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Journal of Management Science & Engineering Research
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ARTICLE

Re-designing Conventional Face Mask by Using Triz (Teoriya Resheniya Izobreatatelskikh Zadatch) Method

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ARTICLE INFO

Article history
Received: 21 December 2020
Accepted: 14 January 2021
Published Online: 30 March 2021

Keywords:
New Normal
Covid-19
Face mask
Re-designing
TRIZ

ABSTRACT

New Normal becomes the way out to keep Indonesia's weakened economy because of covid-19 pandemic stays in balance. Of course, New Normal must be well-balanced with the application of strict protocols to reduce transmission rates and anticipate a surge in new cases. From a few points of pandemic protocols, using face mask is considered as the most-effective basic need. Re-designing the mask is aiming at eliminating the worsening feature and developing the improving feature. This research is developing the widely used 1-ply mask, which doesn't meet WHO standard regarding cloth-material mask that must be made in 3-ply. The method used in this research is TRIZ (Teoriya Resheniya Izobreatatelskikh Zadatch), an inventive problem solving theory to the issues regarding ideas, products, or concepts, in this case is face mask redesigning concept. In this research, the data are collected by doing library research to obtain secondary data that will be processed in qualitative and quantitative methods. The results show the aspects that should be eliminated from cloth-material face mask are brittle for being easily damaged, short period of usage, and non-reusable. After the redesigning concept is carried out using the principles and features of TRIZ method, some aspects such as weight, material, design, and functionality are developed. The result is a relatively light weight face mask because the using of PLA+ filament-based material with good durability and environmentally friendly. This design has a longer period of usage, and the user only needs to replace the additional inserted tissue every 4 hours. The researchers hope that the new design can be further developed by government to deal with New Normal and other possibilities in the future.

1. Introduction

Covid-19 (Novel Coronavirus disease 2019) is a virus that causes mild to severe infections of respiratory tract such as common cold, runny nose, fever, cough, and short breath. These symptoms will be severe if the patient is old and has comorbidities, such as obstructive pulmonary disease, heart disease, so-on. The transmission happened from animals to humans (Zoonosis) and from humans to humans. The spreading cannot be underestimated. For

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 DOI: https://doi.org/10.30564/jmser.v4i1.2714

human to human transmission, it occurs when respiratory droplets from people with Covid-19 reach mucous areas of respiratory tract such as nose and mouth, as well as the eyes. We need to know that the infectious droplets are fluids dispersed from human respiratory tract when talking, coughing, or sneezing. This is a very important thing to comprehend, so that we can anticipate all the possibilities of Covid-19 infections, especially considering the rapid spread.

Early December 2019 became a scourge for the world, as the beginning of the spread of covid-19 occurred in Wuhan, China. The spread was suspected to be occurred because of an unhealthy lifestyle of Wuhan people, by eating unusual animals such as centipede, caterpillar, scorpion, bat, so-on. January 1, 2020, the Huanan Seafood Wholesale Market in Wuhan was closed as being suspected to be the starting point for the spread of Covid-19.

On March 2, 2020, the Indonesian government announced the first 2 positive cases of Covid-19 patients. However, the identification of those cases had found that the case no longer imported but local transmission. The entry of the virus occurred through international gateways in several parts of Indonesia. In January, this new type of corona virus was announced to be transmissible between humans, and had spread to various countries outside China through travel between countries.

3D mask is a type of face mask developed by FTI UMI to deal with Covid-19 pandemic. Before, cloth-material face mask had to be replaced with a new one every 4 hours of usage for a safe using. Above all, market price of masks had been sky-rocketed due to irresponsible practices of hoarding and selling medical masks at unreasonable high prices. Based on the phenomena, the researchers developed a new concept of the face mask to make a longer usage, cheap, efficient, and environmentally friendly, which called as 3D Face Mask.

3D face mask is made from filament materials. Filament is a recycling material made of used plastic and corn extract, while the printing process using 3D printer as the main tool. 3D printer melts the filament, shapes the design, and prints the material into mask. Besides being environmentally friendly and efficient, to use this mask is also convenient. Based on the recommendation to use a mask for 4 hours maximum, by using 3D mask, users can only change the tissue as the main filter, so the inconvenience for changing the mask to a new one in every 4 hours is lessened.

