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New Model for Creating Innovative Solutions in Continuous Improvement Environments

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Abstract

Nowadays the competition factor between companies has been essential in their path to innovation. So, firms try to evolve through continuous improvement methodologies that can significantly improve their activities´ efficiency as well as gain more and more the trust of customers. The Lean philosophy, the FMEA methodology, and the TRIZ methodology can help companies to achieve these goals.

This article is intended to propose a new model called Continuous Improvement Integrated Model with Innovation and Management (CI-IMIM). It promotes a strong alliance between the areas of continuous improvement and innovation as it is specialized in the creation and prioritization of innovative solutions. The FMEA methodology (Failure Mode and Effects Analysis) focuses on the analysis and prioritization of problems depending on the underlying risk, the TRIZ (Inventive Problem-Solving Theory) contradictions matrix (CM) allows the creation of differentiating solutions from the establishment of technical contradictions, the GUT Matrix (Severity, Urgency and Trend) helps in prioritizing solutions, the Brainstorming focuses on screening solutions through feedback gathered from workers 'point of view and the Lean philosophy works as the conducting wire of the entire model. This model is then applied in a real automobile company. Digital Kanban, Visual Management, and 5S stand out here as Lean tools derived from the proposed model. It is also important to mention that persuasion and workers´ motivation capacity are crucial.

Conclusions show a significant improvement of 8 out of 10 KPIs. This proves the practical viability of the new model. The mudas reduction of 14,1% and the 2,2% PCE improvement are KPI improvement examples. For future PDCA cycles, regular follow-up meetings about the studied KPIs, a bigger task informatization in the company, and the application of the Lean tools Mizusumashi, Andon e Heijunka are suggested.

Keywords: FMEA, KPI, Lean, TRIZ

1. Introduction

Nowadays the competitiveness factor between companies/organizations has been decisive in its path to innovation and differentiation. This factor is characterized by the leadership dispute in terms of created value through critical success factors like cost, innovative technology, and product/service customization (Holweg, 2008). The automotive industry stands out as one of the main target sectors of this competitiveness improvement. It is considered the backbone of Gross Domestic Product (GDP) of the countries (Kaitwade, 2020).

In the second half of the twentieth century, the Toyota Production System (TPS) appeared in Japan as a new industrial management philosophy that combines the organizational management Taylorism principles with elements like Just in Time (JIT) and Heijunka. The Lean Manufacturing (LM) concept stands out here (Holweg, 2008).

In twenty first century, there are many successful evidences of the Lean philosophy application, especially in the USA and Germany (Clarke, 2005). However, the effect of the worldwide SARS-CoV-2 outbreak has negatively aggravated the automobile sector since 2020. Environmental implications (air pollution), trade wars (US-China), and tax increases inherent in the sector are also problem sources even though the automobile sector has been adapting better and better to this new reality by using new technologies (Industry 4.0) and continuous improvement methodologies (Clarke, 2005; Kaitwade, 2020).

Besides innovation, the growing use of continuous improvement philosophies with an emphasis on the Lean philosophy is crucial in the company´s way to differentiation. Lean production is an essential philosophy in creating value through the removal of waste and improving operational performance. Although Lean Manufacturing is used by weight in a manufacturing environment, Lean Services have been increasingly applied since the beginning of the 21st century. However, a profound change in mentality is required for the implementation of Lean Thinking in services, and there is often some resistance to change in organizations (Andrés-López et al., 2015). Additionally, Six Sigma has proven to be a useful philosophy for quality improvement in any industry. Consequently, productive income improves as well as customer satisfaction (Raisinghani et al., 2005).

Thus, the alliance between continuous improvement philosophies and innovation has enormous potential, whatever the organization might be. This alliance is about to be tested in a real case study in the improvement of a car´s dealer internal processes namely in the after-sales department.

2. Lean philosophy

The TPS has been the Lean paradigmatic basis since the Toyota Motor Company foundation. The Lean Thinking success has been outrageous as the productivity, reliability, and profitability indexes have been improving (Shang & Low, 2014).

2 models stand out: TPS house and Toyota Way. The TPS house describes Lean as a culture with the following goal: best quality, the lowest cost, the shortest lead time, the best safety, and the highest morale through stable, pull, and standardized processes. The Toyota Way values the people´s role in their environment and continuous improvement where people are the most important element in the operational performance improvement even better than the improvement methodologies and techniques suitable to increase production efficiency. In this way, both models are complementary (J. Liker, 2004; J. K. Liker & Morgan, 2006).

Mudas (literally translated as waste) are concerned with all types of activities that consume resources and contribute to Lead Time improvement without adding value. This means operational waste. There are 7 wastes according to Ohno: Overproduction, Waiting, Transportation, Motion, Overprocessing, Stock, and Defects. Additionally, some authors have been considering the existence of new waste. This waste either refers to the goods/services that do not satisfy the customers´ needs or to the people´s sub utilization which means people´s skills are disused (J. Liker, 2004; Womack & Jones, 1996). Here Lean Thinking appears not just as the antidote for waste but also as a valuable line of thinking which can be divided into 5 principles (Womack & Jones, 1996): Value, Value Stream, Flow, Pull, and Perfection. As can be seen in Table 1, *mudas* can be characterized from Lean Manufacturing and Lean Services perspectives.

Many Lean tools can be applied in the continuous improvement of a company/organization for instance: PDCA (Plan, Do, Check, Act) cycle, VSM (Value Stream Mapping), Kanban, *Mizusumashi*, etc.

Table 1. Characterization of Lean Services *mudas* [adapted from (Andrés-López *et al.*, 2015; Bonaccorsi *et al.*, 2011)]

Muda in the Services sector	LM Analogy	Example	Cause	Corrective Action
Overproduction	Overproduction	Processing items before being required	Poor planning	Levelling
Delay	Waiting	Pending requests	Poor coordination	Flow
Transportation/ Motion	Transportation Motion	Looking for data and information	Poor office housekeeping	Layout change
Duplication	Overprocessing	Repeated unnecessary details	Excessive bureaucracy	Digitalization
Lack of standardization	Stock	Fluctuating lead times	Demand fluctuations	Visual Control
Lack of customer´s focus	Defects	Poor attention to the customer	Lack of motivation	Planned breaks
Obsolescence	Defects	Error or incomplete work	Disorder	5S
Miscommunication	Defects	Transparency inexistence	Lack of bonds between workers	Standardization
Under-utilized resources	Under-utilized resources	Limited responsibility	Inefficient management	Use of workers´ skills
Failure Demand	Inefficient goods/services	Rejected suggestions	Lack of training	Worker´s training
Resistance to change	Inefficient goods/services	Rejected suggestions	Lack of motivation	Awards given to workers

3. Innovation

Although there is not a single definition for innovation, this concept is related to creating something new and different.

According to Tohidi & Jabbari (2012), innovation appears as a way of introducing new products/services in the current market as well as new production processes, new supply sources, or even radical changes in a certain industrial structure. It is important to refer that the main goals for innovation are based on new and disruptive technologies which help in the improvement of some process flexibility, quality, and environmental performance. The reduction in energy and raw material consumption is also a goal (Livotov et al., 2019; Tohidi & Jabbari, 2012).

The implementation of these new innovative technologies relies on the capacity of solving a lot of contradiction factors that appear in conflict with each other. The TRIZ methodology (Theory of Inventing Problem Solving) emerges as one of the best ways to solve these types of problems most effectively and efficiently. Since it was established by Altshuller, the practical application of this methodology has proven to be the most organized and suitable invention and creative thinking methodology for knowledge-based innovation (KBI). TRIZ tools like the inventive algorithm ARIZ, the TRIZ contradiction matrix (CM), and the 76 standard solutions enable users to easily generate innovative solutions for their problems (Livotov et al., 2019).

So, along with continuous improvement methodologies, innovation has a great role in the growth, survival, and success of any organization.

4. New model proposal

This section is intended to illustrate the creation of a new model specialized in the generation of innovative solutions with a corresponding action plan by prioritizing problems and solutions and involving the company´s employees in the referred solutions. The new model is named CI-IMIM which means Continuous Improvement Integrated Model with Innovation and Management.

Before showing the fundaments of CI-IMIM model it is important to understand the reason for its creation (4.2 and 4.3 subchapters).

4.1 Characterization of existing models

Nowadays, there are many models and methodologies that integrate different types of tools within the areas of continuous improvement and innovation. These models are intended to take advantage of the complementarity characteristics of each one of the different tools applied together (Bariani et al., 2004; Toivonen, 2015). The purpose of this combination of tools in this type of model is related to the proposal of innovative solutions in environments of continuous improvement that can solve real problems in a short period of time and that can prevent potential failures in future scenarios (Toivonen, 2015).

