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Application of TRIZ in Inventive Product Design: A Case Study on Baking Tray Rack

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Abstract

Innovation is an important weapon for enterprises to achieve sustainable development in the market. In the large number of product markets featuring dramatic changes today, the products that attract consumers and win their heart must be manufactured to create business opportunities. Therefore, it is more vital to create opportunities of product innovation than to determine consumer needs. Taking the baking tray racks produced by an enterprise for an example, this study innovated the product with the skills and knowledge of TRIZ, a systematic innovation tool, according to consumer needs. In this study, function analysis was adopted to analyze the components and interaction of baking tray racks, and create a function model graph. The causal contradiction chain was analyzed to explore diverse consumer needs for baking tray racks, all the problems were analyzed one by one, and then, interlinked to determine the roots of the problems and identify contradictions. After analysis, 39 engineering parameters were introduced regarding all factors, and the engineering contradiction matrix was employed to seek the inventive principles for innovative ideas. Moreover, the design of the baking tray racks was simplified according to the concept of simplistic design. Eventually, the assumed improved baking tray rack was endowed with three innovative functions: (1) it could be stored away; (2) baking trays of various sizes could be placed on it at the same time; (3) it enabled enterprises to meet consumer needs and be innovative.

Keywords: systematic innovative, TRIZ, baking tray rack

1. Introduction

1.1 Research motives

Western-styled bakeries are scattered across Taiwan and play an essential part in people's daily life. Around 1940, the concepts and skills of various food, such as breads and cakes, were introduced from the West. To date, small traditional stores have developed into central kitchens of mass production, which shows the great need for bread in the Taiwanese diet. The Taiwanese people lead a busy and hasty life, and bread is sold in all convenience stores, which has led to an increasing number of people who buy take-away food to eat on-the-go. Nowadays, there are over 10,000 bakeries in Taiwan, creating an annual sales volume of NTD 60 billion, which accounts for merely one tenth of the annual output of Taiwan's food industry (China Productivity Center, 2016). Although the amount is not too large, this industry plays a significant role in Taiwanese market.

The use of space is particularly important in bread making. All bread-making locations, big or small, feature three steps for bread placement: handmade dough is placed for fermentation; frozen dough is placed for unfreezing; finished bread is placed for cooling after baking. As such placement requires both time and space, the need for space is a big problem; therefore, a vertical structure was adopted as the main architecture of earlier baking tray racks, which allowed many baking trays to be placed, and limited space to be fully used.

In addition to the basic function of wheel installation, a transparent cover could be added or a customized closed baking tray rack could be made according to consumer needs. However, there remain two unaddressed needs and problems in the use of baking tray racks according to the suggestions for manufactures: the baking tray rack occupies too much space; there is limited placement for baking trays of different sizes.

1.2 Research purposes

A baking tray rack is used for storing baking trays; however, traditional baking tray racks were limited by the mainstream design, meaning that all baking trays must be the same size to fit the racks. All commercial spaces represent both an asset and a cost to investors, thus, attention must be paid to how such spaces are used, such as the placement of baking tray racks. According to two problems inherent in the traditional baking tray rack, this study focuses on creative thinking in the design of existing products, and seeks to maximize the use of the space required for baking tray racks.

1.3 Research method and procedure

This study collected the problematic issues of products available on the market in order to identify the shortcomings of the functions of the products, and then, adopted TRIZ, a systematic innovation tool, to design an improved product for the market.

The architecture and procedures of this study are, as follows:

1. Introduction: This section elaborates on the research background, motives, research objectives, problem definition, and research method and procedures.

2. TRIZ: This section illustrates the analytic tool adopted in this study, examines how the solution is proposed according to the contradiction matrix of TRIZ, and offers 40 inventive principles, thus, displaying the ability of the analytic tools of TRIZ, and how it is used in this study.

3. Development procedure: In this section, a series of TRIZ tools are employed to analyze and design the products of the case study.

4. Conclusion and suggestions: The development procedure in this study is described, and suggestions and future directions for product development are proposed.

