ZONE OF TOLERANCE AND PROCESS CAPABILITY IN SERVICES

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Traditional capability indexes (namely $C_p$ and $C_{pk}$) do not cope properly with service performance. In fact, services are not simply characterized by upper and/or lower specification limits, as usually happens in manufacturing environments. Instead, a zone of tolerance based on the customer’s expectations always exists in services, representing the range of service performance that customers define as acceptable.

The first challenge that emerges in the assessment of process capability in services is the development of a methodology to convert perceived performance into real performance. Additionally, one also has to define a set of relationships between the customer’s expectations and perceptions and the service operational characteristics.

Some principles of Quality Function Deployment (QFD), along with some statistical assumptions, constituted the basis for the development of an index to assess service capability. This new service capability index (SCI) reflects how able the companies are to fulfil the expectations of their customers. The index increases from zero to one along the zone of tolerance and, as such, reveals how that zone is being utilized by service performance. An example that illustrates the methodology is presented to stress its potential contribution to researchers and practitioners that intend to apply SPC principles within the service sector.
Zone of Tolerance and Process Capability in Services

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In any process, regardless of how well designed and maintained it is, a certain amount of inherent or natural variability will always exist associated to a stable system of \textit{chance or common causes}.

A process may also exhibit other type of variability provoked by the so-called \textit{assignable causes of variation} (e.g. operator errors or lack of equipment adjustment).

A process that is operating only under chance or common causes of variation \textit{is said to be in statistical control}

A process where assignable causes are present \textit{is said to be out of control}

\textbf{Process capability} is the process natural variability assessed in the absence of assignable causes of variation.
Although specifications are not necessary to perform a Process Capability Analysis, it is rather convenient to evaluate how a process performs regarding its specifications.

Process Capability Indices.
Two of the most used indices for evaluating process capability are $C_p$ and $C_{pk}$

$$C_p = \frac{USL - LSL}{6\sigma}$$  $$C_{pk} = \min\left( C_{pkl} = \frac{\mu - LSL}{3\sigma}, C_{pku} = \frac{USL - \mu}{3\sigma} \right)$$

Ex. The batteries produced in a certain plant exhibit an average voltage of 1.52V with a standard deviation of 0.04V.

Is the process capable?

The process exhibits excessive variation and is deviated from the target.

$C_p = 0.75$  $C_{pk} = C_{pku} = 0.58$
However...the previous indices cannot be directly applied to services!

Two types of frameworks have been developed to deal with consumer’s perceptions of quality

- **Performance-based frameworks** specify perceived performance without any comparative referents
- **Standards-based frameworks** specify “comparative” performance conceptualization of service quality, *i.e.* performance is compared to a standard (expectations)

The most utilized instrument for measuring service quality is SERVQUAL, The first version of the instrument compares service performance against a single expectation standard, the *desired* expectation.

More recently, several researchers have advocated that multi-expectation approaches might be more appropriate for service quality models.
Two levels were proposed for customer’s expectations: the *desired* and the *adequate* levels, separated by a zone of tolerance.

**adequate service** level is the minimum degree of performance a customer finds acceptable. **desired service** is the level of service performance the customer hopes to receive, being a blend of what the customer believes “can be” and “should be.”

The zone of tolerance is a range of service performance that a customer considers satisfactory. Usually it is assumed that levels of service performance within the zone of tolerance are not perceived as different by customers.
Is it service performance a simple higher-the-better characteristic?

Once the zone of tolerance exists, instead of a single lower specification limit one should consider a range that acts like a damper for performance variation. On one hand it is apparent that services are characterized by a false unilateral specification but, on the other, it seems that service levels are bounded by a false bilateral specification.

The usual capability indices cope adequately with situations like the one represented on the right side of figure but not with those similar to the one depicted on the left.
Assuming that levels of service performance within the zone of tolerance are not perceived as different by customers

Zone of tolerance can be modeled by an Uniform Distribution

\[
F(x) = P(X \leq x) = \begin{cases} 
0 & \text{if } x < AS \\
\frac{x - AS}{(DS - AS)} & \text{if } AS \leq x < DS \\
1 & \text{if } x \geq DS
\end{cases}
\]

A Service Capability Index can be proposed based on this distribution.
When the lower tail of performance distribution $(\mu - 3.5\sigma)$ coincides with AS, SCI is equal to zero, which is an extreme situation (Figure a)