The Lean Six Sigma philosophy and the ecological perspective can and should also be considered in the improvement of processes (Wang & Chen, 2010; Yen & Chen, 2005).

/Several methodologies/tools have become evident: the FMEA methodology, the FMECA methodology (Failure Mode, Effects & Criticality Analysis), the Brainstorming technique, the PDCA cycle, the 5Whys technique, the Pareto Diagram, the GUT matrix, the Ishikawa Diagram, the Eisenhower Matrix, the QFD (Quality Function Deployment), the FTA (Fault Tree Analysis), the Kano Model and other quality management such as control charts or scatter diagrams (Costa, 2018; Dias et al., 2020; Ng et al., 2017). The FMEA methodology is the one that stood out the most.

The alliance between the FMEA methodology and the TRIZ methodology is the most frequent in the attempt to create differentiating solutions. There are several examples that prove this alliance: according to Yen & Chen (2005) the application of TRIZ CM was fruitful in the search for solutions related to environmentally unsustainable failure modes shown by

FMEA; in the case of Vysotskaya & Dmitriev (2021), the requirements and basic parameters of the processes under study begin by being identified and analyzed either by the FMEA or by the QFD and later the TRIZ tools emerge as solutions to the technical contradictions highlighted before in the same case study.

The alliance of the areas of continuous improvement and innovation is also very important in the operational improvement of an organization. According to the approach of Wang & Chen (2010), the integration of the Lean Six Sigma philosophy with the TRIZ methodology helped to improve the process in the banking services sector. From a DMAIC cycle, the processes mapped through a VSM and a SIPOC were analyzed to determine the adjacent problems. Before applying the FMEA, a Cause-Effect Matrix, and a Pareto Diagram made it possible to highlight the root causes of the mentioned problems. Then, the application of the TRIZ methodology was useful in the development of solutions, mainly through MC. The combination of Lean philosophy with TRIZ can also be successfully observed through the creation of a continuous improvement model intended to create ideal solutions in a Portuguese company in the food industry. Here several Lean and management tools were used such as the Brainstorming technique, the 5W technique, the PDCA cycle, and the Kano model. Depending on the nature and complexity of the problem detected, the application of TRIZ problem-solving tools could be useful through the application of the 40 inventive principles, MC or Substance-Field Analysis. The 5S and line balancing can also be used as solutions (Dias et al., 2020).

4.2 Gaps

As noted in the previous subchapter, there is an immensity of models that interconnect various tools to get complementary benefits from them. Most of them have some gaps. In this sense, many of the models and/or methodologies of literature are limited.

The main gaps verified in the previous models are the following 6 (Ng et al., 2017; Sutrisno & Lee, 2011; Toivonen, 2015):

1. Difficulty in mapping processes;
2. Inefficiency in the analysis of failures and risks;
3. Psychological inertia;
4. Unknowledge of customer perspectives and needs;
5. Proposal of expensive improvement solutions;
6. Technical contradictions are often without effective resolution.

Table 2. Description of CI-IMIM model parts

New Model part	Topic	Tool/Methodology
I	Problems numerical prioritization	FMEA (First part of FMEA card)
II	Improvement solutions proposal	TRIZ (contradiction matrix)
	Improvement solutions triage and prioritization	GUT
III	Improvement solutions action plans	5W1H
	Worker´s feedback	Brainstorming
IV	Result analysis of taken actions	FMEA (Last part of FMEA card)

Although many of the models mentioned above manage to overcome some of these gaps, there is no single model that has the joint capacity to overcome all these limitations. Considering, for example, the methodology of Dias et al (2020), it manages to provide an integration of Lean tools (e.g., 5S) with management tools (e.g., 5W) and innovation (TRIZ). In this sense, this methodology overcomes the difficulty gaps in the mapping processes, psychological inertia, neglect of customer perspectives, and technical contradictions that are often without effective resolution. However, the inefficiency in the analysis of failures and risks and the proposal of solutions for costly improvement emerge as the biggest limitations of the methodology. The application of the FMEA methodology and the 5W1H technique would, by hypothesis, make this methodology even richer. Considering now the perspective of Costa (2018), the model incorporates the FMEA methodology, the 5W2H technique, and the GUT matrix, which reinforces the detailed and prioritized analysis of failures and risks and the mapping of processes. Despite this detailed analysis, the solution generation process does not follow any pattern or algorithm for creating innovative solutions, and feedback from internal and/or external customers is not considered.

4.3 New model structure

This model combines a mix of integrated tools which provide an intuitive and differentiating line of reasoning. In this way, it is possible to create innovative and differentiating solutions that directly involve the company's employees.

Each of the tools/methodologies used in the new model is allocated to its conceptual intervention area (topic) and part of the model (Table 2).

Through this model, it becomes possible to create solutions with action plans efficiently and innovatively. Additionally, the gaps evidenced in the previous subchapter cease to exist.

As CI-IMIM focuses on the phase of problem analysis and planning of improvement solutions (Plan), on the development of action plans for solutions and their implementation (Do), on the monitoring and analysis of the results (Check), and serves as a starting point for the discussion of results and the follow-up of future actions (Act), it seems to fit into a PDCA cycle.

Thus, it becomes possible to create solutions with action plans associated with their implementation efficiently and innovatively.

Although the model does not have any original Lean tool in its structure, the culture of the CI-IMIM model resides in the so-called Lean Thinking. In this sense, the culture of waste reduction is implicit in the model, namely during the process of generating innovative ideas via TRIZ methodology. Consequently, the solutions generated can be associated with Lean analytical tools, for example the application of VSM along with CI-IMIM model can help to overcome the process mapping so common gap.

4.4 New model fundamentals

Figure 1 schematically represents the new model over 4 parts sequentially.

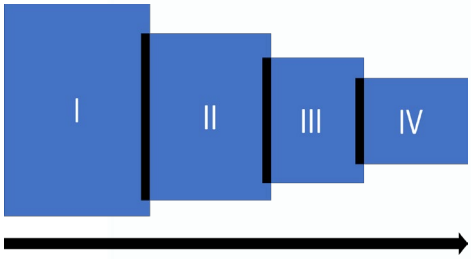

Figure 1. Sequence of CI-IMIM model parts

Each of the parts is characterized by a table of characteristic indicators. The last column(s) of the table of each part correspond(s) to the first column(s) of the following part table. For example, the last 2 columns of the table in Part I (Table 4) correspond to the first 2 columns of the table in Part II (Table 5). In this way, the CI-IMIM parts relationship can be called a cascade-shaped relationship. This connexion between parts of CI-IMIM favors its use in practice.

a. Part I

CI-IMIM is initialized with Part I where it starts by considering the problems associated with the respective root causes (inputs). These problems (failure modes) are characterized with the service stage and department in which they are inserted and the type of agents/employees of the company who are involved in the occurrence of the problem in the respective service stage.

Then, the problems associated with the root causes are numerically prioritized through the calculation of the associated RPN. This calculation follows the criteria of the FMEA chart according to Geum et al (2011).

The severity index (S) measures the severity of the failure effect caused by the associated failure mode, the occurrence index (O) measures the probability the root-cause responsible for the associated failure mode, and the detection index (D) measures the probability that the implemented means of control detect the root cause or the effect of the associated failure mode before it reaches the customer. The quantitative and qualitative scales can be found in Table 3. The classification of indices S, O, and D is between coefficients 1 and 9. According to the NPR classification, problems with an NPR greater than or equal to 200 are, by convention, considered priority

Table 3. Qualitative and quantitative scales of S, O and D [adapted from (Geum et al., 2011)]

Coefficient	Level	Criteria (S)	Criteria (O)	Criteria (D)
1	NO	No effect	Failure unlikely; History shows no failure	High quality available detection means
2	VERY SLIGHT	Customer not annoyed; Very slight effect on system performance	Rare number of failures likely	Proven Means of Detection
3	SLIGHT	Customer slightly annoyed; Slight effect on system performance	Very few failures likely	Simulated means of detection
4	MINOR	Customer experiences minor nuisance; Minor effect on system performance	Few failures likely	Detection means only tested at an early stage
5	MODERATE	Customer experiences some dissatisfaction; Moderate effect on system performance	Occasional number of failures likely	Detection means created in pre-simulation
6	SIGNIFICANT	Customer experiences discomfort; System performance degraded but operable and safe	Medium number of failures likely	Detection means compared to other similar systems
7	MAJOR	Customer very dissatisfied; System performance severely affected but functioning and safe	Moderately number of failures likely	Detection means compared to other type of components
8	SERIOUS	Customer very dissatisfied; System inoperable but safe	High number of failures likely	Disapproved or unreliable means of detection
9	EXTREME	Potencial hazardous effect; System able to stop servisse (potentially null performance)	Very high number of failures likely	No known techniques available

Table 4. Part I from CI-IMIM model

Service Stage	Department(s)	Agent(s)	Failure Mode	Failure Effect	S	Failure Cause	O	Current Control Measures	D	RPN	
										Index	Classification
Type of worker´s service	Departments (macro level) in which the corresponding service stage problem occurs	Elements of the company involved in the occurrence of the problem in the respective service stage	How the service fails	Consequent result of the occurrence of the failure mode	Severity of the failure effect caused by the associated failure mode	System failure which causes a certain failure mode	Likelihood of the root cause causing the corresponding failure mode	Ways of detecting current service failures	Likelihood that the implemented control means will detect the root cause or the effect of the corresponding failure mode before it reaches the customer	Risk Priority Number resulting from the product between S, O and D	Problem priority order

problems and, therefore, move on to the next part (Part II). The only exception is related to problems whose NPR is less than 200, but where the S index is maximum (G=9) so the associated problem also passes to the next part. In case of a tie of NPR's, the order of classification is arbitrary, and it is usual to follow the order in which the problems were initially presented.