Products are everything offered to the market to fulfill wishes or needs. The term of product is including tangible goods, services, events, places, organizations, ideas or combinations of mentioned things. Siswanto Sutojo (2005: 78) states that companies must pay attention to several important factors in formulating their product strategy [1]. The first factor is the strategy in selecting market segments that has been decided. The second factor is understanding the essence of product in buyer's point of view. The third factor is product strategy at the extent of product series, individual product combination, and product combination as a whole. Furthermore, the fourth factor is the focus of marketing strategy at each stage of product life cycle [1].

A product is considered as good if it has the quality which fits to customer wishes, with as minimum defects as possible. Quality control has the functions to suppress the number defective products, to maintain products quality that meet company standards, and to prevent continuous distribution of defective products to consumers [2].

According to Montgomery (2001), Quality Control is a "Purposeful activity. With technical Quality Control activities or management, product characteristics can be measured, compared with product specifications or requirements, then performed appropriate improvement measure for any difference between the actual appearance, according to standard" [2].

TRIZ (Theory of Inventive Problem Solving) is generated from Russian acronym "Teoriya Resheniya Izobreatatelskikh Zadatch", a method developed by Genrich Altshuller. TRIZ has stages or algorithms for problem solving, started from determining the specific problem by identifying the contradiction that occurs. The identified contradictions that have been resolved will be applied into general solutions to create specific solutions (Navas, 2014). The stages in this research used several theories related to TRIZ method, consisted of the innovation situation questionnaire, diagram of situation model, direction for innovation, and inventive principles. [3].

According to Putri and Oemar (2017), problem solving process with TRIZ method has three stages, as follows:

(1)Identifying the problem by finding out all possible factors that could become a problem.

(2)Classifying the problem by determining the supporting and opposing factors into 39 technical parameters, and using the contradiction matrix to find the solution as its further settlement pattern.

(3)Finding problem solutions that have to be done in resolving the contradictions by using 40 creative principles

Quality Function Deployment (QFD) is a methodology in design and development process of a product or service which able to integrate the "consumer's voice" into design

DOI: https://doi.org/10.30564/jmser.v4i1.2714

process. QFD is actually a way for companies to identify and fulfill consumer needs and desires for the products or services they produce [4].

Yuliarty, et al. (2013) states that QFD brings a number of benefits to organizations that seek to continually increase their competition in improving their quality and productivity. The benefits of QFD include:

(1)Focus on the customers. QFD requires to muster up input and feedback from customers. The information is then translated into a set of customer's specific requirements.

(2)Time Efficiency. QFD can reduce the time needed in product development because it focuses on specific, clear identification of customer requirements.

(3)Teamwork orientation. QFD is a teamwork orientation approach. All decisions in the process are based on consensus and obtained through in-depth discussion and brainstorming.

(4)Orientation to documentation. One of the products generated from QFD process is comprehensive document of all data related to the whole processes, and its comparison with customer requirements.

Another benefit that can be obtained from implementing QFD is customer focused [5] including getting input and feedback from customers related to their needs and expectations. This is important, because the performance of an organization cannot be separated from customers, especially if the competitors are doing the same thing.

QFD process is started from market segmentation research to find out the prospective customer for the product, customer characteristics and needs, and then evaluates the market competition level. The results of market research are technically translated into a product design that fits customer requirements. It is then continued with *process design* which is designing product manufacturing process to find out the characteristics of each part or stage of production process. Then, the operation or production process and the flow of production process are determined. Lastly, production plan and implementation which resulted in products according to customer needs is arranged [6].

2. Research Method

The steps in this study consisted of several stages. The first step was the identification of the problems that occur. The problem in this case was how to redesign conventional mask into an excellent item in terms of quality and comfort by using TRIZ method, with the help of Quality Function Deployment (QFD) tools.