2. Analytic tools of TRIZ

2.1 Development of TRIZ

TRIZ is an abbreviation consisting of the initial letters of four English words transliterated from Russian, namely, Teoriya, Resheniya, Izobreatatelskikh, and Zadatch, literally meaning the "Theory of the Inventive Problems Solving". It is a systematic method of thought proposed by Genrich Altshuller, a Russian patent attorney and inventor (Savransky, 2000).

In addition to product design, TRIZ is applied to business, society, quality management, finance, marketing, and architecture (Yan et al., 2014). Savranky (2000) stated that only TRIZ could effectively solve some problems, including unknown reasons or directions. Additionally, some Top 500 enterprises succeeded in enhancing their productivity and quality through TRIZ, which demonstrates its great importance for enterprises. One of the features of TRIZ is that it can convert harmful resources into useful resources, eliminate contradictions, and replace the original compromise (Mann & Winkless, 2001; Su & Lin, 2008).

2.2 Functional analysis

Function analysis (FA) is helpful in detecting negative functions and the most fundamental problems of a system. When distinguishing the relations among the functions of systematic and definition components, function analysis can be divided into four types: useful, harmful, excessive, and insufficient, which are represented by the arrows shown in Fig 1.

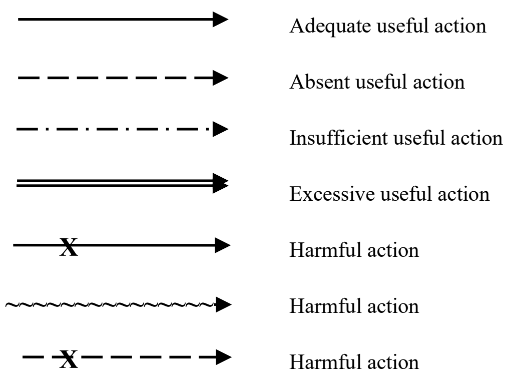

Fig. 1 Function signs (Savransky, 2000)

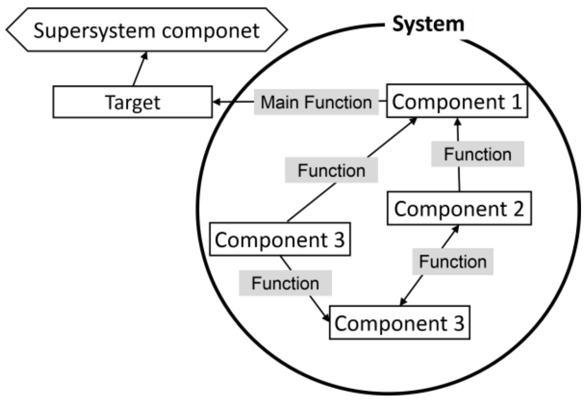

Fig. 2 Function analysis example

In function analysis, a supporting tool can enhance the FA -- functional hierarchies, whose architecture includes the constituents and functions between the system and the subsystem. Its strength is that it can simplify the system (see Fig. 2).

2.3 Engineering contradiction

Contradiction is one of core concepts in TRIZ. Among over 150,000 patents across the world, Altshuller identified contradictions among the 39 engineering parameters and the 40 inventive principles to put forward the contradiction matrix, in order to obtain a standard solution for thinking within a short time. Engineering contradiction occurs in causal analysis, where a reason can improve one result, while worsening another.

There are core problems in contradiction, thus, the 40 inventive principles of TRIZ are intended to help enterprises determine the causes for problems, and seek improvements.

