Service quality monitoring by performance indicators: a proposal for a structured methodology

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Abstract: The evaluation of service quality is usually carried out using a suitable set of Performance Indicators (PIs). In general, the development of a proper set of PIs is a fundamental prerequisite to monitor organisation or process performances. Many conceptual models have been proposed in the literature. The question is how to make these models operative. This paper aims to describe a structured methodology to identify a set of PIs for service quality monitoring. First, the service is mapped in order to identify its main activities. Then, the Quality Function Deployment (QFD) methodology is applied. Relations between the service quality determinants and the corresponding indicators are established and analysed. The monitoring of a service often implies the definition of large PI sets. To make quicker indicators analyses and process anomalies identification, a subset of the most critical PIs is selected (Performance Dashboard). This subset is used for the earliest monitoring of the system.

In this paper, different selection techniques are proposed and compared. The methodology has been experimentally tested on a Help Desk (HD) service. The obtained results are proposed and discussed.

Keywords: service quality; performance measurement system; PMS; performance indicators; quality indicator; indicators dashboard.

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1 Introduction

The measurement of a process performance or service quality is usually carried out by developing a Performance Measurement System (PMS) (Evans, 2004).

Defining a PMS is not an easy task. Many authors tried to give a 'recipe' in order to help organisations and practitioners in constructing a proper PMS (Neely *et al.*, 1995; Austin, 1996; Brown, 1996). Nevertheless, it is still difficult to find an 'all-around' approach which integrates the concepts of process modelling, indicators definition and their synthesis and impact on the analysed process (Hauser and Katz, 1998; Melnyk *et al.*, 2004; Franceschini *et al.*, 2006b).

In PMS construction, the most critical aspect is identifying an appropriate set of indicators which 'adequately' represents the system at hand (Franceschini *et al.*, 2006b).

In the literature, many works suggest how to choose and organise a set of indicators that refers to a given goal (Bouyssou *et al.*, 2000; Melnyk *et al.*, 2004; Banker *et al.*, 2004; Damien *et al.*, 2005; Ramayah *et al.*, 2007). Each method relies upon a conceptual reference which gives the logical basis of a theoretical framework.

Kaplan and Norton first introduced the *balancing* conceptual reference and the relative Balance Scorecard framework (Kaplan and Norton, 1992; Kaplan and Norton, 1996; Kaplan and Norton, 2001). The authors' idea was to translate the company mission (focused on a set of perspectives or dimensions) into a critical set of measurements.

Kaplan and Norton's *Balanced Scorecard* identifies a set of indicators for each of the four dimensions (financial, customer, internal business process, learning and growth) that explain the creation of value in an enterprise. The four dimensions are mutually connected. The basic idea of the Balanced Scorecard is to give a correct (balanced) weight to all of the important dimensions of a process.

The *Critical Few* approach is focused on the synthesis of the identified Performance Indicators (PIs) (Performance-Based Management Special Interest Group, 2001). Very often, it is difficult to analyse the indicators' effects and their mutual correlations. The problem is to minimise the number of critical indicators: *pluritas non est potenda sine necessitate* (Thorburn, 1918). The Critical Few approach is based on the selection of indicators which balance all of the relevant aspects of a system.

Controlling a system with the smallest number of parameters is also the aim of the Dashboard model. The *Performance Dashboard* is a graphical tool that synthetically shows the performances of a process or organisation (Bourne and Neely, 2003; Eckerson, 2005; Lohman *et al.*, 2004; Neely *et al.*, 1995). It considers the most critical indicators and their effects on the whole system.

The impact that is exerted by an indicator onto the system should be considered as well. The indicators may influence the overall behaviour of a system with sometimes uncontrollable consequences (Barnetson and Cutright, 2000; Hauser and Katz, 1998).

From the literature review, three important concepts stand out: the indicators' choice, their synthesis and their impact on the monitored system. In particular, the *balancing* conceptual reference emerges as an important logical foundation of the PMS construction. Nevertheless, all of the considered works do not fully suggest how to operationalise the concept of a balanced set of PIs. These observations are the starting point of this article.

After giving a general definition of 'indicator' (Section 2), we describe in depth a methodology to construct a balanced PI set (Section 3). The first step is process representation (Section 3.1). Then, according to the process representation perspective, the representation targets are defined (service quality determinants). For each of them, at least one indicator is identified (Section 3.2). The last step lies in the performance dashboard construction (Section 3.3). The relevant and critical aspects of the suggested methodology are summed up in the Conclusion (Section 4).

2 Definition of indicator

The definition of *indicator* is strictly connected to the notion of *representation target*. A representation target is the operation aimed to make a *context* or part of it 'tangible' in order to perform evaluations, make comparisons, formulate predictions, take decisions, *etc.* In a given context, one or more different representation targets can be defined. An indicators set is a tool which operationalises the concept of 'representation target' (Franceschini *et al.*, 2006b; Franceschini *et al.*, 2006a; Cecconi *et al.*, 2007).

For example, if the context is the 'logistic process' of a company, the representation target may be the 'classification of suppliers'. The 'delivery time' and 'lead time' can be two of the possible related indicators.

According to the Representation Theory of Measurement, there is a strict connection between the concepts of 'indicator' and 'measurement'.

Given a representation target, we define A as the set of all the possible empirical manifestations of a process, $A = \{a_1, \ldots, a_i, \ldots\}$ and R as the family of empirical relations (*i.e.*, equivalence, order, composition, *etc.*) among the elements of A, $R = \{R_1, \ldots, R_m, \ldots\}$, then the empirical system E as $E = \langle A, R \rangle$ (Roberts, 1979).

Analogously, if Z is a set of symbols $Z = \{z_1, \ldots, z_i, \ldots\}$ and P is a family of relations among the elements of Z, $P = \{P_1, .., P_m\}$, then the symbolic system S can be defined as $S = \langle Z, P \rangle$.

Generally, a measurement is an objective empirical function which maps A onto Z (homomorphism: mapping is not one to one) and R onto P (isomorphism: mapping is one to one) (Finkelstein, 2003).

Referring to the Representation Theory, an indicator *I* can be considered a homomorphical mapping from the manifestations of an empirical system onto the manifestations of a symbolic system. In other words, an indicator operationalises the concept of representation target. However, the isomorphical mapping between the empirical and symbolic relations, unlike measurement, is not required.

As a result, the indicator concept includes the measurement concept, but the opposite is not true. On the basis of the Representation theory, measurements can be considered a subset of indicators (Franceschini *et al.*, 2006b; Franceschini *et al.*, 2006a).

It can be shown that, given a specific representation target, the related indicator (or indicators) are not univocally defined (Franceschini *et al.*, 2006b; Franceschini *et al.*, 2006a).