The second step was to conduct literature study over several journals and previous research related to product design and development. The next step was to collect and process the data. First, QFD was used to determine the attributes of consumer needs and desires and then translate them into product specifications. The initial stage was extract the information regarding consumer needs by distributing satisfaction questionnaires to 120 populations (100 respondents) and interests with 14 attributes and 1-5 of Likert scale. Operational definition of this research was:

Table 1. Operational Definition of Research Variables

No	Variables	Operational definition	Categories	Measuring instrument	Scale
1	The level of consumer needs	Research materials taken directly by consumers for the development of a product	•Urgently Needed •Needed •Quite needed •No need •Highly no need	Questionnaire	Ordinal
2	Innovation Situation Questionnaire (ISQ)	Reference based on the concept of a product from sources who are experts in their fields	•Positive >50% •Negative <50%	Questionnaire	Nominal
3	The level of customer satisfaction	To measure the level of consumer satisfaction with the product concept that has been realized	•Very Satisfied •Satisfied •Quite satisfied •Not satisfied •Very dissatisfied	Questionnaire	Ordinal

After the questionnaires being recapitulated, HOQ compilation which consisted of several processes was carried out. The process determined the attributes, technical response, interaction matrix, and specifications and targets. The second step used TRIZ method which aimed to resolve contradictory problems in the design. From HOQ, technical response was obtained based on the highest priority attribute. The next step was to reduce all technical and physical contradictions of technical response through TRIZ method, to improve the performance of existing design. Started with the determination of specific problem obtained from the technical response result to the results of the questionnaire, then proceed with determining the general problem of technical and physical contradictions. The technical contradiction had resolved immediately with contradiction matrix table and *40 inventive principles* tools, while physical contradictions used either *separation principles* tool or *40 inventive principles* tool. The last stage in TRIZ was to find the best solution from the alternative solutions given.

After obtained the chosen alternative, the next step was the process of product design for 3D Ergonomic Masks

 DOI: https://doi.org/10.30564/jmser.v4i1.2714

production. The process was started with designing step by using Sketcup software, converted the shape in 3D printer machine to print the model, and put the material insert. The steps then proceeded to the finishing stage. This step aimed to make a comparison between the initial conditions and the after-redesigning results.

3. Result and Discussion

3.1 Identifying User Needs

Based on the results of satisfaction questionnaires when demonstrating three types of face masks which public usually used, N-95 mask was a reference for product improvement compared to the other face masks because it had the highest level of satisfaction in some of 14 attributes.

Figure 1. N-95 face mask

After obtaining the object for reference, the HoQ matrix was compiled. The first stage was identify VOC (Voice of Customer) through questionnaire with the level of satisfaction and importance were on 14 attributes, resulted from brainstorming through ISQ (Innovation Situation Questionnaire) with doctors at the Sandi Karsa hospital, engineering lecturers, and face mask makers who made conventional cloth masks related to this research, as well as public as face mask users. The next step was to create planning matrix. This matrix recorded the importance of each product's needs and benefits offered to users based on the interpretation of development team and research data.