This Part (Part I) can be seen in the Table below (Table 4) with the indicators "Service Stage", "Department(s)", "Agent(s)", "Failure Mode", "Failure Effect", "S", "Failure Cause "O", "Current Control Measures", "D" and "RPN".

b. Part II

After calculating all the RPNs, the problems with a RPN greater than 200 are the problems which continue to be analyzed in Part II as they have the highest priority (priority problems).

Then, the improvement action proposal phase takes place in CI-IMIM. This phase is concerned with the creation of innovative solutions using the matrix of contradictions (CM), one of the main innovation tools of the TRIZ methodology. This tool allows the creation of innovative solutions through Inventive Principles defined according to certain Engineering Parameters of the referred methodology. According to Altshuller, there are 40 inventive principles and 39 technical parameters. These are defined from the identification of contradictions between parameters which means the identification of a parameter that is intended to improve and another that will have to worsen, contradicting the potential effect from the other.

Thus, the new model focuses on the creation of recommended corrective actions according to the TRIZ methodology CM.

After the proposal of solutions, these are sorted and prioritized with the help of the GUT matrix. This tool measures 3 indexes: the severity of the impact the project may have on the company if it is not carried out soon (G), the urgency of carrying out the project with a deadline (U) and the tendency of the problem to worsen over time if the solution is not implemented (T). This decision support tool fits into the triage and prioritization of improvement actions. The criteria used, by convention, in the selection of improvement solutions is to consider solutions with a GUT index greater than or equal to 45. Afterwards, these are classified in order of priority.

This Part (Part II) can be seen in the Table below (Table 5) with the indicators "RPN", "TRIZ Engineering Parameters", "Chosen TRIZ Principles", "Recommended Corrective Actions", "G", "U", "T" and "GUT" (includes "Index" and "Classification").

Table 5. Part II from CI-IMIM model

RPN									GUT	
Index	Classification	TRIZ Engineering Parameters	TRIZ Invention Principles	TRIZ Principles Chosen	Recommended Corrective Actions	G	U	T	Index	Classification
Risk Priority Number resulting from the product between S, O and D	Problem priority order	Definition of 2 engineering parameters of the TRIZ methodology: an improving feature and a worsening feature depending on the type of problem	Definition of TRIZ inventive principles associated with the considered engineering parameters; it is done through the intersection of these parameters in the matrix of contradictions	Choosing the most suitable TRIZ inventive principle(s) to solve the problem	Improvement solutions design according to the respective TRIZ inventive principle(s)	Severity of impact that the solution could have on the company if it is not carried out soon	Urgency to carry out the solution considering the time factor	Problem tendency to get worse over time if the solution is not implemented	Product result between G, U and T	Improvement solution priority order

c. Part III

The referred improvement actions are then subject to action plans that define the description of what the solution is ("What?"), the reason for its creation ("Why?"), in which department the employee works (" Where?"), when does it act ("When?"), who is involved ("Who?") and how to carry out the action in practice ("How?"). Here in Part III, the 5W1H management tool will be used. This can be seen in Table 6.

Before implementing the solutions, some of the company's employees will give their feedback about the referred solutions. Involving people is, therefore, a critical piece in the acceptance of project solutions.

Brainstorming and Kaizen meetings will be held to assess the acceptance of the company's workers involved in the solutions described so far. Consequently, the solutions with positive feedback move on to the next part (Part IV) which is the implementation itself. Solutions that may be considered useful in the long term do not move on to the next part of the new model since the solutions to be implemented only concern short medium-term improvement actions.

This Part (Part III) can be seen in Table 6 with the following indicators: "GUT" (includes "Index" and "Classification"); "Sorted Corrective Actions" (incorporates "What?", "Why?"; "Where?" "When?" "Who?" "How?" and "How much does it cost?") and "Feedback" (includes "Approval" and "Decision").

Table 6. Part III from CI-IMIM model

GUT		Sorted Corrective Actions						Feedback	
Index	**Classification**	**What?**	**Why?**	**Where?**	**How?**	**Who?**	**When?**	**Approval**	**Decision**
Product result between G, U and T	Improvement solution priority order	Description of the solution	The reason for the solution	Department or worker where the solution operates	Way of performing the solution in practice	Persons in charge involved in the solution	Improvement period	Worker opinion regarding solutions	Approval of the solution (☺/☹)

d. Part IV

After having decided on the solutions that will be implemented, Part IV (Table 7) takes place in the model. Here, the respective results are measured. It is necessary to remember which modes, effects, and causes of failure justify the implementation of such improvement solutions. Control measures are also illustrated and updated here.

Finally, the implemented actions will be (as in Part I) subject to a numerical evaluation by calculating a new RPN (RPN'). The criteria used to calculate the S, O, and D indices in Part I are repeated here in Part IV. Then, the RPN' will be compared with the previous RPN to verify the positive or negative impact of the action taken to solve the corresponding problem. This phase concerns the final part of what is usually present in the FMEA chart. Additionally, there is a last column with a value which corresponds to the difference between the previous RPN and the RPN' along with an arrow depending on whether the NPR has gone up or down.

This Part (Part IV) can be seen in the Table 7 with the following indicators: "GUT" and "Result of Taken Actions" (includes "S´", "O´", "D´", "RPN´" and "Comparison with previous NPR").

Table 7. Part IV from CI-IMIM model

Feedback		Implemented Solution	Respective Failure Mode	Respective Failure Effect	Respective Failure Cause	Updated Controls Detection	Result of Actions Taken				
Approval	**Decision**						**R´**	**P'**	**N´**	**RPN´**	**Comparison with previous NPR**
Worker opinion regarding solutions	Approval of the solution (☺/☹)	Proposed solution that is going to be implemented and that is valued by workers	How the service fails	Consequent result of the occurrence of the failure mode	System failure which causes a certain failure mode	Updated ways of detecting current service failures	Severity of the failure effect caused by the associated failure mode after solution	Likelihood of the root cause causing the corresponding failure mode after solution	Likelihood that the implemented control means will detect the root cause or the effect of the corresponding failure mode before it reaches the customer after solution	Risk Priority Number resulting from the product between S, O and D	Comparison of Risk Priority Numbers before and after implemented solutions(↑/↓)

4.5 Practical Application Instruction

As CI-IMIM model practical application is very promising, it built a generic methodology that represents the practical application instruction along with CI-IMIM model (Figure 2). Its specific steps are included in detail in Figure 3.