3 Construction of the performance indicators set

The methodology that is proposed here entails the following steps:

Step 1 process mapping (Section 3.1)

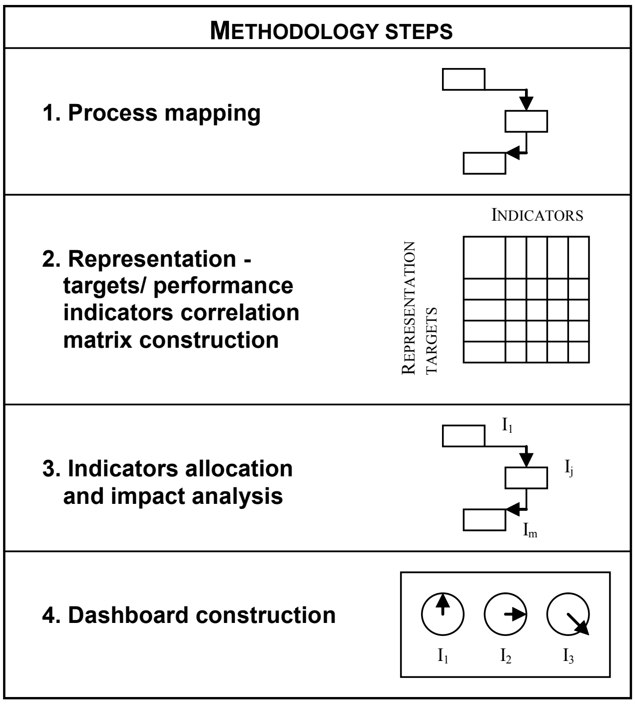
Step 2 representation targets/PIs relationship matrix construction (Section 3.2)

Step 3 indicators allocation and first-impact analysis (Section 3.3)

Step 4 Dashboard construction (Section 3.4).

These steps are reported according to their order of application. A synthesis is reported in Figure 1.

Figure 1 The main steps of the methodology for PI set construction



3.1 Process mapping

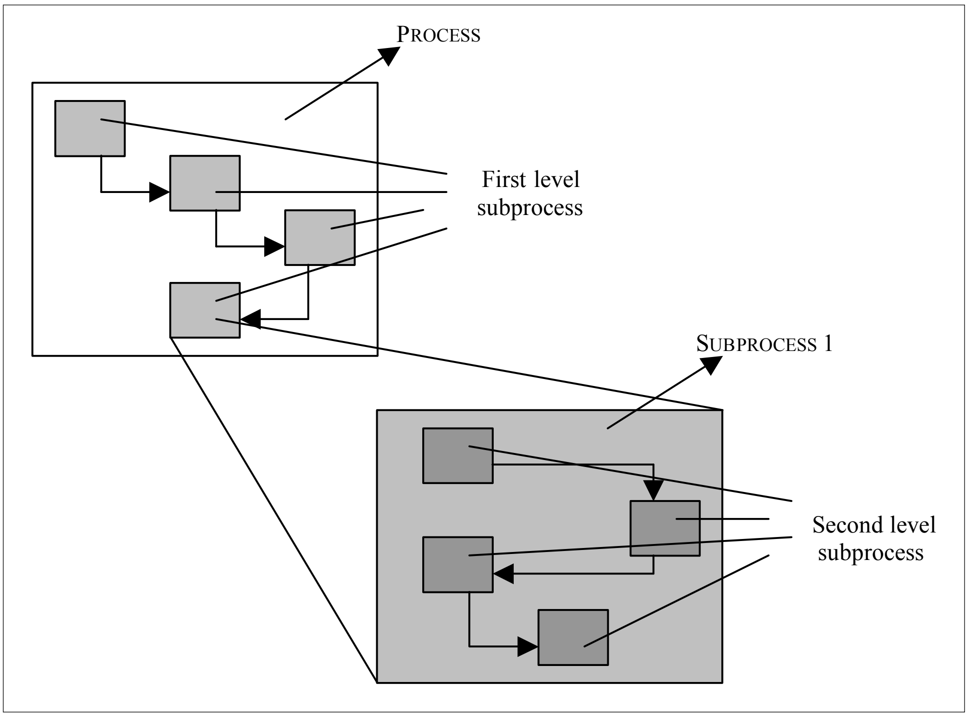
Mapping is a basic tool for process description and analysis. Many software applications allow representing process performances. Integrated DEFinition (IDEF) Methods, Computer Integrated Manufacturing Open System Architecture (CIMOSA) and Domain-Specific Modeling (DSM) are some examples of the most common methodologies used for process modelling and simulation (CIMOSA, 1993; Draft Federal Information, 1993; Mayer *et al.*, 1995; Ulrich and Eppinger, 2000).

A process map shows in a graphical way the process *iter* through the different organisation units.

The developed activities and the relative responsible subjects (or actors) are described. The information flow between the different organisation units is also included.

A process can be fractioned into the subprocesses of different levels (Figure 2). In the definition of the level of detail, we have to consider the parent process complexity. It is important to note that no more than four or five levels should be defined. A higher number of levels could imply an excessive detail. As a consequence, the risk of focusing attention on some marginal aspects of the process is very high. This means that we could have an unbalanced set of PIs. The last level consists of basic processes that are composed of activities with specific actors and PIs.

Figure 2 The decomposition of a main process into subprocesses



Generally, process map analysis brings process rationalisation (the identification and removal of bottlenecks, circles, *etc.*) and the identification of the monitoring points for process quality control (see Section 3.3).

3.1.1 Process mapping of a Help Desk service

The methodology described in this article has been experimentally tested on the Help Desk (HD) service of a broadcasting company. The map of the HD service is reported in Figure 3.

