designs

Article

Design for Six Sigma and TRIZ for Inventive Design Applied to Recycle Cigarette Butts

Giampiero Donnici, Leonardo Frizziero, Alfredo Liverani and Christian Leon-Cardenas *

DIN, Department of Industrial Engineering, Alma Mater Studiorum University of Bologna, Viale Risorgimento 2, 40136 Bologna, Italy
* Correspondence: christian.leon2@unibo.it

Abstract: A deep research and analysis of a "critical waste" object has been carried out, understood as a subject that does not fare high on the separate collection and recycling system yet: the cigarette butt. This acknowledged social waste is the first among all the garbage detected everywhere around neighborhoods worldwide, and is therefore the epicenter of a situation so worrying that it is necessary to find a solution concerning the environmental pollution. The present exercise was developed, by means of proper product design methods like TRIZ and QFD driven by DFSS rulings, to conceive of new products and services in order to create incentive for the smokers to lessen the environmental pollution problem. The social implications are about the possibility of modifying the bad habits of the smokers and making the user act consciously towards the environment. Throwing the cigarette-stub in the new collection device, rather than on the ground, enables users to enjoy both moral and economic returns. The "Buttalo" service is aimed to incentivize the population to fight against environmental pollution whilst helping smokers to be conscious about it.

Keywords: Design for Six Sigma (DFSS); quality function deployment (QFD); benchmarking analysis; Top-Flop analysis; TRIZ

check for updates

Citation: Donnici, G.; Frizziero, L.; Liverani, A.; Leon-Cardenas, C. Design for Six Sigma and TRIZ for Inventive Design Applied to Recycle Cigarette Butts. *Designs* **2022**, *6*, 122. https://doi.org/10.3390/designs6060122

Academic Editors: Julian D. Booker and Bhanu Shrestha

Received: 5 November 2022
Accepted: 28 November 2022
Published: 1 December 2022

1. Introduction

Technological innovation has allowed society to dramatically accelerate the pace of new product creation [1]. Software evolution during the past decade has allowed companies to reduce the total development time needed to design and test products [2], as well as increasing diversification [3]. This resulted in the creation of products that better satisfy the needs that they have been designed for, including environmentally-friendly solutions [4] and sustainability [5]. However, this new ease in product creation has developed an oversaturation of some markets, with the existence of many useful products that ultimately fail to capture the attention of the consumer as the offerings increase [6]. The study of surprising product features is crucial to design a product that has to spark attention, interest, and generates mass conversations [7]. Expectations from the public are related to functional, behavioral, or structural variables whose canalization would depend on the information processing triggered by the product features and are crucial to surprise the way in which the need is satisfied by it [8,9]. The establishment of the rather unusual path to solve a problem is what qualifies a product as innovative. There are methods that can help product creators to canalize innovation depending on the different inputs that a product conception may get, such as inbound open innovation [10], as well as team-centered and individual-centered innovation [11], and TRIZ [12]. The last of which takes on the experience and skills of thousands of experts that enabled a rapid and creative problem-solving manner. TRIZ enables one to have an area-based database [13], together with the common principles of originality, which form the basis of innovation. TRIZ recognizes and organizes these principles and uses them in a predictable manner. This approach adds reliability to the problem-solving process by setting a number of dependable tools aimed at reaching the desired target.

However, smoking-related waste represents the disposal of 2.6 cigarettes per person per year [14] among municipal waste around our societies today. There are materials that, like some plastics, still represent a major limitation in the recycling system, and are also traceable as the causes of waste pollution, both environmental and marine. One of these materials is now a huge wake-up call for environmental/sea pollution: cigarette butts. It has proven to be recognized as one of the main causes of these phenomena. The cigarette butt is a waste material not yet classified. It is generally considered as undifferentiated waste. It is important, however, to know its chemical characteristics in order to understand that it is not necessary to amalgamate this waste with the rest of the undifferentiated collection. The chemical/toxic substances it contains make it potentially a dangerous waste. A modest proportion of the more than 4000 toxic substances remain in the filter [15]. There is no precise data on the quantities and nature of the substances that remain trapped in the filter because it varies according to production methods. In addition, the amount of chemicals that remain in the filter is strongly related to the method of smoking. Moreover, several global and regional quantitative estimates are available on the size of the release of these materials into the environment. At a global level, the number of butts dispersed each year in the wild is estimated at 4.500 billion (4.5×10^{12}), a very high percentage (between 75% and 97%) of those actually smoked [16]. Thereafter, research on proper product development under Design for Six Sigma methods led to finding an out-of-the-box way to catch the public's attention, helping to create consciousness on this element of general knowledge. The smoking filter mixes the higher toxicity remnants of tobacco after consumption [17,18]. Smoking filters are at a superior rate sourced from plastic, non-biodegradable material, with an alarming pace in contributing to today's environmental change and to the social aspects derived [19]. The aim of this study is to conceive a product that is able to unmistakably stand out for its uniqueness. This novelty will be exploited to gain conscious thinking about two major subjects of social interest, street littering, and smoking habits. Therefore, a novel, yet feasible and practical product would be created by means of the application of a combination of the DFSS approaches to add value across all the stages of the product development. This procedure will be enriched by the application of the TRIZ method to enrich the novelty and uniqueness of this product, by establishing the key winning characteristics. The methodology found in the literature will be structured to resolve the case study following DFSS guidelines, and applying TRIZ to aid in decision making, accordingly. Afterwards, the product characteristics will be portrayed, analyzed and prioritized appropriately to find out the top requirements of the product. This tool for market discovery, if canalized accordingly to design-inspired product development methods like IDES, a proper product design will be drawn as well as the steps for achievement. This study hopes to achieve full model validation, and presents a preliminary cost analysis.

2. Materials and Methods

Design for Six Sigma: DMADV

The DMADV approach, which is the one we'll utilize for our analysis, is the one most frequently employed in the field of Design for Six Sigma. The five distinct phases of this approach are define, measure, analyze, design, and validate, as was already indicated. Each phase has a distinct goal, and the final phase will have produced a design that follows the Design for Six Sigma approach.

1. Define. The client's wants and demands are gathered during the initial stage. It is crucial to pay attention to the issues customers face when interacting with a certain product that is already on the market or which novel products could meet their needs, both expressed and unexpressed. It is always in this phase that the TRIZ methodology can be applied to solve any inventive problems.

For achieving this, this study will apply TRIZ, that is a methodology aimed to develop innovative ideas [20] that was developed in Russia starting in 1946 by Genrich Saulovich Altshuller, a Soviet engineer, scientist, journalist, and writer, and his collaborators. The formulation of the problems in terms of technical contradictions turns out to be one of the fundamental steps of the TRIZ: if a problem cannot be formulated in terms of technical contradictions, then that problem is not a problem for the TRIZ [21]. The quality function deployment (QFD) analysis is a procedure to identify the technical specifications of the product based on a unique evaluation of the user's requirements [22], and nowadays is the most selected method for gathering product characteristics [23–25].

2. Measure. To convert the needs of the client into technical knowledge, the quality function deployment (QFD) [22,26,27] study is conducted at this step. In this approach, it is possible to acquire design-related qualities that effect whether or not the client's expectations are met.

Additionally, this section will employ the Relative Importance Matrix and Dependence/Independence Matrices, which will aid in gathering the information needed to investigate the items on the preceding list, specifically to draw attention to any dependency links that may already exist. Evaluation matrices can be used to determine the independence or relative relevance of links between requirements. The Interrelation Matrix is a tool for assessing how various needs or concepts are related in terms of dependency (first use) and/or relative importance (second use); it is also used to clarify priorities and determine the optimal grouping of tasks.

