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Developing a standard coding system for spare parts management to enhance operational efficiency and reliability

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In the present paper, we introduce a new classification system for spare parts within a medium to large-sized company operating in the packaging sector. This system was designed with two main objectives: to establish a well-structured product hierarchy with clearly defined technical attributes and to implement a "speaking code" system that simplifies identification. To develop this framework, we first analyzed historical Enterprise Resource Planning (ERP) data, an integrated system designed for managing business processes. We then refined the classification iteratively, ensuring that interchangeability was preserved through critical parameters. The process also incorporated multiple validation steps, gathering feedback from technical experts and international stakeholders to enhance accuracy. A key innovation of this approach is the introduction of the "speaking code," an alphanumeric string that systematically encodes both hierarchical and technical data. This eliminates reliance on free-text descriptions and ensures a structured, standardized method for classification. The code follows a three-tier structure - Category, Family, and Group - where each group is assigned essential technical characteristics, allowing for more precise classification. The first application of this system focused on the "Belt" family, demonstrating clear improvements in the organization of spare part data. The revised hierarchy introduced more detailed differentiation within groups, addressing inconsistencies found in the previous system. Looking ahead, future enhancements may include the integration of Artificial Intelligence (AI) and machine learning for automated classification, as well as efforts to standardize the system internationally to align with global operational needs. While this new classification system represents a significant improvement, its long-term success will depend on continuous optimization based on real-world feedback and evolving business requirements.

Keywords: Spare Parts Management; Standard Coding System; Operational Efficiency; Packaging Industry; Maintenance; Reliability.

1. Introduction

Effective spare parts management is critical to ensuring the reliability, safety, and efficiency of industrial operations. In manufacturing environments, particularly in sectors such as packaging, unplanned equipment failures can lead to costly downtime, increased operational risks, and safety hazards. Properly structuring maintenance materials and spare part inventories is therefore essential to reducing disruptions and optimizing resource allocation. However, many companies struggle with fragmented classification systems, inconsistent coding methods, and inefficient spare part retrieval processes, leading to delays in maintenance and increased risk exposure.

The literature underscores the critical role of effective spare parts classification in enhancing inventory management and minimizing downtime. Braglia et al. (2004) introduce the Multi-Attribute Spare Tree Analysis (MASTA) methodology, which helps identify the most critical spare part categories and define appropriate management strategies. Similarly, Hu et al. (2018) highlight the need for a comprehensive framework that integrates strategic, tactical, and operational decisions in spare parts management. Cavalieri et al. (2008) emphasize a systematic approach, advocating for structured classification and coding methods to improve operational efficiency.

Reliability-centered maintenance (RCM) principles further reinforce the importance of systematic spare parts classification as a cornerstone of operational resilience (Moubray, 1997). Studies indicate that misclassified or untraceable spare parts contribute to higher failure risks and increased maintenance costs (Sherwin, 2000; Kennedy et al., 2018). Additionally, ISO 14224 (2016), the international standard for reliability data collection, underscores the necessity of structured data management in maintenance planning and asset reliability analysis.

In line with these principles, developing a standardized coding system enhances the ability to track, identify, and manage spare parts efficiently, thereby improving both operational continuity and risk mitigation.

This paper presents a new classification system designed to address these challenges by introducing a structured product hierarchy and an intuitive "speaking code" system for spare parts identification. The methodology follows an iterative approach, leveraging historical Enterprise Resource Planning (ERP) data - an integrated system designed for managing business processes - validation processes, and expert feedback to refine the classification logic.

The system is implemented within a medium to large-sized company in the packaging sector and aims to:

- Establish a clear and standardized product hierarchy with well-defined technical attributes
- Improve interchangeability assessment through predefined classification rules
- Enhance inventory traceability by eliminating reliance on free-text descriptions
- Integrate the system with a widely used ERP software such as SAP (Systems, Applications, and Products in Data Processing) to enable real-time spare part monitoring.

