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Environmentally friendly non-medical mask: An attempt to reduce the environmental impact from used masks during COVID 19 pandemic

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HIGHLIGHTS
• Increasing the consumption of masks during the pandemic of COVID 19 leads the mask waste and environmental problem.
• Cloth mask as personal protection become a usual custom.
• Various alternative material cloth properties for making non-medical masks.
• Selection alternative material based on filtration efficiency, breathability, and environmental impact.
• Environmentally friendly cloth material for mask to reduce the environmental impact from used masks.

GRAPHICAL ABSTRACT
Selection for material alternative for environmentally friendly non-medical masks to reduce environmental impact caused by increasing mask waste during COVID-19 pandemic.

ABSTRACT
During COVID-19 pandemic, wearing a mask has become a usual custom as a personal protection in every activity. The growth in consumption of face masks leads the increasing of mask waste and became a particular problem in environment. This study uses analytic hierarchy process (AHP) to determine appropriate material for making environmentally friendly non-medical mask. Filtration efficiency, breathability, and environmental impact index are defined as main criteria and carried out 26 alternative material from previous study. AHP presents a ranking of priority for all the alternative materials with Quilt and Cotton 600 TPI are the best values and fulfilled the material characteristics required by WHO. The sensitivity analysis generates some material with constant global priority results, such as Quilt, Cotton 600 TPI, Quilting cotton, Polycotton, and Polypropylene fabric 1. Quilting cotton with woven structure becomes the third ranking of alternative material, and Polypropylene fabric 1 is the worst material for making environmentally friendly non-medical mask.

1. Introduction
The world is facing a pandemic due to COVID-19, a severe respiratory syndrome caused by a novel coronavirus (SARS-CoV-2) since December 2019 (Patrício Silva et al., 2021). It was later declared a global health emergency by World Health Organization (WHO) on 30th January, based on the increasing number of cases in the world (Saadat et al., 2020).

COVID-19 is transmitted through respiratory contact, principally via small droplets when speaking, coughing or sneezing (Howard et al., 2020; World Health Organization, 2020). Based on the characteristics of transmission route, the Government and WHO recommend personal

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protection as a method to cut the spread. One of the main standards used in the health care system is focused on the use of personal protection equipment (PPE) such as masks and gloves, as a public health intervention to curb the spread of the disease (Leung et al., 2020; Rubio-Romero et al., 2020). The use of face mask has been recommended in community settings by different health authorities from several countries such as China, Hong Kong, Singapore, UK, USA, and Germany (Feng et al., 2020). A healthy individual wears mask as a protection when in contact with an infected individual, while the infected individual wears a mask to prevent transmission (World Health Organization, 2020). A face mask decreases the excretion of respiratory droplets from infected individuals and helps reduce the spread of infections (ECDC, 2020).

Wearing a mask has already become a custom in communities as a personal protection in every activity. Using a simple mask is better than no mask to protect the user and others (Chua et al., 2020). Its use has widely been applied in communities as a response to the pandemic related to the respiratory problem (Konda et al., 2020; Lepelletier et al., 2020). During this pandemic, more face masks were consumed, leading to the increase in mask waste, which has become a particular problem and further causes new environmental problems (Fadare and Okoffo, 2020; Patrício Silva et al., 2020) and impact on future sustainable waste management practices (Ilyas et al., 2020).

Studies about the use of face mask have been widely discussed from the material perspective, which investigates the alternative material that has the ability to capture particles and droplet (filtration efficiency), breathability and comfortability (Aydin et al., 2020; Bagheri et al., 2020; Chua et al., 2020; Clase et al., 2020; Davies et al., 2013; Konda et al., 2020; Rengasamy et al., 2010; Rogak et al., 2020; Tcharkhtchi et al., 2021; Teesing et al., 2020; Wilson et al., 2020; Zhao et al., 2020), from the perspective of utility (Howard et al., 2020; Lepelletier et al., 2020; Phan and Ching, 2020; Rubio-Romero et al., 2020; Wang et al., 2020; Yang et al., 2020) and after use impact (Aragaw, 2020; Fadare and Okoffo, 2020; Ilyas et al., 2020; Vanapalli et al., 2021). Although, a lot of studies about face mask have been carried out for several months, the number of studies in material choice, especially those that considered the environmental impacts due to the waste is still limited. Furthermore, there are still less number of studies that observed the design, choice of material, layering and shape of the non-medical masks (World Health Organization, 2020). Only about 20% discussed the effect of COVID-19 pandemic on waste and pollution in the environmental science topic research (Patrício Silva et al., 2021).

