STRATEGY SELECTION FOR DIGITAL TRANSFORMATION IN SME SIZE CALIBRATION LABORATORIES

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Abstract – Keeping pace with the leading countries on the path to digital transformation in metrology is difficult, especially for small or medium size calibration laboratories (other than the national metrology institutes) in less technologically developed economies. This work aims to illustrate the use of analogue tools to facilitate the selection of digital transformation strategies to follow or even to create one own one. As an example, the tools used to develop digital calibration certificate issuance are shown. These applications can help improve the comprehension of the pathway to digital transformation in metrology.

Keywords: digital transformation, Kano model, QFD, HoQ, calibration laboratory

1. INTRODUCTION

The digital transformation of the international quality infrastructure will be affecting calibration and testing laboratories all around the world [1]. Most of the calibration laboratories with an infrastructure smaller than a national metrology institute in the less advanced technological economies will be challenged to keep track of the digitalisation pathway [2]. Progress to date is mainly led by the national metrology institutes of developed countries [3]. Its alternative pathway proposals could challenge incorporation into the digitalisation process of the laboratories in the follower countries, especially the calibration laboratories that are part of small and medium-sized companies [4].

Different strategies for the pathway to digital transformation have been exposed elsewhere [3], and the requirements of the proposed digital calibration certificate (DCC) have been addressed from different reference frames [5, 6]. The four areas of the general structure for a DCC have been stated: administrative data, measurement results, comments, and documents [5, 7]. Even when the cited literature has examples for each of the four areas, the different scenarios for the several quantities [7] that a laboratory could manage are not few. So, tools more oriented to a self-assessment could be needed.

The same situation arises with the different proposals to DCC published elsewhere [5, 6]. For a small or medium size laboratory that wants to know what could be the consequences of implementing one of these two alternatives or even develop its own, there is a need for a tool to assess the impact of the selection.

This work proposes the use of two well-known and solid-founded Japanese quality tools as an aid for understanding the digitalisation pathway a calibration laboratory must face. The two tools are the Kano Model (KM) [8] and the Quality Function Deployment (QFD) [9]. The KM essentially allows categorising elements according to a hygiene-motivator pair. On the other hand, QFD allows visualising the consequences of the relationships between sets of characteristics and different system processes. The following sections illustrate the use of both tools with an example of the DCC.

2. METHODOLOGY

Application of the appropriated quality tools could help visualise the consequences of a particular strategy to digitalisation from a calibration laboratory.

2.1. The Kano Model

The Kano Model comprises two elements: a diagram and a questionnaire [8]. Together, they allow the product/service design team to categorise the customer requirements. Its main contribution is the discovery of two categories of customer requirements other than the more-is-better classic one (the linear category). On the other hand, the Kano questionnaire allows the customer to make their voice heard and, through its answers to a couple of questions, determine which requirement belongs to each category.

Here, an adaptation of the KM to the fundamental structure of the DCC was developed and used. Instead of customer satisfaction, the Kano diagram Y-axis shows the "Readiness to the deployment of a DCC". Furthermore, the categories of the KM no longer are customer-satisfaction related. Instead, they reflect the four data areas proposed for the DCC [5, 7]. However, here are titled: mandatory, partially-regulated, optional, and complementary, as shown in the Results section.

2.2. QFD and HoQ

QFD allows propagating the relative importance of the elements in a set while simultaneously highlighting their group impact over another collection of items.

An initial set of items, the customer requirement set, is ranked in importance, usually through some programmable decision-making tool, e.g., the analytic hierarchy process [9]. Then, a set of compliance measurements, sometimes called engineering characteristics, must be found for the customer requirements set [10]. Later, the two sets are round-robin pairwise assessed regarding the correlation strength between the two items in the comparison. Strong correlations are assigned a value of 9, moderate ones a 3, and weak ones a 1. These numerical values will be multiplied by the importance value of the customer requirement involved. Finally, a product sum for every item of the second set is drawn, and its total yields the importance rank of the second set. These steps could be followed as many times as needed, for example, to link the third set of items with compliance measurements and so forth. The Japanese approach also allows linking the third set with the customer requirements, the initial set [10].

The usual way to visually represent the matrix of correlations between any two sets is called House of Quality (HoQ) [11]. The correlation between elements of every new set can also be depicted as the *roof* of the house. Additional features for the house are usually added, as specification limits, even when they were no part of the original Akao's version [10]. In this work, only the use of the additional benchmarking walls will be illustrated.

