiency or relevance), or it will impact another indicator, making a chain that will finally influence the performance. For example, the indicator *"activity between sessions"* has to be:

- *"Low"* to increase the criterion *"efficiency"*, and
- *"High"* to increase the indicator *"quantity of generated knowledge"*.

Whereas the indicator "quantity of generated knowledge" has to be:

- *"Low"* to increase the criterion *"relevancy"*, and
- *"High"* to increase the criterion *"efficiency"*.

If drawing the links between these indicators [36], as shown on Fig. 3, one can consider that most of the indicator are considered as roots, some are intermediary ones, and only the efficacy, relevance and efficiency are pits.

These interrelations put the emphasis on the proposed systemic approach for the performance management of the problem solving process. This network of influence between the indicators is the foundation for the management of the problem solving process.

5 Discussion

5.1 Validation of the net of interrelations through case studies

In this part, the authors will introduce the analysis of three case studies, conducted in two different companies, but with

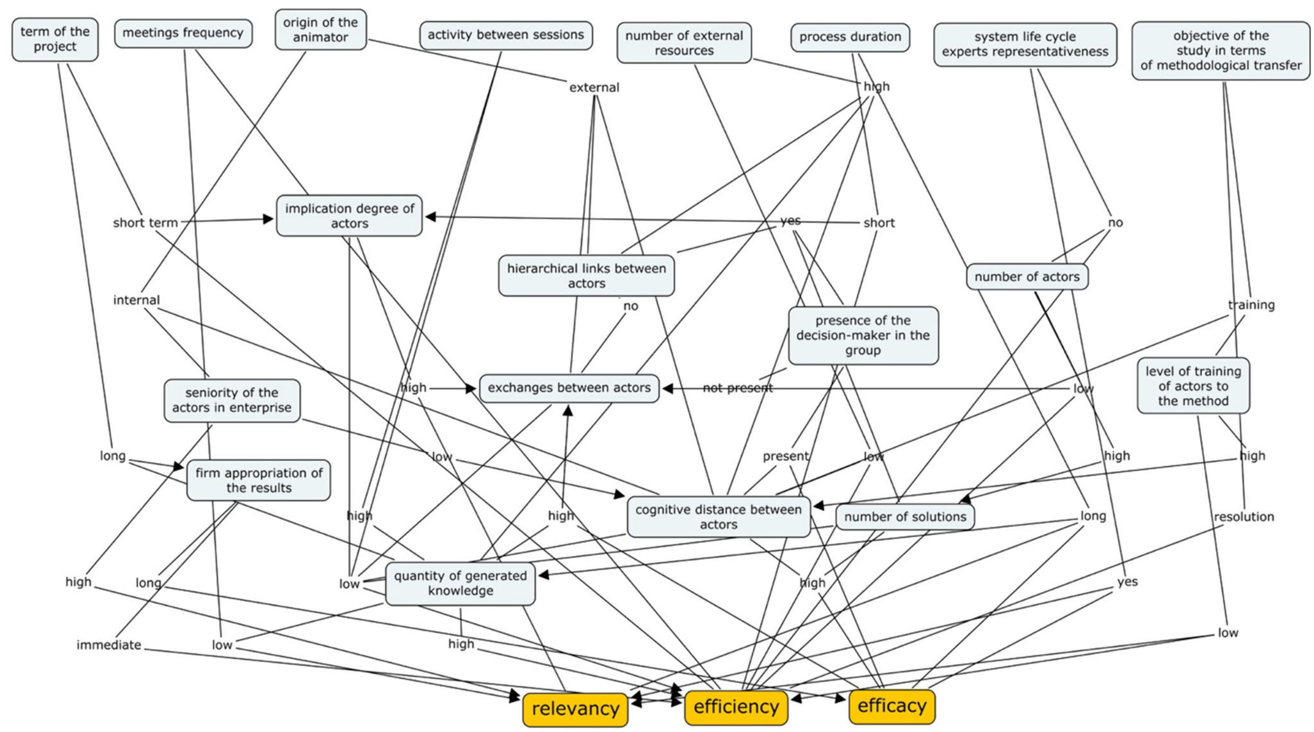

Fig. 3 Interrelations between the dashboard indicators

one similar objective: to help the company in finding new concept by the intervention of one external TRIZ expert.