Therefore, this study provides a method to decide the material for non-medical mask while considering the environmental impact, which has become an important issue. Reducing waste by decreasing PPE and substituting materials with low-carbon reusable alternatives is of high priority (Patrício Silva et al., 2020). This is because, it provides a method to select the material based on filtration efficiency, breathability performance and particularly environmental impact from using fabric as the material of the mask. Furthermore, it discusses about sensitivity analysis from the scenario with several considerations of environmental impact rate. An understanding of new eco-friendly materials used in face masks per se will also inform research focusing on the development of sustainable reprocessing approaches for meeting supply chain shortages arising from ongoing COVID-19 pandemic (Derraik et al., 2020; Rowan and Laffey, 2020, 2021). Testing the material performance, e.g. filtration efficiency, pressure drop, life cycle assessment was not considered, but previous studies were referred to for detailed information on these performances.

The non-medical masks are usually produced by homemade or small enterprise traditionally without considering various aspect, e.g. quality, design, materials used and other aspects. The aim of this study was to select the material used in the production of non-medical mask which will assist individuals and small enterprise in the production of masks that are more environmentally friendly. These cloth masks were fashioned from household items at a low-cost and used as an additional control option to limit the infectious droplets (Zhao et al., 2020).

2. Methods

This study implemented Analytic Hierarchy Process (AHP) to determine the appropriate material for non-medical mask. AHP is a technique which aids in decision making in a complex environment and is designed to select the best from a number of alternatives with many considered variables (Hambali et al., 2010; Vargas, 2010). It has been successful in providing solutions to many practical problem (Cabala, 2010) and widely used in healthcare systems (Requía et al., 2020; Singh and Avikal, 2020; Tran et al., 2020), projects and companies (Vargas, 2010), environmental and community settings (Aydin et al., 2020; Ghosh et al., 2020; Mishra et al., 2020; Pourghasemi et al., 2020; Sarkar, 2020), data and information system (Pietz et al., 2020), and other fields.

The AHP, which was developed in the 70's by Saaty (1990), is elaborated by sequencing the following six-step process.

Step 1. Problem definition. The first step in using AHP is to identify the problem and determine the objectives.

Step 2. Development of hierarchical structure. This step is a hierarchical model for selecting the alternative which consists of various hierarchy levels, with each describing an objective of the decision making, main criteria and alternatives. During this step, the systemic literature review approach was adopted to generate the main criteria and decision alternatives for selecting the material. Systematic literature review is a method to identify, evaluate and synthesize recorded studies carried out by researchers, scholars and practitioners systematically, explicitly and comprehensively (Okoli, 2015). Furthermore, protocol for practical screen to search for literatures published on Google Scholar until 20th of August were applied. One hundred and nine results appeared on combination keywords “mask material” and “COVID-19”, and 88 results were based on combination keywords for environmental aspect “environmental impact index” and “textile”. Based on the results obtained from the search articles, a further selection was made with the criteria of an article that explicitly studied the topic of this study, has the available material characteristics data and environmental impact data especially for fabric and household material which are commonly used for mask production. A total of 38 articles on the characteristics of non-medical masks and their use during pandemic, fabric material and the environmental impact were discovered, which were very adequate for execution.

Step 3. Determination of comparison matrix. This began with comparing the relative importance of two criteria items, using rating which varied from 1 to 9 (Hambali et al., 2010; Vargas, 2010). The value 1 indicated equal value between two criteria, while 9 indicated that the value for criteria (cij) was extremely important compared to others (cij). In this comparison, reciprocal values were automatically assigned for inverse comparison.

A matrix with size [c X c] was generated from the comparison which contained the relative rankings of the main criteria. Afterwards, decision makers produced relative weights to each criterion by calculating the eigenvector or vector priorities. One of the methods used to calculate eigenvector is the average of normalized column (ANC) (Hambali et al., 2010). It was carried out with the normalization calculation by dividing each value in the column of matrix by the total column value. Afterwards, the average for each row of the matrix was calculated with the formula below:

$$w_i = \frac{1}{n} \sum_{j=1}^{n} \frac{c_{ij}}{\sum_{i=1}^{n} c_{ij}}, i, j = 1, 2, \ldots, n$$

