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Using TRIZ and patent information for studying product evolution

Fernando Câmara Labouriau[a], Ricardo Manfredi Naveiro[b]
[a]Instituto Nacional da Propriedade Industrial
[b]Universidade Federal do Rio de Janeiro
e-mails: fernando.labouriau@globo.com; ricardo.naveiro@poli.ufrj.br

Abstract: This paper refers to a framework using product evolution perspective for analysis of product development strategies and processes used by enterprises. The framework combines information from the patent system with some tools obtained from TRIZ methodology. This methodology, initially developed to solve technical problems and innovate and, more recently, play a strategic role in technology forecasting, may also provide an effective rationale to study product development process. A case study is presented defining the maturity level of a reference product by a proxy of the product S-curve, and by decomposing and analyzing the product along 10 evolution trend lines to understand development strategies, forecast future designs and assess competitive products.

Keywords: product development, patents, TRIZ.

1. Introduction

This paper is focused on studying the technical evolution of a product using the information available in the patent system and the tools provided by TRIZ methodology. Accordingly, the product evolution perspective can be used as a framework for understanding the product development process and for evaluating the technological strategies employed by innovative enterprises. In the case study of this paper, the patent retrospective view provided a background for assessing the maturity level of the selected product and the TRIZ evolution trends provided the analytical framework for understanding development strategies and forecasting future designs.

The development of new products became a vital competitive dimension as a result of all changes that occurred in the enterprise environment and currently is playing an essential role in the business strategies of companies as well as the strategic guidance is also influencing the choices and assumptions of such developments.

At the same time, the strategic and proactive use of the intellectual property (IP) information is presented in some methodologies for selecting projects, mapping technological change, generating product concepts, optimizing products, doing competitive intelligence or fostering the co-evolution of patent and product strategies. One of these methodologies is TRIZ, a theory created to favor innovation and improve product design that provided the analytical framework for this case study.

In Section 2, it is presented an introduction to TRIZ with some basic information on the TRIZ tools that were used and the methodology of this work. Section 3 presents the reference product that was studied and the related patent historical data. In Section 4, the reference product is decomposed according some evolution trends for providing the analytical information to be used in the discussion of Section 5 and in the paper conclusion, in Section 6.

2. An introduction to TRIZ and the methodology for the case study

TRIZ is the acronym for the Russian words that mean *theory of inventive problem solving*, a theory created by Genrich S. Altshuller. In his work, after analysing over 200,000 patents, Altshuller concluded that the fundamental principles for ingenuity and problem solution were not limited by contradictions and design compromises (MAZUR, 1996).

Also, according to Nakagawa (2001, p. 01):

> [The] essence of TRIZ [is] the recognition that technical systems evolve towards the increase of ideality by overcoming contradictions mostly with minimal introduction of resources. Thus, for creative problem solving, TRIZ provides a dialectic way of thinking, ie, to understand the problem as a system, to image the ideal solution first, and to solve contradictions.

As innovative patents usually provide solutions to contradictions, these solutions often being identified along repeatable lines of evolution, the theory considers that specific patterns of design evolution could be followed to solve problems. The two main points of these patterns found in the development of a design are the regularities in design evolution and the principles used in innovative solutions (TERNINKO; ZUSMAN; ZLOTIN, 1998). These patterns of evolution were originally called by Altshuller as *general laws of dialectics* or *laws of the development of technical systems*, considered by the author as an effective technology for solving inventive problems (ALTSHULLER, 1984).

Accordingly, Altshuller (1984) proposes TRIZ as an alternative to the traditional view about the art of invention based on innate abilities or inventor diligence whereby many variants of solutions are tested and discarded as "empty" attempts. He also points out the phenomenon of *psychological inertia* represented by the trend for people to drive the search of alternatives to problem solving in areas that are known or close to their specialties. The psychological inertia described by Altshuller resembles to the problem of *functional fixedness* or *fixation* studied in the Design discipline and described as:

> [...] people appear to be unable to see new ways of using objects which could lead to the innovative solution required, because they are blocked or fixated on well learnt uses or properties of the object [...] (PURCELL; GERO, 1996, p. 363).

Following in this section, it is presented the metrics for analysing a system evolution, derived from Altshuller's work with patents (Subsection 2.1), the evolution concepts resulted from the general laws of dialectics (Subsection 2.2) and the methodology used in the case study (Subsection 2.3).

2.1. The four metrics for analysing a system evolution

In his work, Altshuller separated the patents according to five levels of inventiveness: (1) conventional solution; (2) small invention inside a paradigm; (3) substantial invention inside technology; (4) invention outside technology; (5) discovery, a level that represents only 1% of total inventions (TERNINKO; ZUSMAN; ZLOTIN, 1998). And an important contribution of Altshuller's work was to combine his analysis with patents and the S-curve pattern of the life of technological systems, as described in this subsection.

About the S-curve, or the "life curve", he emphasized that (ALTSHULLER, 1984, p. 210):

> The inventor needs to know the characteristics of the "life curve" of technical systems. This is necessary for a correct answer to a problem of vital importance for inventive practice: "ought one to solve a given problem and improve the technical system specified in it or present a new problem and arrive at something which is fundamentally new"?

Figure 1a represents schematically such a curve depicting a system from childhood to maturity, with an initial slow development phase ending at point 'α', a fast development phase ending at point 'β', another slow development phase ending at 'γ' and a final phase that can be one of the alternative curves: stalling (curve 4), degradation (curve 5) or renaissance (curve 6). As it is not always straightforward to get the necessary information to plot a performance S-curve for a system, Altshuller correlated other inventive activities with the S-curve to determine where a product is placed along its evolutionary S-curve. These other metrics are Number of inventions (Figure 1b), Level of inventions (Figure 1c) and Profitability of inventions (Figure 1d). Figures 1a to 1d and the metrics they represent are discussed in details by Altshuller (1984), Fey and Rivin (1999) and Mann (1999).