Figure 3 The process map for the HD service (see online version for colours)

						ACTORS		
No.	**ACTIVITY**	**VOLUME (number/ month)**	**DATA BASE ACCESS**	**CUSTOMER**	**START / END**	**CALL CENTER**	**SECOND LEVEL BODY**	**EXTERNAL BODY**
1	The customer calls directly the second level body for an intervention at his/her own work station (only for institutionalized calls).	N.A.		X	Call			
2	The second level body communicates the call to the Call Center for a trouble ticket opening.	x of 1.703					Call opening request	
3	The Call Center operator opens the trouble ticket and assigns it to the second level body that has communicated the call opening.	x of 1.703	X			Call opening and trouble ticket assignment		
4	The customer calls the Call Center for an intervention at his/her work station.	(y+10%y) of 1.703		X	Call			
5	The Call Center operator opens the call (trouble ticket opening).	(y -10%y) of 1.703	X	X		Call opening; I_7		
6	The operator verifies if the failure could be dealt by phone (first level intervention). If the problem is solved, go to call end.	(y -10%y) of 1.703		X		1st level intervention; I_2, I_3, I_7		
7	If the operator can't solve the problem by phone, assigns the trouble ticket to the second level body or to the external body.	741	X			Trouble ticket assignment to a 2nd or 3rd level		
8	Second level intervention. If the body is not competent, the trouble ticket is transmitted to the call centre; if the problem is solved go to call closing feedback.	584 + x of 1.703		X			2nd level intervention	
9	If the problem is not solved, the trouble ticket is assigned to the external body.	6	X				Trouble ticket assignment to the external body	
10	External body intervention. If the problem is solved, the trouble ticket is transmitted to the first or second level body for the feedback, else the trouble ticket is transmitted to the 1st level again.	163		X				External body intervention
11	Second level feedback: if the problem is solved the trouble ticket is transmitted to the Call Center for the call closing feedback, else the trouble ticket is assigned to the external body.	15		X			2nd level feedback	
12	The Call Center makes the feedback; if the problem is not solved the trouble ticket is assigned to another (or the same) body for the second level intervention, else go to call closing.	507		X		Call closing feedback; I_7		
13	Call closing.	1.647	X		Call end	Call closing; I_1		

Notes: It also includes indicators allocation next to the influenced activity.
Legend: *x*: number of second level body incoming calls; *y*: number of Call Centre incoming calls; 10%*y*: number of lost calls.

This HD service deals with the failure management of the Information and Communications Technology (ICT) area. Three main subjects can be identified: the service user, the HD service supplier (the ICT area of the organisation or an outsourcer) and the service controller (ICT service quality group). A customer who has a problem calls the call centre or the second-level body directly. Moreover, the second-level body or a third-level body (external organisation) intervenes if the call centre operator is not able to solve the problem. At the end of each intervention, a final feedback is supplied.

The map highlights the procedure number (first column from the left), the procedure description (second column), the average volume of calls (third column), the average length of the activities (fourth column), a database access (fifth column), contacts with the customer (sixth column), the process start/end (seventh column) and the different organisation units or external suppliers responsible for the procedures (eighth column).

3.2 Indicators identification

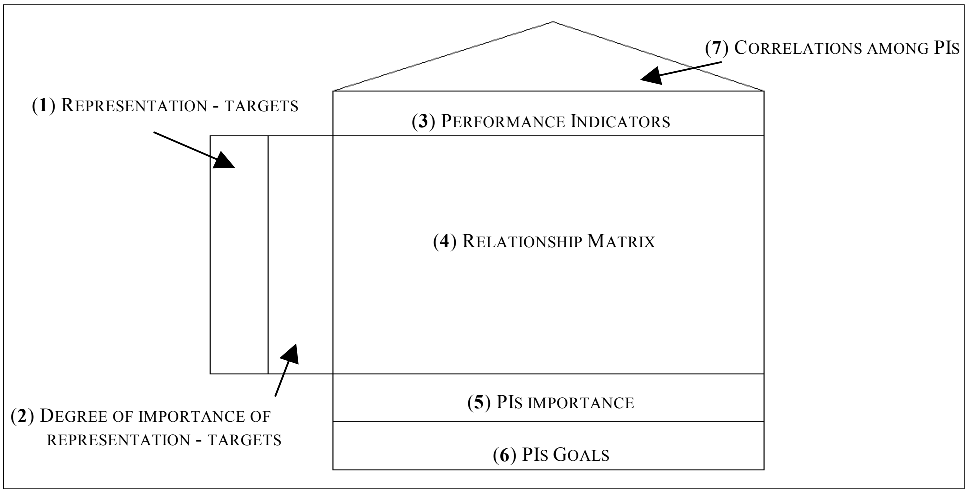
Indicators identification is founded on the adaptation of the Quality Function Deployment (QFD) methodology.

QFD is a tool for laying the project plan of a new product or service in a structured and finalised way (Kogure and Akao, 1983; Franceschini, 2002). It stresses the attention on the analysis of customer requirements from the beginning of a project.

The QFD approach is essentially based on the construction of a table called the House of Quality (HoQ), which synthetically analyses the relations between the customer needs and the technical characteristics of a product/service. The technical characteristics and customer needs are the columns and rows of the so-called relationship matrix (**R**), respectively. The matrix elements indicate if and how each technical factor affects the satisfaction of each customer requirement.

In the present work, the same matrix has been adapted in order to analyse the relations between the representation targets and the corresponding PIs. The original HoQ is modified as indicated in Figure 4.

Figure 4 The main components of the 'adapted' HoQ



The definition of factors that influence the customer perceptions of service quality is a topic of large interest (Palani Natha Raja *et al.*, 2006; Koutouvalas *et al.*, 2005). In the identification of the service representation targets, we refer to Parasuraman *et al.*'s service quality model (PZB model) (see Table 1) (Parasuraman *et al.*, 1985).

For each determinant in Table 1, we may define one or more specific second-level determinants. They consider all of the service aspects.

Table 1 The service quality determinants according to Parasuraman *et al.*'s model

Reliability	Involves consistency of performance and dependability; means that the firm performs the service right the first time; also means that the firm honours its promises.
Responsiveness	Concerns the willingness or readiness of employees to provide service; involves timeliness of service.
Competence	Means possession of the required skills and knowledge to perform the service.
Access	Involves approachability and use of contact.
Courtesy	Involves politeness, respect, consideration and friendliness of contact personnel.
Communication	Means keeping customers informed in a language they can understand and listening to them; may mean that the company has to adjust its language for different consumers.
Credibility	Involves trustworthiness, credibility and honesty; involves having the customer's best interests at heart.
Security	Is the freedom from danger, risk or doubt.
Understanding/ Knowing the customer	Involves making the effort to understand the customer's need.
Tangibles	Include the physical evidence of the service.

Source: Parasuraman *et al.* (1985)

The representation targets' importance (reported in Zone (2) of Figure 4) is evaluated by the subjects who are the focus of the PIs system design.

A very ticklish part of the methodology is represented by the identification of indicators which better operationalise each representation target. The choice of indicators requires a detailed knowledge of the process (Hauser and Katz, 1998).

The representation targets are the starting point for indicators identification. The PIs are the translation of the targets (expressed in a verbal way) into monitorable and controllable variables.

To ensure a total target covering, the PZB model's determinants can be used as a support in indicators identification and classification. The PIs are reported in Zone (3) of the adapted HoQ (Figure 4).

The relationship matrix (Zone (4) of Figure 4) is filled in a qualitative way. An example of commonly used symbols is reported hereafter:

- ⭘: strong correlation
- O: medium correlation
- Δ: weak correlation.