3. Analyze. The design of the new product is developed using the essential features discovered in the second phase. In order to do this, a Benchmarking analysis is conducted, allowing researchers to examine rival products' designs that are similar to the one in question.

Additionally, a Benchmarking technique is used to compare the various items on the market. Benchmarking is a term used nowadays to describe a systematic comparison-based process that enables firms to compare themselves to the best and, more importantly, learn from them in order to enhance their own performance [28]. Following the Benchmarking process, the performance target values that must be met are typically reviewed, and the best practices that must be studied and emulated are found. The tool we will use later, known as Top-Flop Analysis, allows for swift comparison of a certain number of goods on a similarly specified number of selected parameters after Benchmarking has been defined.

4. Design. We move forward with the design of the new product utilizing the appropriate tools based on the outcomes of the analysis phase. The information gathered from the preceding points must all be taken into account in this phase, and every effort must be made to respect them as much as possible.

We also employ a different technique called the What/How Matrix to help us discover which metrics are most important to enhance. This method made it feasible to correlate criteria and characteristics and identify the technical features that needed to be innovated in order to satisfy the most crucial requirements and independents previously discovered.

5. Validate. In this final step, it is categorically declared that the finished product supports the anticipated outcomes. It is feasible to create prototypes that can be tested to see if the product meets the necessary criteria [29].

Once the design is complete, it is required to conduct checks that demonstrate the product has complied with the goals stated and is free from flaws. As a result, it is essential to examine the product's layout, going from style sketches to CAD drawings. The sustainability of the production expenses must be confirmed. It is also feasible to create prototypes that will be tested to see if the product meets the necessary criteria.

3. Results

3.1. Problem Definition

The environmental problem caused by smoking waste has never been tackled, overshadowed by other preventive campaigns that have changed little about the habits of consumers, who often, even unconsciously, throw their butts everywhere, at sea, on the beach, on the street, etc. Young people make up 22.7% of smokers. The ban on smoking in certain places or areas seems to increase (at least in the short term) the problem of abandonment, since smokers are encouraged to smoke outdoors, where it is more likely that the butt will be improperly removed. The latency time in nature, before decomposition is completed, varies from six months to a dozen years, depending on the environmental conditions and depending on the type of cigarette (without filter or with filter). In the United States and Australia, cigarette butts on beaches are a problem. And almost every place, with few exceptions, is not equipped for the disposal of cigarette butts. Therefore, this research begins with the concept of "recycled material," following a logic that leads to the analysis of critical waste, such as cigarette butts, which represent the design object. This item is included in the trend of recycled materials classification at the center of a huge basin of research and analysis aimed at solving environmental and water pollution. Inspecting such a theme inevitably leads to the question of the causes and consequences of environmental pollution. We will then retrace the stages of research, through the theme of recycled materials, understanding what is meant by circular economy, and investigating the system of separate collection, so as to clarify the paths that led the project in a very specific direction: the conception of a collection system of one of the most polluting wastes and most present in our seas and on earth: the cigarette butt. Recycled materials are considered all those materials that come from the recovery of waste materials that, according to strategies and processing methods, are not sent to landfill but become potentially useful materials. The concept of recycled material immediately recalls the phenomenon of "cycle". In fact, we talk about recycled materials in the circular economy system that in recent decades has been known as "one of the main causes of phenomena such as marine and terrestrial pollution" [30] to a phenomenon that introduces the concept of cycle. A point of union between production and disposal is born, which allows for the closure of the circle of life of the product with its recycling. The separate collection of waste is the necessary condition for the principles of the circular economy to provide results. This practice allows the correct collection and disposal of waste materials according to their physical/chemical characteristics. In recent decades, the differentiation of waste has marked a turning point in relation to the environmental condition. For the first time, it has been possible to remedy environmental damage that seemed irreparable. The opportunity to give new life to waste materials that were considered waste to be disposed of in landfills was tested, implementing practices of intelligent disposal and recycling of materials to generate raw materials. The use of these practices gives life to the design of recycled materials, sometimes biodegradable, some potentially recyclable indefinitely. This is therefore the meaning of the concept of recycled material and circular economy: closing the product's life circle in a potentially repeatable cycle, involving the least possible impact on the environment.

3.1.1. Idea Definition: TRIZ

Considering the problems that have been analyzed, we ask ourselves if the TRIZ methodology can offer us the tools for solving these problems. We start from the consideration that on the one hand smokers are pushed for public health reasons to smoke outdoors, but outdoors there are not many bins for cigarette butts, so there is a great dispersion of cigarette butts in the environment. On the other hand, smokers should avoid littering cigarette butts in the environment and this could be easier if they smoked in public places where there are a large number of bins for cigarette butts; in public places, however, there are only a few and limited areas for smokers. We are facing a contradiction. To try to solve this problem in terms of technical contradictions we elaborate the problem and refer to the Contradiction Matrix and the inventive principles related to it, in order to find an innovative solution for the same contradiction.; this solution will be a solution of a general nature which we will then try to decline according to the practical case we have to solve. Let us start with a control parameter: the place to smoke. This control parameter can basically assume two values: smoking outdoors or smoking indoors. Depending on the two values that the control parameter will assume, we will obtain that people close to smokers will be able to breathe harmful fumes more easily (when, for example, smoking indoors) or less easily (when, for example, smoking outdoors). On the other hand, cigarette butts will be collected in special containers more easily (when, for example, smoking indoors) or less easily (when, for example, smoking outdoors) resulting in a worsening of the dispersion of contaminants in the environment. Wanting to represent the previous contradiction with a diagram, we can refer to Figure 1 where a general model of formulation of the problem in terms of technical contradiction is illustrated.

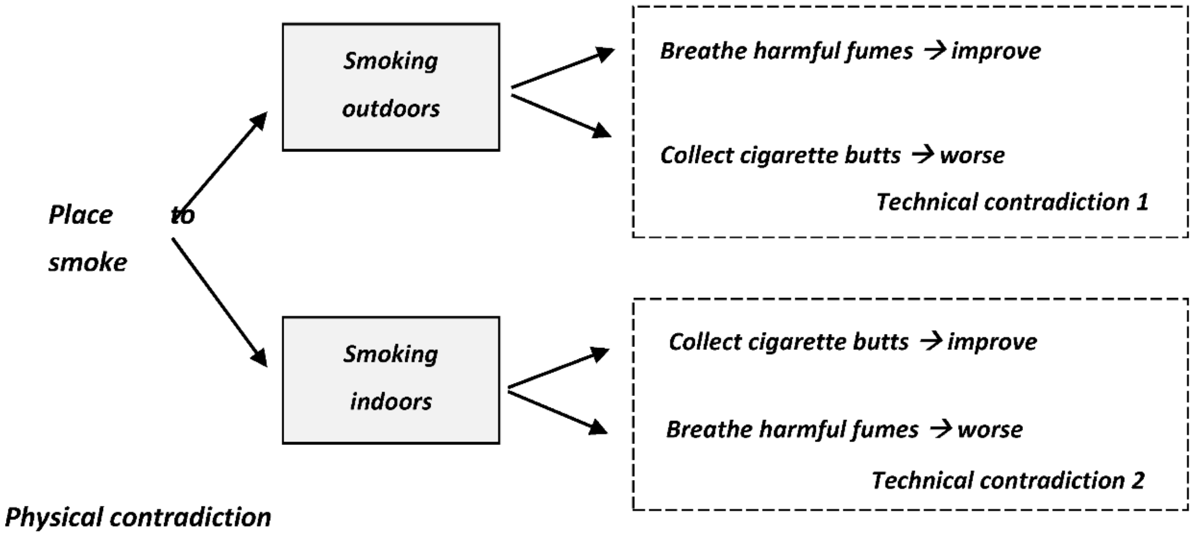

Figure 1. Technical Contradiction.