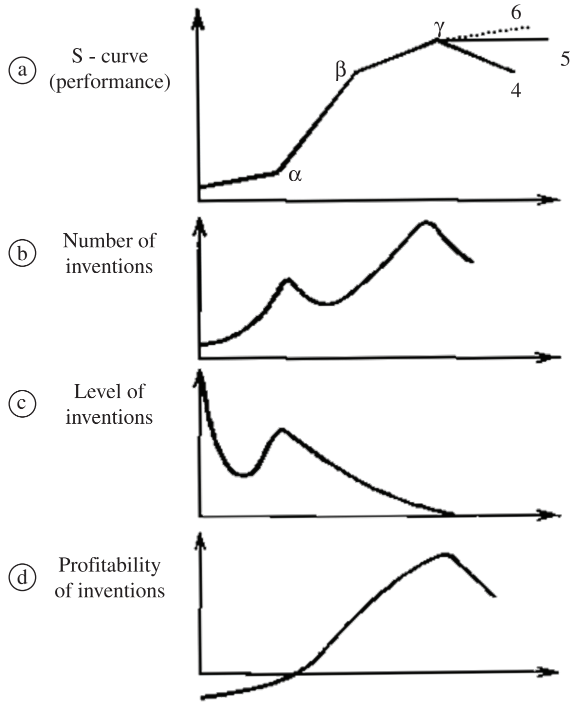

Figure 1. The four metrics for analysing a system evolution. Source: Fey and Rivin (1999).

On his studies with patents, Altshuller realized that at the beginning of a new product or system life there are few but very creative and non lucrative inventions focused on the product or system. The curves in Figures 1b-d present peaks and inflexions that correspond to the points 'α', 'β' and 'γ' in Figure 1a to demonstrate how the quantity, the quality and the profitability of the inventions correlate with the different development phases of the product or system. Specifically for this case study, it is proposed the number of inventions as a proxy for knowing the S-curve and the maturity stage of the product under analysis, as presented in the case study methodology.

2.2. Patterns of evolution and evolutive potential

In Altshuller (2002), the axiom that "the evolution of all technical systems is governed by objective laws" is considered the basis of TRIZ to indentify the patterns or laws by which this evolution occurs. Fey e Rivin (1999, p. 2) provide also an interesting reading of the laws of evolution:

> The laws of evolution reflect significant, stable and repeatable interactions between elements of technological systems and between the systems and their environment in the process of evolution.

However, Fey and Rivin (1999) advice that these laws are more related to a general direction for further system transformation and that a more detailed and specific study of this transformation is provided by the lines of technological system evolution. Similarly, Zhang et al. (2007) consider that a pattern (or law) can encompass several lines of evolution that are more specific and have more predictive power. Mann (2007) also works with 37 evolution trends (or lines) derived from the original TRIZ laws and divided into the dimensions of space, time and interface.

According to Mann (2007), the evolutionary trends were identified in the analysis of thousands of patents and are consistent with the ideality concept that is considered a driver of the technological evolution since the beginning of the TRIZ studies. This author emphasizes that the trends of evolution can play two relevant roles in the technical field, one as a strategic tool for predicting system evolution and the other as a problem solving tool.

Altshuller (2002) and Terninko, Zusman and Zlotin (1998) indicate the following laws or patterns of evolution.

- Evolution in stages (1)

This pattern reflects Altshuller's work with S-curves obtained from the maturity analysis of products and patents to study issues such as the current position of a product or technology, the relationship between the evolution stages of different levels of the system and the occurrence of technological changes, illustrated by Terninko, Zusman and Zlotin (1998) as a succession of S-curves.

- Evolution toward increased ideality (2)

According to Altshuller (1984, p. 228), "[...] the ideal system is [achieved] when there is no system but its functions are preserved and carried out". Or, as stated in Altshuller (2002, p. 16): "The Law of Ideality states that any technical system, throughout its lifetime, tends to become more reliable, simple, effective – *more* ideal".

- Evolution toward increased dynamism and controllability (3)

This pattern refers to the transition from systems with rigid structures to more flexible systems, from static to mobile systems.

- Increased complexity then simplification (reduction) (4)

This refers to evolving by the addition of elements or functions, possibly resulting in a new homogeneous or heterogeneous system, followed by a subsequent rejection of the elements in excess and back to a single system, in order to start a new cycle

- Evolution toward micro level and increased use of *fields* (5)

Technological systems tend to evolve from macro systems to micro systems, the transition from a macro to a micro system being accomplished with the use of different types of energy fields in order to achieve better performance or control. According to Altshuller (1984), a system can be restructured modifying its working organ on a macro level, called as "irons", to a working organ that acts on a micro level as molecules, atoms, ions, electrons, etc., but preserving the system functions.

- Synchronization and desynchronization, or symmetry and asymmetry (6)

The systems evolve by matching or mismatching their elements in order to improve performance and to compensate for undesired effects

- Non uniform development of system elements (7)

Since each element can have its own S-curve, the system elements can evolve differently and have a different timing for reaching its development limit, thus creating weak links in the design. This pattern shows that, according to Terninko, Zusman and Zlotin (1998, p. 133), "understanding the interaction of all the components that influence performance is key to understanding the design."

- Automation or evolution toward decreased human involvement (8)

This pattern can be regarded as a consequence of the pattern Evolution toward micro level and increased use of *fields* so that systems evolve and assume repetitive tasks, thus allowing people to concentrate on intellectual work.

Associated with the evolution patterns or trends there are the concepts of *evolutionary limit* and *evolutionary potential* of an existing system, the evolutionary potential being defined as the difference between the current stage and the evolutionary limit, a development limit of the system. Thus, a system can be compared with the general trends of TRIZ and be positioned in the evolutionary lines of these trends to identify the stages that have not been explored yet, in order to define the evolutionary potential of the system (MANN, 2007).

2.3. Case study methodology

A reference product was selected to perform the case study, the product and its related technology being described in more details in Section 3. Prior to any work, exploratory consults were done at the reference product manufacturer web page and about some basics of the reference product technology.

The main steps for getting information and doing analysis were the following (the information and graphics obtained through steps 'a' to 'd' are presented in Sections 3 and 4, and discussed in Section 5):

- Determination of the S-curve or the maturity stage using the metric of Number of inventions

The patent classification structure was used to obtain a historical patent count for the two major technical characteristics of the reference product.

- Searching into patent databases for patents of similar or analogous products

This step includes searching for other patents of the reference product manufacturer, searching for patents of exemplar designs (remarkable designs that can represent evolution steps in the product history) and searching for patents of competitive products or technologies.

- Selection of the evolution trends most suitable to the reference product

Considering that the 37 evolution trends proposed by Mann (2007) are more specific and detailed than the rather generic patterns or laws of evolution, there were selected 10 trends, from the 37 trends list, that would better represent the product under study in the space, time and interface dimensions.

