Assessing a customer complaint indicator: a case study in the automotive sector

Reis, A.M.[1,2], Costa, J.M.[2], Sousa, S.D. [1] and Costa, L.[1]

[1] ALGORITMI Research Centre, School of Engineering, University of Minho, Guimarães, Portugal;

[2] Bosch CarMultimedia, Braga, Portugal

Introduction - Key Performance Indicators (KPIs) are used in many organizations to facilitate decisions and actions. A KPI life cycle is composed of four phases: design, implementation, use, and review. In the review phase, indicators may eventually be deleted, included, or replaced. The literature lacks analyses of the real improvement caused by the implementation and use of revised KPIs.

Purpose - This paper presents a real case of a reviewed KPI that was implemented in a leading company in the automotive electronics industry.

Methodology - The Methodology adopted was the Case Study.

Findings - The KPI that went through the review is related to customer complaints. Despite having overcome the limitation that triggered its creation, new shortcomings were perceived by management during the use phase. Three situations are presented to exemplify the limitations of previous and current indicators, concluding that the most critical drawback is present in both: the lack of a clear purpose. Therefore, assuming certain purposes, suggestions for improvement are proposed.

Keywords: Customer Complaint; Performance Indicator; Quality Management System.

Paper type: Case Study.

1. INTRODUCTION

A Key Performance Indicator (KPI) is a management tool that measures progress toward a project or process target and can be used in all kinds of organizations. When combined, groups of KPIs can form Performance Measurement Systems (PMS). Each management system, e.g., Logistics Management System, and Quality Management System (QMS), has a specific set of KPIs.

The QMS includes internal KPIs, which summarize compliance with engineering specifications, and external KPIs, which include customer complaint indicators (Sanchez-marquez *et al.*, 2020). If the QMS works well, both internal and external KPIs must reflect customer satisfaction. Indeed, quality control leads to the continuous evaluation and modification of the system to meet the changing needs of the customer (Mitra, 2016). Particularly, customer complaint indicators and their management processes are essential for avoiding and mitigating customer dissatisfaction.

While there are several studies on what constitutes the quality of a KPI concerning its support for decision-making and on how to assess this quality (Braz, Scavarda and Martins, 2011; Gutierrez *et al.*, 2015; Sousa, Nunes and Lopes, 2015), more empirical research is needed to describe and understand the variety of implementation processes that organizations follow in different contexts (Melnyk *et al.*, 2014). It is necessary to build an understanding of the precise definitions of existing KPIs, the rationales behind these, the data used, the limitations that users experienced with them, and ideas that people are working on to improve the existing system. In general, the literature lacks an analysis of real-life cases of practical problems encountered during the implementation and operability of KPIs (Van Camp and Braet, 2016).

From this background, this study aims to fill these gaps by reporting on and analyzing problems of implementation and use of a KPI through a Case Study. The study was conducted within a reference company in the automotive electronics industry, which is a Tier 1 supplier that works directly with a variety of Car Manufacturers. The case study focused on the customer complaint indicator, an external KPI, used in the QMS.

The rest of this paper is organized as follows. Section 2 presents a literature review on performance indicators, QMS, and the Complaint System in the Automotive Sector. Section 3 presents the case study, describes the analyzed KPIs highlighting their problems, and suggests improvements to overcome their limitations. In Section 4, the paper ends with conclusions and future research directions.

2. LITERATURE REVIEW

2.1 Performance Indicators

Performance indicators are used in many organizations to facilitate decisions and actions, monitor performance, identify areas that need attention, intensify motivation, improve communication, and strengthen responsibility (Melnyk *et al.*, 2014). Despite the great attention of scholars and practitioners to designing KPIs (Globerson, 1985; Neely *et al.*, 1997; Lohman, Fortuin and Wouters, 2004; Neely, Gregory and Platts, 2005; Lucianetti, Battista and Koufteros, 2019), there are also other vital processes in its life-cycle (Matos, Ensslin and Ensslin, 2020): implementing (Keathley-herring, 2017), using, and reviewing (Braz, Scavarda and Martins, 2011; Gutierrez *et al.*, 2015). These phases are represented in Figure 1.

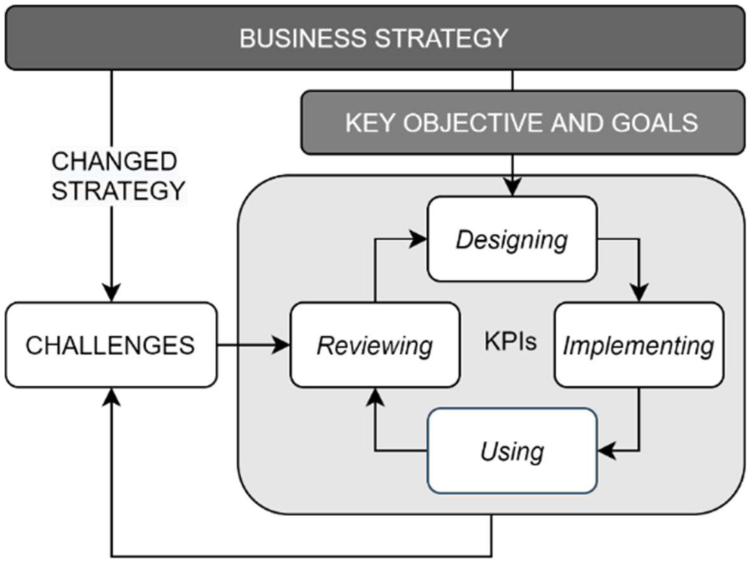

Figure 1 - The KPI life cycle. Source: adapted from (Almström et al., 2017).

The necessary conditions and characteristics that PMS must meet are still a challenge that must be properly addressed by researchers (Goshu and Kitaw, 2017). Nevertheless, some guidelines facilitate the design of appropriate KPIs, as shown in Table 1.

Table 1 - Characteristics of performance indicators.