By standardizing spare parts classification, this research provides a structured approach to minimizing operational risks, reducing downtime, and enhancing maintenance efficiency. The findings contribute to the broader field of reliability engineering and industrial risk management, offering a scalable solution that can improve decision-making processes in asset-intensive industries.

The remainder of this paper is structured as follows. Section 2 describes the methodology for developing the classification system, emphasizing the iterative refinement process and validation steps. Section 3 introduces the "speaking code" concept, outlining its hierarchical structure and technical attributes. Section 4 explores ERP integration, detailing how the system supports spare part searches and alerts for interchangeable items. Section 5 focuses on the application of the methodology on the "Belt" family, demonstrating improvements in spare part organization and retrieval efficiency. Section 6 discusses the initial implementation results, challenges, and potential refinements based on operational feedback. Section 7 concludes with future developments, including Artificial Intelligence (AI)-based automation and international standardization efforts.

2. Methodology

The classification system was developed around two primary objectives:

- Defining a product hierarchy with corresponding technical attributes
- Creating an intuitive "speaking code" system for easy identification

The process began with an analysis of historical data extracted from the ERP system, followed by the iterative construction of a new hierarchy. Technical characteristics were assigned based on existing descriptions and functional requirements, ensuring that critical parameters for interchangeability were preserved. To maintain classification accuracy, multiple validation steps were integrated, including feedback from the company's technical experts and input from opinion leaders across different countries.

Each spare part was classified according to a set of essential characteristics. To prevent errors and duplications, SAP was configured to generate alerts for potentially interchangeable items, requiring cross-verification before final assignment. The coding supervisor is responsible for approving final classifications, ensuring consistency and accuracy.

Alongside the hierarchy, standardized data entry templates were developed to eliminate inconsistencies in free-text descriptions and facilitate structured searches. This approach ensures that similar items are correctly grouped while avoiding unnecessary complexity and improving overall system efficiency

3. Speaking code development

A key innovation in the new system is the "speaking code", an alphanumeric string generated by SAP that concisely encodes both hierarchical and technical data. This code provides a structured yet compact representation of a spare part, replacing the previous free-text descriptions.

3.1. *Structure of the speaking code*

Each speaking code follows a predefined structure organized into three levels (Figure 1):

- *Category*. This represents the first level of classification, containing information about the type of spare part. However, the "machines" category has been removed, narrowing the selection to either mechanical or electrical spare parts.
- *Family*. The second level in the hierarchy provides more specific information about the spare part, indicating whether it is a motor, a pump, a drive, etc.
- *Group*. The group further refines the classification within the family, offering a higher level of detail. Each group will be associated with a set of technical characteristics, ensuring precise cataloging and facilitating future searches. For example, if a spare part belongs to the mechanical category and falls under the belt family, we can expect to find groups such as flat belts, toothed belts, and so on.

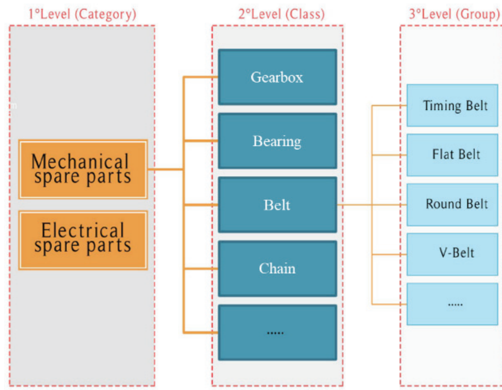

Fig. 1. Structure of the speaking code.

3.2. *Definition of technical characteristics*

Each group within the classification structure is associated with a defined set of technical characteristics, essential for accurately describing the spare part. The selection of these parameters was guided by the principle of interchangeability, which was prioritized over considerations of performance and efficiency. Two spare parts are considered interchangeable if one can replace the other in case of failure, even temporarily, to manage an emergency. To facilitate this, parts with identical technical characteristics are assigned to the same SAP code.