Table 2. Planning Matrix

How / Where	Proses pembuatan masker	Bentuk utama badan masker	Bentuk clip dalam masker	Jenis bahan badan utama masker	Bentuk tali penyangga masker	Lebar badan masker	Panjang tali penyangga masker	Jenis bahan tali penyangga	Panjang *clip* dalam masker	Panjang badan utama masker	Lebar clip dalam masker	Jenis bahan clip dalam masker	Importance to Customer (ItC)	Customer Satisfaction Performance (CuSP)	Competitive satisfaction performance: Produkpesaing 1	Produkpesaing 2	Produkpesaing 3	goal	Improvement ratio	Sales point	Raw weigh	Normalized Raw Weigh	Custtomer Rating
Kemudahan Dalam Penggunaan		◎	○		◎								4,44	4,4	4,24	4,34	4,12	4,31	0,98	1,5	6,5	0,07	8v
Dimensi masker menutupi seluruh bagian mulut dan hidung		◎	△	◎		◎	△	△	△	◎	△	◎	4,58	4,6	4,48	4,4	4,36	4,48	0,97	1,5	6,7	0,07	2v
Ketersediaan fitur plug in mask untuk mengganti tissue filter setiap beberapa waktu			◎						○		◎	◎	4,32	4,42	4,28	4,18	4,16	4,27	0,97	1,5	6,3	0,06	11v
Ketersediaan tali penyangga yang terbuat dari karet elastis							◎	◎					4,54	4,6	4,54	4,48	4,24	4,48	0,97	1,5	6,6	0,07	3v
Ketersediaan ruang sirkulasi udara pada ujung masker di bagian mulut dan hidung		◎				◎				◎			4,5	4,42	4,36	4,36	4,36	4,4	1	1,5	6,7	0,07	5v
Kekuatan Badan Utama Masker	○	◎				◎				◎			4,5	4,6	4,28	4,12	4,24	4,35	0,95	1,5	6,4	0,07	6v
Kekuatan clip dalam masker untuk menyanggah filter tisue			◎						◎		◎		4,54	4,54	4,46	4,4	4,42	4,47	0,99	1,5	6,7	0,07	4v
Kekuatan tali penyangga pada masker							◎	◎					4,42	4,46	4,42	4,26	4,32	4,38	0,98	1,5	6,5	0,07	9v
Kesesuaian masker dengan kontur wajah pemakai		◎				◎				◎			4,66	4,56	4,36	4,52	4,4	4,5	0,99	1,5	6,9	0,07	1v
Kestabilan masker saat digunakan untuk menyaring udara		◎	◎	○	◎			◎				○	4,46	4,56	4,44	4,32	4,34	4,42	0,97	1,5	6,5	0,07	7v
Sirkulasi udara dan hambatan mulut pada masker stabil karena mempunyai rongga		◎				◎				◎			4,4	4,38	4,24	4,36	4,16	4,31	0,98	1,5	6,5	0,07	10v
Service Produk													4,22	4,42	4,08	4,24	4,38	4,27	0,97	1,5	6,1	0,06	13
Variasi bentuk dan desain masker		◎	○	○	○			○				○	3,9	4,08	3,98	4,02	3,94	3,98	0,98	1,5	5,7	0,06	14
Harga Masker	◎	○	○	◎	○	◎	◎	◎	◎	◎	◎	◎	4,28	4,38	4,24	4,32	4,24	4,29	0,98	1,5	6,3	0,07	12
Tingkat kepentingan absolute	1,26	3,5	2,1	3,1	1,26	2,1	1,89	1,26	1,62	2,94	1,89	1,26											
Prioritas Perancangan	9	1	5	2	10	4	11	12	7	3	6	8											

Technical response was determined after planning matrix had obtained. Technical response is a reference or technical specification which will be carried out to fulfill each attribute. In other words, technical response is a solution provided by producers to meet what consumers want. This specification consists of metrics and metric values.

Table 3. Technical Response

Atribut	Metrik
Kemudahan dalam penggunaan	Bentuk
	Material
	Bentuk clip penyangga
Dimensi masker menutupi seluruh bagian mulut dan hidung	Bentuk
	Bentuk clip penyangga
	Material
	Ukuran
Ketersediaan fitur *plugin mask* untuk mengganti *tissue filter* setiap beberapa waktu	Bentuk clip penyangga
	Material
	Ukuran
Ketersediaan tali penyangga yang terbuat dari karet elastis	Material
	Ukuran
	Ketebalan
Ketersediaan ruang sirkulasi udara pada ujung masker di bagian mulut dan hidung	Bentuk
	Ukuran
Kekuatan badan utama masker	Bentuk
	Ukuran
	Material
Kekuatan *clip* dalam masker	Bentuk
	Ukuran
	Material
Kekuatan tali penyangga pada masker	Bentuk
	Ukuran
	Material
Kesesuaian masker dengan kontur wajah pemakai	Bentuk
	Ukuran
Kestabilan masker saat digunakan untuk menyaring udara	Kerapatan Filter
	Bentuk
Sirkulasi udara dan hambatan mulut pada masker stabil karena mempunyai rongga	Bentuk
	Ukuran badan masker
Service Produk	Jenis layanan
	Bentuk masker
Variasi bentuk dan desain masker	Bentuk
	Warna
	Ukuran
	Material
Harga masker	Biaya produksi
	Material
	Bentuk
	Desain
	Warna
	Variasi

Based on recapitulation results of *user needs* attributes shown in Table 2 and Table 3, most respondents expected face masks as protective equipment which designed to provide satisfaction and improve masks performance during the usage. Furthermore, 5 functional attributes were generated from some of summarized *user needs* attributes, which able to represent all of *user wants* attributes. Those 5 functional attributes are shown in Table 4 below.