Characteristics of performance indicators	**Description**
Derived from strategy with an explicit purpose	Performance measures need to be positioned in a strategic context, as they influence what people do (Neely, Gregory and Platts, 2005).
Clearly defined	Performance measurement must be easy to understand (Neely et al., 1996, 1997), and having clear and accurate syntax and semantics (Domínguez et al., 2019).

Provide timely and accurate feedback	The systems that exist inside or outside the company may be inadequate to provide accurate timely information necessary to make a good decision because of the inability to quantify or even assess the potential loss (Defeo, 2016).
Relevant	To keep performance indicators relevant, evolution management must be adopted considering KPI's traceability, modification, and change propagation (Domínguez et al., 2019).
Visual impact	Visual management techniques that integrate strategic and operational perspectives engaging people in a conversation on the strategy and performance of the organization should be applied (Bititci, Cocca and Ates, 2016).
Focus on improvement	The management team must identify improvement opportunities and prioritize changes based on the collective view on the maturity of their performance management practices (Bititci et al., 2015).
Precise	Organizations need to reflect the uncertainty of their systems and contextual factors in their performance measures to improve them (Sousa, Nunes and Lopes, 2015).
Acceptability by the user community	Imposition by top management for a strong focus on a selected set of indicators can have important motivational effects. However, if mid-level managers and employees do not sufficiently understand or agree to such prioritization, tensions and dissatisfaction are likely to arise (Jordan and Messner, 2012; Gutierrez et al., 2015).

About the implementation phase of KPIs, Neely et al. (1996) point out that the practical reasons frequently mentioned for implementing a PMS usually fall into five general categories: monitoring performance, identifying areas that need attention, and intening motivation, improving communication, and strengthening responsibility. On account of these issues, Gutierrez et al. (2015) point out some drivers to facilitate KPIs implementation: top management commitment, workshops to ensure common understanding among employees, and training sessions to promote proactive behaviour.

Within the use phase of the KPIs, "assessing the implementation of strategy'" and "challenging the strategic assumptions" are the two main subdivisions (Nudurupati, Garengo and Bititci, 2021). Likewise, as the competitive environment of a company changes, the KPIs must be adjusted (Almström *et al.*, 2017).

The KPIs can be revised on four levels: (1) revision of the strategy assumptions; (2) revision by changing KPI priorities, deleting, adding, and/or replacing them; (3) revising an individual KPI definition; (4) revising the KPI target value (Neely *et al.*, 2000; Bititci, Suwignjo and Carrie, 2001; Almström *et al.*, 2017). Challenges faced by companies that wish to improve their KPIs are related to decentralized reporting history; deficient insight into cohesion between metrics; uncertainty about what to measure; little communication between users and developers of performance measures;

fragmented IT infrastructure; and data availability limitations (Lohman, Fortuin and Wouters, 2004; Gutierrez *et al.*, 2015).

Many authors indicate that more empirical research must describe and understand the variety of implementation processes that organizations follow in different contexts (Braz, Scavarda and Martins, 2011; Melnyk *et al.*, 2014; Gutierrez *et al.*, 2015; Sousa, Nunes and Lopes, 2015). It is necessary to build an understanding of the precise definitions of existing KPIs, the rationales behind these, the data used, the limitations that users experienced with them and ideas that people are working on to improve the existing system, and how changes in information system changes can impact existing reports (Wouters and Sportel, 2005). In general, the literature lacks an analysis of real-life cases of practical problems encountered during the implementation and operability of the KPIs (Van Camp and Braet, 2016).

2.2 Quality Management and Complaint System in the Automotive Sector

QMS in automotive companies involves the entire process of design, procurement, manufacturing, and post-sales service, and each one of these phases must be planned to meet customer expectations (Mitra, 2016). While the predictability of the quality system can be understood as the ability to control customer satisfaction through internal KPIs, quality feedback is the ability of the system to recalibrate internal controls in an environment of continuous improvement, preventing future customer complaints (Sanchez-Marquez *et al.*, 2020).

A complaint management process is a systematic approach that includes all efforts connected to the detection of product failures and process flaws that enable an organization to identify and review possible weaknesses within its internal and external processes (Tuertmann *et al.*, 2016). Since establishing a complaint handling system is essential for addressing customer dissatisfaction and preventing similar problems from reoccurring, it is very important to standardize the complaint management system (S.Phabmixay, Rodríguez-Escudero and Rodríguez-Pinto, 2019).

The quality of a manufacturer's products depends not only on its own process/assembly quality but also on the quality of the components supplied by its suppliers (Hsieh and Liu, 2010), therefore, defects or potential defects may appear at any point of the supply chain. In other words, within a supply chain, there are risks associated with upstream suppliers (i.e. the sourcing process) and downstream customers (i.e. the delivery process) (Nel and Simon, 2020). Accordingly, companies at any point in the supply chain might eventually receive complaints. Figure 2 presents the flow of complaints and reporting in a supply-chain network consisting of multiple suppliers.