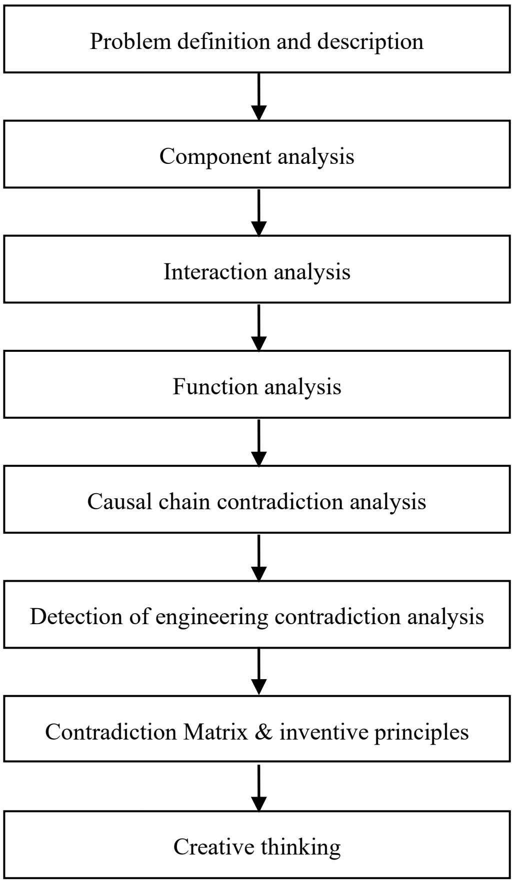

Fig. 3 Development procedure

3. Development procedure

The overall product development and design procedure is as shown in Fig. 3. First and foremost, problem definition is conducted to determine needs and problems. Then, the analytic tools of TRIZ are adopted for improvement until the inventive principles are obtained to assess and define feasible approaches.

3.1 Problem definition and description

Currently, there are limitations on the framework breadth of baking tray racks, and there is no universal standard for breadth in the market. Meanwhile, as the breadth of supporting sheets affects heat radiation, baking trays of the same breadth cannot be placed on a rack. Due to the mainstream design, baking tray racks cannot be stored away, thus, the use of space for baking tray racks is limited.

Therefore, two problems are defined in this study: **baking trays of different sizes cannot be placed on the baking tray rack** and **baking tray racks cannot be hidden**. These two problems are analyzed in the following sections.

3.2 Component analysis, interaction analysis, function analysis, and cause effect chain analysis

In component analysis, a rack can be divided into several components which include X framework (horizontal breath), Y framework (horizontal depth), Z (vertical height), supporting sheet, weld, shaft, brake, wheel, big backing tray, medium baking tray and small backing tray (see Fig. 4 and 5).

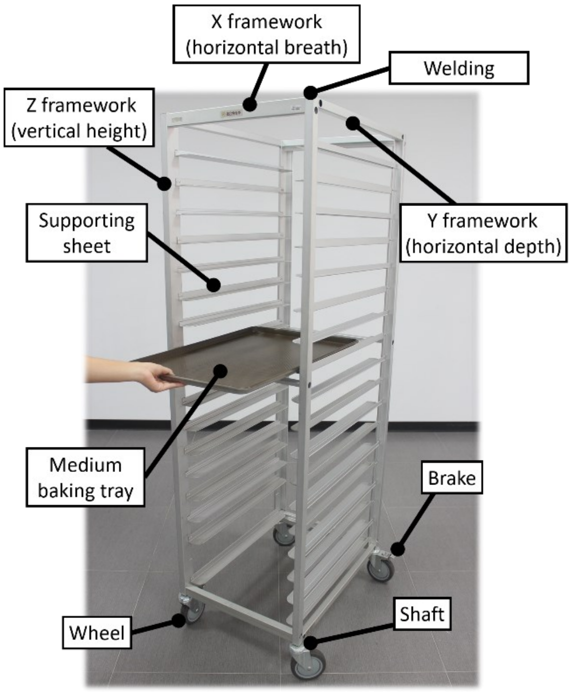

Fig. 4 The component analysis of the backing tray rack

Fig. 5 The component analysis of three different sizes of backing trays

All the components are analyzed the interaction between components. The symbol "+" is marked if there is interaction, while the symbol "-" is marked if there is no interaction (see Table 1). Then, function analysis is employed to define the contents and importance of functions according to the existing interaction among the components It helps identify useful and harmful functions, and categorize useful functions into three levels, basic, auxiliary and additional functions, and three degrees, normal, insufficient and excessive (see Table 2).

The function analysis table is converted into a function model (see Fig.6), which shows that excessive and insufficient "placement function" exists among large and small baking trays on the supporting sheets. The same problem could be found in the capacity of the X framework. According to the component analysis of the capacity among baking tray racks, the framework was divided into X, Y, and Z framework, and two paralleled baking tray racks would touch each other. According to the problem, the supporting sheets and framework require improvements.