Once the **R** matrix is filled in, the different indicators are ranked. The classic method used is the *Independent Scoring Method* (ISM). Denoting by w_j the absolute importance of the j-th indicator ($j = 1, 2, \ldots, m$), we have:

$$w_j = \sum_{i=1}^{n} d_i r_{ij} \quad (1)$$

where:

d_i = the level of importance of the i-th representation target, $i = 1, 2, \ldots, n$
r_{ij} = the specific level of correlation between target i and indicators j
(we set the following values: *weak* correlation $r_{ij} = 1$, *medium* correlation $r_{ij} = 3$, *strong* correlation $r_{ij} = 9$)
n = the total representation targets number
m = the total number of indicators.

The relative importance of the indicators is also calculated.

The indicators' absolute and relative importance is reported in Zone (5) of Figure 4.

It is important to observe that converting correlation symbols into numbers is an arbitrary operation which confers cardinal properties to information which has only ordinal properties (Franceschini, 2001; Franceschini, 2002; Roberts, 1979). This could mean that the final weight that is associated to a technical characteristic could not totally reflect customer requirements.

The subsequent step of the methodology is the goal setting for each indicator. They are established by process analysers according to their process knowledge, empirical experience and benchmarking with the main competitors (Zone (6) of Figure 4).

In the 'roof' of the HoQ (Zone (7) of Figure 4), the correlation matrix among the indicators is reported. The correlations among the indicators are expressed through the use of qualitative symbols. We can use the same symbols that were reported before to suggest the intensity of correlation.

At present, process analysers establish correlations among the indicators on the basis of a mere qualitative reasoning (Neely *et al.*, 1995; Austin, 1996; Brown, 1996).

Two indicators are defined to be correlated if they influence the same representation targets.

By observing a general Relationship Matrix, it may be noted that in many cases, correlated indicators influence the same representation targets. That can be a starting point for building an automatic tool to indirectly define the correlations among the indicators. As a matter of fact, if the i-th indicator influences the u-th and v-th representation targets, it is likely that the j-th indicator correlated to it influences the same representation targets.

However, if the mutual dependence may imply the presence of a correlation, the opposite is not generally true. The presence of an induced dependence on the indicators is a necessary (but not sufficient) condition to sentence that two indicators are correlated. It is the designer who must confirm the possible sufficiency. It must be highlighted that the concept of correlation that is suggested here is more extensive than the concept of statistical correlation. The correlation degree is expressed in qualitative terms and based on empirical considerations.

The procedure provides for the following steps:

Step 1 construction of a binary matrix ($\mathbf{B} \in \mathfrak{R}^{n,m}$) that is obtained by encoding the Relationship Matrix symbols into numbers according to the following rule:

$\forall i, j$ if $r_{ij} =$ ● then $b_{ij} = 9$, or if $r_{ij} =$ O then $b_{ij} = 3$, or if $r_{ij} = \Delta$ then $b_{ij} = 1$

Step 2 normalisation of the **B** matrix column vectors ($\mathbf{b}_j \in \mathfrak{R}^n$, $j = 1, \ldots, m$). $\mathbf{N} \in \mathfrak{R}^{n,m}$ is the new normalised matrix:

$$n_{ij} = \frac{b_{ij}}{\sqrt{\sum_{i=1}^{n} b_{ij}^2}}.$$

A simple example of the building process of matrix **N** starting from matrix **R** is reported in Figure 5.

Step 3 construction of the transpose of **N** ($\mathrm{N}^{\mathbf{T}} \in \mathfrak{R}^{m,n}$)

Step 4 calculation of the $\mathbf{Q} = \mathbf{N}^{\mathbf{T}} \times \mathbf{N}$ matrix ($\mathbf{Q} \in \mathfrak{R}^{m,m}$), whose elements are the direction cosines of the **B** matrix column vectors:

$q_{ij} = n_i^{\mathrm{T}} \cdot n_j = \cos(\mathbf{n}_{\mathrm{i}}, \mathbf{n}_{\mathrm{j}})\ \forall\ i, j = 1, \ldots, m$

Step 5 choice of a threshold k ($0 \le k \le 1$)

Step 6 if $\forall i, j\ q_{ij} > k$, then we establish a potential correlation between the i-th and j-th indicators. The results of this translation are reported into the roof of the HoQ

Step 7 the process analyser considers the established correlations and confirms or rejects them. Finally, we obtain the correlation matrix $\hat{Q}$ among the indicators.

Figure 5 The building process of the **N** matrix starting from the **R** matrix using a standard 'translation' of the **R** matrix symbols

R =

●	O	
Δ		O
	Δ	

B =

9	3	0
1	0	3
0	1	0

N =

0.99	0.95	0.00
0.11	0.00	1.00
0.00	0.32	0.00

Notes: Legend: ● = 9, O = 3, Δ = 1.

3.2.1 *Indicators' identification for the Help Desk service case study*

A simple example of the suggested methodology for the HD case study is reported in Figure 6.

Figure 6 Example of the ‘adapted’ HoQ obtained for the HD service

Δ = 1 (weak correlation) *O = 3 (medium correlation)* **O** *= 9 (strong correlation)*		*Performance indicators*								
Representation target	*Importance*	*I_1) Correctness in addressing calls*	*I_2) Answers’ precision*	*I_3) Answers’ uniformity*	*I_4) Time before the appropriate body takes a call*	*I_5) Perceived competence*	*I_6) Answered calls (percentage)*	*I_7) Courtesy during the call*	*I_8) Data-keeping and safety*	*I_9) Number of activated lines*
O_1) Reliability	5	**O**	O	**O**	O	Δ			O	
O_2) Responsiveness	5				**O**	Δ				
O_3) Competence	4	**O**	**O**	**O**		**O**				
O_4) Access	4						**O**			O
O_5) Courtesy	3			Δ				**O**		
O_6) Communication	3		Δ	**O**		Δ		O		
O_7) Credibility	3	Δ		O		O				
O_8) Security	5	Δ							**O**	
O_9) Understanding/ Knowing the customer	4	O	Δ	Δ		Δ		O		
O_{10}) Tangibles	3									**O**
Absolute importance		101	58	124	60	62	36	48	60	39
Relative importance (%)		17.18	9.86	21.09	10.20	10.54	6.12	8.16	10.20	6.63
	Obtained value	93%	H	H	22 min	L	98%	M	3%	3
	Goal value	>90%	H	H	20 min	H	>99%	H	<5%	5

Notes: Legend: H = high, M = medium, L = low.

We identified the HD service customer as the central subject in the PIs’ system design. It is important to notice that for the sake of simplicity, only the first-level determinants are reported. The indicators’ absolute and relative weights are calculated according to the ISM approach. Finally, the PIs’ goal values are defined.