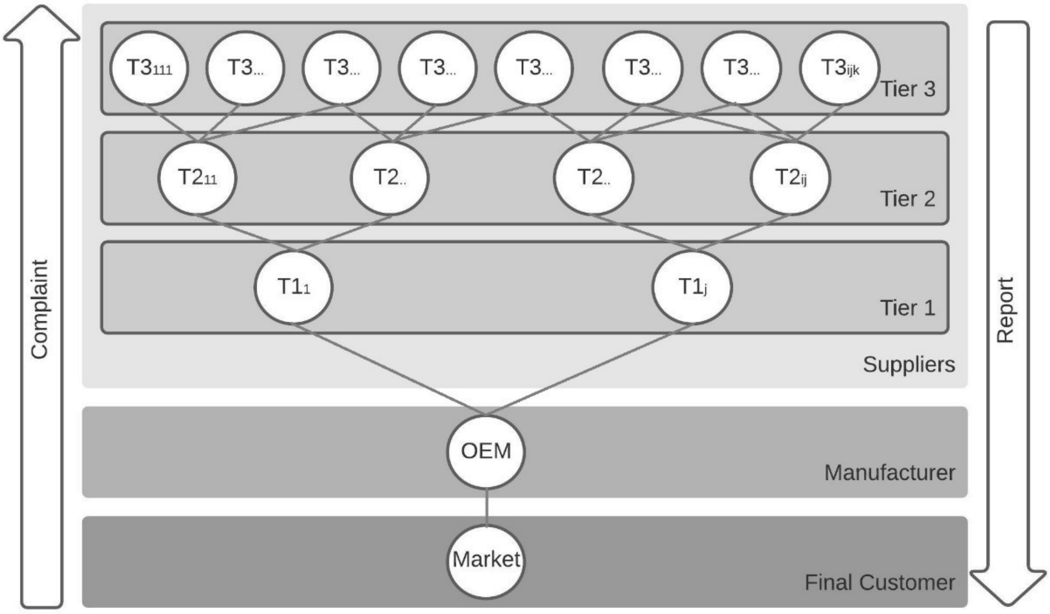

Figure 2 - Complaint Handling System in a supply-chain network consisting of multiple suppliers.

The Original Equipment Manufacturers' (OEM) focus is on designing cars, promoting cars, ordering from vendors, and assembling the vehicles. In the tier system, Tier 1 suppliers are companies that supply parts or systems directly to OEMs, usually working with a variety of car companies. Many firms supply parts that wind up in cars, even though these firms themselves do not sell directly to OEMs. These firms are called Tier 2 suppliers. The term Tier 3 refers to suppliers of raw, or close-to-raw, materials like metal or plastic. Tier 3 supplies to all levels - OEMs, Tier 1, and Tier 2 companies - as all need raw materials.

From the final customer up to the suppliers, the arrow in Figure 2 shows the flow of complaints. Any element of the supply chain can identify defects originating from its suppliers, for example, a Tier 1 can identify defects and formalize a complaint to Tier 2 companies.

In order to identify the root cause of a failure and to handle fault complaints, a standard procedure commonly used by the automotive industry is the 8D process (D for disciplines), installed by the German Association of the Automotive Industry (VDA) (VDA, 2017). When the 8D process is completed, a report is filled out to summarize how the root causes were determined and eliminated, and also what was done to contain the problem to prevent the root cause from happening again (Blank, 2014).

Comprehensive performance measurement is one of the main challenges in achieving data-based claims and fault management (Tuertmann *et al.*, 2016). Empirical studies on KPIs in this sense are needed and can bring many benefits to industries, as the use of customer satisfaction measures symbolically implies that the organization lacks processes that support their use in promoting improvements (Birch-Jensen *et al.*, 2020). Aware of the importance of customer satisfaction, this work, as an empirical study, evaluates current and previous established customer complaint KPI within a case study to be described in the next section.

3. CASE STUDY

The case study took place in a reference company (Company A) in the automotive electronics industry, which is a Tier 1 supplier working with a variety of OEMs. Located in Portugal, Company A is part of a large international organization with more than 3000 employees. The company has certifications for quality ISO 9001 and IATF 16949.

The research protocol was deployed in three major phases, as shown in Figure 3. The information sources were semi-structured interviews, data collected from the Enterprise Resource Planning (ERP), and internal documents of the company. The company where this work was done considers the data confidential, and the university research team signed a confidentiality agreement. For this reason, this paper does not specify the KPI values. Nevertheless, numerical hypothetical examples are given to discuss the problems with the KPIs. In Phase 3, suggestions are presented to overcome these limitations.

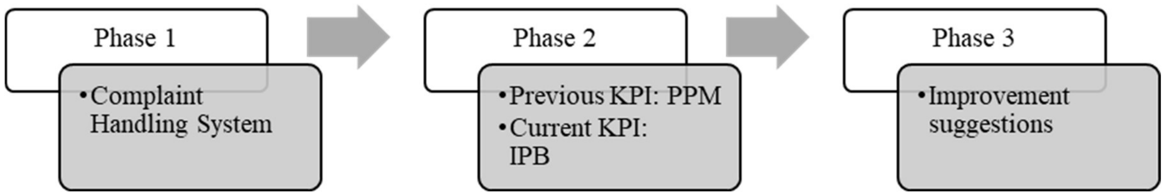

Figure 3 - Research protocol phases.

3.1 Phase 1: Complaint Handling System

Figure 4 presents a supply chain where a part labelled as Product 3 is provided by a Tier 2 to Company A (Tier 1 Supplier), who produces Product 2 as part of Product 1 to the OEM, that finally produces the car, which is then sold to the final customer.