Table 1 Interaction analysis

	1.X framework	2.Y framework	3.Z framework	4.Supporting sheet	5.Weld	6.Shaft	7.Brake	8.Wheel	9.Big baking tray	10.Medium baking tray	11.Small baking tray
1		+	+	-	+	+	-	+	-	-	-
2	+		+	-	+	+	-	+	-	-	-
3	+	+		+	+	+	-	+	+	-	-
4	-	-	+		-	-	-	-	-	+	-
5	+	+	+	-		+	-	-	-	-	-
6	+	+	+	-	+		+	+	-	-	-
7	-	-	-	-	-	+		+	-	-	-
8	+	+	+	-	-	+	+		-	-	-
9	-	-	+	-	-	-	-	-		-	-
10	-	-	-	+	-	-	-	-	-		-
11	-	-	-	-	-	-	-	-	-	-	

Table 2 Function analysis

Function	Objective	Classification	Level	Degree
Brake				
Stop	Wheel	Useful	Auxiliary	Normal
Shaft				
Support	X framework	Useful	Auxiliary	Normal
Support	Y framework	Useful	Auxiliary	Normal
Support	Z framework	Useful	Auxiliary	Normal
Rotate	Wheel	Useful	Auxiliary	Normal
Wheel				
Support	Shaft	Useful	Auxiliary	Normal
Welding				
Fix	X framework	Useful	Auxiliary	Normal
Fix	Y framework	Useful	Auxiliary	Normal
Fix	Z framework	Useful	Auxiliary	Normal
Fix	Supporting sheet	Useful	Auxiliary	Normal
Fix	Shaft	Useful	Auxiliary	Normal
Supporting sheet				
Support	Medium baking tray	Useful	Basic	Normal
Z framework				
Locate	Supporting sheet	Useful	Auxiliary	Normal
Support	X framework	Useful	Auxiliary	Normal
Support	Y framework	Useful	Auxiliary	Normal
Block	Big backing tray	Harmful	n/a	n/a
Y framework				
Support	X framework	Useful	Auxiliary	Normal
Support	Z framework	Useful	Auxiliary	Normal
X framework				

Function	Objective	Classification	Level	Degree
Support	Y framework	Useful	Auxiliary	Normal
Support	Z framework	Useful	Auxiliary	Normal