The calculation of correlations among the indicators for the case study are reported in Figure 7.

The **R** matrix (Figure 7a) is extracted from the HoQ reported in Figure 5. Then, the **B** matrix is constructed using the standard encoding of the correlation symbols (**O** = 9, O = 3, Δ = 1) (Figure 7b). The **N** matrix is reported in Figure 7(c). The **Q** matrix is calculated (Figure 7d) and finally, the $\hat{\boldsymbol{Q}}$ correlation matrix among the indicators is obtained for a threshold $k = 0.75$ (Figure 7e).

Figure 7 The construction of the correlation matrix among the indicators for the HD service

(a) **R** =

O	O	**O**	O	Δ			O	
			O	Δ				
O	**O**	**O**		**O**				
					O			O
		Δ				**O**		
	Δ	**O**		Δ		O		
Δ		O		O				
Δ							**O**	
O	Δ	Δ		Δ		O		
								O

(b) **B** =

9	3	9	3	1			3	
			9	1				
9	9	9		9				
					9			3
		1				9		
	1	9		1		3		
1		3		3				
1							9	
3	1	1		1		3		
								9

(c) **N** =

0,68	0,31	0,56	0,32	0,10	0,00	0,00	0,32	0,00
0,00	0,00	0,00	0,95	0,10	0,00	0,00	0,00	0,00
0,68	0,94	0,56	0,00	0,93	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,32
0,00	0,00	0,06	0,00	0,00	0,00	0,90	0,00	0,00
0,00	0,10	0,56	0,00	0,10	0,00	0,30	0,00	0,00
0,08	0,00	0,19	0,00	0,31	0,00	0,00	0,00	0,00
0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,95	0,00
0,23	0,10	0,06	0,00	0,10	0,00	0,30	0,00	0,00
0,00	0,11	0,00	0,00	0,00	0,00	0,00	0,00	0,95

(d) **Q** =

1,00	0,88	0.80	0,22	0,75	0,00	0,07	0,29	0,00
0,88	1,00	0,77	0,10	0,92	0,00	0,06	0,10	0,00
0,80	0,77	1,00	0,18	0,71	0,00	0,25	0,18	0,00
0,22	0,10	0,18	1,00	0,13	0,00	0,00	0,10	0,00
0,75	0,92	0,71	0,13	1,00	0,00	0,06	0,03	0,00
0,00	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,32
0,07	0,06	0,25	0,00	0,06	0,00	1,00	0,00	0,00
0,29	0,10	0,18	0,10	0,03	0,00	0,00	1,00	0,00
0,00	0,00	0,00	0,00	0,00	0,32	0,00	0,00	1,00

(e) $\hat{Q}$ =

k = 0.75	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	X	X	X		X				
I_2	X	X	X		X				
I_3	X	X	X						
I_4				X					
I_5	X	X			X				
I_6						X			
I_7							X		
I_8								X	
I_9									X

Notes: Symbols within the **R** matrix (7a) are standard-encoded (7b, **O** = 9, O = 3, Δ = 1). The **N** (7c) and **Q** (7d) matrices are calculated. The $\hat{Q}$ correlation matrix (7e) is obtained by fixing a threshold k = 0.75.

3.3 Indicators' allocation and impact analysis

The third step of the methodology is the indicators' allocation into the process.

The elements to consider are the physical monitoring points (for example, in our case study, at the end of the call of the customer, during the intervention, *etc.*), monitoring procedures (for example, interview of the final customer, recording of the intervention, *etc.*) and who is assigned to monitor indicators.

The principal instrument in this phase is the process map (see Section 3.1).

There is a strong connection between the PZB determinants and indicators' allocation within the process. For example, an indicator which affects 'courtesy' will be allocated in a point where there is interaction between the organisation and the final customer.

The process map with some indicators allocated for the HD service is reported in Figure 3. Indicator I_1 ('Correctness in addressing calls') is allocated next to activity 'Call closing' because it refers to the call as the whole. Indicators I_2 ('Answers' precision') and I_3 ('Answers' uniformity') are positioned next to activity 'First Level Intervention'. They refer to the answer given by the interviewed operator and so on.

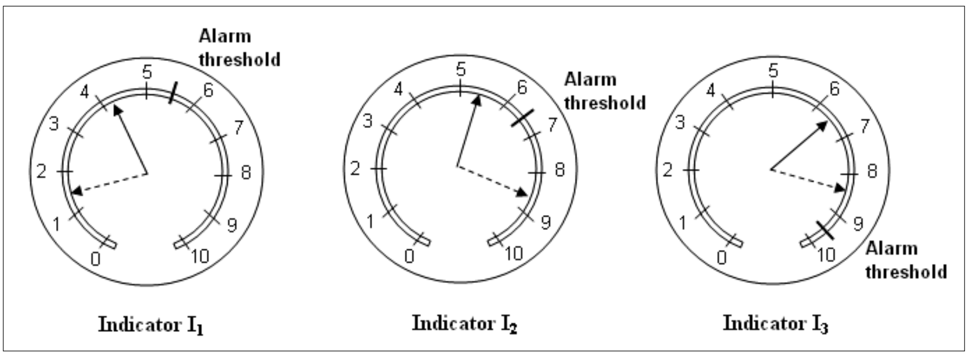
In this phase, a preliminary analysis of the indicators' *impact* on the system is also performed. Different indicators may differently influence the overall behaviour of a system with uncontrollable consequences (Barnetson and Cutright, 2000; Hauser and Katz, 1998).

3.4 Construction of the Dashboard

Zone (3) of the adapted HoQ (see Figure 4) presents a large number of indicators that are not all equally important. For this reason, it could be useful to 'distil' them using the '*Critical Few*' approach. A subset of the previously identified indicators is extracted and included within a *Dashboard*. The Dashboard is the starting point of a general diagnostic examination of the process. If an indicator that is included in the Dashboard assumes an undesired value, then the related detailed indicators are analysed more in detail.

A possible Dashboard representation is reported in Figure 8. The bold segment is the alarm threshold. If an indicator manifests a value which is higher than this threshold, then an anomaly is signalled. The continuous and dotted arrows represent the present and past values of the indicator, respectively.

Figure 8 The graphical scheme of a Dashboard of indicators



The synthesis' indicators can be selected ('*distilled*') according to different operational approaches. In the following paragraphs, we provide a detailed description of three of them:

1 synthesis based on the concept of 'relative importance'

2 'minimum set covering' synthesis

3 synthesis based on the indicators' degree of correlation.

The choice of a technique depends on the examined process, the type of representation and the characteristics of the collected data.