3. RESULTS AND DISCUSSION

The two quality tools described in the Methodology section were applied over the DCC. The results and their discussion are shown next.

3.1. Kano Diagram

The proposed diagram for the KM is shown in Fig. 1.

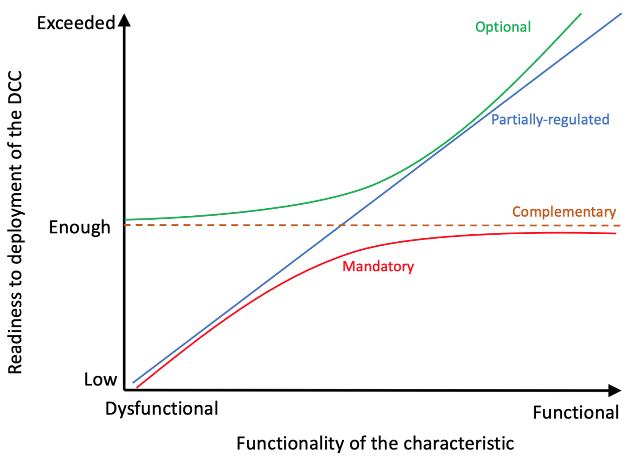


Fig. 1: Kano Diagram for the DCC characteristics.

Table 1 shows the relationship between the four areas of the DCC [5, 7] and the proposed KM in Fig. 1. A description of the four categories is included, along with examples taken from [7].

3.2. Kano Questionnaire

Given a new type of data to be included in the DCC, paired questions will allow choosing its best-suited category in the proposed KM. This selection offers time savings during the deployment of the DCC.

Table 1: Categories of the KM proposed for the DCC.

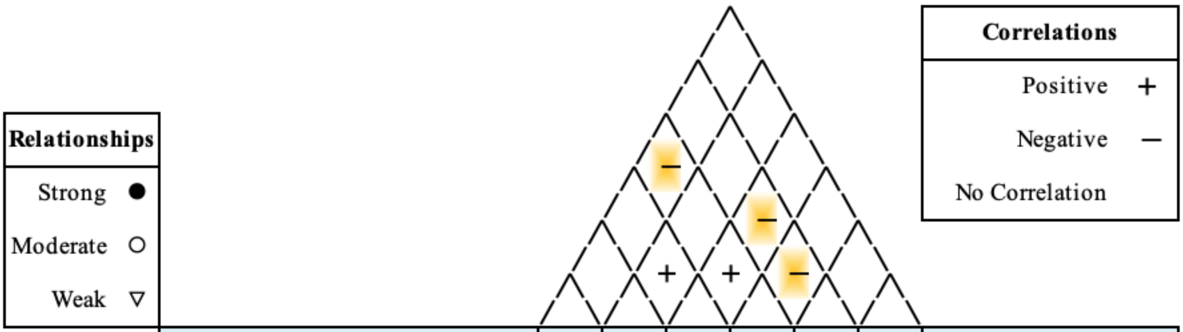
Category	Description	Examples
Mandatory	When all data here are functional, the deployment of the DCC is ready, but if only one is missing, the DCC can not be deployed.	laboratory ID, item under calibration, customer ID
Partially-regulated	Flexible due to variations in calibration items. Neglect of data functionality could delay (or even prevent) the deployment of the DCC.	measurement value, expanded uncertainty, coverage probability
Optional	Data here improve the explanation of measurement results. The absence of data does not affect the fulfilment of the DCC requirements.	calibration curves
Complementary	All data that being or not in the DCC does not impact its accomplishment of the requirements.	human-readable certificate

The paired question must be formulated as follows:
Functional question: "If the data are *functional*, how well do you think the requirements of a DCC are fulfilled?"
Dysfunctional question: "If the data are *dysfunctional*, how well do you think the requirements of a DCC are fulfilled?"

Both questions must be answered on a Likert-type scale (1-very poor, 2-poor, 3-fifty-fifty, 4-well, 5-very well). The two answer yields a coordinate that indicates the KM category to which the data belongs, according to Table 2. There, "Q" means *Questionable*: a non-sense couple of responses, "O" stands for *Optional*, "P" stands for *Partially-regulated*, "R" implies *Reverse* (the intention of the questions pair was inverted), "C" stands for *Complementary*, and "M" stands for *Mandatory*.