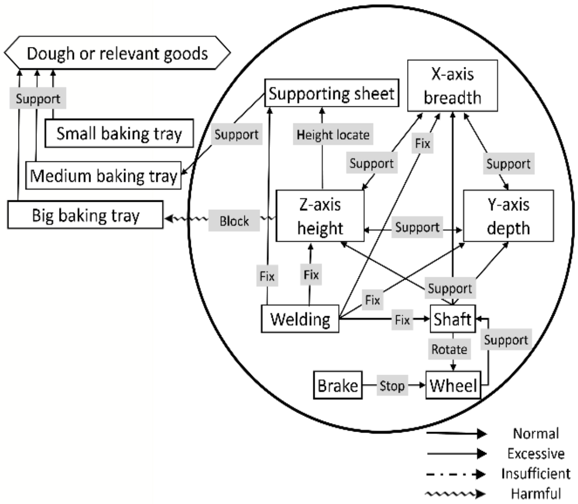

Fig. 6 The function model of baking tray rack

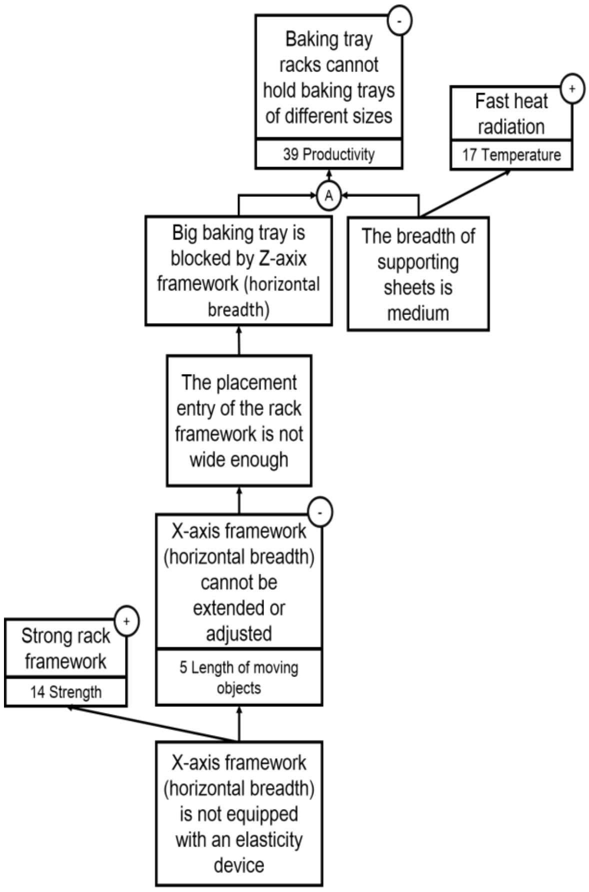

Fig. 7 Causal contradiction analysis (first issue)

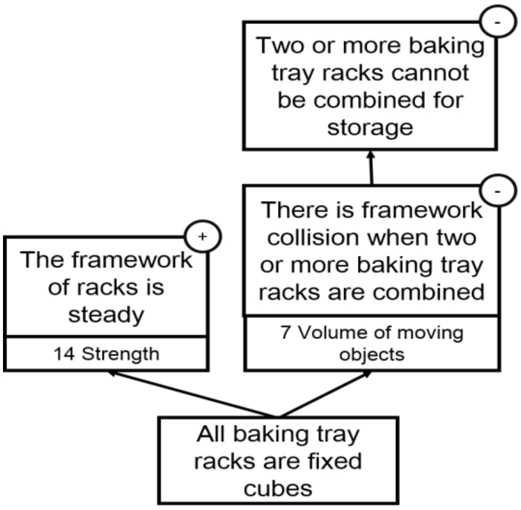

Fig. 8 Causal contradiction analysis (second issue)

Eventually, according to the defined problems, these 2 issues were taken for causal chain contradiction analysis (See Fig. 7 and 8). The engineering parameters were retrieved, and the deteriorating and improving parameters were defined one by one. Regarding placement, the reasons for the problems in supporting sheets and frameworks were analyzed: the breadth of supporting sheets was medium; the framework could not be extended or adjusted. Each of these two reasons formed an engineering contradiction, thus, forming the 40 inventive principles consistent with the contradiction matrix.

3.3 Contradiction matrix

In the causal contradiction analysis, the engineering parameters marked with "+" presents as improving features, while those marked with "-" denote the worsening features, as caused by providing a certain parameters. These features were classified as 39 engineering parameters and based on the principles of high-quality patents concludes 40 inventive. Therefore the contradiction matrix was used to determine the corresponding 40 inventive principles which and helped us to deal with these contradiction (Savransky, 2000). The first issue of current backing tray rack is that it is designed to hold a unique size of trays. However, there are usually many different sizes of trays in the working environment (see Fig. 9). Secondly, there are usually more than one backing tray rack which cause a problem when being stored (see Fig. 10).

Fig. 9 The first issue of the current backing tray rack

Fig. 10 The second issue of the current backing tray rack

While using cause-effect-chain analysis, we find that the root causes of these problems are the contradiction between 'strong rack framework' and 'X framework cannot be extended or adjusted' and the contradiction between 'the framework of racks is steady' and 'there is framework collision when two or more backing tray racks are combined' (see Tables 3 and 4).

Table 3 Engineering Matrix of the Contradiction Between Strength and the Length of Moving Objects

Worsening Parameter / Improving Parameter	5. Length of Moving Objects
14. Strength	1. Segmentation
	15. Dynamization
	8. Anti-weight
	35. Parameter changes

Table 4 Engineering Contradiction Matrix of Strength and the Volume of Moving Objects

Worsening Parameter / Improving Parameter	7. Volume of Moving Objects
14. Strength	10. Preliminary action
	15. Dynamization
	14. Sphere Shape
	7.Nested doll

When considering the approach how to apply the listed inventive principles to products; each inventive principle provides a solution direction rather than an absolute solution; therefore, it is necessary to take countermeasures most suitable for the products, according to the features and functions of the products. The inventive principles, showing in the contradiction matrix, are presented in order of decreasing frequency of their use in past patents (Savransky, 2000). In this study, the inventive principles of "Parameter changes" and "Nested doll" are chosen for generating inventive solution for new products.

