Using Indicators for System Complex Safety

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Abstract - *In our modern societies, technological systems are taking on a large part in numerous domains such as automatic control, calculation, communication, information technologies, etc. They are put in place in more and more fields e.g. production, defense, national security, space, etc. These very important developments are offering new possibilities such as distributed cooperative and concurrent decision making based on complex dynamic systems or on advanced simulation capacities. To facilitate decision making in various fields such as transport, energy or even risk management, it is necessary to define indicators generated by such systems in order to deliver engineers or managers an image of the considered object and it's evolution. This image must be coherent, reliable and sustainable in order to participate at the decision in a complex sociotechnical environment.*

The aim of the article is to present our approach to define this category of new indicators.

Keywords: Safety assessment, indicators, system complex, risk management.

1 Indicators

Modern systems are usually and inherently very complex because of the simultaneous integration of different technics and technologies. Using such systems for safety offers new perspectives but at the same time clearly raise the question of the relevance of the information that feeds the decision making process.

With these critical conditions, information that is erroneous (totally or partly), obsolete, inadequate, etc. is leading quickly to wrong decision. The cause of the deviation can be due to the way the system is working itself (design level) but also due to the fact that it does not report relevant information in all cases.

This can be due to errors of functioning, but also due to the right way of working itself (from system perspective) but unexpected (from the user standpoint). To avoid this kind of deviation you can define indicators that clearly give the right picture of the way the system is working, but also give a relevant picture of the target of the system and its evolution.

An indicator is a measure that enables to assess the efficiency of the considered object in order to predict the information that is susceptible to have an impact on its performance goal. An indicator can be an individual measure or a set of measures and its associated analysis that can predict performance before the goal is fully achieved. The performance of the considered object can be an indicator to measure its performance in its environment (system, process,…).

Indicators allow a good control based on a good understanding on performance itself and its evolution. Predictability of the future is not always taken into account by measurement process. Without the right indicators, it is difficult to assess probability to conduct up to the end a complex activity meeting constraints such as frame, calendar, quality and budget, etc.

A classical measure (a conventional measure) gives information on historical and real data. An indicator must rely on trend on conventional measures or demonstrated correlations that can give a predictable analysis. An indicator could rely on the evolution of a list of constraints to predict the future behavior of a process.

Although we use same data, a fundamental difference is that indicators (compared to conventional measure) have an objective to meet information needs that can be either predictive or prospective. Even if indicators seem to be similar to existing measures and use same basic data, the difference lies on the way this information is collected, assessed, interpreted and used to give information and knowledge on the future.

Indicators are supposed to be used to enlarge the set of all the existing measures that are already in place into the organizations. To optimize efficiency, indicators must be put in place via a measurement structure of the organization (generally based on

CMMI[1] principles), that enables to automatize the way to gather, analyze and interpret data.

We also have to note that indicators often mean we have to use empirical data to define scheduled objectives and the thresholds that are used to analyze and interpret. When these data are not available, we often use an expert judgment in order to define initial goals and thresholds until a good historical can be gathered.

A qualitative or quantitative indicator belongs to one of the 3 types below:

- Lagging indicator
- Leading indicator
- Coïncident indicator

The concept of the 3 types of indicators (lagging, leading, coïncident) is a long story. It started in 1938 with a book written by Mitchell, Wesley C., and Arthur F. Burns. Statistical Indicators of Cyclical [1]. Since that date, numerous articles demonstrated the interest of such indicators. The evolution of the last years make it easier to use them considering alert needs in order to go from a reactive control mode (reaction to a lagging indicator) to a proactive control mode (action on leading indicator).

Some of these indicators give information on past performance. They are called indicators of result (lagging indicator). As an example, for a ship, the logbook registers the distances. Another kind of indicator gives information on the ongoing performance that can have an effect on future performance. They are called indicators of action or advanced indicators or piloting indicators or alert indicator (leading indicator). This is the case for the anemometer or the radar that allow the pilot to be alerted of a potential hazard, to anticipate any phenomenon with the right picture. Coïncident indicator put in evidence events almost happening at the same moment.