Table 4. Functional Attributes of User Need

Num	Attributes
1	Easy to use
2	Safe to use
3	Comfortable
4	Flexible
5	Enticing

3.2 Determining TRIZ Inventive Principles

Here were several types of problem models: Physical Contradiction, Engineering Contradiction, and Substance

DOI: https://doi.org/10.30564/jmser.v4i1.2714

Field Model. The next step was to determine the Inventive Principles as reference in designing the new model of face mask based on the results of the selected *improving feature* and *worsening feature* attributes.

3.2.1 Improving Feature and Worsening Feature.

To solve the designing problems, TRIZ used 39 × 39 table of contradiction matrix attributes, consisted of improving feature and worsening feature. In the first stage of design problem solving, improving feature was determined based on the identified need attributes.

Table 5 and 6 show the improving feature and worsening feature based on the need attributes.

Table 5. Improving Feature

Num	Attributes	Improving Feature
1	Easy to use	*Ease of Use* (10)
2	Safe to use	*Reliability* (04)
3	Comfortable	Shape (21)
4	Flexible	*Ease of Manufacture* (09)
5	Enticing	Shape (21)

Table 6. Worsening Feature

No	Attributes	Improving Feature
1	Easy to use	Strength (28)
2	Safe to use	*Ease of Manufacture* (09)
3	Comfortable	*Weight of fixed object* (33)
4	Flexible	Strength (28)
5	Enticing	*Ease of Manufacture* (09)

Improving features and *worsening features* that had been identified and shown in Table 5 and Table 6 indicate that there are various contradictions between the improvement parameters for problem solving among all five problem attributes. One of them is *ease of use* (10) and *strength* (28) for *easy to use* attributes. Then, the desired improvement for *easy to use* attributes is *ease of use* (10) in the main part, but *strength* (28) becomes consideration parameter in convenience improvement to use the main tool. Likewise, for other attributes such as *safe to use* or *enticing* must be solved based on selected TRIZ contradiction matrix. From the results of contradiction obtained, the problem solving was decided through *inventive principles* according to the rules of TRIZ method, so that problem solving could be resolved.

Table 7. Inventive Principles

No	Atribut	*Improving feature*	*Worsering Feature*	*Inventive Principles*
1	Mudah digunakan	*Easy of use (10)*	*Strength (28)*	04, 09, 12, 17
2	Aman digunakan	*Reliability* (04)	*Productivity (01)*	01, 03, 14, 30
3	Nyaman digunakan	*Shape* (21)	*Weight of the fixed object* (33)	02, 07, 10, 12
4	Fleksibel	*Easy of Manufacture (09)*	*Strength (28)*	02, 03, 09, 12
5	Menarik	*Shape (21)*	*Easy of Manufacture (09)*	03, 04, 09, 19

Based on Table 7, several references in resolving contradictions of problem attributes were obtained. *Ease of use* (10) and *strength* (28) on *easy to use* attribute were solved by the approaches of *replacement of mechanical matter* (04), *change in color* (09), *local property* (12), and *use of composite materials* (17). The problem with *easy to use* attribute was the ease of wearing masks for people, especially to prevent the spread of viruses and bacteria, and on one side, by not reducing the quality. Based on the parameters in selected inventive principles, the contradiction could be resolved by *replacement of mechanical matter* (04). Thus, the solution for the qualification is replacing the existing mechanical material on face mask with other mechanical material which more convenient to use. *Shape* (21) and *weight of the fixed object* (33) on the convenient attribute produces *preliminary action* (02) *dynamization* (07), *copying* (10), and *local property* (12). Based on the inventive principles offered, *local property* (12) was chosen. In detail, the solutions consist of changing or replacing the basic material structure of existing masks with other material structures with no negative impact for user's health, so that the mask will provide comforts for user when wearing them. *Ease of manufacture* (09) and *strength* (28) on the *flexible* attribute produced several inventive principles which consisted of *preliminary action* (02), *segmentation* (03), *change in color* (09), and *local property* (12).

