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PROPOSAL OF A SYSTEM OF INDICATORS TO MEASURE PERFORMANCE OF PROBLEM SOLVING PROCESS IN DESIGN

N. Maranzana, S. Dubois, N. Gartiser and E. Caillaud

Keywords: performance, indicators, problem solving, design

1. Introduction

Evaluation of performance is of great interests for companies wishing to increase their competitiveness. There can be several ways to evaluate performance, globally on the company level, or individually for each of the company processes. Problem solving is one of the key stakes in inventive design, and presents as particularity to be hardly manageable. Due to its particularities, the question of evaluation of performance for problem resolution in design remains. In this article, a proposal is done to understand the role of different inductors on this performance.
To reach this goal a methodology to build a system of inductors is described ; a list of indicators is then defined in order to propose a dashboard for problem resolution process. The objective of the authors is to capitalize enough experiments to model the role of inductors on performance.
A first part of the article will be dedicated to the definitions of the different concepts : performance and problem resolution in design (in this article, the studied design process is inventive design process). A second part will depict the followed methodology to build the system of inductors and their indicators, as a last part will briefly present one capitalized experiment.

2. Performance of problem resolution in design, definitions

2.1 Design performance: state of the art

Prior to the building of a system of indicators to measure performance of problem solving in design process, we are going to define: what is performance, how to measure it, and what is the definition of each of the terms in the literature.
First of all, what is performance ? Managers, like Lorino, qualify the performance as everything that contributes, for the company, to reach the strategic objectives [Lorino, 2003]. 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, on this assumption, the company performance is multidimensional. Performance is positioned by Gibert at the centre of a triangle combining the notions of efficiency, effectiveness and relevance [Gibert, 1980]. These concepts can be defined in the triptych : objectives, methods, 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.

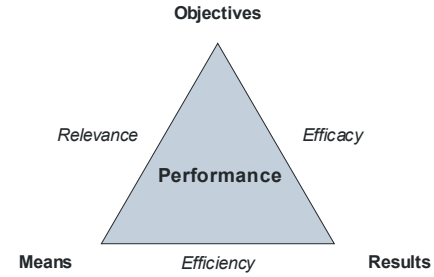

Figure 1. Performance triangle [Gibert, 1980]

The company including various activities, it is necessary to evaluate all of them to obtain the global performance of the system. Gartiser *et al.* propose to expand the Gibert triangle's to all the organization activities to build a global coherence (triptych: ends, culture, structure) [Gartiser *et al.*, 2004].

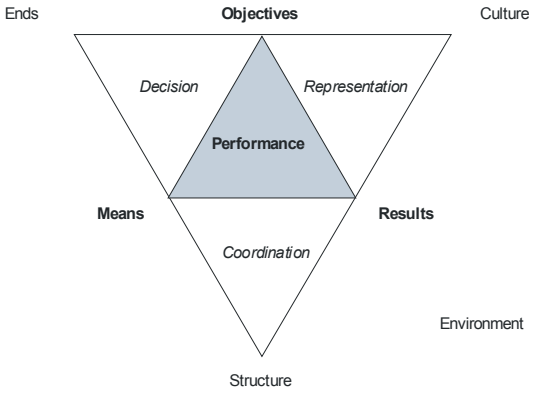

Figure 2. Company general politics [Gartiser *et al.*, 2004]

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 companies evolve in such a system.

How to evaluate the performance ?
Two evaluation types are being practiced in enterprises :

- an economic evaluation via business accounting (financial reports, ...), and
- a physical evaluation via performance indicators

Having as objective to measure problem solving performance in design process we will look more specifically on this second kind of evaluation.
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 »* [Fortuin, 1988 ; Lohman et al., 2004]. 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 »* [Fortuin, 1988].
To have indicators a global vision it is common to group them together in system. All indicators are defined using multiple criteria, at many levels, and having interactions between them. 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, 2004], while the french association of normalization proposes a ten steps one [AFNOR, 2000].
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

The article will now focus on the object of performance evaluation, namely problem solving in design; then the development of a performance measurement system to evaluate it will be proposed.

2.2. Problem solving in design

Problem solving in design is characterized by diverse dimensions. [Bonnardel, 2000] 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 whole 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 a whole 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 [Simon, 1973]. Problem formulation and problem solving are two concomitant processes.
Simon [Simon, 1987] 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. If trying to model these parallel thinking processes we can detail the process as an 8 steps process.