3.4.1 Synthesis based on PIs' relative importance

The first approach considers the indicators' relative importance. Starting from the indicators' ranking obtained by ISM, we define a minimum importance threshold (a 'cut threshold'). We include into the Dashboard only the indicators which have a weight higher than the threshold. The threshold is fixed usually by considering the desired number of indicators within the Dashboard or the minimum importance percentage that we want to cover.

The obtained Dashboard reflects the maximum importance with respect to representation targets. The main limits of this approach are that it does not consider the correlations among the indicators and it does not guarantee that the selected indicators cover all of the representation targets.

Synthesis based on PIs' relative importance for the Help Desk service case study

Let us consider Figure 5 again. Fixing the threshold equal to 10%, we obtain this subset: I_3 ('Answers' uniformity', 21.09%), I_1 ('Correctness in addressing calls', 17.18%), I_5 ('Perceived competence', 10.54%), I_8 ('Safety and data-keeping', 10.20%), I_4 ('Time before the appropriate body takes a call', 10.20%).

3.4.2 PIs' minimum set covering

The search for the minimum set of indicators that covers all of the representation targets is the second approach for indicator selection. This is a variant of the so-called *set covering problem*, a well-known problem in the field of combinatorial optimisation. In particular, if $M = \{1, \ldots, m\}$ is a finite set and $\{M_j\}$, for $j \in N = \{1, \ldots, n\}$, a given collection of subset of M, we say that $F \subseteq N$ covers M if the $\bigcup_{j \in F} M_j = M$. M_j sets are known as covering sets.

The set covering problem belongs to the set of NP-complete problems which have a nonpolynomial computational complexity. To face the problem in our application, we consider a heuristic algorithm with a polynomial computational complexity (Nemhauser and Wolsey, 1988). In this problem, a weight c_j is associated to each M_j and the solution is a covering set which has the minimum cost. The steps of the Nemhauser algorithm are as follows:

Initialisation:

$$M^1 = M, \;\; N^1 = N, \;\; t = 1$$

Solution generation at step $t > 1$:

a calculate c_j; select $j^t \in N : c_t = \min_j \left\{ c_j / \max \left| M_j \cap M^t \right| \right\}$;

$N^{t+1} = N^t \backslash \{j^t\}$; $M^{t+1} = M^t \backslash M_j$

If $M^{t+1} \neq \varnothing$ then $t = t + 1$, go to *step (a)*

If $M^{t+1} = \varnothing$ then *stop.*

The solution is given by all the elements $j \notin N^{t+1}$.

In our specific situation, M is a set which contains the representation targets and N is the set of indicators.

In particular, the weight that is associated to each indicator could be evaluated as the cost for obtaining it. The costs are essentially given by the complexity of the monitoring procedure.

The proposed algorithm operates as follows:

Step 1 The indicator with the highest number of relations with representation targets is selected. If two indicators present the same number of symbols in the relative column of the **R** matrix, the one with the lowest weight is chosen.

Step 2 The selected indicator is eliminated from the **R** matrix and included in the Dashboard.

Step 3 The symbols which are on the same rows as the ones of the eliminated indicator at Step 2 are also eliminated from the **R** matrix.

Step 4 The steps are iterated until the **R** matrix is empty.

This algorithm always provides a set covering. However, it is not necessarily a minimum set of indicators. Furthermore, it does not consider the correlations among the indicators and their importance. A second option is to consider a method which combines the two operative approaches: the indicators' relative importance and the *set covering problem*. We define the new approach as the *minimum set covering problem with the maximum importance*. The final solution is given by the minimum number of columns of the **R** matrix (indicators) which have the maximum total weight. c_j represents the indicators' weight, calculated according to the ISM. In detail, the new *minimum set covering problem* follows the same steps of the Nemhauser algorithm, except for Step 1. This step implies that if we select two indicators with the same number of symbols, then we include in the Dashboard the one which has the highest weight:

Initialisation:

$$M^1 = M, \;\; N^1 = N, \;\; t = 1$$

Solution generation at step $t > 1$:

a calculate c_j; select $j^t \in N : c_t = \max_j \left\{ c_j / \max \left| M_j \cap M^t \right| \right\}$;

$N^{t+1} = N^t \backslash \{j^t\}$; $M^{t+1} = M^t \backslash M_j$

If $M^{t+1} \neq \varnothing$ then $t = t + 1$, go to *step (a)*

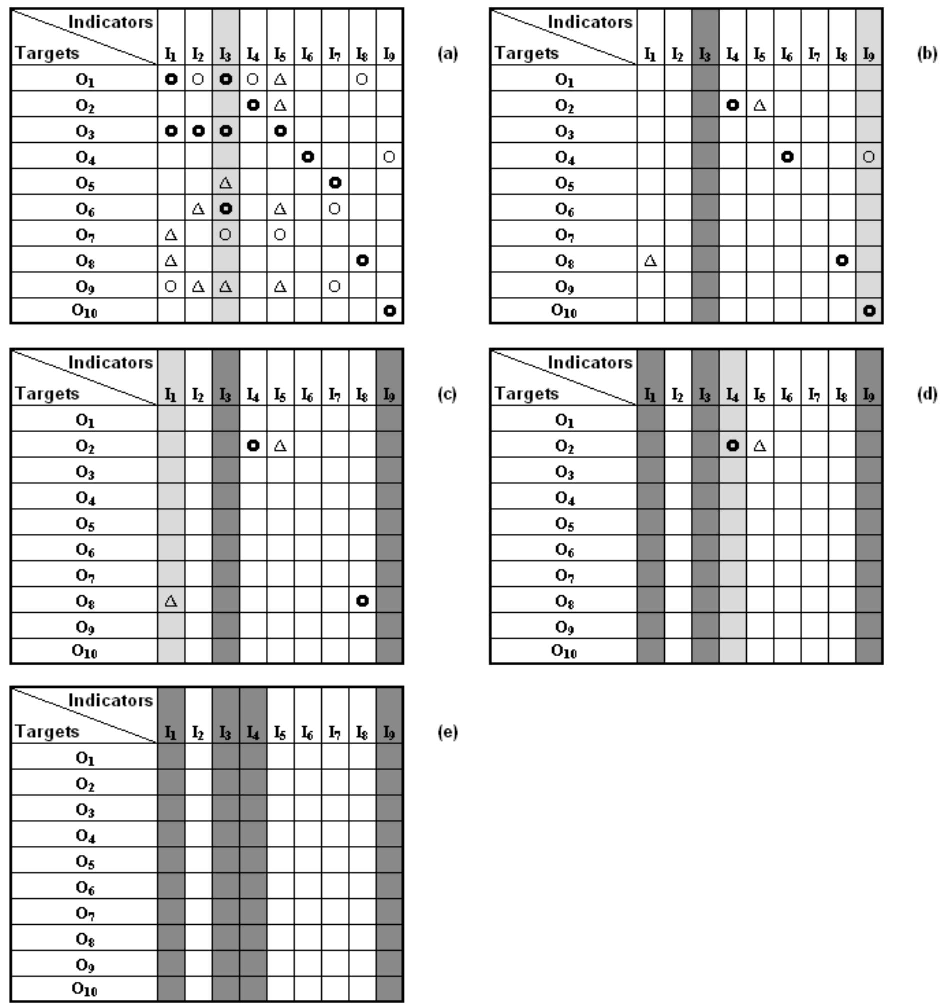
If $M^{t+1} = \varnothing$ then *stop.*

The *minimum set covering problem with the maximum importance* algorithm's main limit is that it always provides a covering, but it does not guarantee that the obtained set of indicators is the minimum one. Furthermore, it does not consider the correlations among the indicators.