From the inventive principles offered, *segmentation* (03) was selected. In detail, the solutions consist of dividing an object or system into separate parts and make an object or system to be easy to dismantle. Furthermore, the *attractive* attributes *shape* (21) and ease of manufacture (09) produced inventive principles consisted of *segmentation* (03), *replacement of mechanical matter* (04), *change in color* (09), and *transition into another dimension* (19). Based on the inventive principles offered, the chosen one was *changed in color* (09). In detail, the solutions consist of changing or adding color variants to the mask which fitting the environment so that it gives a cheerful vibes instead of frightening effect on user.

3.3 Realization of Design and Work Process

After carried out the quantitative analysis stage to get

 DOI: https://doi.org/10.30564/jmser.v4i1.2714

the appropriate redesign results, the next step was made a prototype of the new design by using 3D Printer as shown in the image below:

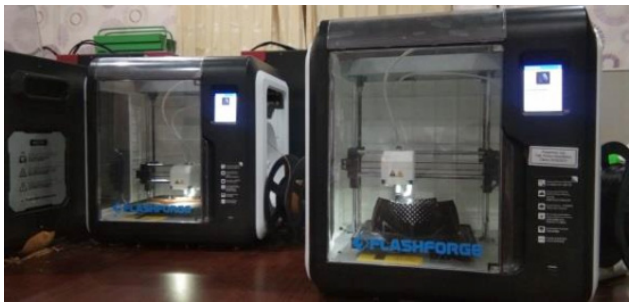

Figure 2. 3D Printer

The initial stage was to create a design in the Sketchup application which then converted into a file that can be printed. 3D printer read the design and generated a product prototype for a particular amount of time, by using a specified material called filament. Filament is shown in Figure 3.

Figure 3. Filament

Filament used was a PLA + type consisted of organic material from corn extract, which then processed with thermoplastic method to form a filament as shown in Figure 4. After the printing process complete, it resulted as mask body as follow:

Figure 4. Mask Prototype

After the prototype finished, the next step was to conduct a direct test to people. The main point of the test was to find out whether the design was in accordance with the real conditions of user or not.

Figure 5. User Prototype

This mask was made of a material which strong enough for various conditions and had a longer period of usage compared to other masks. Additional value for the strong material was a clip inside the mask that functioned as a clamp for the filter tissue on the mask to keep the tissue intact, which considered as able to extend its usage period and made it more *flexible* because it allowed user to simply replace the tissue instead of buying a new mask.

After successfully made the prototype, the campus, especially the Faculty of Industrial Technology had begun to mass producing the masks to be distributed to paramedics and planned to distribute them to the public as an important item for Covid-19 prevention. Currently, 3D masks have been used by the campus volunteer team as their main equipment in conducting volunteer activities. It is hoped that this research will have a good impact on New Normal and that the government will be responsive to this research.

4. Conclusions

From the conducted research, which is product redesigning by using TRIZ method, 14 attributes of needs are obtained for processing the design data. Of the 14 needs attributes, there are 5 functional attributes that can represent all of the attributes of users' desires. Those 5 attributes of function are: 1. *Easy to use*. 2. Safe to use. 3. Provide comfort 4. Flexible 5. Give an enticing impression.

Based on the functional attributes, the problems are resolved using the *Improving Feature* and *Worsening Feature* of TRIZ method. The results are: 1) material changes to prevent damage by using strong materials, 2) change the material structure into environmentally friendly materials, 3) make cheerful designs and colors to avoid awkwardness, and 4) relatively light weight. 3D masks currently have been produced and developed by Muslim University of Indonesia, especially in Faculty of Industrial Technology and have been used by Relawan Bantuan

DOI: https://doi.org/10.30564/jmser.v4i1.2714

Kemanusiaan (Humanitarian Aid Volunteers) and paramedics. The new design of 3D face mask has got positive reviews because of its better quality compared to other conventional masks.

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