- P1 the recognition of an unsatisfactory situation, this is the intention required to initiate a design process
- P2 the clarification of the objectives of the design process, where the unsatisfactory feeling is translated into evaluation criteria
- P3 the clarification of the difficulties why the objectives can not be reach by known ways
- P4 the formulation of the root of problem by the identification of the means for resolution
- P5 the building of a generic concept of solution
- P6 the specification of the generic principle of resolution by the identification of the specific way to implement it
- P7 the evaluation of the gap between the proposed solution and the objectives
- P8 the modification of the initial situation

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, particularly in design, is a group, a team, works, as many actors act on it. Depending of the company strategy, the methodology used to solve problems will imply only internal actors (actors from the company) or be based on external ones. This decision depend both on

the availability of competences in the company and on different strategic decisions (external feedback, crisis resolution …).
The project leader, the animator, and the decision-maker are three main actors of a project (but not necessarily 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 well 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 of the development of found solutions.

The project will also require other resources, knowledge and competences that will be found either internally either externally.

2.3 Performance of problem resolution in design

In the frame of inventive design, problem resolution is the research of unknown solutions. Due to the open-ended en ill-defined characteristics of inventive problems, processes of resolution are still not 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. To understand the role of the various dimensions of problem resolution and their impact on the performance of the process, a system of indicators will be proposed.

3. Definition of a system of indicators for problem resolution in design

To build a Performance Measurement System for problem resolution in design, the five steps methodology described in §2.1 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 figure 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.

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	% trained, % untrained, % to train
		group composition, representativeness	system life cycle experts	yes, no
		group inhibitions	hierarchical links	same level, different levels, gap
		mobilized resources	number	numer
		enterprise culture	age, seniority	age average from the group and standard deviation
		project priority in the point of viewof 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	duration of the project	duration	weeks, months / firm medium length
		mobilized resources	time	hours
		availability of information	number of backloops	number
		project actors involvement	meetings frequency	/ months
		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 revelance	goals adequacy	% of the specifications satisfied
		resolution impact	number of solutions	number (short term , medium term)
		generated knowlege outside project	changing directions	number
		other inputs than resolution	generated knowlege	concepts, patents, projets kept to be initiated
		innovative degree, area of the solution	firm appropriation	immediately, technology transfer, research

4. Use of system of indicators as dashboard

The defined system of indicators enables the following up of problem resolution in design through the dashboard presented in table 2. This dashboard is the one extracted from a case study animated by one external expert of a research laboratory as animator for one industrial inventive project.
No real conclusions could be extracted from this dashboard, and as the study is at its beginning, only three case studies have been capitalized through such dashboard.

5. Conclusion

The presented study is a very first step to understand and precise what is performance for problem resolution in design. The objective is to define this performance and to understand how to make process resolution more competitive. By the accumulations of data through the proposed dashboard, we aim at modelling, with Design of Experiments tools, the role of the different inductors on performance for problem resolution.

Table 2. Dashboard of a problem resolution process

	object	indicator	measure
Context of the problem **Human resources**	animator	origin	external
		goal	training
	project actors	trained to the method	20% trained,40 % untrained, 40% to train
		system life cycle experts	yes
		hierarchical links	different levels: no direct link
		number	5
		age, seniority	average: 12,4 / standard deviation: 8,4
		implication degree	% time allocated to the project / number of projects
	decision maker	term	short-term
		importance	priority
		presence in the group	no
	external resources	number	0
Efficiency	process	duration	6 months
		time	12 jours
		number of backloops	1
		meetings frequency	2 / months
		exchanges between actors	elevated
		activity between sessions	medium
Efficacity	result	goals adequacy	80%
		number of solutions	2 short term, 3 middle term
		changing directions	1
		generated knowlege	one patent, one new direction of research
		firm appropriation	immediately for short term solution, research for middle term

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Nicolas Maranzana
INSA Strasbourg Graduate School of Science and Technology
Design Engineering Laboratory (LGECO)
24 boulevard de la Victoire
67084 Strasbourg Cedex
France
Tel.: +33 (0)3 88 14 47 00
Fax.: +33 (0)3 88 14 47 99
Email : nicolas.maranzana@insa-strasbourg.fr