- Definition of the current evolution stage in each trend considering the reference product or the exemplar designs of similar technology, and plotting the evolutionary potential curve.

3. The reference product and related patent information

The chosen reference product is the 18 liters (approximately 5 gallons) square metal pail manufactured by Brasilata, a can manufacturer established in Brazil since 1955.

A pail is a kind of metal can or bucket used for containing paints, flammable liquids and other products. Metal cans or "tin cans" have been manufactured in the last two centuries for containing a multitude of products, from edibles and beverages to several industrial products (according to the Wikipedia (2013), the first patented can was invented by the Englishman Peter Durand, in 1810). Can sizes range from 0.2 liter to 30 liters and the usual shape is cylindrical but square or polygonal shapes are also popular as they are more effectively packed for storing or transportation.

The reference product is described in the Brazilian patent application BRPI0901615 (filed in 14.05.2009) and is designed for containing flammables in accordance with international standards. Figure 2 shows the reference product (all patent documents cited in this paper can be found in the ESPACENET web page, see References).

Square and cylindrical metal pails are normally formed by a container body or vertical wall joined to bottom and cover walls. The body usually has a vertical joint made by welding or seaming on the metal plate. Seaming is a hook type of joint, leakage proof, that is also the preferred way for joining the body to the bottom and cover walls.

Inventions using seam joints date back to more than a century ago, at least, see Figures 3 and 4 below (the patent application dates are informed between brackets, after the patent numbers).

Patent information was searched considering the patent classification structure and the keywords related to some product technical characteristics. It was mainly used the european patent classification EC, from the European Patent Office (EPO), for metal containers formed by two or more rigid components (B65D7 main group) and the EC classification for lids or covers for rigid and semi-rigid containers (B65D43 main group). Searches were done at the Espacenet free access database and at the Epodoc database, a proprietary database of the EPO (the EC classification system was replaced in January 2013 by the CPC system, a cooperative classification system developed by the United States Patent and Trademark Office – USPTO and the EPO).

There were selected the Brasilata patent documents related to the development of the reference product and the most historically relevant worldwide documents, some of them being discussed in more details in Section 4. Histograms of the patent applications to the USPTO were obtained for inventions classified as B65D7 main group (Figure 5) and B65D43 main group (Figure 6).

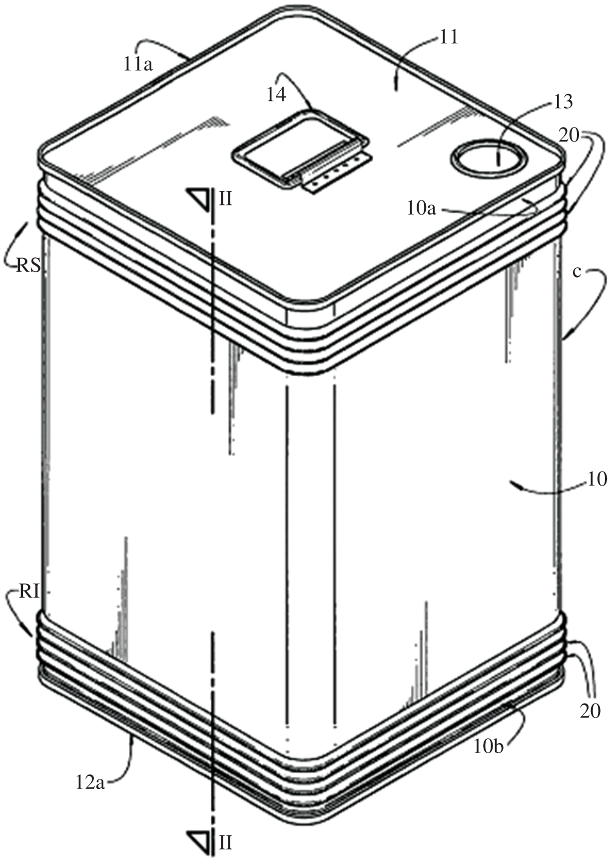

Figure 2. The square pail according to the BRPI0901615.

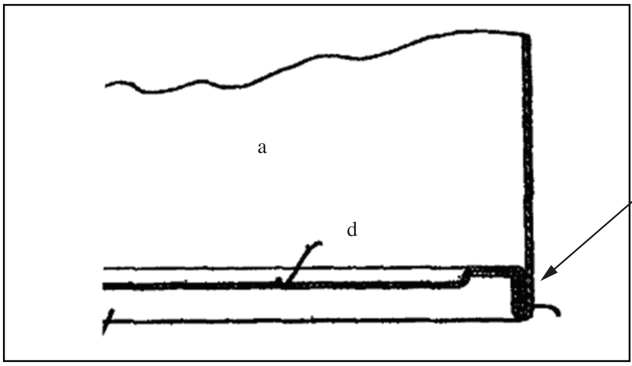

Figure 3. GB191126611 (28.11.1911).

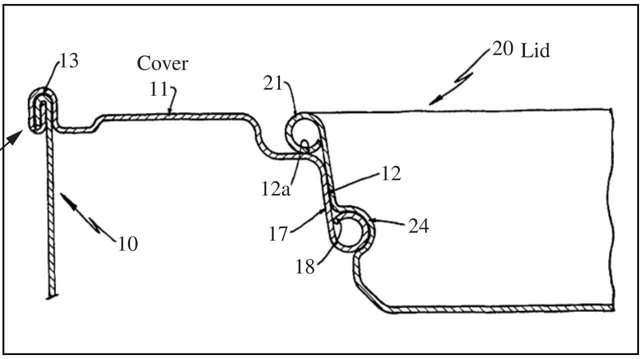

Figure 4. BR7400485U (03.05.1994).

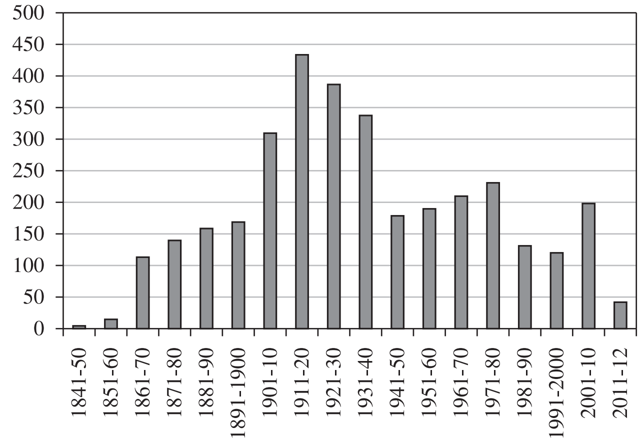

Figure 5. Applications to the USPTO of inventions classified as B65D7.