If we express the previous technical contradiction through the technical parameters of the Altshuller Matrix, we obtain the following problem representation (Figure 2):

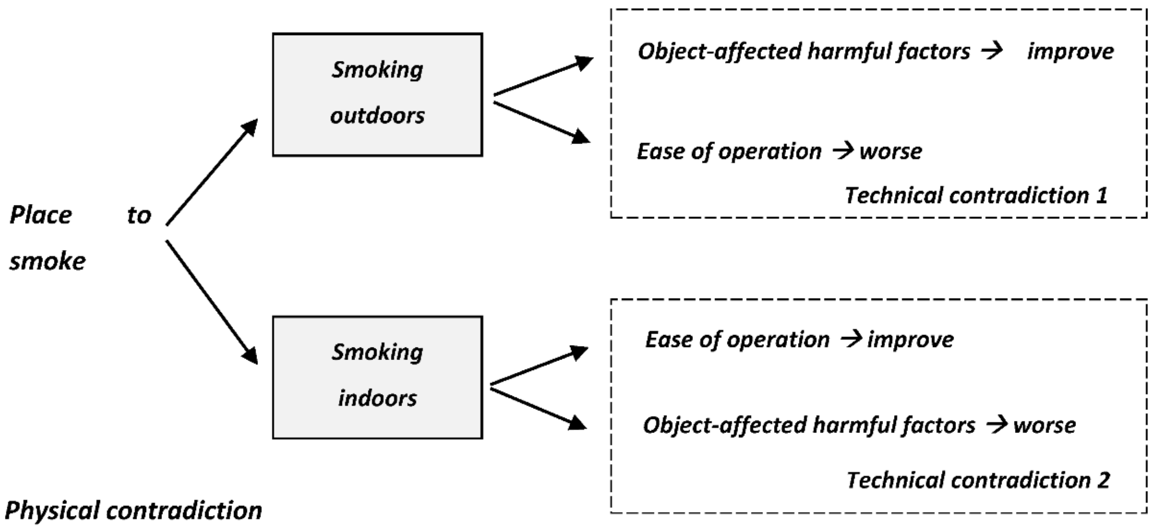

Figure 2. Technical contradiction expressed through the technical parameters of Altshuller Matrix.

Through the Altshuller Matrix it is possible to identify which are the general solving principles that can resolve the technical contradictions highlighted (Figure 3).

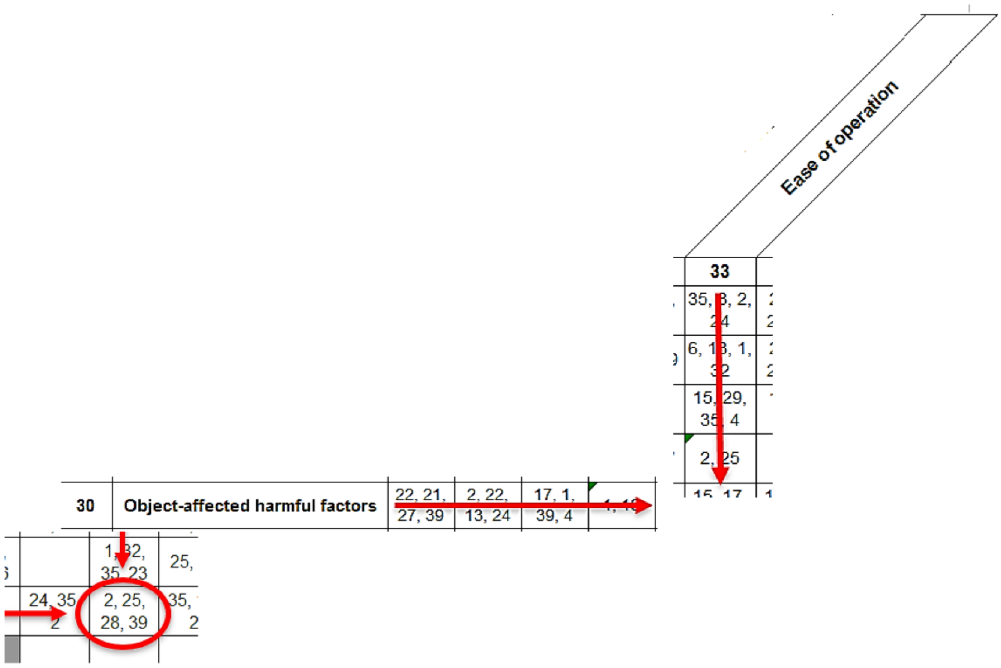

Figure 3. Solving principles resulting from the Altshuller Matrix. *The horizontal arrow indicates which technical parameter improves, while the vertical arrow indicates which technical parameter worsens. The cell intersected by the previous arrows indicates the possible technical solutions and these are highlighted by a circle.

The solution principles obtained are the following:

2 = Taking out (extraction, separation, removal, segregation)
25 = Self-service, self-organization (make use of waste materials and energy)
28 = Replacement of a mechanical system with fields
39 = Inert environment or atmosphere (introduce a neutral substance or additive into the object).

Principle 2 suggests separating cigarette butts from any other material, then carrying out a separate and specific collection for these objects, principle 25 suggests using waste material such as a cigarette butt instead of throwing it away, and finally principle 39 suggests joining the cigarette butt together with other material in order to make it inert and no longer polluting.

It is from these considerations that the idea of building a new product was born, to meet all the considerations just made.

3.1.2. Define: QFD—Six Questions

The field of action must be identified, therefore the design of an incentive collection service for cigarette butts, as these are the main requirements and characteristics that this must be identified in order to innovate and satisfy the needs.

We ask six questions, whose answers if elaborated, return the requirements necessary for the product to meet the needs (Table 1).

In this first phase, some characteristics that the product must possess have been identified. These features are: intuitive, comfortable, funny, functional, fast, affordance, visible, eye-catching, pleasant to the eye, strategic position, accessible, resistant to atmospheric agents, and smart.

Table 1. Six Questions.

Question	Answer	Requirement
Who?	All the smokers	Functional
What?	A mechanism to encourage collection	Intuitive, fun, convenient, eye-catching, quick
How?	Through a smart service that encourages the user economically and morally	Smart, affordance
When?	Every time you smoke a cigarette	Functional, fast
Where?	In cities, outdoors	Visible, pleasing to the eye, resistant to weather agents, accessible
Why?	To make citizens aware of the environmental damage caused by a cigarette butt	Smart

3.2. Measure

Measure: Relative Importance Matrix—Dependence/Independence Matrix

The requirements found through the six questions are inserted in the rows and columns of the Matrix of Relative Importance (Figure 4). Each value in the row is compared with the value in the column and is evaluated 0 (row requirement is less important than column requirement), 1 (both requirements have the same importance), or 2 (row requirement is more important than column requirement). Then, all values are added along the lines, and you can get a ranking of the most important requirements. The most important requirements are: resistant to atmospheric agents, smart, and functional.