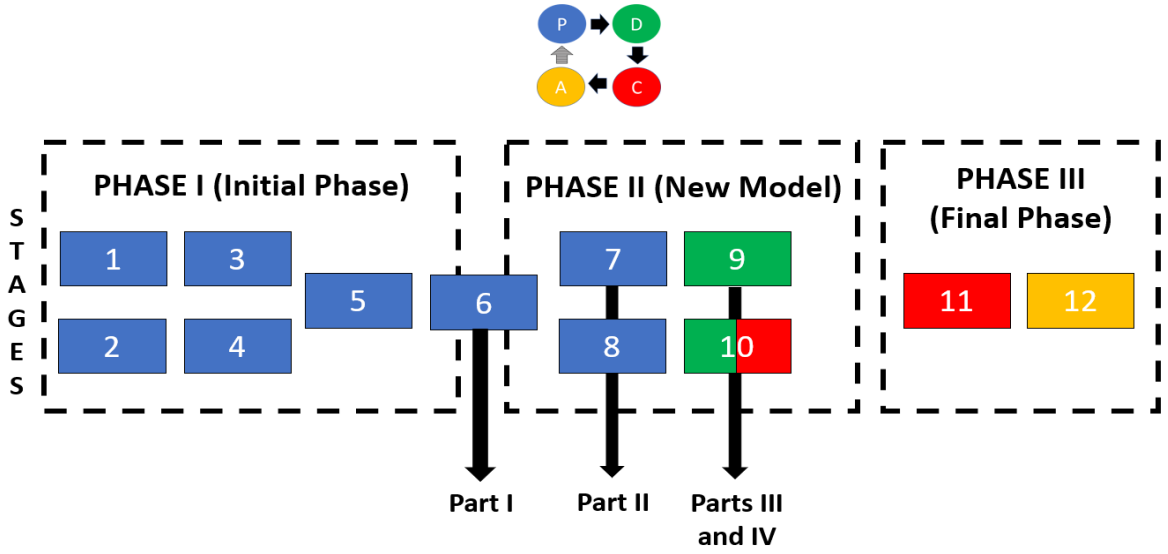

Figure 2. CI-IMIM practical application instruction

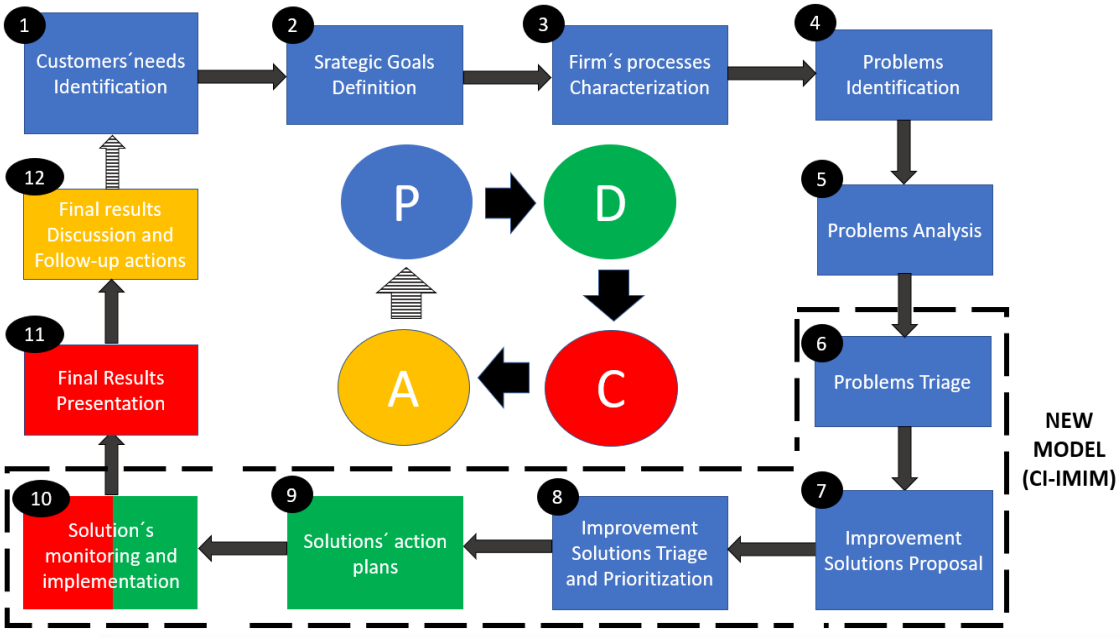

Figure 3. Description of practical application instruction stages

Through the previous explanation of CI-IMIM parts, it becomes clear that the new model includes the following 5 stages: problems triage, improvement solutions proposal, improvement solutions triage and prioritization, solutions´ action plans and solution´s monitoring and implementation. As it can be seen in Figure 3, these steps correspond to stages 6 to 10. However, if it is intended to integrate the model in a practical application scenario is also important to first understand the path to this identification of problems as well as it is essential to understand the path after discovering the improvement solutions via CI-IMIM model.

The methodology shown in Figure 2 is organized into 3 Phases (I, II, and III) with 12 Stages (1 to 12). As

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it was referred, the new model parts (I, II, III, and IV) correspond to stages 6 to 12 from Phase II. In addition, this methodology is based on a PDCA cycle. As it can be seen, the "Plan" includes the first 8 stages while the "Do" encompasses another 2 stages (9 and 10), the "Check" incorporates the 11th stage, and the "Act" corresponds to stage 12. Besides, the "Check" stage is either done simultaneously with the "Do" phase or at the end.

In general, the "Plan" step includes the customers´ needs identification, the strategic goals definition, the internal processes characterization, and the problems and solutions identification, analysis, and prioritization. The "Do" step involves the solutions´ action plan and implementation whereas the "Check" step is related to the solutions monitoring and results presentation. The final step "Act" corresponds to the discussion of the obtained results and the follow-up actions. The new model incorporates part of the "Plan", and all "Do" and "Check" steps. This can be seen in Figure 3.

So, the integration of the CI-IMIM model in case studies proves to be an asset in decision making regarding innovative solutions in continuous improvement environments, which allows for solving a certain number of problems of any company or organization.

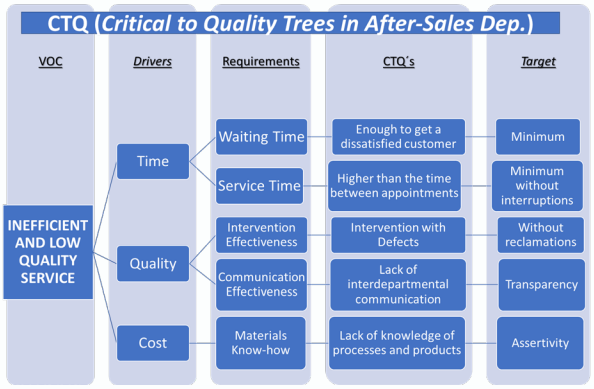
5. CI-IMIM in practice

After the theoretical explanation of CI-IMIM, it is time to apply the new model in a real case study. In this way, a case study is about to be carried out in a Portuguese car maintenance company. So, the validation of the new model is about to be studied here.

This case study occurred between March and July (2021). Although this case study followed the referred practical application instruction, this article aims to study Phase II in more detail as new model parts correspond to stages 6 to 10.

5.1 CI-IMIM background

In Phase I, it is important to have an initial notion of the most critical aspects for the customer in terms of service quality. In this context, a Critical to Quality Tree (CTQ) tree was built, representing the 3 After-Sales macro departments (MECHANICS, COLLISION and PARTS). This CTQ (Figure 4) served as the basis for translating the customers´ broad needs (internal and/ or external) into specific, actionable, and measurable performance requirements. It is possible to see that the Voice of the Customer (VOC) has 5 different CTQ aspects. All CTQs have a direct relation



with external customers except the CTQ "Lack of interdepartmental communication" which is directly

Figure 4. Customers' needs identification via CTQ tree

associated with internal customers.

After absorbing the most critical needs of the company's customers, it becomes essential to define the strategic objectives which the company is intended to achieve. In this way, a Balanced Scorecard (Figure 5) is built where a strategic map and SMART (Specific, Measurable, Attainable, Realistic and Time-Bound) KPI´s are shown. The strategic map interrelates 7 different strategic goals organized according to their point of view: Financial, Customer, Internal Business Processes and Learning and Growth. Besides, there are

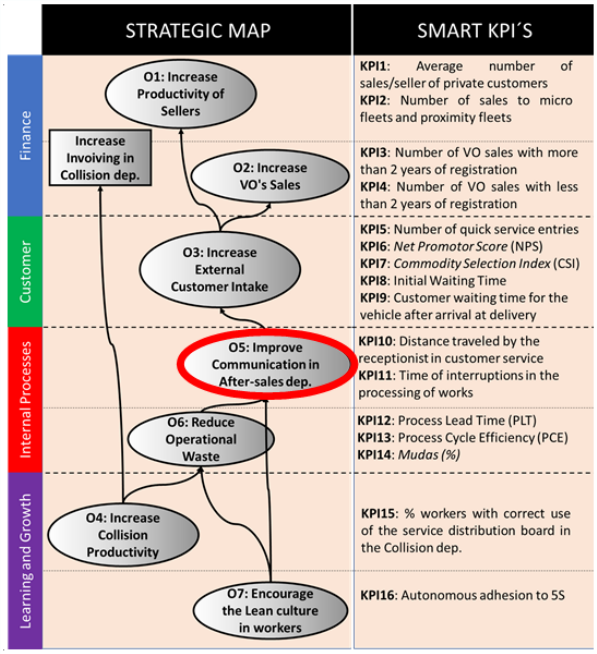


Figure 5. Balanced Scorecard of the company

specific KPI´s related with the referred perspectives and goals. After meeting with the top management, it was decided to focus attention on the 5th Strategic Objective regarding the improvement of interdepartmental communication in the After-Sales department. There are 10 relevant SMART KPIs (KPI5 to KPI16 except KPI15). All these KPIs are directly related to the work of the receptionists.