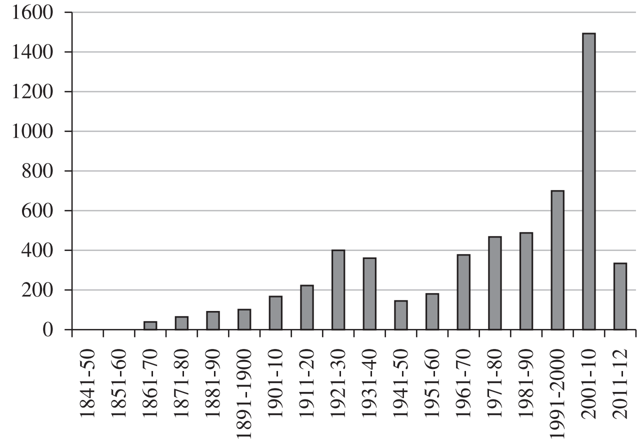

Figure 6. Applications to the USPTO of inventions classified as B65D43.

On comparing these histograms with Altshuller's metric Number of inventions (Figure 1b), one can observe the following points:

- Both histograms present oscillations in the number of inventions as the product technology evolves, similarly to Figure 1b;
- B65D7 main group (Figure 5) shows a decreasing invention rate for the body design of multi-component metal cans, probably indicating that the technology is very mature and beyond point 'γ' in the S-curve of Figure 1a;
- B65D43 main group (Figure 6) indicates a remaining effort to improve can lids and covers and one may assume that the S-curve of these components is still in a slow development pace, probably between points 'β' and 'γ' (it must be observed also that this main group refers to either metal and non-metal cans);
- In general, the metal pail technology is in a mature stage thus providing enough information about product evolution for understanding past development strategies as well as for devising future development alternatives and possible threats.

Also there were made searches for containers made wholly or mainly by plastics for comparing the case study product with a competing technology, in the discussion of Section 5. See a histogram of plastic containers in B65D1 main group (containers formed in one piece, made of plastics or other materials), in Figure 7.

Plastic containers seem to be still in a fast development stage, probably reaching point 'β' in the S-curve of Figure 1a. One may suggest that the emergence of the plastic industry during the second half of the twentieth century impaired the metal container development from that time on.

4. TRIZ evolution trends of the reference product

This section presents the evolution trends that were considered the most suitable for evaluating the reference product, based on the research work made by Mann (2007) to expand the original Altshuller's laws to 37 trend lines of evolution. Mann divided these trend lines into the space, time and interface dimensions as they favor to change the perspective on problems and to think about situations from all angles (MANN, 2007).

The trends used in the case study are mainly focused on the space dimension to match with the "container" characteristics of the product under analysis - items 'a' to 'f', below, are trends in the space dimension, item 'g' is a time trend and items 'h' to 'j' are interface trends. The selected trends are presented here considering that normally technical evolution occurs through stages in trend lines that evolve from left to right in its way to enhance ideality.

At the end of this section, a radar plot is drawn showing the evolution of the 10 selected trends for the reference product and the overall metal pail technology.

- Space segmentation (a)

Monolithic solid → **Hollow structure** → Structure w/ multiple hollows → Capillary / porous structure → Porous structure with active elements

This trend is derived from the law of evolution toward micro level and increase use of fields (pattern no. 5, in Subsection 2.2) whereby systems evolving from macro to micro level can improve their performance or control. Examples of product evolution along this line show results in reducing weight or use of material, improving heat transfer or strength properties, adding new functions, etc.

It was considered that the current stage of pails is 'hollow structure' (current stages are in bold type in the trend lines), as this structure is typical for containers with a free internal volume to be filled with liquids, powder, particulates, etc.

- Surface segmentation (b)

Smooth surface → **Surface w/ 2D rib protusions** → 3D roughened surface → Roughened surface + active elements

This trend as well as the trends of items 'c' and 'd' are also derived from the law of evolution toward micro level and increase use of fields. Typically, evolution in surface segmentation results in better grip, traction, heat transfer or aerodynamic controllability, among other improvements.

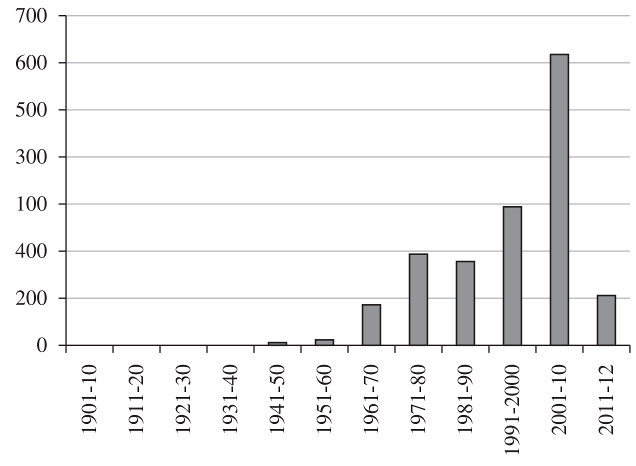

Figure 7. Applications to the USPTO of plastic containers and B65D1 group.

Many patents of pails and buckets found in this work presented 2D ribs or beads on side wall for reinforcement purposes in order to prevent wall buckling when sheet metal thickness is reduced, see examples in Figures 8 and 9. Also Brasilata manufacturer had some earlier designs with wall reinforcements, but regarding the reference product the side ribs seen in Figure 2 have another purpose as it will be discussed below (see Dynamization, item 'f').

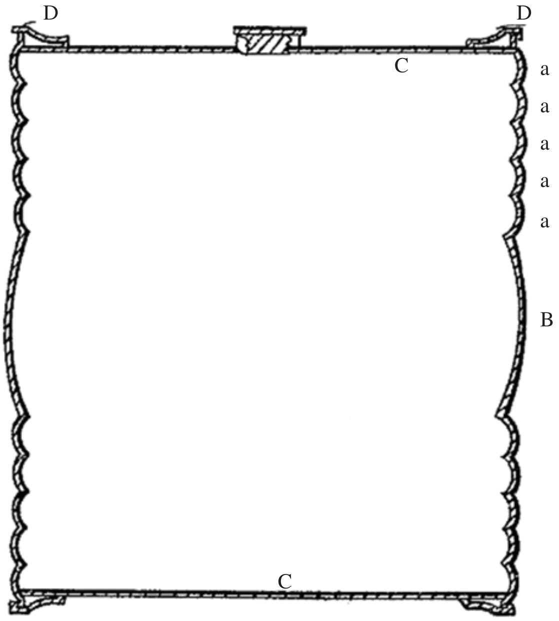

Figure 8. US16944 (31.03.1857).