PIs' minimum set covering for the Help Desk service case study

The example of Figure 5 ($c_j = 1\ \forall\ j = 1, \ldots, 9$) is reported in Figure 9.

Figure 9 Example of indicators' synthesis based on the *Nemhauser algorithm* for the HD service



Notes: At the first iteration (9a), the selected indicator is highlighted in light grey. In 9(b) (second iteration), the symbols are eliminated from the matrix according to the algorithm. The previously selected indicator is highlighted in dark grey, while the presently selected one is highlighted in light grey. At the third iteration, after eliminating the symbols from the matrix, I_1 is selected (highlighted in light grey in 9c). Then, the new selected indicator is I_4 (see 9d, fourth iteration). The iterations stop when the matrix is empty (9e), fifth iteration). The Dashboard contains the indicators I_1, I_3, I_4, I_9.

According to the Nemhauser algorithm, the first selected indicator is I_3. It has the highest number of symbols (in Figure 9a, the selected column of the **R** matrix is highlighted). According to Steps 2 and 3, I_3 and the symbols on the rows are eliminated (see Figure 9b). The second selected indicator is I_9. The procedure is iterated until the **R** matrix is empty. The final Dashboard is given by: I_3, I_9, I_1, I_4.

With reference to the example in Figure 5, an application of the *minimum set covering problem with the maximum importance* is reported in Figure 10.

Figure 10 Example of indicators' synthesis based on the *minimum set covering problem with the maximum importance* for the HD service

(a)

Targets \ Indicators	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
O_1	◎	○	◎	○	Δ			○	
O_2				◎	Δ				
O_3	◎	◎	◎		◎				
O_4						◎			○
O_5			Δ				◎		
O_6		Δ	◎		Δ		○		
O_7	Δ		○		○				
O_8	Δ							◎	
O_9	○	Δ	Δ		Δ		○		
O_{10}									◎
Relative importance	17.18	9.86	21.09	10.20	10.54	6.12	8.16	10.20	6.63

(b)

Targets \ Indicators	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
O_1									
O_2				◎	Δ				
O_3									
O_4						◎			○
O_5									
O_6									
O_7									
O_8	Δ							◎	
O_9									
O_{10}									◎
Relative importance	2.86	0	0	25.71	2.86	20.57	0	25.71	22.29

(c)

Targets \ Indicators	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
O_1									
O_2				◎	Δ				
O_3									
O_4									
O_5									
O_6									
O_7									
O_8	Δ							◎	
O_9									
O_{10}									
Relative importance	5.00	0	0	45.00	5.00	0	0	45.00	0

(d)

Targets \ Indicators	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
O_1									
O_2									
O_3									
O_4									
O_5									
O_6									
O_7									
O_8	Δ							◎	
O_9									
O_{10}									
Relative importance	10.00	0	0	0	0	0	0	90.00	0

(e)

Targets \ Indicators	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
O_1									
O_2									
O_3									
O_4									
O_5									
O_6									
O_7									
O_8									
O_9									
O_{10}									
Relative importance	0	0	0	0	0	0	0	0	0

Notes: At the first iteration (10a), the selected indicator is highlighted in light grey. In 10(b) (second iteration), the symbols are eliminated according to the algorithm. The relative importance row is updated. The new selected indicator is highlighted in light grey, while the previously selected one is highlighted in dark grey. At the third iteration (10c), after eliminating the symbols and updating the relative importance row, I_4 is selected. Following the same procedure, I_8 is selected (fourth iteration, see 10d). Since the matrix is empty, the iterations stop (10e). The Dashboard indicators are I_3, I_4, I_8 and I_9.

The first selected indicator is I_3. I_3 has the highest number of symbols in the relative **R** matrix column and the highest weight (21.09%) (Figure 10a). The final Dashboard is given by: I_3, I_4, I_8, I_9. Comparing the solution obtained with that of the Nemhauser algorithm, we find the same set of indicators except for I_8, which replaces I_1.

3.4.3 Synthesis based on indicators' correlation

Trying to overcome the limits of the two previous approaches, we suggest the following procedure, based on the concept of correlations among the indicators:

Step 1 Construction of the $\hat{Q}$ correlation matrix among the indicators after fixing a threshold *k* (see Section 2.2)

Step 2 Indicators which have no correlations in the $\hat{Q}$ matrix are removed and included in the Dashboard. The following procedure is applied:

- Step 2.1 selection of the indicator which has the highest number of correlations. If two indicators have the same number of correlations, then we include the indicator with the minimum cost
- Step 2.2 removal from $\hat{Q}$ of the selected indicator
- Step 2.3 removal from $\hat{Q}$ of all the other indicators correlated with the indicator selected at Step 2.1
- Step 2.4 iteration of the procedure until the $\hat{Q}$ matrix is empty (excluding the elements placed on its diagonal)

Step 3 If the obtained set of indicators does not cover all the representation-targets, increase *k* and go to Step 1, else STOP.

Using more formal expressions, Steps 2.1 to 2.4 can be rewritten in the following way:

Initialisation:

$$S^1 = S,\ T^1 = \varnothing,\ \ t = 1$$

Solution generation at step t > 1:

a select $i^t \in S^t : \max\left|S_{i^t} \cap S^t\right|$

$$T^{t+1} = T^t \cup i^t; \qquad S^{t+1} = S^t \setminus S_{i^t}$$

If $S^{t+1} \neq \varnothing$ then $t = t + 1$, go to *step (a)*

If $S^{t+1} = \varnothing$ then *stop.*

In the initialisation, *S* is a set which contains all of the indicators that are present in $\hat{Q}$ after the removal of the indicators with no correlations (see Step 2).