Given the complexity of spare part classification, it is impractical to define an exhaustive list of parameters for each item, as this would result in an excessive administrative burden. Therefore, a balanced approach was adopted: the selection of a sufficient yet manageable number of characteristics that ensure clear identification while minimizing the workload for codifiers and users. However, this method implies the exclusion of certain parameters that, in specific applications, might affect interchangeability. In such cases, the final responsibility for accurate classification falls on the codifier. SAP plays a crucial role in this process by generating alerts when a newly classified item appears similar to an existing one. It is then the responsibility of the codifier to perform a cross-check to confirm whether the items are truly interchangeable or if an additional distinguishing characteristic warrants a separate SAP code. The objective of defining technical characteristics is to establish a standardized framework for classifying spare parts, effectively acting as a filtering mechanism that groups similar items. The final decision, however, remains with the codifier, who must assess whether an item fits within the same classification or requires differentiation.

The technical characteristics assignment was developed in parallel with the creation of the new classification hierarchy. This process involved analyzing data extracted from the ERP system, examining the previous family structures, and systematically defining the new groups while assigning them relevant technical characteristics. The initial selection of characteristics was proposed by the Consortium, balancing the previous coding system's requirements with the technical parameters deemed essential for accurate classification.

This process was inherently iterative for two main reasons:

(i) Structural refinement. As the analysis progressed, certain spare parts and families emerged that required a reassessment of the classification logic.
(ii) Collaborative review. Once the family has been defined, its groups, and their technical characteristics, the proposal underwent a structured review by the company. A dedicated committee facilitated discussions between the two entities, refining the classification based on the company's internal feedback from highly qualified technical personnel.

Despite this rigorous validation process, the true efficiency of the classification structure and the selected characteristics will only be confirmed during the implementation phase. This will determine whether the hierarchy and parameters allow for easy identification of spare parts during the coding process.

To ensure completeness and consistency, codifiers are required to fill in all designated fields when classifying a spare part. Missing information must be retrieved to guarantee proper identification. Additionally, in most cases, the selection process is facilitated by predefined lists (drop-down menus), reducing errors associated with free-text entries and standardizing the classification workflow.

The logic behind the creation of the descriptive string is fairly straightforward. The system gathers information from both the hierarchical structure and the technical characteristics (Figure 2), combining and abbreviating them to generate a concise yet informative record.

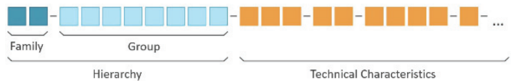

Fig. 2. Structure of a generic speaking code.

For clarity, an example of the descriptive coding assigned to the Timing Belt group, part of the Belt family, is provided: "Be-TimingBelt-S-AT10-mm-C-1111,1-222,2". Without delving into the specific meaning of each field, it is evident that the structure incorporates two pieces of information related to the product hierarchy and six technical characteristics. In total, this string consists of 38 characters, where the hierarchical information represents abbreviations of the family and group definitions. For each group, a careful selection process was conducted to include the most relevant technical parameters necessary for accurate identification.

4. Interaction with the ERP System

Following the design of the product hierarchy, the definition of technical characteristics, and the logic for generating the descriptive code, the IT department developed the user interface for SAP.

To facilitate data integration into the system, dedicated templates were created. These templates, progressively populated during the implementation phase, contain all relevant information regarding part codes and cataloged items. In addition to specifying which characteristics must be included for each group, the templates define essential metadata such as data type, field length, and validation rules, ensuring a structured and error-minimized data entry process.

Each group has its own template, which includes structured tables for entering technical parameters corresponding to each warehouse item, as well as detailed instructions for constructing the descriptive code.

The implementation phase requires close collaboration between warehouse personnel - responsible for spare part identification - and the company's IT department. Instead of performing a bulk data upload at the end of the process, data entry is distributed progressively throughout the implementation period.

Although the initial structures are loaded into SAP, they remain modifiable to accommodate unexpected needs arising from warehouse analysis. However, once templates are fully populated and committed to the system, modifications become irreversible.