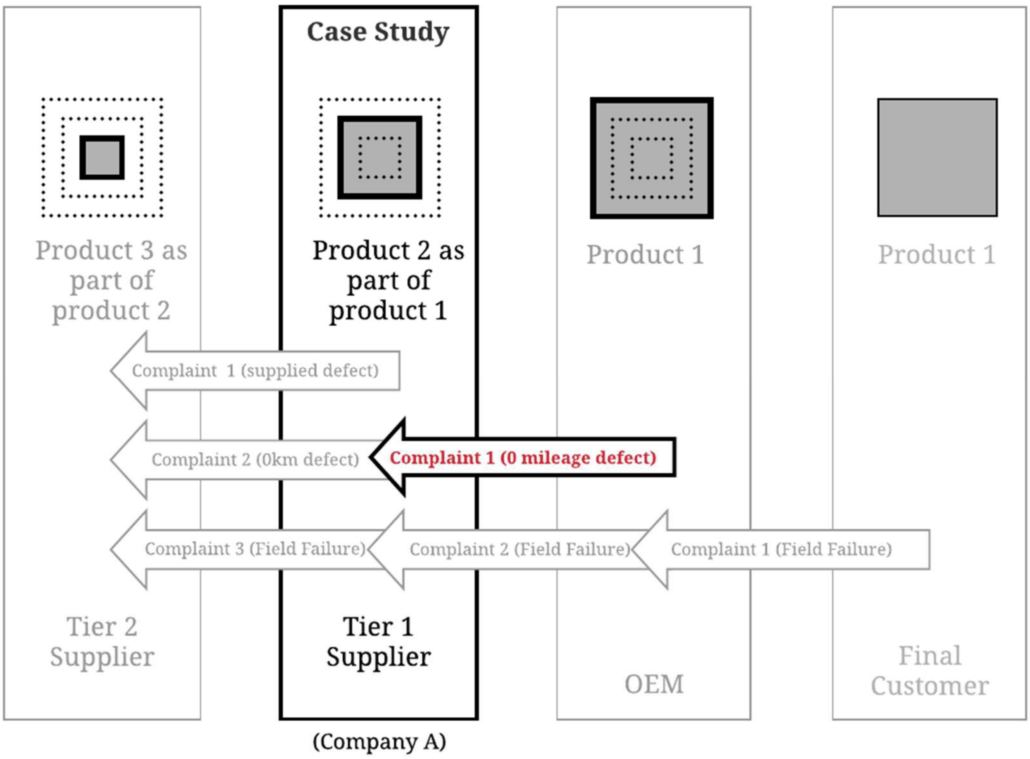

Figure 4 - Origin and types of complaints in the supply chain of Company A.

In Company A, external complaints are divided into two types according to their origin, which can be from the customers' factories (OEM) or the final customer (market). When a defective part is detected by the OEM, the claim counts as a "0 (zero) mileage defect", which can be found before the part is assembled in the car (for instance during an incoming inspection done at an OEM), or after it has already been installed. Complaints about uninstalled products are usually related to cosmetic defects, for example, labelling errors. These defects are rarer, as they are more easily detectable thorough inspection during production. When products are already installed in vehicles at OEM, they can reproduce failure modes that result in more critical defects, such as software or electronic problems. This paper analyses a KPI related to the complaint type "0 mileage defect", indicated in red in Figure 4.

The complaints handling process of Company A is based on the 8D method (Riesenberger and Sousa, 2010). The 8D method is applied for internal and external complaints. The timeline presented in Figure 5 shows important events of "0 mileage" complaints arranged in the order they happen, from the production date of a product, which eventually is found as defective, to the closed investigation of its failure root cause.

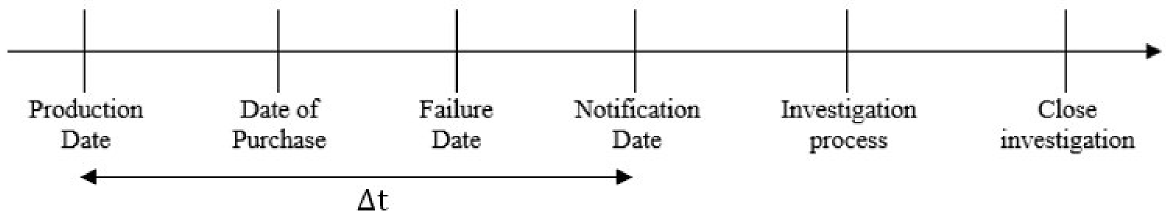

Figure 5 - Complaint handling process timeline.

Considering all the complaint data of Company A from January 2016 to March 2021, a total of 3364 complaints were recorded. Figure 6 is a histogram that presents the frequency of days between the Production Date and the Notification Date (Δt), showing that about 50% of the notifications happen eight weeks after the Production Date.

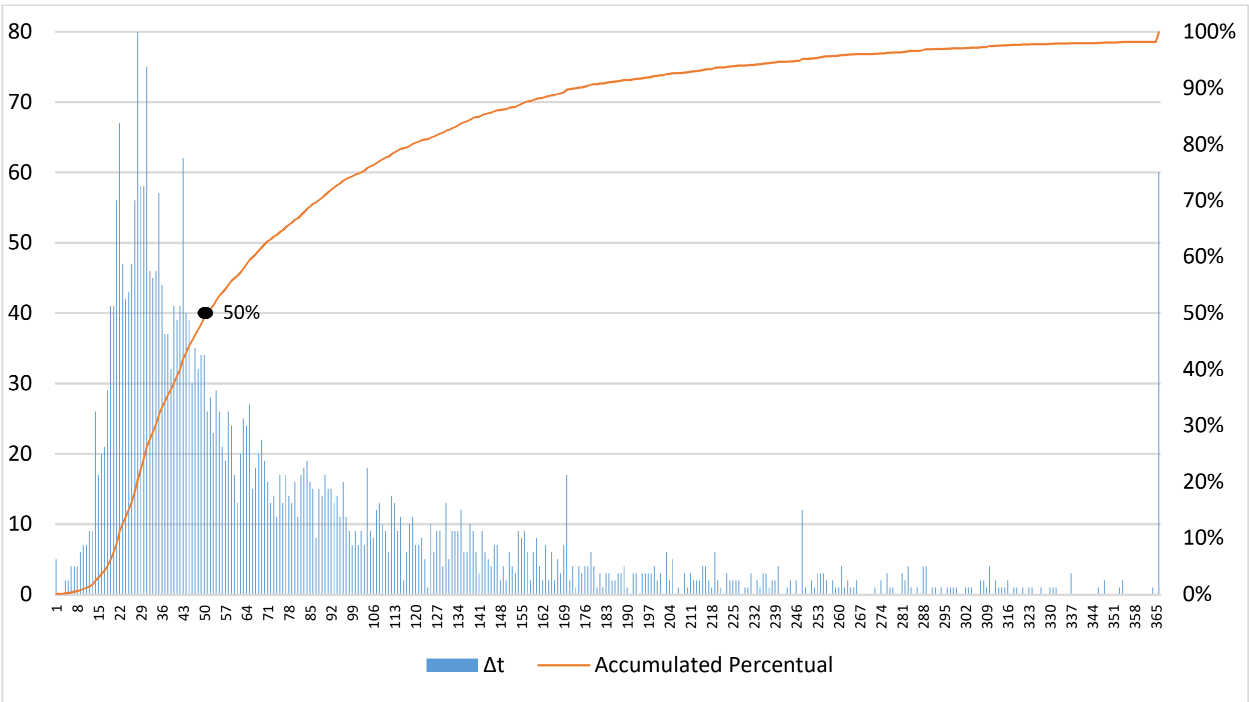

Figure 6 - Days between Production Date and Notification Date (Δt).