As previously mentioned, the observation focused on the MECHANICS department (Reception, Car Repair, and Car Wash). Reception is the first department for direct contact with external customers. 3 receptionists, the Head of Car Repair department, and the mechanics are the active company's agents in Reception. In customer service situations there can be 3 different situations: scheduled appointments (priority), unscheduled appointments, and no appointments. These appointments typically concern overhauls, repairs, and car rentals, among others. The customer´s request is organized through the customer file which incorporates the Repair Order (RO) and other relevant information about the appointment and the process.

In the Car Repair department, there are 8 mechanics and 1 Head of Car Repair department. Both interact actively in this department as well as with the receptionists and the Parts Clerk at MECHANICS. Each mechanic starts by cleaning the place of work and starts a new service after having gone to pick up the vehicle at the park. In the intervention itself, mechanics follow a preventive maintenance plan for overhauls and corrective maintenance for repairs.

The Car Wash department is coordinated by an outsourced company with 3 washers. Both the receptionist and the mechanic can access them here if they need to know the location in a queue or if a vehicle is ready or to transport a vehicle to/from this department.

The identification of problems occurred though internal documents, which were carefully analyzed, and the following Lean tools: direct observation (including Gemba Walks), VSM, Spaghetti Diagram, and 5S Checklist. Surveys and SIPOC were also used. Some of the Current State VSM results are presented in Table 8. The results indicated 37,9% of muda if it is considered the total time of analysis of 24 daily hours (8 hours per receptionist). Here, 7% was a necessary waste. After identifying all the problems in MECHANICS (34 in total), it was time to analyze them and distinguish causes and effects.

Table 8. NVA and VA time in Reception (Current State VSM)

Non-Value-Added Time (NVA)		Value-Added-Time (VA)
External NVA	Internal NVA	
06:37:33	02:27:43	14:54:43
72,91 %	27,09 %	

The problems identified were then deeply analysed through the Ishikawa Diagram and the 5Why´s technique. In this way, it was possible to get all root causes of the problems in the company.

After 15 root causes had been identified, it was useful to decide the most important root causes for the company according to O5. So, it was necessary to carefully choose the root causes to fight by allocating them in an Eisenhower Matrix (Figure 6). The criterion for choosing the root causes to fight was centered on choosing the most important causes for the company's performance. Thus, the priority quadrants are the top quadrants: Quadrant II (+ Important and + Urgent) and Quadrant I (+ Important and – Urgent). The causes allocated in Quadrant II are the following: "Lack of compliance with procedures", "Inappropriate procedure", "Lack of communication mechanism between Reception, Car Repair, and Car Wash", "Lack of PPE" and "Bad schedule planning". These are the 1st priority. Those with 2nd priority correspond to those in Quadrant I: "Resistance to change" and "Wrong management of priorities and tasks by the Head of Car Repair". The next phase (Phase II) was responsible for the application of a new model where the problems associated with the most important root-causes are studied.

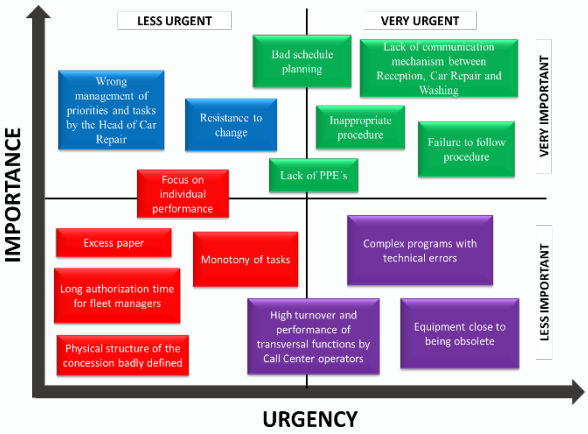


Figure 6. Eisenhower Matrix for identified root causes

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5.2 CI-IMIM application

Phase II focuses on all the steps involved in CI-IMIM. Before applying the new model to this case study, it is important to point out that the inputs to the model are based on the corresponding problems of the previously most important root causes.

Since the new model is intended to provide a creative and innovative vision of solutions organized by priorities involving people in them, this model will be applied to help achieve the strategic objective of improving interdepartmental communication in APV (O5).

After using the Eisenhower matrix to qualitatively sort out the most important root causes for the strategic objective in question (O5), the corresponding problems will be deeply analyzed to be prioritized quantitatively. In this way, the inputs of the CI-IMIM are the

problems associated with the previously screened root causes.

As can be seen in Table 9, the service stages are communication, worker procedures, schedule planning, task organization, and the role of the Head of Car Repair department. Although the study focuses on MECHANICS, the problems under analysis also encompass agents from COLLISION and PARTS as they are related to MECHANICS. The agents involved are generally receptionists, mechanics, the Head of Car Repair department, Parts Clerks in MECHANICS, and washers. The problems' RPNs under analysis are calculated from the product between the indices G, O, and D. Then, the problems are sorted in order of priority according to the numerical value of the calculated NPR. In case of a tie in NPR, the first tiebreaker is the Eisenhower Quadrant in question, otherwise, the ranking order does not matter.

Table 9. Part I from CI-IMIM model: application

Eisenhower Quadrant	Service Stage	Department(s)	Agent(s)	Failure Mode	Failure Effect	S	Failure Cause	O	Current Controls Measures	D	RPN	
											Index	Classification
1st Priority (+ IMPORTANT and + URGENT)	Communication	MECHANICS	Receptionists and mechanics	Wrong timing in customer phone call for vehicle delivery	Long waiting time to pick up the vehicle after indication of the Reception that vehicle is ready	6	Lack of communication mechanism between Reception, Car Repair and Washing	7	No	9	378	3
			Receptionists, mechanics and washers	Lack of knowledge of the repair/wash status and location of the vehicle	Long distances traveled by workers when delivering the vehicle	6		8	No	9	432	2
					Misplacement of keys on the keychain	5	Failure to follow procedure	6	No	9	270	8
	Storage of vehicle keys	MECHANICS	Receptionists	Keys located on OR trays	Confusion when searching for keys and other documents	4	Inappropriate procedure	3	No	9	108	17
	Processing of works	MECHANICS	Head of Car Repair, mechanics and receptionists	Unnecessary approval of OR by the Head of Car Repair	Delays in processing works	6		9	No	9	486	1
			Mechanics and receptionists	Receptionists' poor understanding of documents filled in by mechanics			Failure to follow procedure	6	Yes (Receptionists usually confirm the documents from mechanics)	3	108	18
	Billing Confirmation	MECHANICS	After-Sales responsible and receptionists	Lack of confirmation of email data regarding ORs provided by receptionists	Delay in receptionists' tasks	4		7	Yes (Receptionists check this situation in their emails)	5	140	16
	Car delivery	MECHANICS	Receptionists and washers	Vehicle poorly washed or delivered without being washed	Poorly performed service	6		5	Yes (sometimes it is detected, and the vehicle goes back to Washing or it even doesn't come back)	5	150	15
	Start of mechanical operation	MECHANICS	Receptionists and mechanics	Lack of work inside the vehicle	Delays in the beginning of the mechanic's service at the Car Repair	4		3	Yes (Mechanic detects this when looking for a vehicle to start a new service)	2	24	22
	Warranty treatment	MECHANICS	Receptionists	Outdated Symptom Code	Return of warranties	7		3	Yes (Receptionists or Head of Car Repair validate warranties before sending it to the Warranty Center)	3	63	20
	Planning with customer	MECHANICS	Receptionists	Lack of prior planning	More time-consuming bureaucratic details	6		7	No	9	378	4
				Lack of agile allocation of vehicle delivery time	Misallocation of vehicle return hours	6		5	No	9	270	9
	Customer service	MECHANICS	Receptionists	Disinfection performed at the end of customer reception instead of occurring immediately after inspection	Lack of focus on newcomers	4		8	No	9	288	7
				High number of daily and pending tasks	Lack of focus on newcomers	3	Bad schedule planning	4	No	9	108	19
					Stress	5		5	No	9	225	12
					High number of missed calls	5		6	Yes (by recording missed calls on the phone)	2	60	21
	Car Repair dep. works	MECHANICS	Mechanics	Lack of safety in the work environment	Negative impact on worker health	9	Lack of PPE's	2	No	9	162	14*
2nd Priority (+ IMPORTANT and - URGENT)	Organization of tasks	MECHANICS, COLLISION and PARTS	Receptionists, mechanics and Parts clerk	Disorganization and clutter of the work environment	Loss of information and/or lack of pride	5	Resistance to change	8	Yes (in the departments where 5S is implemented there are standards to be followed)	6	240	11
		PARTS	Parts Clerk and mechanics	Mechanics await a quote at the parts counter	Inefficient communication between Car Repair and Parts Clerk at the parts counter	6		5	No	9	270	10
	Head of Car Repair depart. role	MECHANICS	Head of car Repair and receptionists	Receptionists depend on the Head of Car Repair in their high number of pending tasks	Frequent interruptions from receptionists to the Head of Car Repair	5		8	No	9	360	5
				Head of Car Repair depends on the receptionists	Frequent interruptions from Head of Car Repair to the receptionists	5	Wrong management of priorities and tasks by the Head of Car Repair	7	No	9	315	6
		MECHANICS and COLLISION	Heads of car Repair and receptionists	Poor interpersonal relationship between macro departments	Inefficient communication between macro departments	5		4	No	9	180	13

Consider, as an example, the failure mode "Wrong timing in customer phone call for vehicle delivery". This failure mode occurs when the receptionists make this phone call right after receiving the customer file from the mechanic. So, the agents involved are the receptionists and the mechanics. Because of this failure mode, the failure effect corresponds to a long waiting time to pick up the vehicle after the indication of the reception that the vehicle is ready. Then, the indices S, O, and D are calculated with the results of 6, 7, and 9. These values mean that this problem triggers a discomfort to the customer that usually occurs moderately in which there are no means of detection used by the company to prevent such occurrence of failure. The RPN index has a high value of 378 which, compared to other NPRs, makes this problem the 3rd most serious problem. So, this problem moves to the next part of the model (Part II), in 3rd place.