Two critical functions within SAP are:

- Introduction of a new spare part. A dedicated input interface has been developed, enforcing mandatory completion of all required fields. The user must first enter commercial and location-related data, then proceed to define the product hierarchy and assign values to the technical parameters. These parameters must be fully specified, except in cases where SAP's conditional logic ("if" statements) allows the omission of non-applicable values.
- Spare part search. Maintenance personnel and warehouse operators can efficiently locate spare parts within SAP using the new classification structure. By filtering items based on their technical characteristics and location information, users can quickly identify and retrieve spare parts from the appropriate warehouse. If a replacement part is needed, the system enables the search for interchangeable items, i.e., those sharing the same technical characteristics. The user can specify the family and group to which the part belongs and enter relevant technical parameters into a search form. It is important to note that SAP's search logic is restricted within groups—detailed characteristic searches can only be performed within a predefined group rather than across multiple groups. Therefore, selecting the correct group is a prerequisite for initiating an effective search.

Once the product hierarchy is selected, SAP generates a guided search interface, allowing users to refine their queries based on available technical characteristics. This process does not necessarily identify a single, specific item, but rather filters a set of items that match the specified hierarchical and technical criteria. After this filtering step, a physical verification is required to pinpoint the exact spare part.

5. The "Belt" family

The first family analyzed is belts, which belong to the mechanical spare parts category. Prior to designing the new structure, a thorough analysis was conducted on SAP data extractions related to belts, which were also classified as a distinct family in the previous coding system. This analysis revealed that the old hierarchy often lacked the three-level classification, frequently stopping at the second level. To enhance clarity, not all groups will be examined in detail, but focus will be placed on the most noteworthy cases. Among the seven groups introduced, the first five differentiate belts based on their morphological characteristics. The last two groups, however, were created based on functional criteria:

- Conveyor belt. Includes all belts that do not transmit power. Structurally, they resemble standard belts (as shown in Figure 3), but their function within the facility differentiates them. Following discussions with the company's technical teams, it was deemed necessary to distinguish these belts from others, both physically in the warehouse and virtually in SAP.
- Special belt. This group exists in almost every family and serves as a catch-all category for belts that do not fit into predefined groups. Special belts have unique characteristics that are not fully described by any of the existing technical characteristic sets. In this group, only the belt type and an additional information field (a free-text entry limited to 20 characters) are recorded. While the new classification structure largely eliminates free-text fields, this exception was made to accommodate unique cases. Data entry fields are otherwise standardized and constrained to prevent input errors.

Given that code creation and management is now centralized under a single responsible entity, the risk of classification errors is significantly reduced.