In the investigation phase, according to the analysis result, the status of the device is changed to "claimed", "analysed", "scrapped", "blocked", or "to return", and the defect liability for warranty is assigned to one of three options: (1) it is determined as a responsibility of the company itself, (2) of the customer, when the defect root cause occurred only after customer delivery, i.e., due to misuse, or (3) specification, when requirements were fulfilled, and the product claimed is actually not defective.

3.2 Phase 2: Evaluation of the Complaint KPIs

3.2.1. Previous and Current KPI

The performance indicator "0 mileage" complaints used by Company A was recently changed due to the need for having an annual closing. Until 2020, the KPI adopted was the "0 mileage defective Parts per Million”, abbreviated as PPM, and in 2021 it was replaced by a new indicator named “0 mileage defective Incidents per Billion”, abbreviated as IPB. Both KPIs are presented in Table 2 based on eleven attributes (Neely *et al.*, 1997) to explore what constitutes a well-designed KPI. Table 2 was filled out according to the data reported in the company's information system and old reports. Most of the information was available, except the "objective" and "who acts on the data" items. That is why these fields were filled with a question mark (?) in Table 2.

Table 2 - Previous x Current KPI.

Title	0 mileage defective PPM	0 mileage defective IPB
Objective	?	?
Scope	7 out of 9 product classes	7 out of 9 product classes
Target	10 percent less than the previous year	10 percent less than the previous year
Formula	$\frac{\sum \text{Produced items in Year Y that fail}}{\sum \text{Produced quantity in Year Y}}$ For any year Y	$\frac{\sum \text{Failure notifications in Year}}{\sum \text{Produced quantity in Year Y}}$ For any year Y
Frequency of measurement	Updated daily	Updated daily with an annual closing
Source of data	SAP	SAP
Who measures?	Automatically	Automatically
Who acts on the data?	?	?
Notes and comments	Calculated by production date	Calculated by notification date
Frequency of review	Top-down approach	Top-down approach

Regarding the performance indicators names, while "Parts" refer to the claimed products, the word "Incident" refers to a claim notification, regardless of the amount claimed: there may be an Incident with only one part claimed, as there may be an Incident with several parts claimed. The words "Million" and "Billion" refer to the unit of measurement.

The company product portfolio includes navigation systems, instrumentation systems, and high-level car radios for the automotive industry, among other automotive electronic components. The scope of both PPM and IPB includes seven out of nine product classes. The target, defined by a top-down approach for all production facilities worldwide, requires the achievement of a result 10 percent better compared to the previous year. The source of data is an ERP system software (SAP), and all the KPI are automatically measured and displayed in a data visualization tool. The indicator reviews are done in a top-down approach (in the last revision the PPM was replaced by the IPB).

Since many product classes have an external complaint rate of around 100 incidents per million, calling it IPB (incidents per billion) may complicate the interpretation of the magnitude of the unit of measurement. In other words, it is simpler to understand the first sentence than the second:

1. 100 items were claimed for every 1 million pieces produced.
2. 100,000 items were claimed for every 1 billion pieces produced.

Another difference between the previous and the current KPI concerns the frequency of measurement. The PPM formula considers the Production Date, while the IPB considers the Notification Date. This implies that the IPB can have an absolute annual closing because when the year is over it is already known how many parts were produced and how many notifications there were, so both the numerator and the denominator of its formula are already defined. PPM, on the other hand, do not allow this annual closing at the end of the year, because only the denominator of its formula is known at this point, while the numerator can keep increasing until there are no more complaints, which can vary depending, for example, on the warranty time defined in the contracts.

Table 3 provides a hypothetical example, with made-up data for confidentiality reasons, to elucidate how the change of the KPI made it possible to carry out an annual closing for the IPB, which was the main motivation behind the KPI revision process.

Table 3 - Complaints by notification year x by production year.

		Notification Year				
		2018	2019	2020	2021	Total
Production year	2016	6	1			7
	2017	136	4	1		141
	2018	**722**	**176**	**8**		906
	2019		960	260	3	1223
	2020			939	165	1104
	2021				85	85
	Total	**864**	1141	1208	253	3466

It illustrates a situation in which among the products produced in 2018, 722 were claimed in the same year of production, another 176 products were claimed in 2019, and another 8 in 2020. Assuming that each notification (incident) refers to a unique claimed part and 12 million products were produced in 2018, the values for PPM by the end of 2018, 2019, and 2020 would be the following:

$$PPM_{2018}^{2018} = \frac{\mathbf{722}}{12000000} 10^6 = 60.17 \text{ defectives per million}$$

$$PPM_{2018}^{2019} = \frac{\mathbf{722+176}}{12000000} 10^6 = 74.83 \text{ incidents per million}$$

$$PPM_{2018}^{2020} = \frac{\mathbf{722+176+8}}{12000000} 10^6 = 75.50 \text{ incidents per million}$$

While the result for the IPB_{2018} would be already static by the end of 2018:

$$\text{IPB} = \frac{\mathbf{864}}{12000000} 10^9 = 72000 \text{ incidents per billion}$$

It is noteworthy that the need for an annual close is what triggered Company A to change the customer complaint KPI from PPM to IPB.

3.2.2 Potential problems of the KPIs

The most important feature of a KPI is to be derived from a strategy with an explicit and clear purpose (Neely *et al.*, 1997; Neely, Gregory and Platts, 2005; Kaplan and Norton, 2007). Based on interviews with workers and managers and after consulting existing information in the company's information system page that reports on KPIs, it was apparent a lack of a clear objective, which is the main problem with both the previous and the current KPIs. Therefore, assuming certain purposes, this section presents three situations that could lead to wrong conclusions and generate misleading policy messages, which are summarized below and detailed afterward.