From the 22 problems identified in Part I, only 13 went on to Part II (60% of the problems identified). It should be noted that all 1st Priority problems (+ Important and + Urgent) affect only the MECHANICS department.

Steps 7 and 8 correspond to Part II of the CI-IMIM. As there are 9 priority problems, these will be analyzed via TRIZ CM which helps in the proposal of innovative solutions for the company. In this way, the inventive principles that matter are responsible for

Table 10. Part II from CI-IMIM model: application

RPN									GUT	
Index	**Classification**	**TRIZ Engineering Parameters**	**TRIZ Invention Principles**	**TRIZ Principles Chosen**	**Recommended Corrective Actions**	**G**	**U**	**T**	**Index**	**Classification**
486	1	Improving "Loss of time" (25); worsening "Difficulty of detecting and measuring" (37)	18, **28**, 32 e **10**	[28] Mechanics substitution	Change procedure (work approval by receptionist)	4	5	3	60	8
				[10] Preliminary action	Training of receptionists regarding the approval of works derived from the car Repair	4	3	3	36	16
432	2	Improving "Loss of time" (25); worsening "Ease of operation" (33)	**4, 28, 10** e **34**	[4] Asymmetry	Motivate workers to contact each other (transparency of information)	4	2	2	16	25
				[28] Mechanics substitution	Digital means to receive vehicle status information (eg app, excel, etc.)	5	5	4	100	1
				[10] Preliminary action	Create a virtual vehicle control board from reception to delivery (eg app, excel, etc.)	4	4	4	64	6
				[34] Discarding and recovering	Washing paper sheet used in the service distribution board (Car Repair) instead of being thrown away to the trash	4	4	4	64	7
378	3	Improving "Adaptability" (35); worsening "Device complexity" (36)	**15**, 29, 37 e **28**	[15] Dynamics	Energizing receptionist: he/she only makes the phone call after getting definitive information about the vehicle being ready; he/she moves into the Car Repair and/or Washing departments	4	5	2	40	15
				[28] Mechanics substitution	Digital means to receive vehicle status information (e.g., app, excel, etc.)	5	5	4	100	2
378	4	Improving "Loss of information " (24); worsening "Loss of time" (25)	**24**, **26**, **28** e **32**	[24] Mediator	Plan in a shared way with other receptionists (teamwork)	3	4	4	48	10
				[26] Copying	Print an expected sheet of information to be needed the following day per customer	2	3	2	12	26
				[28] Mechanics substitution	Create ready-made inputs for future works	3	3	2	18	21
				[32] Colour changes	Planned ROs with different colors from unplanned ROs	2	2	2	8	29
360	5	Improving "Reliability" (27); Worsening "Adaptability" (35)	13, **35**, **8** e **24**	[35] Transformation of properties	Building a priority framework for the Head of car Repair to streamline their tasks in the right way	4	3	2	24	18
				[8] Anti-weight	Distribute and differentiate team priorities from individual ones	3	3	2	18	22
				[24] Mediator	Training receptionists on some topics	4	4	3	48	11
315	6	Improving "Loss of time" (25); worsening "Ease of operation" (33)	4, **28**, **10** e 34	[28] Mechanics substitution	Planning the Head of Car Repair´s dep. agenda in accordance with the receptionists' planning	5	4	4	80	5
				[10] Preliminary action	Building a priority framework for the Head of car Repair to streamline their tasks in the right way	4	3	3	36	17
288	7	Improving "Adaptability" (35); worsening "Ease of operation" (33)	4, 28, **10** e 34	[10] Preliminary action	Perform Disinfection soon after inspection in the presence of the customer	4	3	4	48	12
270	8	Improving "Reliability" (27); worsening "Ease of operation" (33)	**15**, **34**, **1** e 16	[15] Dynamics	Dynamizing washer: washer puts the keys in the right place, informing (computer-aided with a beep) the receptionist of the vehicle ready	5	5	4	100	3
				[34] Discarding and recovering	Key placement must be done in the right place on the keychain	3	3	2	18	23
				[1] Segmentation	Division into 2 subtasks: place key in the keychain and notify the receptionist personally	3	3	2	18	24
270	9	Improving "Reliability" (27); worsening "Loss of time" (25)	**10**, 30 e 4	[10] Preliminary action	Construction of a task board with tasks for each receptionist	5	4	3	60	9
270	10	Improving "Adaptability" (35); worsening "Loss of time" (25)	**10**, 30 e 4	[10] Preliminary action	Hire/allocate someone to be always available to mechanics (Dynamic Parts clerk)	5	5	4	100	4
240	11	Improving "Loss of information " (24); worsening "Loss of time" (25)	**24**, 26, **28** e 32	[24] Mediator	Put post-its on pending works	3	4	2	24	19
				[28] Mechanics substitution	Conduct weekly 5S internal audits at the Reception	5	3	3	45	14
225	12	Improving "Loss of energy" (22); worsening "Productivity" (39)	28, **10**, **29** e 35	[10] Preliminary action	Define working hours with more breaks and social spirit among workers	2	3	2	12	27
				[29] pneumatics and hydraulics	Have more comfortable chairs at the Reception	2	3	4	24	20
162	14*	Improving "Object-generated harmful factors" (31); worsening "Device complexity" (36)	**19, 1** e **31**	[19] Periodic action	Make the use of PPE's recurring in the Car Repair	3	4	4	48	13
				[1] Segmentation	Have convertible/dismountable PPE's	3	1	3	9	28
				[31] Porous materials	Buy PPE of porous material	3	1	2	6	30

suitable improvement solutions. In this sense, there can be so many improvement solutions for the same problem depending on the number of invention principles applicable to the problem. However, not all inventive principles are applicable, so it is important to select them before moving on to the solution. After the improvement solutions have been noted, they are then sorted using the GUT matrix that classifies them according to the G, U, and T indexes. Finally, the improvement solutions are screened by importance. All of these features can be seen in Table 10.

Consider the example of the problem "Unnecessary approval of RO by the Head of Car Repair department" according to Part I. This issue is associated with the "Inappropriate procedure" root cause. To propose a differentiating solution that valued less wasted time, it was decided to worsen the convenience of use, on the other hand. Thus, the application of the matrix of contradictions of the TRIZ methodology suggested 4 inventive principles: mechanical vibration (18); mechanical substitution (28); color changes (32), and preliminary action (10). It is easy to see that mechanical vibration and color changes correspond to physical inventive principles meaningless to the associated problem. Thus, these are disposable and the other 2 were chosen for improvement proposals. According to the principles of mechanical substitution and preliminary action, respectively, the solutions were to change the procedure (Change procedure – work approval by receptionist) and training of receptionists regarding the approval of works derived from the Car Repair department. Both solutions are quite valid even though when they are classified according to the GUT matrix, only the first one is considered a priority since it has a GUT index of 60 >= 45. After all GUT indexes have been calculated, it was found that this solution occupied the 8th position in terms of the priority of solutions.