RELATIVE IMPORTANCE MATRIX	Intuitive	Comfortable	Funny	Functional	Fast	Affordance	Visible	Eye-Catching	Pleasant to the eye	Strategic position	Accessible	Resistant to atmospheric agents	Smart	Total (Relative Importance)
Intuitive	1	1	2	1	1	1	1	2	2	2	1	0	0	15
Comfortable	1	1	2	1	1	1	2	2	2	1	1	0	1	16
Funny	0	0	1	0	0	0	0	1	0	0	0	0	0	2
Functional	1	1	2	1	1	1	2	2	2	1	1	1	1	17
Fast	1	1	2	1	1	0	0	2	2	1	1	0	0	12
Affordance	1	1	2	1	1	1	0	1	2	1	1	0	1	13
Visible	1	0	2	0	0	0	1	2	2	1	1	0	0	10
Eye-Catching	0	0	1	0	0	0	0	1	1	0	0	0	0	3
Pleasant to the eye	0	0	2	0	0	0	0	0	1	0	0	0	0	3
Strategic position	0	1	2	1	0	0	1	2	2	1	1	0	0	11
Accessible	1	1	2	1	1	1	1	2	2	1	1	0	0	14
Resistant to atmospheric agents	2	2	2	1	2	2	2	2	2	2	2	1	2	24
Smart	2	2	2	1	1	1	2	2	2	2	2	0	1	20

Figure 4. Relative Importance Matrix. The machine counts how many cigarette butts are introduced through an optical system.

The second matrix that is built is the Dependence/Independence Matrix (Figure 5) which identifies which are the requirements that most influence the others. As in the previous one, the requirements are inserted along the columns and along the rows. The values along the rows should be compared with all the values along the columns. In this case, value 0 (row requirement totally independent from column requirement), 1 (row requirement little dependent on column requirement), 3 (row requirement, row dependent on column requirement), and 9 (row requirement very dependent on column requirement) are given.

DEPENDENCE / INDEPENDENCE MATRIX	Intuitive	Comfortable	Funny	Functional	Fast	Affordance	Visible	Eye-Catching	Pleasant to the eye	Strategic position	Accessible	Resistant to atmospheric agents	Smart	Total (Dependence)
Intuitive		1	0	1	3	9	0	1	1	0	0	0	1	17
Comfortable	1		1	3	9	3	0	0	1	0	3	0	9	30
Funny	1	0		0	1	0	0	1	1	0	0	0	9	13
Functional	3	3	1		3	3	0	0	2	0	3	9	3	30
Fast	9	9	3	3			1	0	0	0	3	0	3	31
Affordance	9	3	1	1	3		0	1	1	1	3	0	3	26
Visible	0	1	0	0	0	1		0	0	9	3	3	3	20
Eye-Catching	0	0	0	0	0	1	0		3	0	1	0	9	14
Pleasant to the eye	1	3	9	1	0	9	3	9		3	1	0	9	48
Strategic position	1	1	0	1	1	0	9	0	0		9	3	1	26
Accessible	3	3	0	1	3	3	3	0	0	9		0	3	28
Resistant to atmospheric agents	0	0	0	9	0	0	0	0	0	0	0		0	9
Smart	9	9	9	9	3	1	0	0	0	3	3	0		46
Total (Independence)	37	33	24	29	26	30	16	12	9	25	29	15	53	

Figure 5. Dependence/Independence Matrix.

The most independent requirements are: intuitive, comfortable, and smart.

The analysis of the two previous matrices leads us to say that the characteristics on which to focus the design of the innovative product are: intuitive, comfortable, smart, resistant to atmospheric agents, and functional.

3.3. Analysis

Analysis: Benchmarking—Top-Flop Analysis

From the Benchmarking analysis it is possible to obtain the Top-Flop Analysis (Figure 6) to define the Delta, that is the minimum number of characteristics to be improved in order to have innovation. The market analysis was performed on 10 different types of binders, and after the evaluations a delta of 2 was obtained. This means that it is necessary to innovate 2 + 1 characteristics to obtain an innovative product.

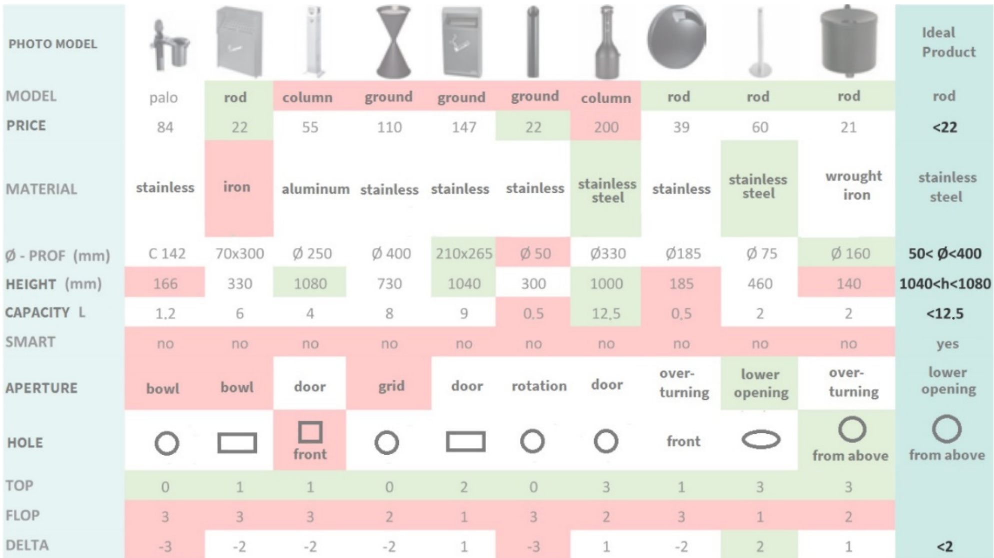

PHOTO MODEL											Ideal Product
MODEL	palo	rod	column	ground	ground	ground	column	rod	rod	rod	rod
PRICE	84	22	55	110	147	22	200	39	60	21	<22
MATERIAL	stainless	iron	aluminum	stainless	stainless	stainless	stainless steel	stainless	stainless steel	wrought iron	stainless steel
Ø - PROF (mm)	C 142	70x300	Ø 250	Ø 400	210x265	Ø 50	Ø330	Ø185	Ø 75	Ø 160	50< Ø<400
HEIGHT (mm)	166	330	1080	730	1040	300	1000	185	460	140	1040<h<1080
CAPACITY L	1,2	6	4	8	9	0,5	12,5	0,5	2	2	<12.5
SMART	no	no	no	no	no	no	no	no	no	no	yes
APERTURE	bowl	bowl	door	grid	door	rotation	door	over-turning	lower opening	over-turning	lower opening
HOLE			front					front		from above	from above
TOP	0	1	1	0	2	0	3	1	3	3	
FLOP	3	3	3	2	1	3	2	3	1	2	
DELTA	-3	-2	-2	-2	1	-3	1	-2	2	1	<2

Figure 6. Benchmarking—Top-Flop analysis.

3.4. Design

3.4.1. Design: What/How Matrix

Depending on the results obtained from the analysis phase, we proceed with the design. In the same way as seen before, in Figure 7 the requirements are arranged along the rows and characteristics along the columns. This time we ask ourselves how much the requirement along the row is influenced by the characteristic along the column.