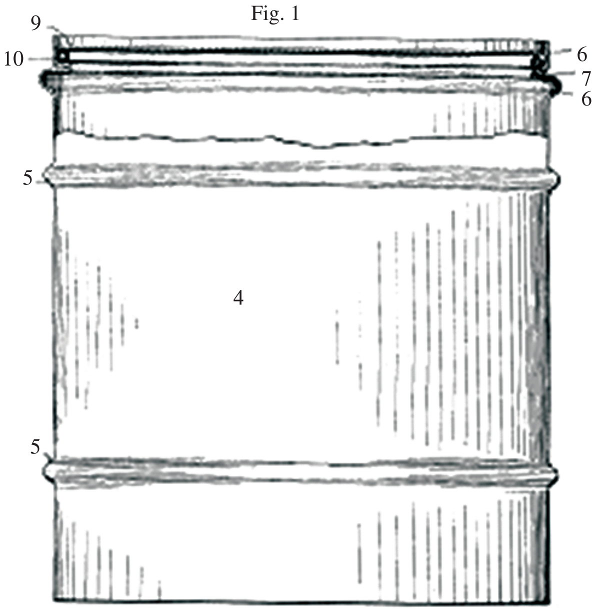

Figure 9. US1385413 (27.01.1919).

- Object segmentation (c)

Monolithic solid → Segmented solid → Particulate solid → **Fluid** → Segmented fluid (foam, aerosol) → Gas → Plasma → Field → Vacuum

In this trend, the analysis was elevated to an upper level and considered the segmentation of the contained product instead of studying the container segmentation itself as, according to Altshuller (1984), when a system had exhausted the possibilities of development it should be included as a part of a supersystem with further development taking place at the supersystem level (see also item 'h', Nesting-up).

Object segmentation is appointed by Mann (2007) as a "do more with less" trend, as evolution in this trend facilitates transport or packing, increases system flexibility, mixing capability or dispersion rate, facilitates flow-rate controlling, among several other possibilities.

Normally, the products contained in pails or buckets are fluids, however a change in the physical state of the filled product may improve container parameters or product application. For instance, an application process could be developed to employ products in particulate form, thus improving the process performance in a supersystem level, albeit resulting in a regression at the product level (from 'fluid' back to 'particulate solid') – a typical example is paint in powder form that is used in the electrostatic painting process of metal parts.

- Webs and fibers (d)

Homogeneous sheet structure → 2D regular mesh structure → 3D fibre alignment according to load conditions → Addition of active elements

This trend is focused on the evolution of materials as the development of composites and materials with active elements that improve strength/weight ratios, increase flexibility or durability, add new functions, etc.

Traditionally, metal containers are made of thin homogeneous sheet, as the reference product and many other examples in this paper, so this trend is still at stage one. However, it was found an example of a pail that could be manufactured from a metal/plastic composite sheet (see Figure 12 and item 'g', Matching to external non-linearities), so metal containers may be evolving to the second stage, the '2D regular mesh structure' stage.

- Geometric evolution (volumetric) (e)

Planar structure → **2D structure** → Axy-symmetric structure → Fully 3D structure

The reasoning for this trend line, as well as for the linear Geometric evolution line, is that although real live is in a 3D world traditional manufacturing were dominated by 1D or 2D systems. Mann (2007) states that both the linear and volumetric geometric evolution trends have important relationship with the manufacturing technology and the emergence of new capabilities in this area has paved the way for product evolution towards fully 3D dimension with several benefits in load distribution, flow distribution, ergonomics, strength, surface area, etc.

Square or polygonal pails are defined by their cross section in 2D dimensions, so they are in the second stage, as the reference product. In the other hand, cylindrical pails or buckets are considered in the third stage, as they have an 'axy-symmetric structure' (a structure of revolution).

- Dynamization (f)

Immobile system → **Jointed system** → Fully flexible system → Fluid or pneumatic system → Field based system

This trend line is equivalent to the evolution line of increasing flexibility and is based on the law of evolution toward increased dynamism and controllability (pattern no. 3, in Subsection 2.2). According to Fey e Rivin (2005, p. 121), in the law of increasing dynamism (flexibility)

> Technological systems evolve in the direction to more flexible structures capable of adaptation to varying performance regimes, changing environmental conditions, and of multifunctionality.

The reference product represents a good example of the stage 'jointed system' where flexibility is improved: the pail body has corrugations to weaken the side wall instead of strengthening it in order to protect the upper or lower seams and the integrity of the lid seal in cases of pail falls (see Figures 10 and 11).

- Matching to external non-linearities (g)

Linear consideration of system → **Partial accounting of non-linearities** → Full accommodation of non-linearities

This is a time trend derived from the law or pattern synchronization and desynchronization, or symmetry and asymmetry (pattern no. 6, in Subsection 2.2). It accounts for the identification of non-linearities that a system may

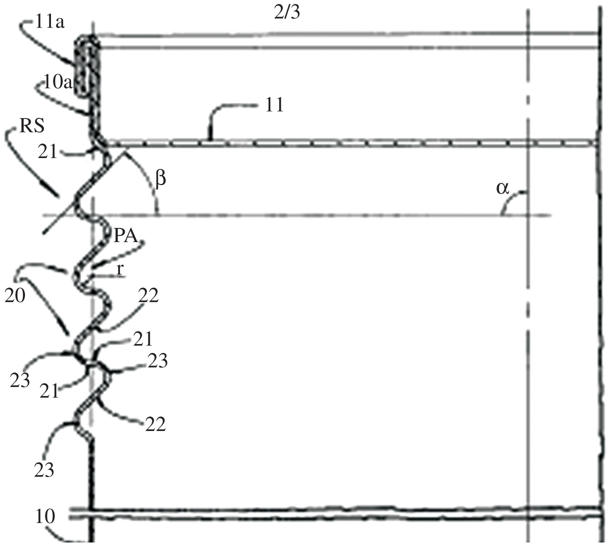

Figure 10. BRPI0901615 – upper side.

be exposed during operation, the evolution occurring with contradiction-breaking designs that solve these non-linearities. The evolution upon this line would reduce complexity, cost and risk of catastrophic failure, or improve reliability and user safety.