The result of this average is called approximate eigenvector ($w_i$).
Furthermore, consistency analysis of the comparisons called consistency rate (CR) was carried out. The objective was to determine whether the decision marker has been consistent in the choices of criteria (Vargas, 2010). Firstly, the maximum eigenvalue (\( \lambda_{\text{max}} \)) was calculated with the following formula (Cabala, 2010):

\[
A_w = \sum_{j=1}^{n} c_{ij} \times w_j
\]

\[
\lambda_{\text{max}} = \frac{1}{n} \sum_{i=1}^{n} (A_w)_{ij} w_i
\]

Secondly, the consistency index (CI) was calculated with the formula below:

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1}
\]

Thirdly, consistency rate (CR) was determined by the ratio between consistency index and the random consistency index (RI) with the following formula:

\[
CR = \frac{CI}{RI}
\]

In which RI was following index by Hambali et al. (2010) and Alonso and Lamata (2006) as shown in Table S.1.

**Step 4.** Repetition of the sequence in step 3 for the next level in the hierarchy. This step was carried out to evaluate the alternatives with some considerations to the criteria presented.

**Step 5.** Development of global priority ranking to determine the best alternative arrangement. The calculation of the global priority was carried out by summing the multiplication of the priority of each criterion by its alternative.

**Step 6.** Selection of the best alternative decision according to the results of the calculation of global priority.

### 2.1. Sensitivity analysis of the evaluation system

The final result from the selection of alternative was highly dependent on the priority result of criteria, in which the value of relative ranking among the main criteria was based on subjective judgements. Therefore, the stability of the ranking from various criteria had to be tested. The sensitivity analysis was performed by utilizing various scenarios to discover the effect of different factors on making the best decision in alternatives selection.

### 3. Results and discussion

According to the AHP steps, the results of this study were described as follows:

**Step 1.** This study was concerned with the problem of determining the best cloth material for the production of non-medical mask by considering filtration efficiency, pressure drop or breathability and environmental impact.

**Step 2.** This step described a three-level hierarchy, as shown in Fig. 1. Level 1. The first level of hierarchy was the objective of the decision-making model from this study, which was used to determine the best cloth material for environmentally friendly non-medical mask. Level 2. The second level represented the main criteria for selecting the material. This is the major factor that affects the selection process, which was determined based on the type of problems that contribute to the objective (Hambali et al., 2010). The main criteria in this study was obtained from the systematic literature review stage and specified in two important characteristics, namely filtration efficiency and pressure drop or breathability. It was based on practical considerations for non-medical mask production by World Health Organization (2020), and other study as in Chua et al. (2020), Aydin et al. (2020), Tcharkhtchi et al. (2021), Konda et al. (2020), and Zhao et al. (2020), as shown in Table S.2.

It was emphasized that filtration efficiency may block the droplets, which is a more important criteria compared to breathability based on previous studies.

Furthermore, another important criterion was considered in this study which was environmental impact. For this criterion, the results of study by Muthu et al. (2012) was determined, which discussed about environmental impact and ecological sustainability for textile fibers. Important textile fibers were evaluated by considering various factors that reflect their ecological sustainability. The model developed led to Environmental Impact Index of ten chosen fibers such as cotton, organic cotton, wool, flax or linen, nylon 6, nylon 66, polyester (PE), polypropylene (PP), acrylic and viscose.

In this study, the Environmental Impact Index (EI) from previous studies was and was expressed as a scoring system from CO2 absorption/O2 emission (Y1), renewable resources (Y2), land use (Y3), fertilizers and pesticides (Y4), recyclability (Y5), biodegradability (Y6), life cycle assessment which were calculated from impact indicator, such as energy needs, water consumption and CO2 emissions (Y7).

\[
EI = \sum \alpha_i Y_j = \alpha_1 Y_1 + \alpha_2 Y_2 + \alpha_3 Y_3 + \alpha_4 Y_4 + \alpha_5 Y_5 + \alpha_6 Y_6 + \alpha_7 Y_7
\]
Environmental Impact index for ten chosen fibers is shown in Table S.3.

A total of two out of seven factors for ecological sustainability from a previous study described the condition of fibers after use, such as recyclability and biodegradability, referred to as end-of-life options, which also contribute to disposal issues. Fiber recyclability is the ability of fiber to be recycled and this refers to the conversion of old products which were discarded after use into new ones. Biodegradability is used as a standard measurement of the environmental friendliness with textile product and microorganisms take part in this process (Muthu et al., 2012).

From this point, Environmental Impact index was considered to be part of the main criteria to determine the cloth for environmentally friendly non-medical mask.