WHAT / HOW MATRIX	Model	Price	Material	Diameter	Height	Capacity	Smart	Aperture	Hole
Intuitive	9			3	1	1	9	9	9
Comfortable	9		3	9	9	9	9	9	9
Functional	9	1	1	9	9	9	9	9	9
Resistant to atmospheric agents	3	1	9						3
Smart	9	9	9	9	3	3	9	9	9
Total	39	11	22	30	22	22	36	36	39

Figure 7. What/How Matrix.

Additionally, numerical evaluations of the relationship's kind will be applied in this scenario: nothing (empty box, equal to 0), weak (1), medium (3), and strong (9). Then, we determined the sums by rows and columns. The maximum value of the line sum identifies the need that is most influenced by the column's parameters, and the maximum value of the column sum identifies the parameter that is most crucial to meeting the customer's requirements.

From the results of all the matrices, it was finally possible to define, in a scientific and considered way, the characteristics of the device to innovate:

- The type of model, which influences its functionality.
- Make it smart, this will make it intuitive, fun, and will create a terrain on which to intervene to encourage the user morally and economically.
- The type of hole and aperture that will directly affect the user experience.

Satisfy the need to reduce the presence of butts from the streets, and not least, improve the behaviour of the user smoker by ensuring that he cares about throwing the butt into the dedicated collection devices. It is assumed, then, that the best way to do this is to change the perception of the value that each smoker has of the butt, which today, is zero, providing the appropriate tools to understand the potential of such a waste. The mission is made possible by the collection of characteristics and requirements previously studied, which allows us to design the innovative and incentive system of collection, "Buttalo".

3.4.2. "Buttalo" System

The "Buttalo" system consists of a smoker, a contactless card, a smart bucket and a smartphone (Figure 8).

Figure 8. "Buttalo" system.

When the user decides to integrate with this system, he is given a "Buttalo" contactless card to associate with their account. By downloading the application, it is possible to register the user's name and their card. Once the cigarette is consumed, the user brings the card closer to the upper face of the bucket to open the flap and throw the butt. The technology inside the bucket is able to count the butt, or the butts, and immediately send feedback to the user.

Feedback is very important within this system. In fact, thanks to this feedback the user can increase their sensibility and give value to the butt.

The user opens the bucket door and throws inside the butt, this is detected and the data on the action is sent to their smartphone. The first useful feedback for the user is then counting how many butts have been thrown (or smoked cigarettes). The architecture of the application must be able to provide a moral incentive to the user. In this regard, an app interface has been designed to represent the current environmental status through cartoon images. The design of a ground with butts appears, and as the user throws the butts inside the "throw it away" collector, they are reduced from the virtual ground and plants grow in their place. The more plants the user is able to grow, the more points they collects. The points collected become coupons, or “coins” to spend within the app. This mechanism provides to the user the economic incentive. Thanks to the possibility of being able to count the single unit, or the flow of butts, these butts move from having no value to a real value.

The smartphone, in addition to having a significant importance to give to the user the moral and economic incentives, is the tool through which it is possible to make this system economically sustainable. Inside the app it is possible to provide a space to be used as an advertising banner to the interest of third parties, who in return offer funding to those who offer the space. There are different types of advertising banners (full-page, video, text ads, etc.), and different types of salaries.

3.4.3. Electronics and Bucket Mechanics

Under the upper plexiglass wall, an NFC reader allows the user to detect the card. Once the card has been detected, and therefore the user, the actuator that opens the flap is activated (Figure 9).

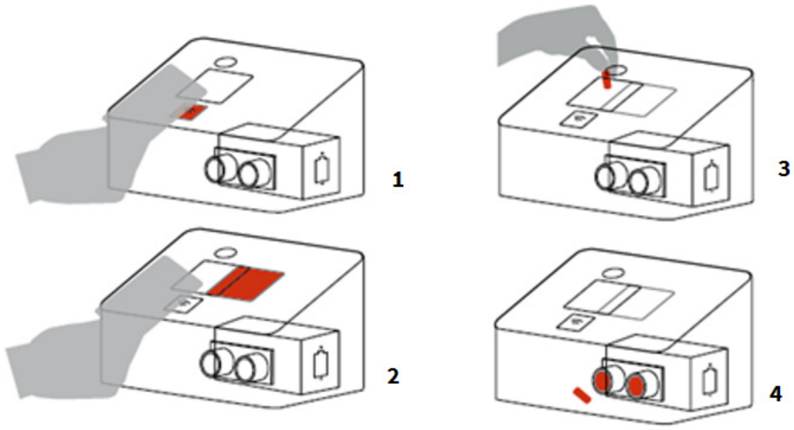

Figure 9. Electronics and bucket mechanics: (**1**). The user swipes the card; (**2**). After the card has been recognized, the top door slides open; (**3**). The user inserts the cigarette butts. (**4**). The machine counts how many cigarette butts are introduced through an optical system.

A type of sliding opening has been chosen, because it is thought to make the user experience more pleasant. Once the door has been opened, the user will be responsible for throwing the butt (or the butts) inside the bucket. A proximity sensor is located near the opening and allows you to count the number of butts. The data thus detected, is sent to the network thanks to the Wi-Fi card, and the user will immediately receive a notification with the counting updated in the app. To make this service as minimally invasive as possible for the city, it has been thought to insert a battery inside the electronic box. This battery must be properly sized, based on the daily use of the bucket, so as to minimize the frequency of battery changes during the phase of unloading the container by environmental operators.

3.4.4. Stylistic Choice

The stylistic research of the device is closely related to the choices of functionality, and therefore to its architecture. Different stylistic trends have been explored, observing the state of the art of the retro, natural, and stone style (Figures 10–12).

The morphology and functioning of the device, compared to the style, suggested simplicity of form, regular and round volumes, and bright colours. The aesthetics of the final object are therefore inspired by a retro style (Figure 13). The device develops in height, occupying the volume of a cylinder with a rectangular base of the dimensions 15 × 20 × 80. It also has an inclination in the upper surface that helps the interaction with the user.

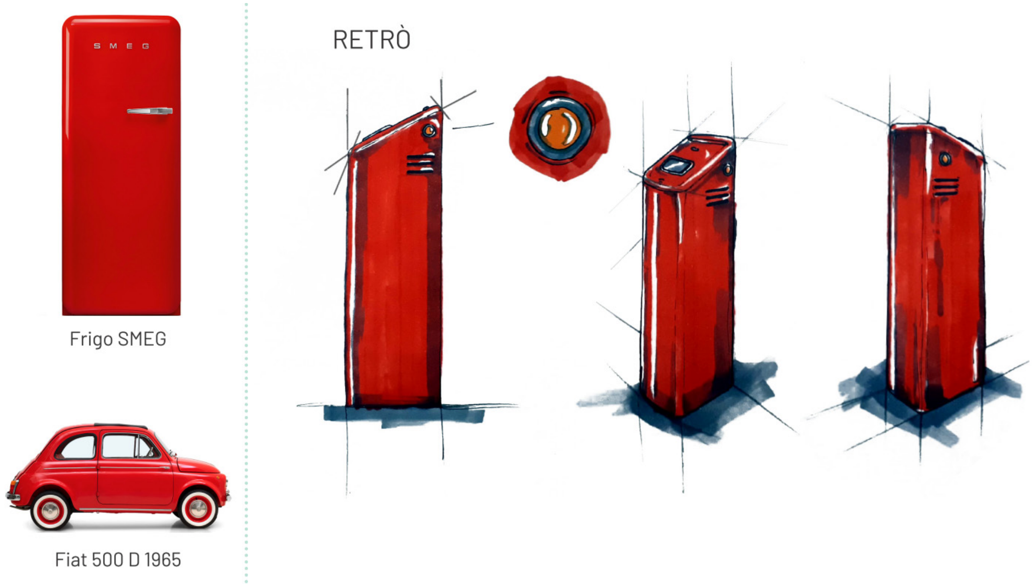

Figure 10. Retro style.