Designs considering multi-stacking of pails, rough handling or harsh ambient conditions may provide such 'partial accounting' as shown in the trend line. The weakening design of the BRPI0901615 wall, as shown above, is an example of such accounting. Some other examples are the reinforced cover to side wall joint made by Electron Beam or Laser welding in the metal or metal/plastic composite can, of Figure 12, and the seal design of a pail lid to withstand vapor pressure of liquid flammables at abnormal temperatures, as shown in Figure 13.

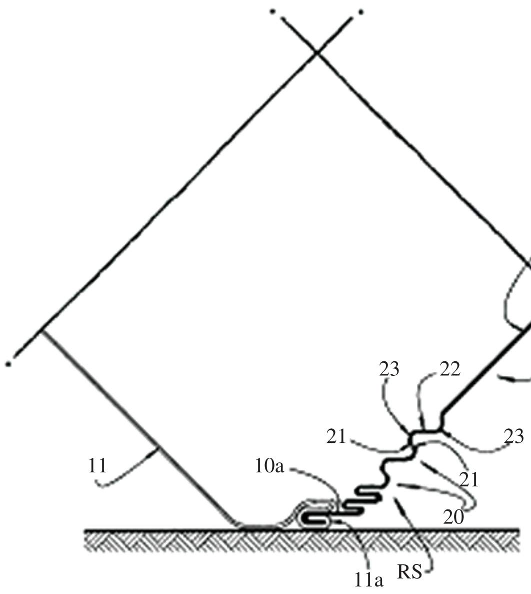

Figure 11. BRPI0901615 – fall test.

- Nesting (up) (h)

Independent structure → Structure connected into higher level system → Completely integrated into higher level system

This is an interface trend, directly derived from the original Altshuller's law of the transition to a supersystem (ALTSHULLER, 1984). According to Mann (2007), this trend considers that "as systems evolve towards more ideal states, functions tend to migrate from subsystem components to higher levels." The reference product as well as any other patented pail found in the searches are at stage one.

- Controllability (i)

Direct control action → **Action through intermediary** → Addition of feedback → Intelligent feedback

Also derived from the law of evolution toward increased dynamism and controllability, this trend achieves its ideal or final stage when the need for a control system disappears and the system becomes self-controlled.

Two examples of the 'action through intermediary' stage were identified:

- Figure 4 shows a Brasilata design that indicates the container violation if there is an unauthorized opening of the lid, as forcing the lid out of its sealing areas will necessarily result in marks and scratches in the container cover;
- Figure 14 refers to a lid design that expands (through the weakening zones '46', see reference numbers in the drawings) to relieve any internal pressure increase that might occur inside the container and at the same time it aligns the wrinkles '47' that are formed to

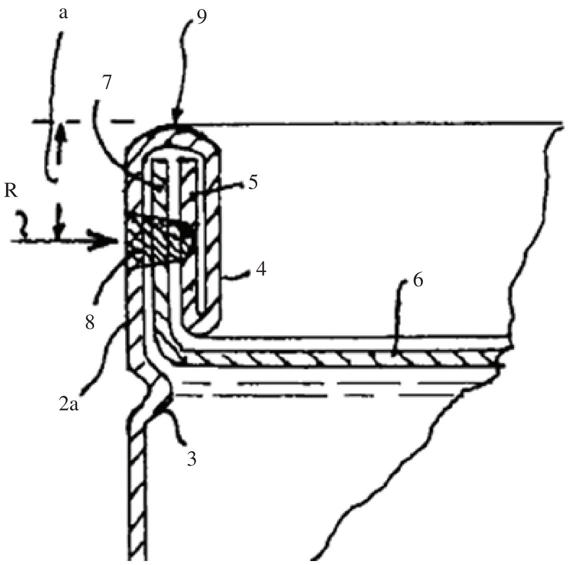

Figure 12. DE3842452 (16.12.1988).

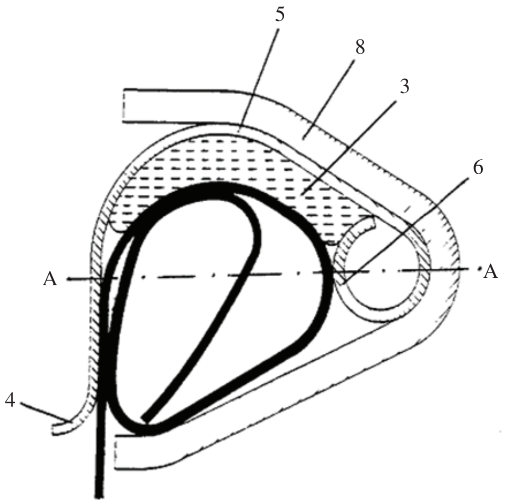

Figure 13. EP0565762 (16.04.1992).