Table 2: KM categories table.

		Dysfunctional answer				
		1	2	3	4	5
Func-	1	Q	O	O	O	P
tion-	2	R	C	C	C	M
al	3	R	C	C	C	M
an-	4	R	C	C	C	M
swer	5	R	R	R	R	Q



Row #	Relative Weight	Assigned Importance	Column # / Engineering Characteristics / Common Requirements of a DCC [4]	1: UTF-8 [12]	2: Regular calibration intervals [13]	3: Traceability data included	4: Attachment capability [6]	5: GNU Privacy Guard (GPG)	6	Competitive Assesment: Our Product: e.g., JSON schema	Competitor #1: XML schema [5]	Competitor #2: PDF/A-3 [6]	
1	26%	10	Machine readable	●			○			3	5	5	
2	23%	9	Traceable to national standards		●	○	▽			2	5	4	
3	18%	7	Constitute proof of traceability		○	●	○			3	5	4	
4	10%	4	Include calibration curves				●	○		2	4	5	
5	23%	9	Use cryptographic signatures					●		3	4	4	
6													
			Technical Importance Rating	231	262	231	246	238					
			Relative Weight	19%	22%	19%	20%	20%					

Fig. 2: House of quality for the DCC minimum requirements [6]. The first HoQ of several that can be made, as needed by the calibration laboratory processes.

3.3. HoQ building results

The first HoQ regarding the DCC could be like the one shown in Fig. 2. For building the HoQ, it is advisable to use a template. There are several available to use or download over the web. The HoQ was filled as follows:

1. The minimal requirements for the DCC [6] were listed in the fourth column from the left.
2. An importance level for every DCC requirement was assigned. Here, the analytic hierarchy process [10] technique was used.
3. Some engineering characteristics, enough to cover all the requirements listed in 1, were written in the second row. To find suitable characteristics, answer the question "How can we be aware of accomplishing the requirement ...?"
4. Relationships intensities (strong, moderate, weak, no-relationship) were chosen when comparing every common requirement of a DCC against every engineering characteristic.
5. Correlations among the engineering characteristics were depicted at the roof using the symbology provided in the template. A positive correlation means that if one characteristic improves, the other enhances.
6. Finally, benchmarking was carried out with the other two published strategies for DCC [5, 6]. The "Our Product" column is shown just as an example of a possible comparison.

3.4. HoQ discussion

The first HoQ ensures that the DCC's common requirements will be satisfied. It was done by establishing a set of technical characteristics that can measure or be accountable for the requirements. All of the elements in the engineering characteristics have strong relationships with at least one of the DCC Requirements. The rule to be satisfied in QFD is to have at least moderate relationships on every row [10].

The house's roof shows several positive and negative correlations. A negative correlation indicates that when one of the two characteristics correlated improves, the other gets worse. As can be seen, attaching a file to another hurts the cryptographic process (it becomes slower). On the other hand, the more capacity the DCC has to include attached documents, the more space there is for traceability data.

The relationships stated in the main matrix have numerical values, being strong = 9, moderate = 3, weak = 1, and no-relationship = 0. The sum by the column of the product of these values times the correspondent Relative Weight percentage (second column from the left) gives the technical importance rating (Fig. 2). The ratings shown are very similar, which means that the engineering characteristics proposed are strongly independent of each other. However, it does not imply that downstream the impacts will remain even.

3.5. QFD discussion

A second, third or fourth HoQ is needed to assess the downstream impacts of the DCC requirements. The building of other houses would be linked as stated in the QFD methodology [10]. For example, a second HoQ would have the engineering characteristics as row titles, and a new set of features would be related with, e.g., the set "Application Processes" [12].

4. CONCLUSIONS

Two well-known proven quality tools have been adapted and applied in deploying the DCC. The Kano Model was adapted to show a more graphical (Kano Diagram) and more pragmatic (Kano Questionnaire) way to choose the category of the DCC structure for a particular calibration datum. Additionally, HoQ and QFD use were demonstrated when the deployment of the DCC requirements was analyzed. Future work will extend the QFD example with more than one HoQ to evidence the impact on posterior processes that the engineering characteristics could have. Also, the effect of the DCC requirements would be shown downstream in the operations of calibration laboratories, especially at a small and medium enterprise size level.

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