2 Limits of the conventional approach

We are going to illustrate the limits of the conventional approach by taking an example using indicators for car traffic control.

To control the traffic on a one way composed by three high speed lanes, we put in place a device that can count each vehicle and for each gives its speed. The speed is regulated. Maximum authorized speed is 110 km per hour and minimum authorized speed is 70 kilometers per hour.

With this information, we put in place indicators with the objective to facilitate decision making for personnel in charge of car traffic control on both fluidity aspect and safety concern.

The number of vehicles driving on one lane gives its yield of use, and so it's possible saturation. The speed gives a picture of safety, for example, by comparing the individual speed of each vehicle with the capacity of the infrastructure. Combined with flow[2] it gives more precision on the yield of use of the lane.

Very quickly we can assess the limits of the use of individual data. First step we have to put in place aggregation function then merging function of individual data in order to build synthesis.

In term of flow, a first aggregation of individual data over a time frame of one or six minutes, for example, makes sense. The calculation remains simple: We sum individual measurement on a period of six minutes.

The yield of use of the road (composed by three lanes) will be calculated by using the sum of the flows of each lane compared to the sum of their respective global capacity. If we want to have an idea of an average flow over a period of six minutes, a simple arithmetic average can be used.

The aggregation of individual speed, without introducing any bias, raises a difficult problem. Let us consider individual data.

1. We have a table of values T(v)[90, 50, 160] that represent measured speeds. The arithmetic average corresponds to a speed of 100 km/h for a maximum authorized speed limit of 110, however 60 % of vehicles are outside the specifications and can be considered as dangerous[3]. The possible aggregations on a given period of time will introduce big bias.

By using a more complex aggregation function, it is possible to deliver a result on the safety level of the road depending on speed measures.

Let us define a weighting table Ct(v,i) that will be initialized taking into account individual speeds such as :

$$if\ T(v,i) \in [70,110]\ then\ Ct(i) = 1, \text{ifnot } Ct(i) = 2$$

It gives for our example weighting values [1,2,2]. The speed coefficient is calculated, for example, with the following algorithm:

$$Coeff = \frac{Echantillon}{\sum_{i=1}^{echantillon}\left(\frac{T(v,i).Ct(i)}{100}\right)} \quad (1)$$

In our example, we calculates *Coeff = 3/5.1 = 0.58.* This value can be round up to 0.6. This clearly demonstrates that 60 % of speeds are out of specification².

[1] CMMI : Capability Maturity Model Integration

[2] Number of vehicles on prefixed period of time.

[3] Mobile zigzag for one and high speed for the other one.

3 Toward new indicators

New indicators must include a management dimension, which corresponds to classical indicators, but equally a piloting dimension that is still to be defined. Difference lies on the fact that information to pilot is directly linked to how to drive action, while management information is dedicated to information structure of the company. In order to facilitate how to use them, so how to interpret them, they can be organized in synthetic scorecard. Research from Kaplan and Norton on the notion of "balanced scorecard" [2] [3] is a key contribution to our field of study.

More precisely : "a performance indicator that can help a manger, at an individual or more often at a team level, to pilot the action up to the objective or that can allow to assess the result …" [4].So it is not an "absolute" measure, a characteristics of the measured phenomenon independently from the observer. It is built by the actor. [5].

As a consequence it is a sophisticated management tool with some specific features. For example:

- The strategic objective to which it is linked, its targets with timeframe and measurable features , the relevant references,
- The clear identification of who is in charge to deliver them, and the one in charge of its performance,
- Frequency and follow up. Son mode de suivi : budgété, réel, historique, …
- Technical definition : formula and calculation convention, sources of information, …
- Segmentation modes to decompose aggregated form : geographical data, type of product, center …
- Presentation (ex : numerical data, tables, graphics, …) and communication list.

Such an indicator is composed by two different functions depending on how it is located compared to the action (se figure 1).