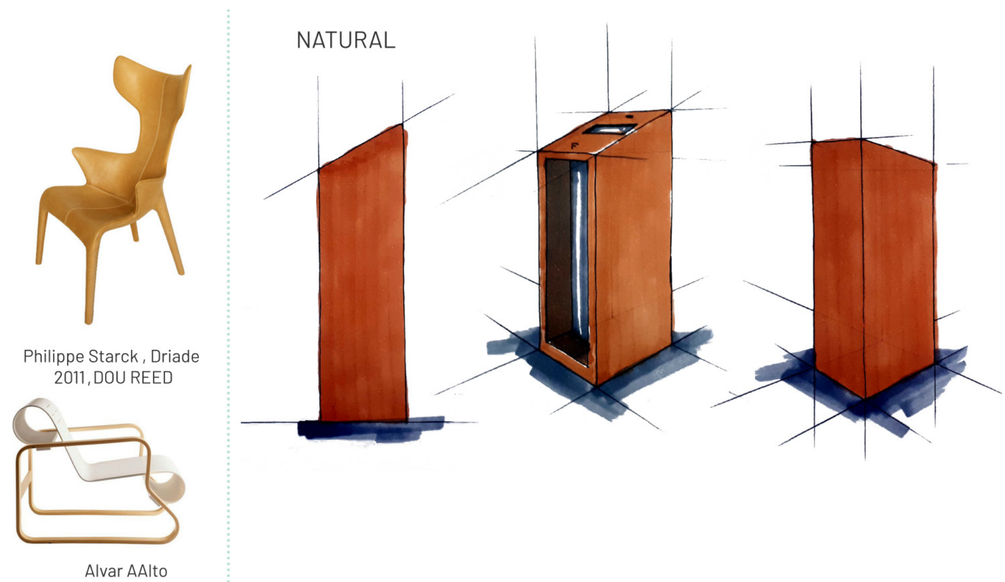

Figure 11. Natural style.

3.4.5. Territorial Distribution

Once the actual measurements of the inner container have been defined, and its capacity, it was possible to make a potential territorial analysis of the distribution of the buckets. Let's take the city of Bologna (Italy) as a case study. First of all, we need to identify a target. Since this system assumes the use of a smartphone, suppose a user aged between 20 and 44 years. The number of inhabitants in Italy within this age group is about 30%. Bologna is a city with a population of 388,367. Therefore, 116,510 people of age between 20 and 44 years. In this age group 28.7% of people smoke. In Bologna there are about 35,000 smokers aged between 20 and 44 years. Considering a consumption of 12 cigarettes per day, 420,000 cigarette butts could fall to the ground every day. The bucket has a volume of 5.36 L, and a capacity of about 2144 cigarette butts. Considering that Bologna covers an area of about 140.9 km^2, at least one bucket per 700 m^2 would be needed. Therefore, to avoid unloading the buckets too frequently, one bucket per 500 m^2 can be assumed.

Figure 12. Stone style.

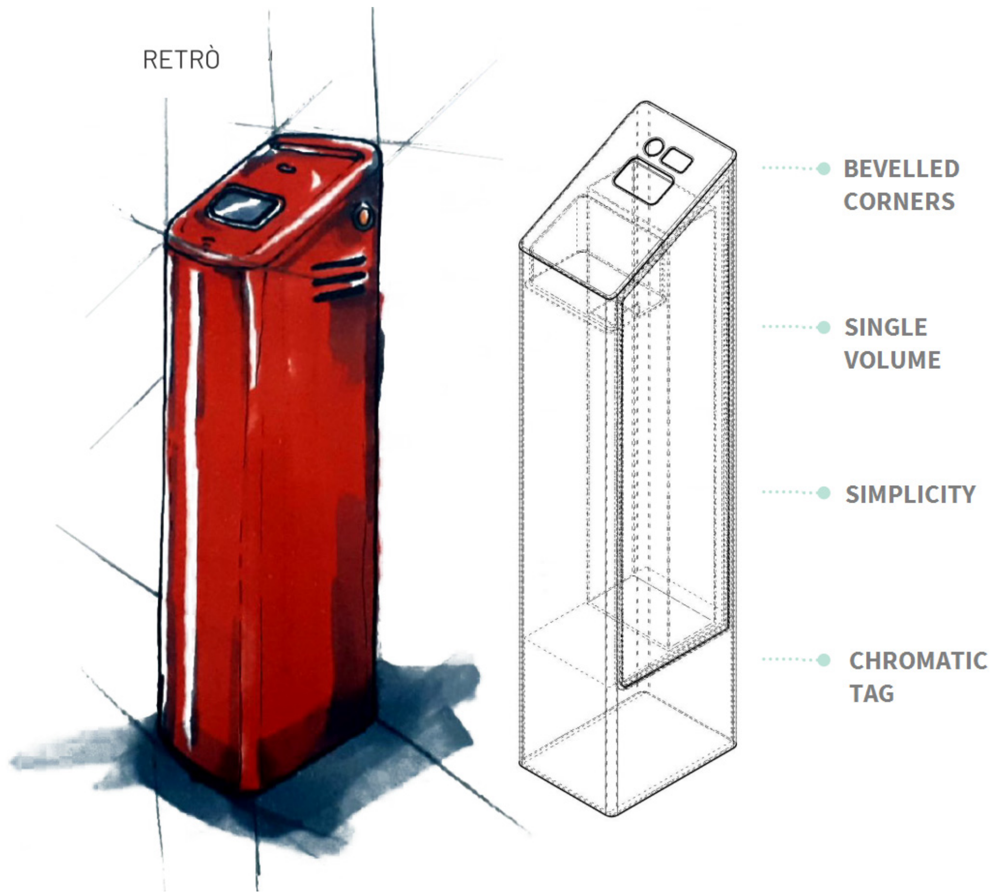

Figure 13. Final Choice—retro style.

3.5. Validate

3.5.1. Validate: CAD 2D Drawings

Initially the 2D CAD drawings were carried out, to better understand if the dimensions of the parts resulting from the sketches were compatible with the constructive reality and use of the object (Figure 14).