- Situation 1: If the objective is to control the production process, the indicators are not useful because they are lagging indicators.
- Situation 2: If the objective is to quantify the failure rate claimed to plan improvement efforts in weak areas, the current indicator is not useful. Since IPB is calculated considering the number of notifications, one single notification can contain numerous claimed parts. This leads to misinterpretation of the indicator as it hides valuable information for understanding problems.
- Situation 3: If the objective is benchmarking, the indicators are not useful. Both the previous and the current KPI aggregate product classes by giving them equal weight. This invites simplistic conclusions as some products with different complexity levels fall under the same measure and the indicator is not capable of identifying which class failed.

Situation 1:

As shown in the histogram presented in Figure 6, both failures and notifications can be out of time. This implies that the number of complaints received in a given year may not indicate the current quality because of this lagged effect. The KPI must provide timely and accurate feedback (Defeo, 2016), which in this case can be understood as the ability of the system to feed customer claims back to production facilities in the form of quality controls (Sanchez-Marquez *et al.*, 2020). However, both PPM and IPB are lagging indicators. In the manufacturing phase, if the process is changing, it is more likely that the detection of changes will be earlier through leading internal indicators than by lagging external indicators (Mitra, 2016). A lagging indicator is mostly used for review purposes in the long term, and, therefore, their focus is not to offer the opportunity for control during the production process or to measure operational performance, but to measure performance at a corporate level (Sangwa and Sangwan, 2018). The existing 8D process can trigger a prompter recalibration of internal quality control to ensure the system continues predicting, reacting, and preventing future customer complaints.

Situation 2:

A possible cause of misinterpretation of the indicator is due to its calculation by notifications (incidents) instead of by claimed parts, as this can hide valuable information for understanding problems. For example, considering that in one year (Year 3 in Figure 7) a notification is reported with several claimed products, the IPB would not show this issue, while if the indicator were calculated by PPM, this situation would be evident.

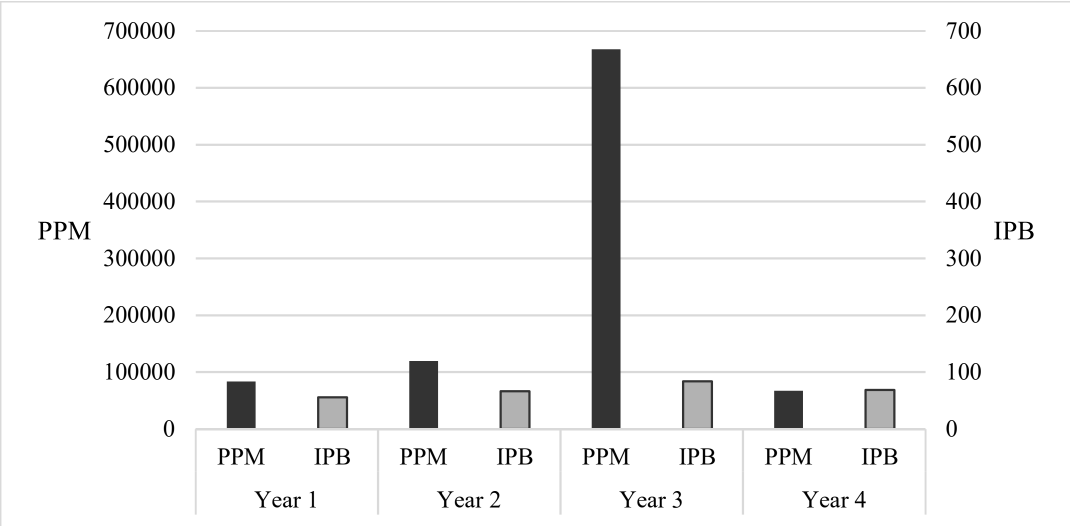

Figure 7 - PPM x IPB.

Situation 3:

The way PPM and IPB indicators are defined give equal weight to all product classes, however, they are different in their complexities. Although it is desirable that all product classes are impeccable regarding quality, they should not be treated in the same way: different strategies may be necessary to achieve the same quality level. For instance, two of the Product Classes are Chassis Sensors and Instrument Cluster, as shown in Figure 8. A Chassis Sensor is a very robust product that rarely fails and is produced in large volumes in Company A. An Instrument Cluster, on the other hand, is produced in a lesser quantity and is, comparatively, a very complex product with more critical variables to be controlled, therefore, the probability of failure is much higher. Aggregating these different Product Classes in the same indicator can generate misleading policy messages (i.e., making it looks like a company's performance is better or worse than what it is).

(a) (b)

Figure 8 - (a) Chassis Sensor; (b) Instrument Cluster

3.3 Phase 3: Suggestions for improvement

The discussion in section 3.2 presents an understanding of the definition of the previous and the current KPI, the rationale behind them, the data used, and some factors that may convey wrong messages. In this section, suggestions to overcome the reported limitations are presented.

Literature states that KPI must be derived from strategy with an explicit purpose, otherwise, they will not be understood as relevant. Thus, the first suggestion to improve the indicator is to make its purpose clear on the company's information system page that reports on KPIs. There may be several purposes for the indicator, for example: (1) Quantify complaint rate by OEMs to assess customer satisfaction; (2) Quantify complaint rate warranty decisions to assess supplier quality; (3) Quantify complaint rate according to product class to identify fault peaks, to find out the weak areas and to plan endeavours for their improvement. According to the established objective, one or more stakeholders will be responsible to act based on the data. This way, the problem of lacking "who acts on the data" field would be solved.

About the scope and the target, although a composite indicator for all the product classes may facilitate the interpretation if compared to a battery of many separate indicators, it is believed that an individual indicator with an individual target should be defined for each product class. Then, instead of aggregating all product classes with the same weight (equal to 1), it is suggested to aggregate them with different weights, considering, for example, product complexity and costs. The weighted composite indicator would better summarize the complex multi-dimensional realities to support decision-makers, by reducing the visible size of a set of indicators without dropping the underlying information base (Joint Research Centre-European Commission, 2008). For this, it is necessary to construct a weighting system and review it periodically as a part of the target and objective setting for the future.