Table 11. Part III from CI-IMIM model: application

GUT		Sorted Corrective Actions						Feedback	
Index	Classification	What?	Why?	Where?	How?	Who?	When?	Approval	Decision
100	1	Digital means to receive vehicle status information (e.g. app, excel, etc.)	Avoid wasting receptionists' time and energy	Reception and Car Repair´s computers	Create a Digital *Kanban* board to control vehicles by repair status	Vasco Soares	Second half July	Overall added value	☺
100	2								
100	3	Dynamizing washer: washer puts the keys in the right place, informing (computer-aided with a beep) the receptionist of the vehicle ready							
64	6	Create a virtual vehicle control board from reception to delivery (e.g., app, excel, etc.)							
100	4	Hire/allocate someone to be always available to mechanics (Dynamic Parts clerk)	Avoid wasting mechanics' time	Car Repair	Place Parts Clerk with an active role in the Car Repair (*Mizusumashi*)	Top management	September/October?	Need to test with extra parts clerk	☹
80	5	Planning the Head of Car Repair´s agenda in accordance with the receptionists' planning	Avoid wasting both time and try avoiding unforeseen events	Head of car Repair and receptionists	Situation points between the Head of Car Repair and receptionists for vehicles in the Car Repair	Head of Car Repair dep.	End of July	This type of control prevents future problems	☺
64	7	Washing paper sheet used in the service distribution board (Car Repair) instead of being thrown away to the trash	Taking advantage of the reuse of paper that would be thrown away and that helps the receptionist to know which vehicles are in the Washing department	Car Repair´s service distribution board	Motivate workers to put the RO's sheets (which they usually put in the trash) in the "Washing" tab of the service distribution board after having taken vehicles to Washing; works as a contingency plan for the Kanban virtual board	Vasco Soares	Second half July	Necessary practice which follows procedure	☺
60	8	Change procedure (work approval by receptionist)	Avoid wasting time in processing works that come from the Car Repair	Reception	Put works directly from the Car Repair to Reception	Head of Car Repair dep.	End of July	More practical	☺
60	9	Construction of a task board with tasks for each receptionist	Help managing and planning receptionists' tasks and priorities	Reception	Create visual management sheet regarding ROs by RO status and by priority of receptionists	Vasco Soares	Second half July	Monitoring ROs becomes more efficient	☺
48	10	Plan in a shared way with other receptionists (teamwork)	Plan for the next day	Reception	Promote sharing moments at the end of each day related with next day customers	Vasco Soares	Second half July	Appointments for the following day are always very incomplete	☹
48	11	Training receptionists on some topics	Decrease dependence on the Head of Car Repair and increase the autonomy of receptionists	Reception	Have weekly training sessions on topics such as warranties, fleet management, continuous improvement, etc.	After-Sales responsible	September/October?	There are many other trainings pending.	☹
48	12	Perform Disinfection soon after inspection in the presence of the customer	Increase focus on newcomers	Receptionists´ inspection	Motivate workers about improving service efficiency with this procedure by alerting them to the waiting time that newcomers have with disinfection at the end	Vasco Soares	Second half July	Logical procedure	☺
48	13	Make the use of PPE's recurring in the Car Repair	Increase the safety of mechanics' operations	Car Repair	Buy PPE's and make workers aware of the importance of their use	After-Sales responsible	Without defined date	Need for gloves of different material	☹
45	14	Conduct weekly 5S internal audits at the Reception	Increase the efficiency of the receptionists´ work	Reception	Create 5S program	Vasco Soares	July and August	Organization and pride are valued, so 5S should be encouraged	☺

Figure 7. Digital Kanban Board in Excel

From the 13 problems, 30 solutions for improvement emerged. Here only 14 went on to Part III (about 50% of the total solutions defined). And here the "Plan" step ends.

Steps 9 and 10 mark the 3rd part of the application of CI-IMIM to this case study (Part III). These steps relate to the "Do" step of the PDCA cycle in play. As can be seen in Table 11, the improvement solutions (ordered by priority) are detailed using the 5W1H tool. In this context, the action plan of the improvement solution is detailed according to the questions "What?", "Why?"; "Where?", "How?", "Who?" and When?".

As can be seen, of the 11 solutions, 7 of them had positive approval from the company's workers. Feedback from employees was obtained from 2 independent brainstorming moments: a formal brainstorming with a receptionist, a mechanic, the Head of the Car Repair department, the person in charge of Quality (intermediate management), the head of the After-Sales (intermediate management) and the General Director (top management) and a series of informal brainstorming sessions with the company's employees for whom the solutions had the greatest impact. In this way, the satisfaction of the company's internal customers is more easily achieved since each of the company's workers got involved, giving their endorsement to the solutions that were effectively decided to implement.

In this sense, the following solutions are considered in order of priority:

1. Digital Kanban board to control vehicles by repair status (7 different repair status in Figure 7);
2. Regular meetings between the Head of Car Repair department and receptionists for vehicles in the Car Repair department;
3. Motivate workers to put the RO's sheets (which they usually put in the trash) in the Washing tab of the service distribution board after the service is finished and before taking vehicles to the Washing (contingency plan for the Digital Kanban board);
4. Orientate customers´ files directly from the Car Repair department to the reception department;
5. Create Visual Management sheet (task and priority planning table) regarding RO´s by RO status and by priority of receptionists (Figure 8);
6. Motivate workers in improving the efficiency of the service with this procedure, alerting them about the waiting time that new arrivals have with the disinfection being carried out at the end;
7. Create 5S program to create new continuous improvement routines in Reception (Figure 9).

Figure 8. Visual Management sheet in Excel

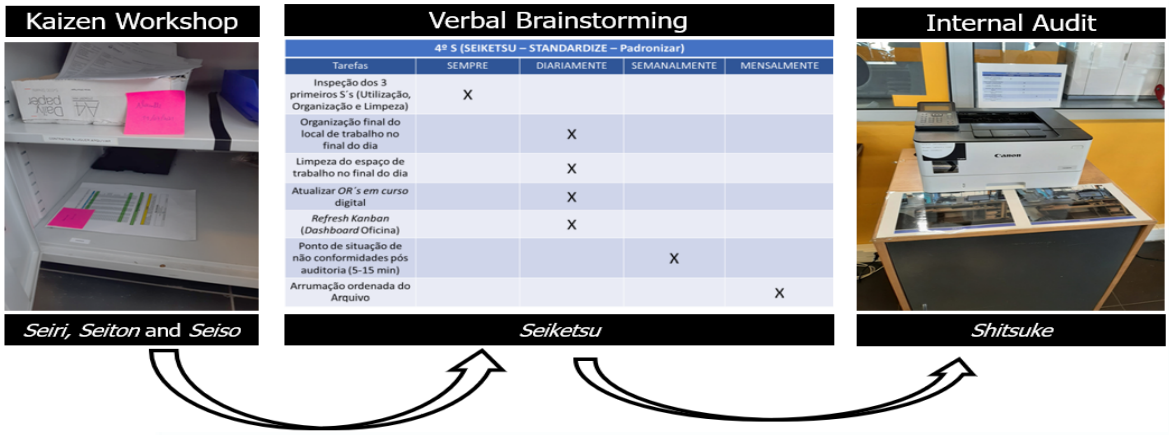

Figure 9. 5S Program (Kaizen Workshop + Verbal Brainstorming + Internal Audit)

5.3 CI-IMIM Validation

After having implemented all 7 improvement solutions together, several types of results were obtained:

results from Part IV of CI-IMIM, data from the New Current VSM, and other indicators. This step corresponds to the "Check" of the PDCA cycle.

Regarding the results from Part IV of CI-IMIM, these are present in the last 2 columns of Part IV. The 7 solutions are here associated with the respective mode, effect, and cause of failure (also present in Part I of the new model) to facilitate the calculation of the new NPR indices (NPR'). Part IV is shown in Table 12. It should also be noted that these 7 improvement actions aim to combat 9 failure modes.

According to Part IV of CI-IMIM, all the proposed solutions had a positive effect on the problem they were intended to solve. The calculation of the NPR´ followed a subjective criterion. The solutions "Digital Kanban board to control vehicles by repair status" and "Motivate workers to put the RO's sheets in the Wash tab of the service distribution board after the service is finished" had the greatest effect in reducing RPNs associated with the lack of knowledge of the repair/wash status and location of the vehicle