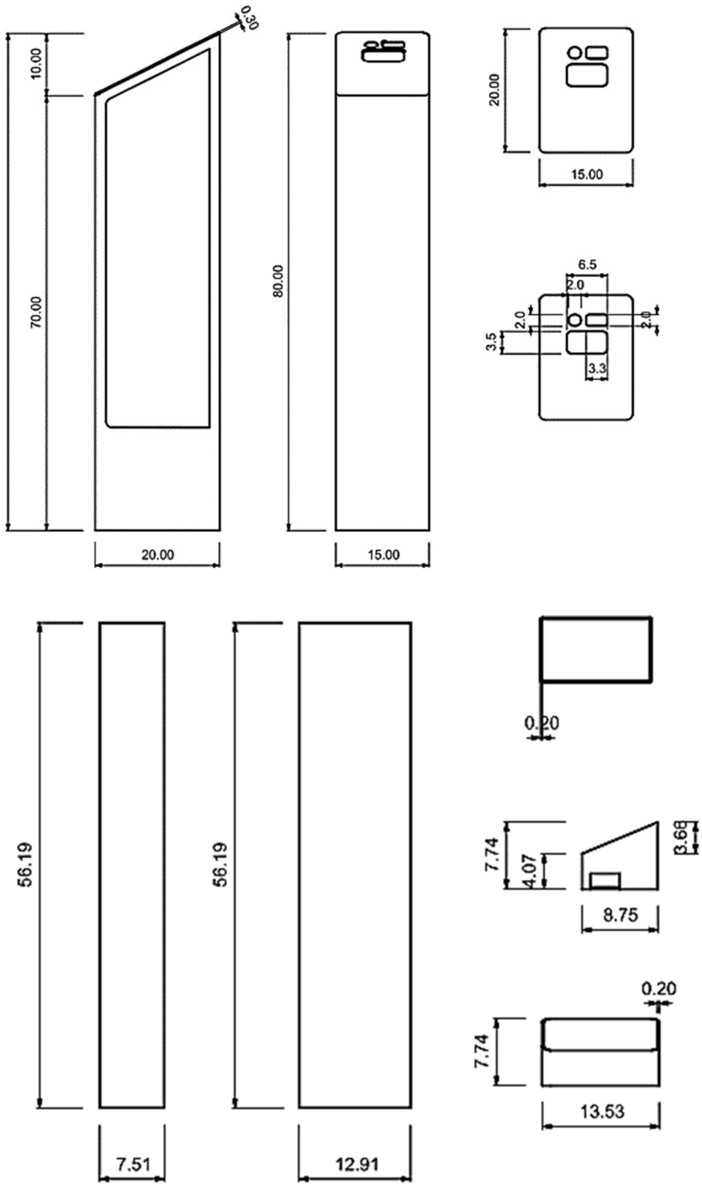

Figure 14. CAD 2D drawings.

3.5.2. Validate: 3D CAD Models

Next, the 3D models of the product are made to further increase the quality of the design and provide the basis for any FEM simulations, rendering, stl file exports for 3D printing, etc. (Figures 15 and 16).

3.5.3. Validate: Budget—Resources & Materials

It is also necessary to carry out budget checks, both relating to the staff employed for the design of the product and relating to the materials used to produce it.

The project is expected to develop over a period of 3 years, the first for analysis and research, the second for design, and the third for market launch. An analysis was made on the design budget, for a period of one year, in which 4 macro design phases follow one another:

3 months—each
3 months—prototyping
3 months—experimentation
3 months—fine-tuning (m.a.p.)

Figure 15. CAD 3D model.

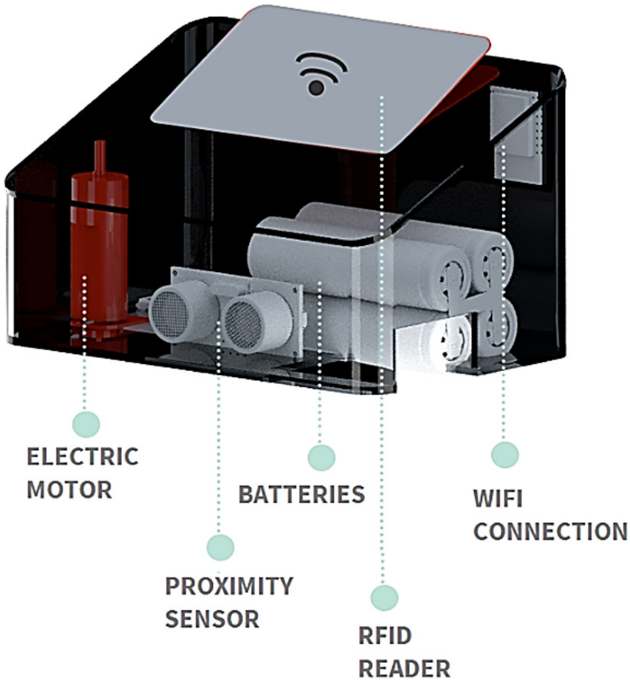

Figure 16. CAD 3D model.

The professional figures who act are 3 designers (a designer, a mechatronic engineer, and a computer scientist), a buyer, and a worker. The remuneration for these figures is 40 euros per hour for the designers, and 30 euros per hour for the workers. We thought of a frequency of 4 working days a week, for 8 h a day. Therefore, the monthly salary compared to the resources is 5.120 euro for the designers, and 3.840 euro for the workers. The amount of costs compared to services over a year, is 132.818,90 euros (Figure 17).

MATERIALS				
STEEL INOX 2 mm	PLEXIGLASS 2/3 mm	MOTOR	ARDUINO	PROXIMITY SENSOR
(30X30) **26,20 €** (70X70) **74,80 €**	(100x50) (22x17) **13.96 €**	**20 €**	**10 €**	**15 €**
WIFI SHIELD	CASE BATTERIE	BATTERY	RFID READER	LED
20 €	**5 €**	**7,90 €**	**3 €**	**5 €**

PROCESSING	
STEEL LASER CUT **30 €**	PLEXIGLASS **30 €**
PIEGA **10 €**	CUT PLEXIGLASS **30 €**
VERNICE **10 €**	
SALDATURA **10 €**	

SINTHESYS	MATERIALS	RESOURCES	PROCESSING
CAD 3D		**24.320 €**	
PROTOTYPING	**186,9 €**	**37.760 €**	**120 €**
SPERIMENTATION		**51.200 €**	
MAP		**19.200 €**	

TOTAL 132.818,9 €

Figure 17. Budget—Resources & Materials.

4. Discussion

The method of Design for Six Sigma approach DMADV was implemented successfully to conceive a product that is demonstrated to be valuable to the public, and technically feasible to manufacture. The QFD and TRIZ tools applied for this study have helped to collect the set of product characteristics that will guarantee the success of this product.

The "Buttalo" service has only been designed but has not yet been implemented, therefore we do not actually know the consequences that its introduction in cities could have and how it could change the bad habits of smokers.

A validation phase would therefore be extremely important to confirm the validity of the project. The creation of the service and the installation of a certain number of collection and recycling stations in a limited area of a city, such as, for example, the central area of the city of Bologna, could give further indications both as regards the actual effectiveness of the service, both as regards the improvement of all its constructive and operational aspects.

5. Conclusions

The "Throw it away!" service can be an excellent incentive for the user in the fight against environmental pollution. It is a means by which the smoker user can change their bad habits and act in an environmentally conscious manner, throwing the butt in the collection device instead of on the ground and enjoying both a moral and economic return. It is therefore expected that the service can be adopted in cities, and that it can become part of the smoker's imagination.

The method of the Design for Six Sigma DMADV approach integrated with TRIZ has given comforting results and it will certainly be very interesting to explore its use in the design of products with a high level of innovation; we therefore wish to conduct further studies and applications in the future practices related to DFSS and TRIZ integration.