Visualization of the results should receive proper attention, given that the visualization can influence interpretability (Joint Research Centre-European Commission, 2008). The study of KPIs and their metrics lends itself to Shneiderman's visualization mantra, "overview first, zoom and filter, then details-on-demand" (Shneiderman, 1996). Therefore, rather than just representing the indicator as a static quality figure with its target, it is important to make available visualization technique that communicates more information. Through an analytic dashboard, it is possible to enable the users to explore the indicator as they wish for emphasizing a particular set of information, for example: (1) filtering the complaints by OEMs to assess customer satisfaction; (2) filtering according to warranty decisions to assess supplier quality; (3) filtering according to product class to identify fault peaks to find out the weak areas and to plan endeavours for their improvement.

4. CONCLUSIONS

To fulfil its functions, KPIs need to be well designed, implemented, used, and reviewed. This paper analyses one of the most important KPIs used in the QMS of a company in the automotive industry, addressing the evolution of the KPI, identifying limitations, and suggesting improvements. The case study supports the relevant role of continuously reviewing existing measurement systems to keep pace with the competitive environment (Wouters and Sportel, 2005; Braz, Scavarda and Martins, 2011).

The current indicator, called IPB, was adopted in 2021. Formerly, it was calculated differently and had a different name: PPM. The main problem with both indicators is the lack of a clear purpose. Therefore, assuming certain purposes, this article presents some examples of situations that can lead to wrong conclusions and generate misleading policy messages:

- Previous (PPM) and current (IPB) KPIs are lagging indicators, not allowing to control the production process and measuring operational performance.
- IPB is calculated using the number of notifications that may contain several claimed parts. This can hide valuable information and lead to misinterpretation of data.
- In PPM and IPB, products with different levels of complexity are aggregated under the same indicator, which can invite simplistic conclusions as some products with different complexity levels fall under the same measure and the indicator is not capable of identifying which class failed.

The changes in the complaint KPI considered concepts proposed and discussed in the literature, such as the aggregation and disaggregation of measures. The disaggregation of some measures, i.e., by product classes and by customer's OEM, can improve the ability of decision makers to quickly identify the source of an operational problem and take appropriate action, in accordance with (Globerson, 1985; Joint Research Centre-European Commission, 2008). The new proposed KPI intends to more accurately identifying which product classes need more control and improvement in their production process, to consequently reduce external failures and customer complaints, driving customer satisfaction. Therefore, the suggested IPM is disaggregated by product class, and individual targets, challenging yet realistic, must be set up to each class.

Reflecting on the case study experiences, we stress that it is important at some stage to take a “fresh look” and try to think individually and in group sessions about new measures, because taking measures that already exist as a starting point for further development can inhibit change and innovation (Wouters and Sportel, 2005). Just looking at the previous indicator (PPM) and at the current indicator (IPB) hindered creativity in creating the first version of the new indicator suggested. The questions and ideas that the researchers brought up during the case study were essential to develop and revise the proposed indicator (CPPM) until reaching the final version presented here. Therefore, this study supports the statement by Wouters and Sportel (2005) that it is important to identify what exists and then to step back to have completely new ideas.

As a future research direction, it is suggested to develop a weighting system to combine the product classes into a meaningful composite indicator, involving experts and stakeholders, and to validate the proposed performance indicator by doing empirical study or case studies. Another research direction is related to test the cause-and-effect relationships between internal and external indicators, i.e., to test if the DPMO of each Product Class can be related to the complaints in order to diagnose how the quality management system works in terms of feedback, as suggested by (Sanchez-Marquez *et al.*, 2020).

ACKNOWLEDGMENTS

This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the R&D Units Project Scope: UIDB/00319/2020.

REFERENCES

Almström, P. *et al.* (2017) *Sustainable and resource efficient business performance measurement systems - The handbook*. Produktion2030.

Birch-Jensen, A. *et al.* (2020) ‘Use of customer satisfaction measurements to drive improvements’, *Total Quality Management and Business Excellence*, 31(5–6), pp. 569–582. doi: 10.1080/14783363.2018.1436404.

Bititci, U. S. *et al.* (2015) ‘Value of maturity models in performance measurement’, *International Journal of Production Research*, 53(10), pp. 3062–3085. doi: 10.1080/00207543.2014.970709.

Bititci, U. S., Cocca, P. and Ates, A. (2016) ‘Impact of visual performance management systems on the performance management practices of organisations’, *International Journal of Production Research*, 54(6), pp. 1571–1593. doi: 10.1080/00207543.2015.1005770.

Bititci, U. S., Suwignjo, P. and Carrie, A. S. (2001) ‘Strategy management through quantitative modelling of performance measurement systems’, *Int. J. Production Economics*, 69, pp. 15–22.

Blank, R. (2014) *Warranty Claims Reduction: A Modern Approach with Continuous Improvement Techniques*. CRC Press.

Braz, R. G. F., Scavarda, L. F. and Martins, R. A. (2011) 'Reviewing and improving performance measurement systems: An action research', *International Journal of Production Economics*, 133(2), pp. 751–760. doi: 10.1016/j.ijpe.2011.06.003.

Van Camp, J. and Braet, J. (2016) 'Taxonomizing performance measurement systems' failures', *International Journal of Productivity and Performance Management*, 65(5), pp. 672–693. doi: 10.1108/IJPPM-03-2015-0054.

Defeo, J. A. (2016) *Juran's Quality Handbook: The Complete Guide to Performance Excellence*. Seventh Ed. OH, United States.

Domínguez, E. *et al.* (2019) 'A taxonomy for key performance indicators management', *Computer Standards and Interfaces*, 64(December 2018), pp. 24–40. doi: 10.1016/j.csi.2018.12.001.

Globerson, S. (1985) 'Issues in developing a performance criteria system for an organization', *International Journal of Production Research*, 23(4), pp. 639–646. doi: 10.1080/00207548508904734.