Table 12. Part IV from CI-IMIM model: application

Feedback		Implemented Solution	Respective Failure Mode	Respective Failure Effect	Respective Failure Cause	Updated Controls Detection	Result of Actions Taken				
Approval	Decision						R´	P'	N´	RPN´	Comparison with previous NPR
Overall added value	☺	Create a Digital *Kanban* board to control vehicles by repair status	Wrong timing in customer phone call for vehicle delivery	Long waiting time to pick up the vehicle after indication of the Reception that vehicle is ready	Lack of communication mechanism between Reception, Car Repair and Washing	Yes (if customer is waiting too long in the queue, there is evidence)	6	5	4	120	↓ 258 (120 < 378)
			Lack of knowledge of the repair/wash status and location of the vehicle	Long distances traveled by workers when delivering the vehicle		Yes (tabs "State" e "Parking place" in the Excel Virtual *Kanban* board)	6	5	3	90	↓ 342 (90 < 432)
				Misplacement of keys on the keychain	Failure to follow procedure	Yes (tabs "State" e "Parking place" in the Excel Virtual *Kanban* board)	5	4	3	60	↓ 210 (60 < 270)
This type of control prevents future problems	☺	Situation points related with vehicles in Car Repair	Head of Car Repair depends on the receptionists	Frequent interruptions from Head of Car Repair to the receptionists	Wrong management of priorities and tasks by the Head of Car Repair	Yes (tab "Situation point with Head of Car Repair" in the Excel Virtual *Kanban* board)	5	5	3	75	↓ 240 (75 < 315)
Necessary practice which follows procedure	☺	Motivate workers to use the "Washing" tab in the service distribution board	Lack of knowledge of the repair/wash status and location of the vehicle	Long distances traveled by workers when delivering the vehicle	Lack of communication mechanism between Reception, Car Repair and Washing	Yes (check by visual observation if mechanics use the "Washing" tab)	6	5	3	90	↓ 342 (90 < 432)
More practical	☺	Put works directly from the Car Repair to Reception	Unnecessary approval of OR by the Head of Car Repair	Delays in processing works	Inappropriate procedure	No	6	5	9	270	↓ 216 (270 < 486)
Monitoring ROs becomes more efficient	☺	Create visual management sheet related with RO´s in progress	Lack of agile allocation of vehicle delivery time	Misallocation of vehicle return hours	Failure to follow procedure	Yes (visual Management in Excel of the RO's in progress allows to control the information of all vehicles in progress)	5	4	3	60	↓ 210 (60 < 270)
Logical procedure	☺	Disinfection right after inspection in customer service	Disinfection performed at the end of customer reception instead of occurring immediately after inspection	Lack of focus on newcomers		Yes (visual control)	4	2	2	16	↓ 272 (16 < 288)
Organization and pride are valued, so 5S should be encouraged	☺	5S program	Disorganization and clutter of the work environment	Loss of information and/or lack of pride	Resistance to change	Yes (periodical audits)	5	6	3	90	↓ 150 (90 < 240)

(reduction of 342 values compared to the previous RPN).

Some of the new current state VSM results are presented in Table 13. The results indicate 23,8% of

Non-Value-Added Time (NVA)		Value-Added-Time (VA)
External NVA	Internal NVA	
03:08:44	02:34:34	18:16:41
54,98 %	45,02 %	

Table 13. NVA and VA time in Reception (New Current State VSM)

muda if it is considered the total time of analysis of 24 daily hours (8 hours per receptionist). Here, 7% is a necessary waste.

Figure 10. 5S Program Results for 1 Receptionist

The 5S results from one of the receptionists´ workplaces can also be seen in Figure 10.

After having obtained the results present in the previous step (stage 11), the same results will be discussed and analysed in depth (stage 12). At this stage, the "Act" of the PDCA cycle is distinguished. The evolution of the indicators under study is shown in Table 12.

The application of CI-IMIM in this case study proved to have been very fruitful in terms of finding innovative solutions suitable for solving the main problems observed in the MECHANICS department. As mentioned above, the solutions "Digital Kanban Board to control vehicles by repair status" and "Motivate workers to use the Wash tab" were the most successful ones. The first solution mentioned involves workers from all micro departments of MECHANICS (Reception, Car Repair and Car Wash departments). Although the fulfilling of the post-Inspection Disinfection procedure did not have the greatest impact, this solution was the one that obtained the lowest NPR (NPR went from 288 to 16). All indicators had a positive evolution. In fact, the average of the differential presented in the last column of Part IV of the new model had the value of 249. So, this evolution was significant. One of the main reasons involved here was the fact that the control measures have been improved for cases with no detection mechanism. Additionally, it was found that 5 out 13 root causes previously investigated were fought: "Lack of communication mechanism between Reception, Car Repair and Car Wash departments"; "Lack of compliance with procedure"; "Wrong management of priorities and tasks by the Head of Car Repair department"; "Inappropriate procedure" and "Resistance to change". The first 2 were the most valued according to the criteria of the new model.

Table 14. Summary table of the evolution of KPI´s

Indicators	Description	Perspective	Before	After	Target	Evolution
RPN	CI-IMIM RPN´s	All	…	…	0	POSITIVE
KPI6	Net Promotor Score (NPS)	Customer	87,9%	73,9%	100%	NEGATIVE
KPI7	Customer Satisfaction Index (CSI)	Customer	9,3	9,1	10,0	NEGATIVE
KPI8	Initial Waiting Time	Customer	10,3 min	7,3 min	0 min	POSITIVE
KPI9	Customer waiting time for the vehicle after arrival at delivery	Customer	20 min	7,8 min	0 min	POSITIVE
KPI10	Distance traveled by the receptionist in customer service	Internal Processes	658 m	614 m	334 m	POSITIVE
KPI11	Time of interruptions in the processing of works	Internal Processes	7,4 min	6,0 min	0 min	POSITIVE
KPI12	Process Lead Time (LT)	Internal Processes	3h e 21 min	2h e 36 min	1h e 34 min	POSITIVE
KPI13	Process Cycle Efficiency (PCE)	Internal Processes	20,2%	22,4%	100,0%	POSITIVE
KPI14	*Mudas* in Reception	Internal Processes	37,9%	23,8%	7%	POSITIVE
KPI16	Voluntary adhesion to 5S by receptionists	Learning and Growth	0%	33%	100%	POSITIVE

Thanks to the solutions proposed via CI-IMIM, most of the KPIs relevant to this case study (KPI6 to KPI14 + KPI16) evolved positively comparing March (initial month) with July (final month). These are presented in Table 14.

In the future, the follow-up of actions takes place, from now on, in the project to establish actions aimed at the maintenance, analysis, and improvement of the applied improvement solutions (PDCA cycle Act). In this sense, these actions serve as a starting point for new action plans to catapult a new PDCA cycle. In this way, the identification of new problems, improvement opportunities, and solutions take place again. Some of the suggested actions are as follows:

1. Follow-up meetings – serve as a form of formal monitoring of the referred KPIs;
2. Procedure manuals/good practice guides for new solutions – allows the creation of standards that feed the learning culture of the company's employees;
3. Existence of an extra parts clerk who is dynamic in the Car Repair department (*Mizusumashi*) – this operator can simultaneously do his/her tasks and be close to the mechanics with pre-planned material.
4. Implementation of an *Andon* system in the event of certain signs – sound/light signals that allow workers to be aware of a problem and/or some outstanding action intervening in their tasks;
5. Level scheduling of appointments through a *Heijunka* system – unscheduled appointments (scheduled with the Head of Car Repair) should occur less and less gradually; while they occur, they must be dealt with by the receptionists and not with the Head of Car Repair to avoid as much as possible unforeseen events or other interruptions;
6. Computerization of tasks which involve communication between departments through an app or web app that can be accessed on tablets by workers – makes the Digital Kanban mechanism more intuitive and faster.

8. Conclusions

This article is involved in the design and application of a new model specialized in the creation and prioritization of differentiated and innovative solutions through continuous improvement and innovation methodologies and with the company´s involvement, too. This model is called CI-IMIM. The practical application of the new model occurred in a Portuguese car dealer company. It was intended to achieve strategic goal 5 (O5) which corresponds to the improvement of interdepartmental communication in After-Sales in MECHANICS.

Theoretically, CI-IMIM seemed to be very useful in any company/organization that would like to create and prioritize unique solutions. Besides, it proved to fit well with tools like the Ishikawa diagram, the 5Why´s technique, and the Eisenhower matrix.

In the present case study, Phase II is the study methodology phase which is effectively concerned with the application of the new model. This model is divided into 4 parts. In summary, 22 problems were identified in Part I. Here, 13 problems passed to Part II where 30 improvement solutions arose. 14 (3 repeated) out of 30 solutions passed to Part III where 7 solutions were selected to be implemented in the company. The "Digital Kanban board to control vehicles by repair status." and "Motivate workers to use the Wash tab" were the most successful solutions as they were responsible for a greater reducing effect in the RPN index. The Visual Management sheet and the 5S program were other Lean solutions that stand out in MECHANICS, namely in the reception.

Between March and July, 8 of the 10 KPIs were significantly positive, which proves the practical validation of CI-IMIM in car dealers like the one here. The KPIs of Internal Processes were the ones that stood out the most in a positive way, such as the PCE which improved by 2.2%, and the mudas in Reception which decreased by 14.1%. However, the NPS and CSI indicators evolved negatively because of the pandemic context and the need for an adaptation period that allows the new solutions to be well assimilated by the company.

For future work, it is recommended that new PDCA cycles should be based on the maintenance, analysis, and improvement of the improvement solutions applied in this case study. Follow-up meetings, procedures associated with the new solutions, more computerized tasks, and systems with Mizusumashi, Andon and Heijunka are suggested.

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