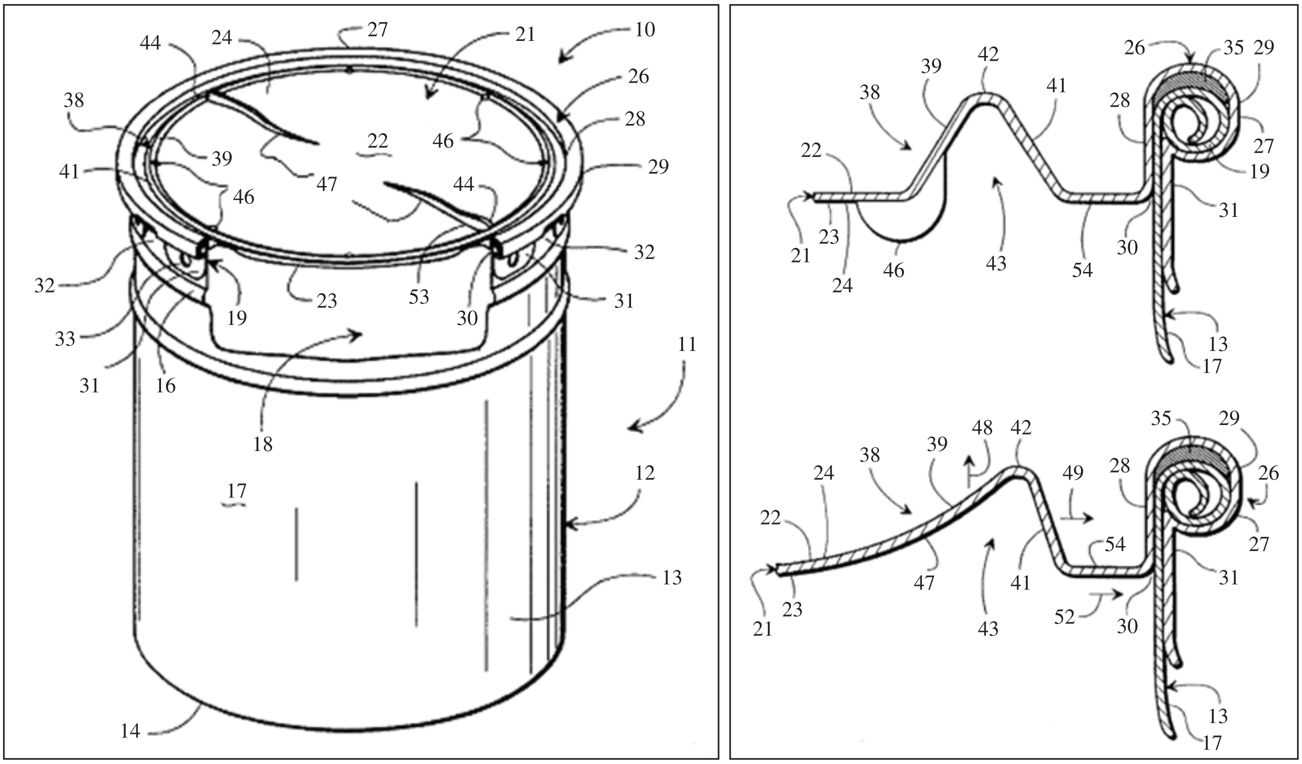

Figure 14. US5685449 (21.03.1996).

the closing lid lugs '31' to minimize the chances of breaching the seal.

- Customer purchase focus (j)

Performance → Reliability → Convenience → **Price**

Mann (2007) correlates the stages in this trend to the S-curve of a system, 'performance' being placed at the system childhood, 'reliability' and 'convenience' at the raising part of the curve and 'price' at system maturity.

As the can technology is two hundred years old and also, as it was observed from the patent search, the technology is in its maturity stage and price seems to be the main focus, the price reduction strategy being accomplished primarily by means of design changes that result in thickness reduction of can metal parts. This is particularly relevant for the container structure or body design as shown by the decreasing patent rate in Figure 5. The cover wall and lid designs still present an inventive effort, as shown in Figure 6, to cope with customer needs concerning reliability, convenience and price.

The radar plot of Figure 15 shows the current stage of the evolution trends of metal pail technology with some trends more advanced than others. The shadow area is related to the reference product and the overall pail technology, whereas the line crossing the 'webs and fibers' trend line at 2,50 (mid scale) extends this area taking into account the metal/composite pail as a more developed design. The evolutionary limit of the technology is the periphery of the radar plot and the evolutionary potential is the area between the current stage area and the periphery. A discussion on the past evolution and possibilities for future exploration is presented in next section.

5. Discussion

In this section it is discussed the development strategy used by the metal can industry and the prospective for the metal as well as for the plastic pails using the information gathered from the patent system and the trend analysis made with the reference product.

The overall design strategy was pursued to obtain packed product integrity (no leakage or contamination) together with container reliability in rough handling and multi-level stacking. This was accomplished by the seaming or double-seaming design, by using body walls with ribs or corrugations to minimize buckling, by reinforcement in the bottom area and by continuously improving the upper wall and lid design to fulfill special containers applications. Cost reductions were obtained mainly through metal thickness reduction and specialized can manufacturing technology. Brasilata followed the same pattern developing different wall corrugation profiles to reduce metal thickness as well as produced inventions in the cover and lid design area to improve reliability and usefulness.

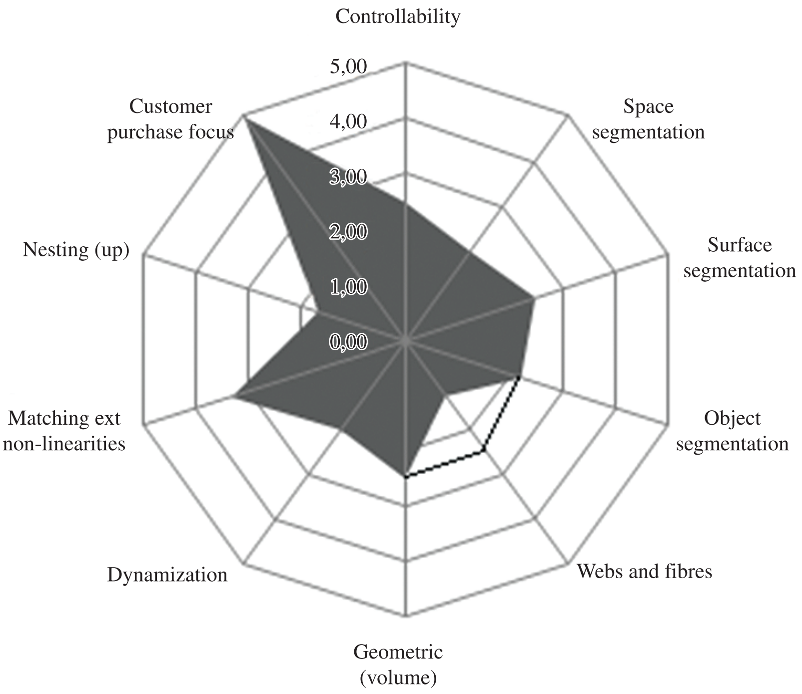

Figure 15. The radar plot of metal pail evolution.

The 'surface segmentation' with 2D rib protusions wall is a typical *local quality* inventive principle of TRIZ that has being used in many product designs as a reinforcement solution. However, in the reference product the introduction of ribs or grooves to weaken the wall and protect the seams and seals is based in another TRIZ design principle, the *convert harm into benefit* principle, also known as "blessing in disguise". In the other side, looking into the plastic pail technology, it was found a pail with 3D rib protrusions that benefits from the plastic manufacturing capabilities to enhance further this trend (see Figure 16).