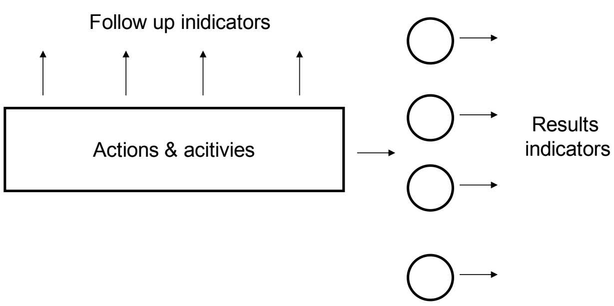

Figure 1: indicator of result or follow up [4]

It can be an indicator of result. In that case, it gives an assessment of the final result when the action is completed.

But it can also be a follow up indicator. It allows to anticipate or to react on time. By definition, the result indicator comes too late to shift the action.

The way it is located compared to the structure of power and responsibility gives it also a final duality (fig 2). The corresponding reporting gives an indication of the percentage realization of the objectives, which can be considered as a control a posteriori, and the piloting whose objective is to adapt actions in progress.

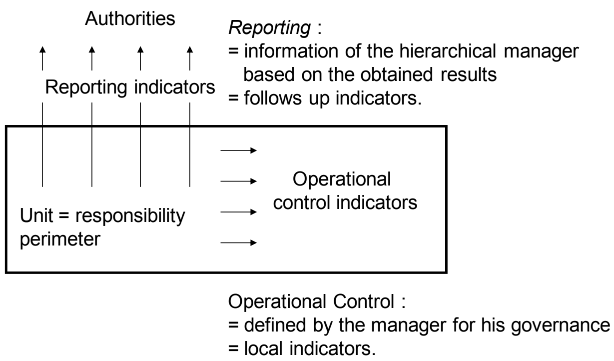

Figure 2: Leading indicator or reporting [4]

The composition of such an indicator must take into account aspects linked to operational relevance such as, for example, combining indicator / action, the question of “controllability", and the impact of levers on actions.

It is also necessary to take into account some aspects linked to strategic relevance such as, for example, the association of indicator / objective [6], [7], the measure of the completion of the results (Indicator of result), and data on how actions are implemented (Leading Indicator).

This reflexion must be completed with another dimension concerning the cognitive efficiency. Indeed, these indicators are used by the actors in a given context. They influence the action and the way it is understood. It is so necessary to define how to read them, to understand and to interpret as soon as the indicators are designed. It is the only condition to set a frame to take into account the context of the actor, and that is easy to use.

Some questions are rising when we want to define indicators. Do we want to use financial indicators, or non financial, or use a mix of both? If we define non financial indicators, is it better to valorize the stakes? What is the right number of indicators to get a clear and coherent picture?

It appears necessary to dissociate management indicators and piloting indicators [8].

The way indicators are organized within a scorecard, for example as for balanced scorecard, makes it possible to have both types of indicators financial and non financial. Indicators are organized in four parts: learning, process, customers and financial aspect. Inside the scorecard, indicators are linked with a causal model.

4 Proposal to define a methodology to build indicators

To build new indicators, on the scheme above, it is necessary to put in place lagging indicators, of a classical type, and leading indicators, that are still to be defined. An important problem is to take into account, at initial design level, cultural differences that can exist through the same organization (different jobs and state of the art, level of education, social origins,…) or in the various locations in different countries of an international company.

A specific focus must be put on the models which, although they are at the same time part of the indicator, are necessary to determine it (calculation process) and how to interpret it. The mathematical approach and the following modeling phase have a direct impact on the relevance of the indicator (pertinence, reliability, « easy to use",…). Handrails such as, for example, the definition of functioning segments, restrictions, …, allows to put in place real time control process. Steps of aggregation and consolidation of data allow ensuring that the dynamics of information within the organization (geographical or organizational grouped together, reporting to the upper level, …) do not introduce bias, so do not destroy its coherence.

While defining indicators and the way they are organized, it is necessary to define a test and validation protocol that will be based on a set of selected data. The protocol must represent the way the organization is working, and the set of data has to work properly for the main expectable cases of use.

The approach exposed in our article is only a first step that needs to be developed. Application domains are numerous especially for safety people management and associated indicators such as frequency rate and severity rate [9]. The objective is to determine a methodology to define and put in place indicators able to control on one hand the way the system is working and on the other hand to give a coherent picture of the observed phenomenon and its evolution.

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