3.4 Innovative thinking and procedure of inventive principles

Following is an interpretation of inventive principle 35, "Parameter changes": Change physical states or change measurable parameters (Savransky, 2000). Therefore, the general solution is used to consider certain solutions. By focusing on the supporting sheets, the original mutually paralleled supporting sheets were developed into five angle-based change combinations (see Fig. 11).

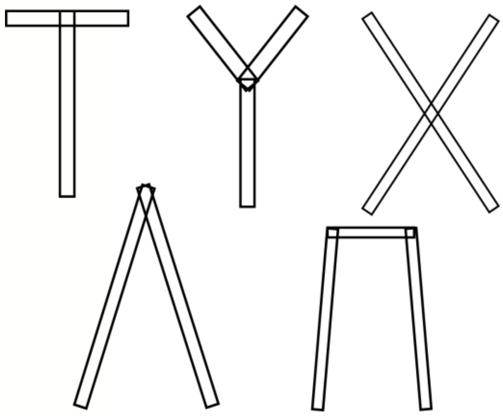

Fig. 11 Angle-based Change Combinations of Supporting Sheets (Top View)

Following is an interpretation of inventive principle 7, "Nested doll": An object or system is placed in another object or system (Savransky, 2000). This inventive principle shows that shopping carts are among the existing products that share the same concept (see Fig. 12). This product can be stored away in the nesting position due to its horizontal angle of elevation and the vertical supporting structure on one side.

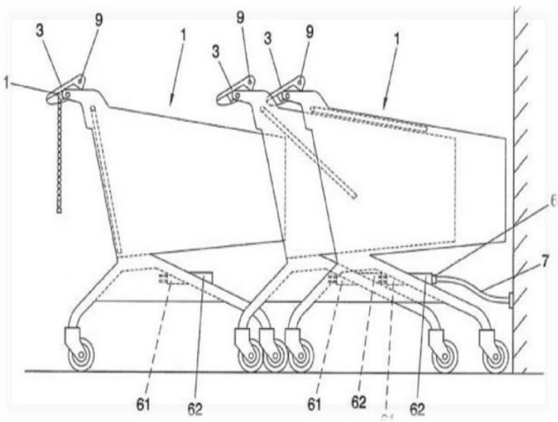

Fig. 12 Side View of Shopping Cart
Source: Gomera Rincon, Jose Antonio Perez Robles, Judith, Spanish patent NO. U201030810 (July 29, 2010.)

Following is a description of the best solutions to the two above-mentioned problems, placement and storage, are listed as the below:

1. The number of Z frameworks (vertical) is reduced from 4 to 2.

2. The supporting function of supporting sheets is merged into an XY framework (horizontal) to create "a framework that supports baking trays".

3. Trapezium is adopted for the angle combination of the XY framework (horizontal).

4. The angle of elevation of the XY framework (horizontal) is 15°.

According to the above-mentioned proposals, an "innovative baking tray rack" was designed in this study. In addition to maintaining a simplistic design and avoiding making products more sophisticated, this study developed the following functions:

1. The overall form of the innovative baking tray rack is similar to a shopping cart. It can be stored away and save space (see Fig. 13 and 14), thus, reducing wasted space when the rack is left unused.

2. The trapezium-shaped XY framework (horizontal) allows the placement of baking trays of different sizes, which diversifies the use of the baking tray rack (see Fig. 15).