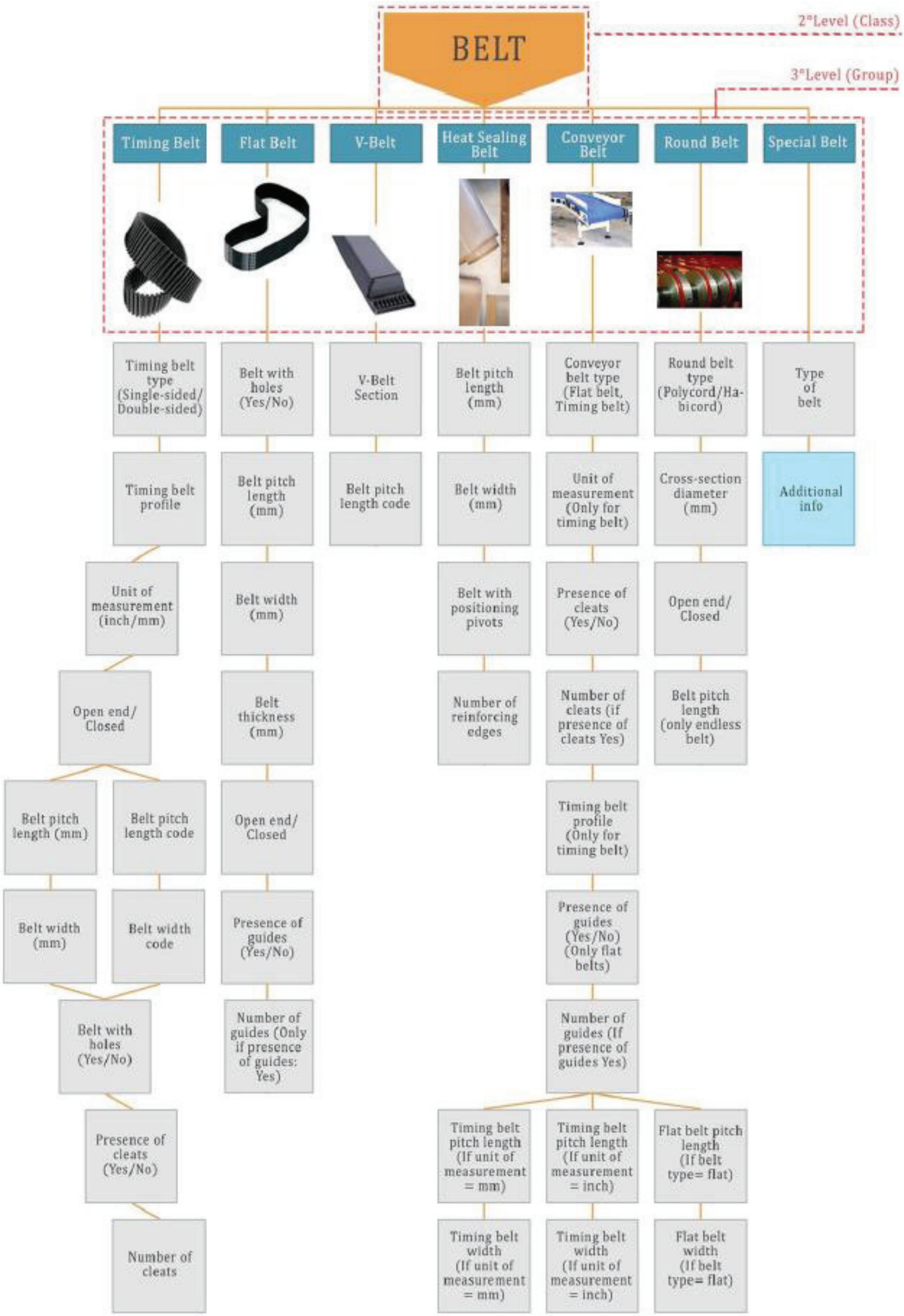

Fig. 3 Structure of the "Belt" family.

5.1. Tooth belts

The tooth belt group includes nine technical characteristics. Some of the key parameters and their rationale are as follows:

- Belt type. It defines whether the belt has single or double teeth. This field is restricted to predefined values and managed through an SAP dropdown selection menu.
- Belt profile. It Specifies the tooth profile, represented by an alphanumeric string. This characteristic is also predefined and managed through SAP's help file.
- Unit of measurement. Introduced for certain tooth profiles (e.g., L, XL), which are conventionally measured in inches instead of millimeters. This field triggers an if-logic within SAP: Selecting "mm" enables entry for belt pitch length and belt width (both in mm). Selecting "inch" disables these fields and activates belt pitch length code and belt width code instead.
- Open End/Endless. It specifies whether the belt is stored as a roll (open-ended) or pre-cut for direct use. Open-ended belts do not require a length specification, as it would need constant tracking. Instead, an internal logic assigns a default length of 1 (since SAP does not accept a length value of zero).
- Belt pitch length and Belt width. Numeric fields available only when "mm" is selected as the unit of measurement. These fields define the belt's developed length and width.
- Belt pitch length code and Belt width code. Alternative fields used when the "inch" unit is selected. Instead of direct inch values, they contain a code that can be converted into measurable values. Since these codes are printed directly on the belts, they facilitate quick identification.
- Presence of cleats and Number of cleats. If cleats are present (dropdown selection: Y/N), the user can enter the number of cleats. Otherwise, this field remains disabled.

Once the product hierarchy and technical characteristics have been defined, SAP automatically generates a descriptive code that synthesizes the most relevant attributes of each item. To keep the code concise while maintaining clarity, only a selection of key technical parameters is included.