When the lower tail of performance distribution $(\mu - 3.5\sigma)$ coincides with DS, SCI is equal to 1 (Figure b)

If the whole process is above DS, SCI will always be above 1

Negative SCI values represent performance levels below the acceptable minimum;

Any SCI value between 0 and 1 represents the “safety margin” that is available, i.e. the percentage of the tolerance zone still available (between AS and A). Equally, $(1-SCI)$ is the fraction of the tolerance zone that has already been “consumed” (Figure c)
To assess service capability one must assure the match between service quality (the quality of what the operation delivers) and the quality of service as perceived by the customer, *i.e.*, between **internal measures** based on operational records (unavailability of an ATM, time to answer a phone call, etc.) and **external measures** obtained directly from customers (satisfaction questionnaires, complaints, etc.).

**Simply stated, perceived performance must be converted into real performance.**

This can be achieved:

- Through the equivalence of percentiles for real and perceived performance;
- Through the utilization of the QFD’s principles to convert user’s needs (or customer’s demands) into quality characteristics.
Example:
The Bank Yes wants to study a critical characteristic: time to approve personal credit requests.
The record shows that the average time has been 48 hours with a standard deviation of 5 hours (Real Performance)

Customers were asked to fill the three-column format of SERVQUAL as follows (Perceived Performance)

<table>
<thead>
<tr>
<th>Waiting time for credit approval at Bank Yes</th>
<th>My minimum service level</th>
<th>My desired service level</th>
<th>My perception of Bank Yes performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>1 2 3 4 5 6 7 8 9</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td>1 2 3 4 5 6 7 8 9</td>
<td>1 2 3 4 5 6 7 8 9</td>
</tr>
</tbody>
</table>

Adequate service has an average of 4.9 points
Desired service has an average of 7.1 points
Perceived performance has an average of 5.4 points with a standard deviation of 0.9 points
Assuming a Normal distribution, the corresponding percentiles of the average scores for adequate and desired services will be:

\[ P(X \leq 4.9) = \phi(-0.56) = 0.288 \quad \text{and} \quad P(X \leq 7.1) = \phi(1.89) = 0.971 \]

A QFD-style matrix can be used to relate perceived and real performance.

<table>
<thead>
<tr>
<th>Type of Characteristic</th>
<th>Time to approve personal credit requests</th>
<th>Average of minimum service level/ (percentile)</th>
<th>Average of adequate service level/ (percentile)</th>
<th>Average of Direct XYZ perceived performance/standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting time for credit request approval</td>
<td>LB</td>
<td>4.9 / (28.8 per cent)</td>
<td>7.1 / (97.1 per cent)</td>
<td>5.4 / 0.9</td>
</tr>
<tr>
<td>Mean</td>
<td>48 hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5 hours</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
To compute the values of AS and DS in terms of real performance, one should be aware that the time to answer customer’s requests is a lower-the-better characteristic. Thus, the opposite tail of the distribution has to be considered, that is (100 per cent – percentile per cent)

DS and AS can be easily calculated, in terms of real performance, as follows:

\[ \phi^{-1}(0.029) = -1.89 \Rightarrow -1.89 = \frac{DS - 48}{5} \Rightarrow DS = 38.6 \text{ hours} \]

\[ \phi^{-1}(0.712) = 0.56 \Rightarrow 0.56 = \frac{AS - 48}{5} \Rightarrow AS = 50.8 \text{ hours} \]
Service Capability Index has to be adjusted for lower-the-better and higher-the-better characteristics as follows:

\[
SCI_{LB} = \frac{AS - (\mu + 3.5\sigma)}{|DS - AS|} \quad SCI_{HB} = \frac{(\mu - 3.5\sigma) - AS}{|DS - AS|}
\]

As regards Bank Yes, \( SCI_{LB} = -1.20 \) Sometimes the Bank performs worst than the acceptable minimum

The bank has to decrease its average time to assure a performance that is always better than the acceptable minimum!

How much?

This happens when \( SCI_{LB} = 0 \) Average time must not exceed 33.3 hours
Conclusions

• The existence of a zone of tolerance in services does not allow the utilization of the common capability indices;
• To assess service capability it is vital to promote the match between internal measures and external measures;
• A Service Capability Index, that considers the zone of tolerance, is proposed;
• A methodology to relate real performance and perceived performance is proposed. This methodology is based on the equivalence of percentiles as well as on the QFD principles;
• The methodology allows the assessment of the required process improvements.