The first case, conducted in a high-end home appliances company, has been the first collaboration of the authors with this company. It was defined as a case study where the only objective was to find solutions without any training aim. The implication of the actors has been important and the results have been very interesting, with two deposited patents. The second case is a second case within the same company, but with a training objective. The effect of these two-opposite objectives was less implication of the group on the problem resolution, less activity between the sessions, and thus a result that was not satisfying on the problem resolution. This result can also be explained by the fact that the importance was less than for the first case, as it was not a short-term project. The last presented case is also a problem resolution case with training objectives, with a company developing X-ray flat panel digital detectors, but with fewer people, and people who were more implicated into the considered project. Thus the result was satisfying, and one patent as been deposited. The details of these cases are presented on Table 3.

5.2 A net of interrelations as a management tool

The previous cases enabled to build, by instantiation, three networks of interrelations, by considering the values of the indicators. On Fig. 4, the three networks are represented and the boxes have been coloured as soon as the value of the indicator was discriminating. Thus the origin of the animator, internal or external is discriminating, but the number of actors being a middle value is not considered as discriminating.

There are many studies trying to evaluate the general performance of inventive activities in inventive project [37], but the fact is that it is always a very relative evaluation. But another interesting approach is to help in configuring and defining, a priori, the structure of the process if aiming at increasing efficiency, relevancy, or efficacy.

By considering the discriminative values and considering the impact on the performance, this enabled to classify the three case studies as more relevant and efficient than effective for the first case, mainly efficient for the second and more effective and relevant for the last. For the three cases, this reflects exactly the impression actors of these projects had at the end of the study. The result could be a little surprising for case 1, as the first impression could be that the result was also effective and satisfying. But after discussion with the group, one feedback was that the group was convinced that the found result could have been found without this study, as it was not far from their ideas they had before, but that one of the main benefits was to find it in relative short time.

These considerations thus validate the previously defined interrelations between the indicators, and the fact that some configurations of projects are more oriented towards efficiency rather than efficacy, and vice versa.

Table 3 Indicators of the three case studies

	Object	Indicator	Case 1	Case 2	Case 3
Context of the problem Human resources	Animator	Origin	External	External	External
	Animator	Goal	Resolution	Training	Training
	Project actors	Trained to the method	40 % trained, 60 % untrained	40 % trained, 60 % untrained	20 % trained,40 % untrained, 40 % to train
	Project actors	System life cycle experts	Yes	Yes	Yes
	Project actors	Hierarchical links	Different levels	Different levels	Different levels: no direct link
	Project actors	Number	7	7	5
	Project actors	Age, seniority	Average: 11	Average: 11	Average: 12,4 / standard deviation: 8,4
	Project actors	Implication degree	40 %	40 %	60 %
	Decision maker	Term	Short-term	Short-term	Short-term
	Decision maker	Importance	Important	Middle	Important
	Decision maker	Presence in the group	Yes	Yes	No
	External resources	Number	0	0	0
Efficiency	Process	Duration	6 months	6 months	6 months
	Process	Time	7 meetings of 4 h	6 meetings of 4 h	12 h
	Process	Number of backloops	2	2	1
	Process	Meetings frequency	Each two weeks, only the last one postponed	Lot of variations	2 / months
	Process	Exchanges between actors	Important	Important	Elevated
	Process	Activity between sessions	Important	Few	Medium
Efficacity	Result	Goals adequacy	100 %	0 %	80 %
	Result	Number of solutions	1 short term, 1 long term	2 long term	2 short term, 3 middle term
	Result	Changing directions	0	0	1
	Result	Generated knowledge	Two patents		One patent, one new direction of research
	Result	Firm appropriation	Immediate	Long	Immediately for short term solution, research for middle term

So, one proposal of the authors is to take now this net of interrelations to define, a priori, the context of projects, in regard of the desired performance, what is considered as more important between efficacy, efficiency and relevancy?

6 Conclusions

This article presents a global approach to manage the performance of the problem solving process in innovative design. A set of indicators, a criteria, and a network of interrelations has been built in order to be able to define a priori the way innovative projects have to be built in regard of a given strategy. Few case studies have been considered till now, but one of the main conclusions is that the global measure of the performance is not really significant, as all the considered studies lead to quite equivalent measure. Could the study be efficient, if not such much time is spent on it, or could the result be satisfying, as real innovative solutions have been found, the global criteria do not differentiate these studies. Thus the authors rather propose to define a “strategic performance” by defining which aspect of the performance is