3. The angle at which baking trays are placed increases from one to many, which enhance the efficiency of use.

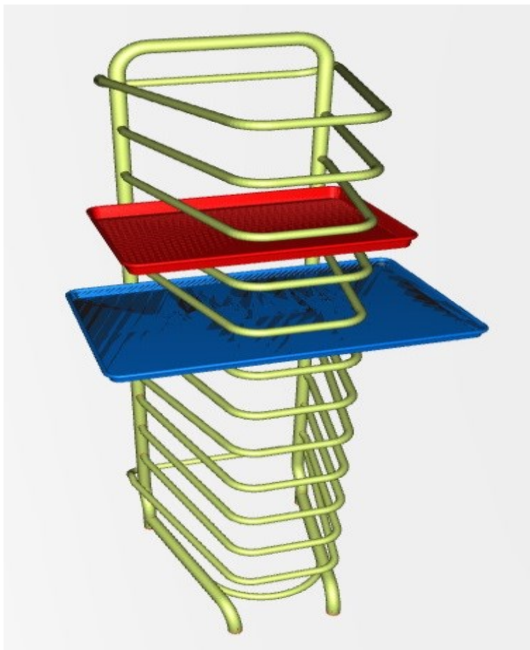

Fig. 13 Storage of the Innovative Baking Tray Rack (Top View)

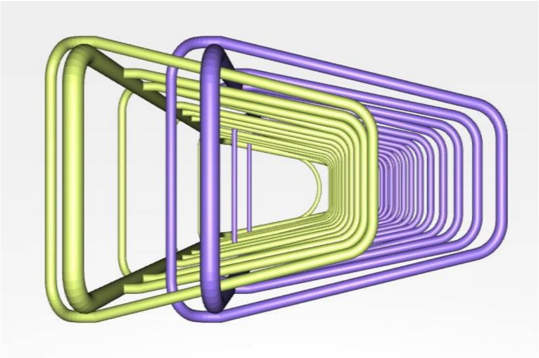

Fig. 14 Storage of the Innovative Baking Tray Rack (Side View)

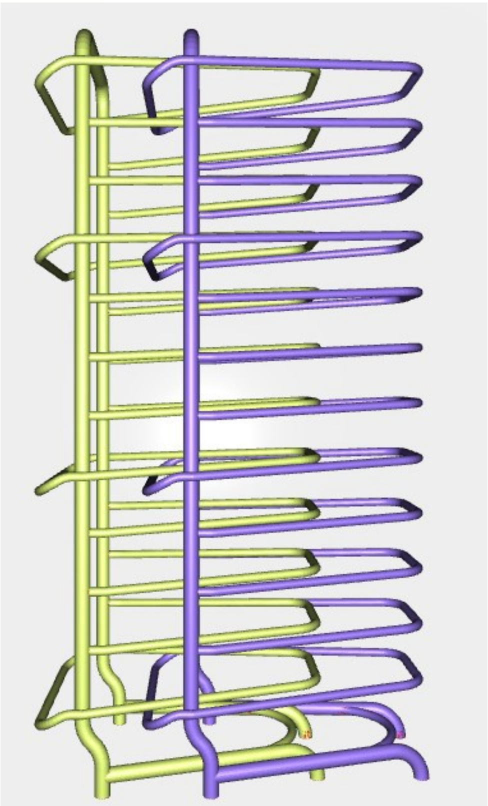

Fig. 15 Placement of Baking Trays of Different Sizes

4. Conclusion and suggestions

Three innovative functions are combined in this innovative product: baking trays of different sizes can be placed at the same time; baking trays can be placed at different angles; the rack can be stored away, which are functions best demonstrated in a central kitchen featuring mass production. Usually, a large number of baking tray racks are needed in a central kitchen for the placement of baked foods. In addition to diversifying the movements of bakers and the placement of baking trays, this innovative baking tray rack can hold baking trays of different sizes. Hence, the innovative product has great value.

In addition to a large central kitchen, this innovative product is applicable to small and medium sized baking rooms. In consideration of limited assets, small and medium bakers often choose a small area for production, thus, this innovative product will contribute to flexible utilization of space according to the production demands of these bakers. Moreover, when baking trays are renewed, the new ones would likely be different from the old ones in size, thus, this innovative product can well meet renewal needs and maximize the use of limited space.

However, there are still some problems to be solved in innovative baking tray racks. For instance, it remains unknown whether there will be a safety problem regarding space when there is excessive space caused by the placement of large baking trays. These problems require further discussion in future studies.

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