For tooth belts, the descriptive code varies depending on whether the belt is pre-cut (endless) or open-ended (stored in a roll). In the case of a pre-cut belt, the generated code follows a structured format. For example, the code Be-TimingBelt-S-T10-mm-C-1111,1-22,2" conveys multiple pieces of information. The first part, "Be-TimingBelt," represents the product hierarchy, identifying the belt family and the belt group. The letter "S" specifies that the belt has a single-tooth profile, while "T10" defines the tooth profile and pitch. The abbreviation "mm" indicates that the unit of measurement is in millimeters. The letter "C" signals that the belt is closed-loop, meaning it is pre-cut and ready for use. The numbers "1111,1" and "22,2" correspond to the belt's pitch length and width, respectively, both measured in millimeters.

For an open-ended belt, which is stored in rolls, the code takes a slightly different form. The sequence "Be-TimingBelt-S-L-inch-O-1-075" reflects these variations. Here, the letter "L" signifies a pitch measurement of 3/8 inches, while "inch" replaces "mm" to indicate that the belt's dimensions follow the imperial system. The letter "O" denotes that the belt is open-ended rather than pre-cut. Since the length of an open-ended belt is not fixed, the value "1" is used as a placeholder. The width of the belt is represented by "075," a coded value that, when divided by 100, provides the actual width in inches.

To aid users in interpreting these codes, reference materials such as the system taxonomy for product hierarchy and the SAP help system for technical specifications are available.

6. Discussion

The introduction of the new classification The introduction of the new classification structure has significant potential for enhancing warehouse management and operational efficiency by standardizing coding procedures and eliminating inconsistencies. A key achievement is the creation of specific groups with well-defined technical characteristics, allowing for more precise classification. Additionally, the development of a descriptive coding system has improved spare part traceability, streamlining identification and retrieval processes. Despite these advantages, certain challenges require evaluation during implementation. Retrieving necessary coding information may prove difficult, potentially slowing the cataloging process and leading to classification errors. If such issues arise, refining the set of technical characteristics may be necessary. Another critical aspect is operator adoption, as the success of the new system depends on user engagement. Although the structured approach is more intuitive than the previous system, initial resistance to change could hinder adoption. Providing comprehensive training, technical support, and validation will be essential to ensuring a smooth transition.

7. Conclusions and future developments

The introduction of the new classification hierarchy and coding system represents a significant advancement in spare parts management within the company. The rationalization of families, the definition of groups with specific technical characteristics, and the adoption of a descriptive code offer a structured and scalable approach, capable of improving both operational efficiency and the reduction of warehouse immobilizations. By standardizing the classification process, this system enhances spare part traceability, reduces human error, and optimizes maintenance procedures, ultimately contributing to improved reliability and reduced operational risks. Furthermore, the methodology offers a replicable framework that can be extended to other industrial sectors facing similar inventory management challenges. However, the work completed so far constitutes only the initial phase of a broader process. The next crucial step will be the implementation phase, during which the actual functionality of the new structure in the operational environment will be evaluated. At this stage, it will be essential to monitor any difficulties encountered by users and collect data on the system's effectiveness in facilitating spare part search and coding processes.

A potential future development involves integration with advanced data management tools, such as artificial intelligence or machine learning systems, which could further enhance the automation of the classification process. For instance, AI-driven image recognition and natural language processing could streamline the identification and categorization of spare parts, reducing reliance on manual data entry and improving classification accuracy. Additionally, predictive analytics could be employed to anticipate spare part demand, optimizing stock levels and reducing procurement lead times. Another area for improvement concerns international standardization, ensuring that the classification system can be uniformly applied across all company sites. This will require a careful review of the terminology used and potential adaptation to local regulations. Ultimately, the new classification structure represents an important innovation in spare parts management. Its successful adoption has the potential to redefine best practices in inventory management, reducing inefficiencies and strengthening industrial resilience. However, its full success will depend on its ability to adapt to real operational needs and evolve over time through a continuous process of improvement and optimization. As companies increasingly embrace digital transformation, this methodology provides a foundational step toward a more data-driven, automated, and standardized approach to spare parts classification.

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