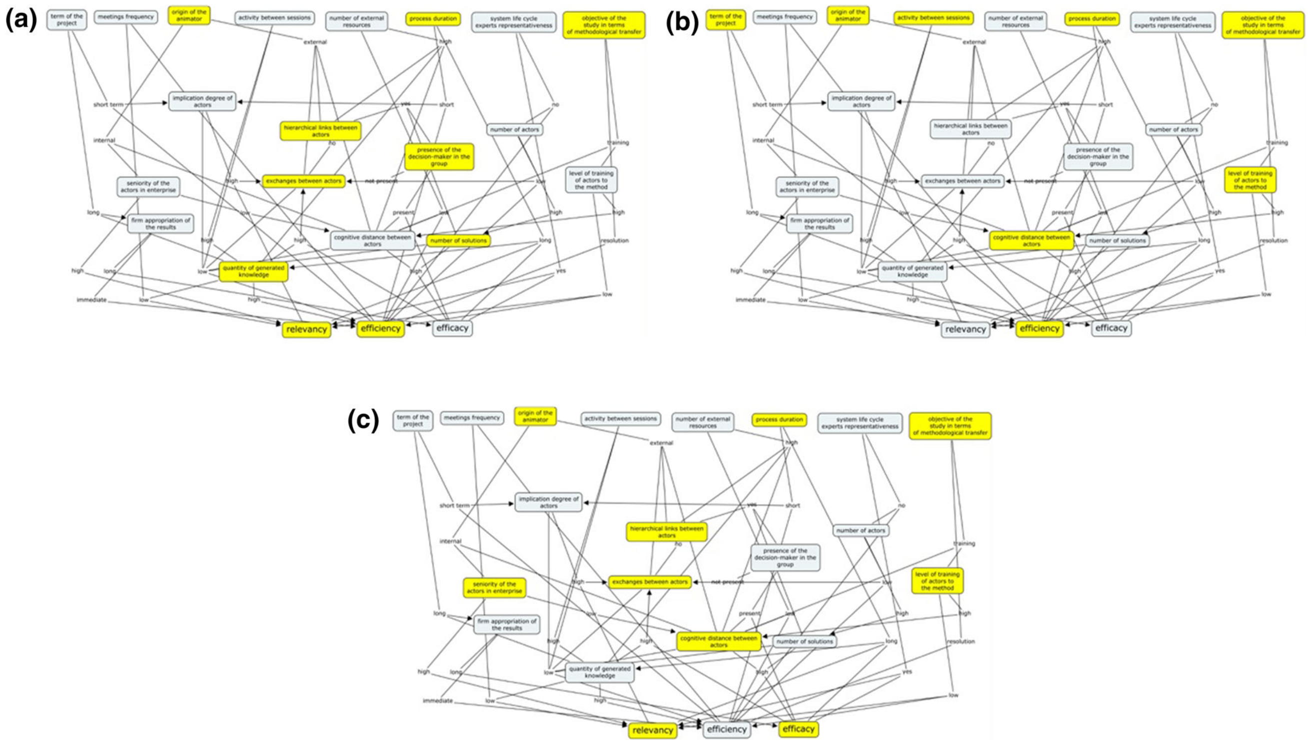

Fig. 4 Net of interrelations of the case studies

primordial, between relevancy, efficacy and efficiency. And then, based on this strategic choice, the net of interrelations enables to fix the a priori conditions of the project to fit this strategy.

One of the first activities will now be to consolidate these data. A larger collection of case studies has to be collected. The validation process is a two-step process: validation of the identified links between the considered indicators, and validation of the completeness and relevancy of the set of indicators, to ensure that this set enable a reliable representation of any situation.

The objective is to be able to understand how to act on the problem solving process to increase its global performance. The full term objective is to enable to manage the activity of problem solving, with a global enterprise point of view. Building a high-performance problem solving process means enabling the enterprise to be global high-performance process.

Thus this approach could also be enriched by the consideration of other activities and the links with existing activities performance measurement tools will have to be considered.

One of the obvious considerations is that proposing such a dashboard to consider the performance will impact the perception of the actors of innovation on innovation. The nature and the degree of this impact will also have to be evaluated. One of the risks is that such indicators lead to a kind of formalisation of the process of problem resolution, and so some people could oppose formalisation and creativity. But methods issued from TRIZ [38], for example, have demonstrated that having a formalised method could in fact increase inventiveness. Even more recent studies propose to build a continuum between optimization approaches (which are recognized as being formalized and manageable) and inventive approaches [39]. So the questions of a global performance evaluation of the problem solving process, this process being inventive or not, will also have to be considered.

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