Author Contributions: Conceptualization, G.D. and L.F.; methodology, L.F.; software, G.D.; validation, G.D., A.L. and L.F.; formal analysis, C.L.-C.; investigation, L.F.; resources, G.D.; data curation, C.L.-C.; writing—original draft preparation, C.L.-C.; writing—review and editing, G.D.; visualization, G.D.; supervision, L.F.; project administration, A.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Genkin, E.; Filin, S.; Velikorossov, V.; Kydyrova, Z.; Anufriyev, K. The Fourth Industrial Revolution: Personnel, Business and State. *E3S Web Conf.* **2020**, *159*, 4012. [CrossRef]
2. Cooper, R.G. The Drivers of Success in New-Product Development. *Ind. Mark. Manag.* **2019**, *76*, 36–47. [CrossRef]
3. Sandberg, J.; Holmström, J.; Lyytinen, K. Digitization and Phase Transitions in Platform Organizing Logics: Evidence from the Process Automation Industry. *MIS Q.* **2020**, *44*, 129–153. [CrossRef]
4. Tseng, M.-L.; Islam, M.S.; Karia, N.; Fauzi, F.A.; Afrin, S. A Literature Review on Green Supply Chain Management: Trends and Future Challenges. *Resour. Conserv. Recycl.* **2019**, *141*, 145–162. [CrossRef]
5. Manavalan, E.; Jayakrishna, K. A Review of Internet of Things (IoT) Embedded Sustainable Supply Chain for Industry 4.0 Requirements. *Comput. Ind. Eng.* **2019**, *127*, 925–953. [CrossRef]
6. Sjödin, D.; Parida, V.; Jovanovic, M.; Visnjic, I. Value Creation and Value Capture Alignment in Business Model Innovation: A Process View on Outcome-based Business Models. *J. Prod. Innov. Manag.* **2020**, *37*, 158–183. [CrossRef]
7. Becattini, N.; Borgianni, Y.; Cascini, G.; Rotini, F. Investigating Users' Reactions to Surprising Products. *Des. Stud.* **2020**, *69*, 100946. [CrossRef]
8. Aligica, P.D. *Public Entrepreneurship, Citizenship, and Self-Governance*; Cambridge University Press: Cambridge, UK, 2018; ISBN 1-316-94673-8.
9. Khadilkar, P.R.; Cash, P. Understanding Behavioural Design: Barriers and Enablers. *J. Eng. Des.* **2020**, *31*, 508–529. [CrossRef]
10. Pinarello, G.; Trabucchi, D.; Frattini, F.; Manfredi Latilla, V. How Firms Use Inbound Open Innovation Practices over Time: Evidence from an Exploratory Multiple Case Study Analysis. *R&D Manag.* **2022**, *52*, 548–563. [CrossRef]
11. Pellizzoni, E.; Trabucchi, D.; Buganza, T. When Agility Meets Open Innovation: Two Approaches to Manage Inbound Projects. *Creat. Innov. Manag.* **2019**, *28*, 464–476. [CrossRef]
12. Barry, K.; Domb, E.; Slocum, M.S. TRIZ Grows TRIZ, 2022. Available online: https://www.aitriz.org/documents/TRIZCON/Proceedings/Domb-Slocum-Barry-TRIZ-Grows-TRIZ.pdf (accessed on 18 January 2022).
13. Hmina, K.; Sallaou, M.; Arbaoui, A.; Lasri, L. A Preliminary Design Innovation Aid Methodology Based on Energy Analysis and TRIZ Tools Exploitation. *Int. J. Interact. Des. Manuf.* **2018**, *12*, 919–928. [CrossRef]
14. Bade, R.; White, J.M.; Tscharke, B.J.; Ghetia, M.; Abdelaziz, A.; Gerber, C. Anabasine-based Measurement of Cigarette Consumption Using Wastewater Analysis. *Drug Test. Anal.* **2020**, *12*, 1393–1398. [CrossRef]
15. Kurmus, H.; Mohajerani, A. The Toxicity and Valorization Options of Cigarette Butts. *Waste Manag.* **2020**, *104*, 104–118. [CrossRef]
16. Zhang, Y.K.; Gao, L.; Hong, Y.; Shen, W.-J.; Wang, Y.; Zhu, J.H. Sustainable Sorbent Derived from Discarded Cigarette Butts for Elimination of Tobacco Specific Nitrosamines Carcinogen. *Environ. Technol. Innov.* **2021**, *24*, 101825. [CrossRef]
17. Araújo, M.C.B.; Costa, M.F. From Plant to Waste: The Long and Diverse Impact Chain Caused by Tobacco Smoking. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2690. [CrossRef]
18. Slaughter, E.; Gersberg, R.M.; Watanabe, K.; Rudolph, J.; Stransky, C.; Novotny, T.E. Toxicity of Cigarette Butts, and Their Chemical Components, to Marine and Freshwater Fish. *Tob. Control* **2011**, *20*, i25–i29. [CrossRef]
19. Zafeiridou, M.; Hopkinson, N.S.; Voulvoulis, N. Cigarette Smoking: An Assessment of Tobacco's Global Environmental Footprint across Its Entire Supply Chain. *Environ. Sci. Technol.* **2018**, *52*, 8087–8094. [CrossRef]
20. Spreafico, C. Quantifying the Advantages of TRIZ in Sustainability through Life Cycle Assessment. *J. Clean. Prod.* **2021**, *303*, 126955. [CrossRef]
21. Casner, D.; Livotov, P.; Da Silva, P.K. TRIZ-Based Approach for Process Intensification and Problem Solving in Process Engineering: Concepts and Research Agenda. In *Advances and Impacts of the Theory of Inventive Problem Solving*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 217–229.
22. Ginting, R.; Ishak, A.; Fauzi Malik, A.; Satrio, M.R. Product Development with Quality Function Deployment (QFD): A Literature Review. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *1003*, 012022. [CrossRef]
23. Rampal, A.; Mehra, A.; Singh, R.; Yadav, A.; Nath, K.; Chauhan, A.S. Kano and QFD Analyses for Autonomous Electric Car: Design for Enhancing Customer Contentment. *Mater. Today Proc.* **2022**, *62*, 1481–1488. [CrossRef]
24. Mazur, G.; Belt, Q.F.D.R. Beyond ISO 16355: QFD for a Digital World. In Proceedings of the 23rd International QFD Symposium, Tokyo, Japan, 7–8 September 2017; pp. 106–110.

25. Elhegazy, H.; Ebid, A.; Mahdi, I.; Haggag, S.; Abdul-Rashied, I. Implementing QFD in Decision Making for Selecting the Optimal Structural System for Buildings. *Constr. Innov.* **2020**, *21*, 345–360. [CrossRef]
26. Purushothaman, K.; Ahmad, R. Integration of Six Sigma Methodology of DMADV Steps with QFD, DFMEA and TRIZ Applications for Image-Based Automated Inspection System Development: A Case Study. *Int. J. Lean Six Sigma* **2022**, *13*, 1239–1276. [CrossRef]
27. Vanany, I.; Maarif, G.A.; Soon, J.M. Application of Multi-Based Quality Function Deployment (QFD) Model to Improve Halal Meat Industry. *J. Islam. Mark.* **2019**, *10*, 97–124. [CrossRef]
28. Lankford, W.M. Benchmarking: Understanding the Basics. *Coast. Bus. J.* **2022**, *1*, 8.
29. Huang, S.; Wang, G.; Lei, D.; Yan, Y. Toward Digital Validation for Rapid Product Development Based on Digital Twin: A Framework. *Int. J. Adv. Manuf. Technol.* **2022**, *119*, 2509–2523. [CrossRef]
30. Bhavya, G.; Belorkar, S.A.; Mythili, R.; Geetha, N.; Shetty, H.S.; Udikeri, S.S.; Jogaiah, S. Remediation of Emerging Environmental Pollutants: A Review Based on Advances in the Uses of Eco-Friendly Biofabricated Nanomaterials. *Chemosphere* **2021**, *275*, 129975. [CrossRef]