The metal can industry has not evolved much in the 'space segmentation' and 'web and fibers' trends. If an example of a metal pail in the second stage of 'web and fibers' trend line was found (the metal/plastic composite pail of Figure 12), a more advanced 3D fibre aligned, third stage in the evolution line, was found within the plastic pail industry (the multi axially oriented synthetic plastic/plastic composite container of the US3305158).

Multiple hollow and capillary/porous structures could be evolutions in 'space segmentation' to improve strength and container safety, but probably it would be necessary to combine them with evolutions in trends like 'object segmentation' (about the products that are filled in the containers) and 'nesting-up' (improvements in higher level systems as the product application processes).

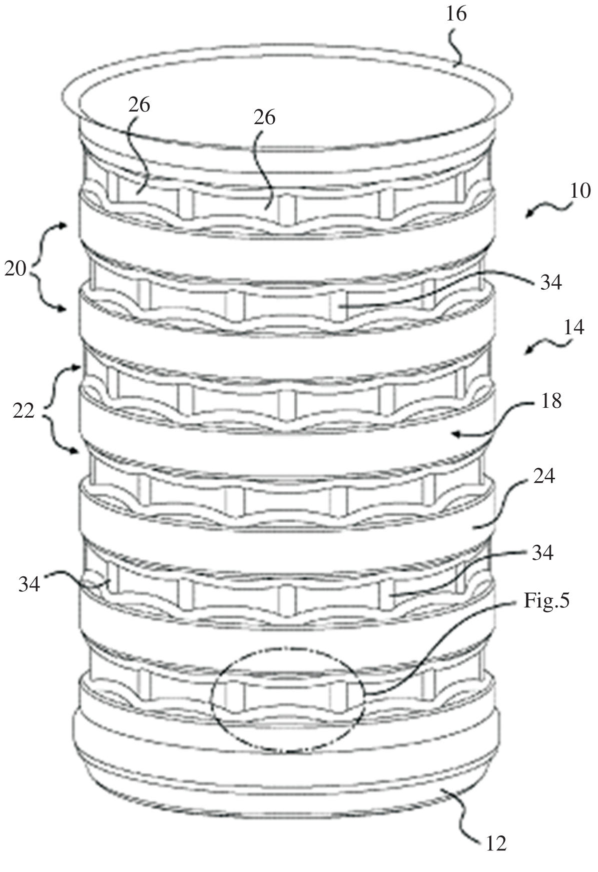

Figure 16. US20110226788 (08.11.2010).

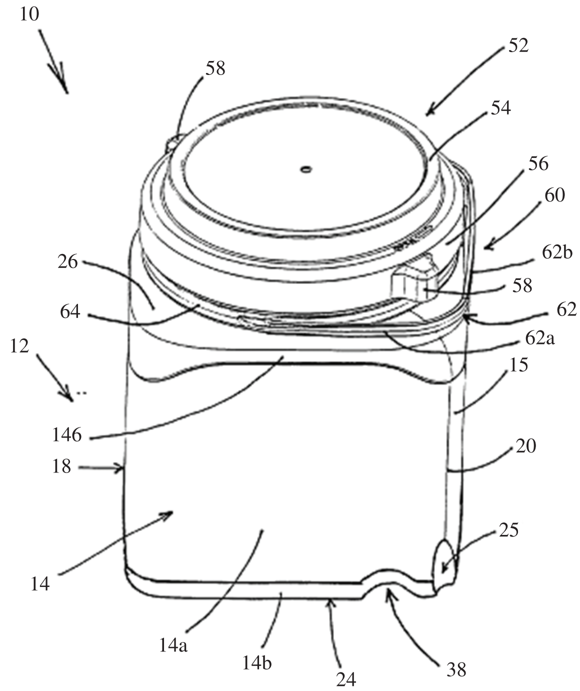

Figure 17. US20040011831 (02.07.2003).

The evolution in trends like 'dynamization', 'matching to external non-linearities', 'controllability' and 'customer purchase focus' resulted mainly from customization and product reliability efforts made by the metal can industry. Another example is a multi-use container manufactured by a seaming or double-seaming process that produces square pails with low curvature corners and high sealing ability for storing food, beverages or discrete products as storage batteries (European patent EP1892191) – in this case, the evolution in the 'customer purchase focus' trend line was a jump to the convenience stage (providing a container for multi-use applications) without impairing its reliability or performance.

Plastic containers, in the other side, have evolved more sharply or present a more promising future for technical evolution. Figure 16 shows the pail with 3D rib protusions wall mentioned earlier. Figure 17 presents a major advantage of plastic containers as they can progress easily in the 'increasing asymmetry' trend line "to match the forms that suit the users", as stated by Mann (2007, p. 323).

The radar plot in Figure 15 pictured an evolutionary potential for metal pails that could be promising as many trends are in their initial stages, however the histogram of Figure 5 presents a different situation as the patenting rate of metal containers is clearly decreasing. The best evolution strategy here would be in the direction of composite materials, combining metal, plastics and other synthetic materials. This could induce evolution in trends like 'space and surface segmentation', 'dynamization', 'controllability' and 'decreasing density'.

6. Conclusion

In this paper it was presented a brief introduction to TRIZ – the theory of inventive problem solution -, and was proposed a framework for analysing the technical evolution of products and their technologies. The framework is based in a retrospective view of the product using information obtained from the patent system, this information being used to depict the product in evolution lines that can be regarded as "dimensions" for product decomposition and analysis.

A case study was done having a typical metal pail as an example, the reference product being chosen from the product line of a Brazilian can manufacturer. The patent information provided a proxy of the product S-curve, the metal pail being considered in a very mature level. The patent retrospective view gave also enough insight to define the current product stage in ten trend lines along its way towards ideality. In overall, the product decomposition and analysis process was helpful in understanding the development strategy of the metal can industry, in forecasting future designs and in assessing the potential of competitive products, as plastic containers.

As TRIZ was initially proposed as a methodology for solving technical problems and providing creative solutions in design, and more recently has been deployed as a strategic tool for technology forecasting, it is also envisaged here to employ the methodology combined with the information available in the patent system as an effective rationale for studying the product development process.

In general, the proposed framework can be used to analyse the current evolutionary position of any leading product or technology, and to evaluate future development prospects, or can be applied to a specific product of a firm to define its development strategies and to compare competitive advantages and strategies with other enterprises.

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