Goshu, Y. Y. and Kitaw, D. (2017) 'Performance measurement and its recent challenge: a literature review', *International Journal of Business Performance Management*, 18(4), p. 381. doi: 10.1504/IJBPM.2017.087103.

Gutierrez, D. M. *et al.* (2015) 'Evolution of the performance measurement system in the Logistics Department of a broadcasting company: An action research', *International Journal of Production Economics*, 160, pp. 1–12. doi: 10.1016/j.ijpe.2014.08.012.

Hsieh, C. C. and Liu, Y. Te (2010) 'Quality investment and inspection policy in a supplier-manufacturer supply chain', *European Journal of Operational Research*, 202(3), pp. 717–729. doi: 10.1016/j.ejor.2009.06.013.

Joint Research Centre-European Commission (2008) *Handbook on Constructing Composite Indicators - Methodology and User Guide*, *OECD publishing*.

Jordan, S. and Messner, M. (2012) 'Enabling control and the problem of incomplete performance indicators', *Accounting, Organizations and Society*, 37(8), pp. 544–564. doi: 10.1016/j.aos.2012.08.002.

Kaplan, R. S. and Norton, D. P. (2007) 'Using the Balanced Scorecard as a Strategic Management System', *Harvard Business Review*, (1), pp. 1–14.

Keathley-herring, H. (2017) 'An Approach to Quantify the Factors That Affect Performance Measurement System Implementation', *Engineering Management Journal*, 29(2), pp. 63–73. doi: 10.1080/10429247.2017.1298181.

Lohman, C., Fortuin, L. and Wouters, M. (2004) 'Designing a performance measurement system: A case study', *European Journal of Operational Research*, 156(2), pp. 267–286. doi: 10.1016/S0377-2217(02)00918-9.

Lucianetti, L., Battista, V. and Koufteros, X. (2019) 'Comprehensive performance measurement systems design and organizational effectiveness', *International Journal of Operations and Production Management*, 39(2), pp. 326–356. doi: 10.1108/IJOPM-07-2017-0412.

Matos, L. dos S., Ensslin, S. R. and Ensslin, L. (2020) 'Analysis of the Life Cycles of Performance Evaluation Systems: Characteristics, Functions and Processes', *Cuadernos de contabilidad*, 21. doi: https://doi.org/10.11144/Javeriana.cc21.acvs.

Melnyk, S. A. *et al.* (2014) 'Is performance measurement and management fit for the future?', *Management Accounting Research*, 25(2), pp. 173–186. doi: 10.1016/j.mar.2013.07.007.

Mitra, A. (2016) *Fundamentals of Quality Control and Improvement*, *John Wiley*.

Neely, A. *et al.* (1996) 'Performance measurement system design: Should process based approaches be adopted?', *International Journal of Production Economics*, 46–47, pp. 423–431. doi: 10.1016/S0925-5273(96)00080-1.

Neely, A. *et al.* (1997) 'Designing performance measures: A structured approach', *International Journal of Operations and Production Management*, 17(11), pp. 1131–1152. doi: 10.1108/01443579710177888.

Neely, A. *et al.* (2000) 'Performance measurement system design: Developing and testing a process-based approach', *International Journal of Operations and Production Management*, 20(10), pp. 1119–1145. doi: 10.1108/01443570010343708.

Neely, A., Gregory, M. and Platts, K. (2005) *Performance measurement system design: A literature review and research agenda*, *International Journal of Operations and Production Management*. doi: 10.1108/01443570510633639.

Nel, J. D. and Simon, H. (2020) 'Introducing a process for radical supply chain risk management', *International Journal of Business Performance Management*, 21(1–2), pp. 149–165. doi: 10.1504/IJBPM.2020.106120.

Nudurupati, S. S., Garengo, P. and Bititci, U. S. (2021) 'Impact of the changing business environment on performance measurement and management practices', *International Journal of Production Economics*, 232(October 2020), p. 107942. doi: 10.1016/j.ijpe.2020.107942.

Riesenberger, C. A. and Sousa, S. D. (2010) 'The 8D methodology: An effective way to reduce recurrence of customer complaints?', *Lecture Notes in Engineering and Computer Science*, 2185(1), pp. 2225–2230.

S.Phabmixay, C., Rodríguez-Escudero, A. I. and Rodríguez-Pinto, J. (2019) 'Benefits from the standardisation of the complaint management system', *Total Quality Management and Business Excellence*. doi: 10.1080/14783363.2019.1633295.

Sanchez-marquez, R. *et al.* (2020) 'Diagnosis of quality management systems using data analytics – A case study in the manufacturing sector', 115. doi: 10.1016/j.compind.2019.103183.

Sanchez-Marquez, R. *et al.* (2020) 'Diagnosis of quality management systems using data analytics – A case study in the manufacturing sector', *Computers in Industry*, 115. doi: 10.1016/j.compind.2019.103183.

Sangwa, N. R. and Sangwan, K. S. (2018) 'Development of an integrated performance measurement framework for lean organizations', *Journal of Manufacturing Technology Management*, 29(1), pp. 41–84. doi: 10.1108/JMTM-06-2017-0098.

Shneiderman, B. (1996) 'The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations', in *IEEE Symposium on Visual Languages*, pp. 336–343.

Sousa, S., Nunes, E. and Lopes, I. (2015) 'On the Characterisation of Uncertainty in Performance', *Business Sustainability 2.0*, (January 2011), pp. 82–88.

Tuertmann, R. *et al.* (2016) 'Challenges and design of a data-oriented complaint and failure management', *Total Quality Management and Business Excellence*, 27(7–8), pp. 885–896. doi: 10.1080/14783363.2016.1188000.

VDA (2017) 'Quality Management in the Automotive Industry - Definition of Failure Cause Categories for 8D Reporting', pp. 1–12.

Wouters, M. and Sportel, M. (2005) 'The role of existing measures in developing and implementing performance measurement systems', *International Journal of Operations and Production Management*, 25(11), pp. 1062–1082. doi: 10.1108/01443570510626899.