The solution (Dashboard) is given by the elements of T^{t+1}. In each subset S_{i^t} are included all of the indicators that are correlated with the indicator selected at Step *t*. If indicator i^t (included in the Dashboard) does not respect the alarm threshold, looking into S_{i^t}, it is possible to identify one or more responsible causes.

This algorithm always guarantees a covering (but not minimum) solution. In fact, the iterations can stop when *k* is equal to 1 and this may imply that all of the indicators are included in the Dashboard.

Synthesis based on indicators' correlation for the Help Desk service case study

An example of the synthesis based on the concept of correlations among the indicators is reported in Figures 11 and 12. In Figure 11, we fix the threshold *k* equal to 0.20.

Figure 11 Example of indicators' synthesis based on the concept of *correlations among indicators* (k = 0.20) for the HD service

(a)

k = 0.20	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	X	X	X	X	X			X	
I_2	X	X	X		X				
I_3	X	X	X		X		X		
I_4	X			X					
I_5	X	X	X		X				
I_6						X			X
I_7			X				X		
I_8	X							X	
I_9						X			X

(b)

k = 0.20	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	X	X	X	X	X			X	
I_2	X	X	X		X				
I_3	X	X	X		X		X		
I_4	X			X					
I_5	X	X	X		X				
I_6						X			X
I_7			X				X		
I_8	X							X	
I_9						X			X

(c)

k = 0.20	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	X	X	X	X	X			X	
I_2	X	X	X		X				
I_3	X	X	X		X		X		
I_4	X			X					
I_5	X	X	X		X				
I_6						X			X
I_7			X				X		
I_8	X							X	
I_9						X			X

(d)

k = 0.20	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	X	X	X	X	X			X	
I_2	X	X	X		X				
I_3	X	X	X		X		X		
I_4	X			X					
I_5	X	X	X		X				
I_6						X			X
I_7			X				X		
I_8	X							X	
I_9						X			X

(e)

k = 0.20	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	X	X	X	X	X			X	
I_2	X	X	X		X				
I_3	X	X	X		X		X		
I_4	X			X					
I_5	X	X	X		X				
I_6						X			X
I_7			X				X		
I_8	X							X	
I_9						X			X

Notes: In 11(a), the correlation matrix is reported. Since I_1 has the highest number of correlations, it is selected and highlighted in light grey. In 11(b), the previously selected indicator is highlighted in dark grey. The indicators that are correlated with I_1 are highlighted in light grey. At the second iteration, I_6 is selected (light grey in 11c). Also, indicator I_9 is highlighted (11d) for the correlation with I_6. The last selected indicator is I_7 (11e). The Dashboard indicators are I_1, I_6, I_7.

The first selected indicator is I_1. I_1 has the highest number of correlations (Figure 11a). Subsequently, the indicators that are correlated with I_1 are eliminated (Figure 11b). The second selected indicator is I_6 and the procedure is iterated until we obtain the following Dashboard: I_1, I_6, I_7 (Figure 11e). Since the obtained subset does not cover all the representation-targets (see Figure 5), we fix $k = 0.75$. The procedure is reiterated (see Figure 12). In the first step, we eliminate the indicators which have no correlations (I_4, I_6, I_7, I_8, I_9; see Figure 12a) and we include them in the Dashboard. Then, indicator I_1 is selected because it has the highest number of correlations with other indicators (Figure 12b). The indicators that are correlated with I_1 are eliminated (Figure 12c). The final Dashboard is: I_1, I_4, I_6, I_7, I_8, I_9. The obtained PIs' subset is a covering set. The algorithm stops.

Figure 12 Example of indicators' synthesis based on the concept of *correlations among indicators* ($k = 0.75$) for the HD service

(a)

$k = 0.75$	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	X	X	X		X				
I_2	X	X	X		X				
I_3	X	X	X						
I_4				X					
I_5	X	X			X				
I_6						X			
I_7							X		
I_8								X	
I_9									X

(b)

$k = 0.75$	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	X	X	X		X				
I_2	X	X	X		X				
I_3	X	X	X						
I_4				X					
I_5	X	X			X				
I_6						X			
I_7							X		
I_8								X	
I_9									X

(c)

$k = 0.75$	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
I_1	X	X	X		X				
I_2	X	X	X		X				
I_3	X	X	X						
I_4				X					
I_5	X	X			X				
I_6						X			
I_7							X		
I_8								X	
I_9									X

Notes: In 12(a), the correlation matrix is reported. The indicators with no correlations are highlighted in light grey. In 12(b), the previously selected indicators are highlighted in dark grey. Since I_1 has the highest number of correlations, it is selected and highlighted in light grey. In 12(c), the indicators that are correlated with I_1 are highlighted in light grey. The iterations stop as all the indicators in the matrix have been considered. The Dashboard indicators are: I_1, I_4, I_6, I_7, I_8, I_9.

3.4.4 Some considerations about the proposed synthesis methods

The first method (PIs' relative importance) is the easiest and quickest. It can be used if a rapid PIs' subset identification is needed. Nevertheless, it does not consider targets covering and the indicators' correlations.

The second method (PIs set covering all targets) is characterised by an intermediate level of complexity. On the other hand, it does not consider the indicators' correlations and weights c_j must be carefully evaluated.

The third method (PIs' correlations) has the most complex application. More iterations could be required. Nevertheless, it assures a critical few set that includes 'independent' indicators.

4 Conclusions

In this paper, we presented a structured methodology for designing a PMS in the field of service quality monitoring.

In the literature, many conceptual models have been proposed. The question is how to make these models operative. This paper aims to describe a structured approach to obtain a balanced PIs set.

The heart of the paper is the QFD methodology. First, the process is represented according to a desired perspective. Then, the representation targets (service quality determinants) and relative indicators are identified. The monitoring performances of complex systems often requires a large set of PIs. Extracting a subset of them makes management easier. We suggest as useful support instruments the Critical Few management approach and the Performance Dashboard.

However, this methodology presents some limits. It cannot be applied in a mechanical way. This requires an in-depth knowledge of the process itself.

Moreover, we point out that the proposed distillation techniques represent only an inside view of the possible heuristic methodologies which can be used to select a critical few indicators set.

Nowadays, the research is paying a great attention to the so-called 'PIs' impact'. The topic is not completely new. Skinner identified in 1974 simplistic performance evaluation as one of the major causes of factories getting into trouble (Skinner, 1974). Subsequently, Hill (1999) recognised the role and impact of PMS in his studies of manufacturing strategies. In these and other studies, indicators are often viewed as being part of the infrastructure or environment in which manufacturing must operate (*conceptual technologies*).

Future work will focus on this matter in order to introduce an operative approach for effectively evaluating indicators' impact on the system.

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