Level 3. The third level was decision alternatives. This is the lowest level of the hierarchy and was calculated with various alternatives of household materials, which was a cloth that is commonly available in community. Information at this level consisted of material properties data as the main criteria (filtration efficiency and breathability), which has been evaluated in previous studies, as shown in Table 1.

Furthermore, certain material properties data selection, based on environmental impact data availability, the values of filtration efficiency and pressure drop indicated breathability for some cloth material. In addition, 26 out of 91 data from previous studies were suitable for this study.

### Table 1
Material properties data from previous studies.

| Research source | Code | Description | Material | Pressure drop (Pa) | Filtration efficiency (%) | Environmental impact index (EI) |
|-----------------|------|-------------|----------|-------------------|---------------------------|-------------------------------|
| (Davies et al., 2013) | L1 | Tea towel | Linen | 7.23 | 83.24 | 12 |
| | L2 | Linen | Linen | 4.5 | 60 | 12 |
| | C12 | 100% cotton T-shirt | Cotton | 4.29 | 69.42 | 16 |
| | C13 | Cotton mix | Cotton-based | 6.18 | 74.6 | 16 |
| | C1 | Gauze | Cotton-based | 4 | 79.8 | 16 |
| | C2 | Batik cotton | Cotton-based | 60 | 60.4 | 16 |
| | C3 | Quilting cotton | Cotton-based | 5 | 95.8 | 16 |
| | C4 | Cotton, 600TC | Cotton-based | 35 | 65.8 | 16 |
| | C5 | Single knit jersey, cream | Cotton | 8 | 84.6 | 16 |
| | C6 | Single knit jersey, grey | Cotton | 25 | 59.9 | 16 |
| | C7 | Ribbed knit cotton | Cotton | 17 | 60.3 | 16 |
| | C8 | Double knit jersey, yellow | Cotton | 5 | 78 | 16 |
| | W1 | Wool blend | Wool | 3 | 93.6 | 21 |
| | PE1 | Polyester satin | Polyester | 10 | 86.6 | 30 |
| | PE2 | Polyester peel ply | Polyester | 64 | 99.9 | 30 |
| | PE3 | Polyester crepe | Polyester | 47 | 73.2 | 30 |
| | PE4 | Polycotton | Polyester | 29 | 77.6 | 30 |
| | PE5 | Chiffon | Polyester | 3 | 93.1 | 30 |
| | PE6 | Velvet | Polyester | 2 | 95.1 | 30 |
| | PP1 | Interfacing polypropylene | Polypropylene | 3 | 93.6 | 34 |
| | PP2 | Dry baby wipe | Polypropylene | 5 | 70.9 | 34 |
| | C9 | Used shirt | 100% cotton | 1.37 | 87.9 | 16 |
| | PE7 | New bedsheet | 100% polyester | 3.23 | 74.9 | 30 |
| | CI0 | Quilt | Cotton | 2.7 | 96.1 | 16 |
| | C11 | Cotton (500 TPI) | Cotton | 2.5 | 98.4 | 16 |
| | PP3 | Polypropylene fabric 1 | Polypropylene | 41 | 65 | 34 |

Step 3. This step described the pairwise comparison matrix for level 2, which was the main criteria, as shown in Table 2. After the comparison matrix was determined, calculation of normalization and approximated eigenvector was carried out using the formula (1) shown in Table 3.

Furthermore, consistency analysis was carried out.

Firstly, the maximum eigenvalue ($\lambda_{max}$) was calculated with the following formula (3):

$$\lambda_{max} = \frac{1}{3} \begin{bmatrix} 1.66 \\ 0.59 \\ 0.3 \end{bmatrix} = 3.0183$$

Secondly, the consistency index (CI) was calculated with the following formula (4):

$$CI = \frac{3.0183 - 3}{0.0092} = 0.0158$$

Thirdly, the consistency rate (CR) was calculated with the following formula (5):

$$CR = \frac{0.0092}{0.0158} = 0.58$$

### Table 2
Pairwise comparison level 2 main criteria.

| Main criteria | Filtration efficiency | Breathability | Environmental impact index |
|---------------|-----------------------|---------------|-----------------------------|
| Filtration efficiency | 1 | 3 | 2 |
| Breathability | 1/3 | 1 | 1 |
| Environmental impact index | 1/5 | 1 | 1 |
| Total (sum) | 1.8 | 5.0 | 4.0 |

### Table 3
Comparison level 2 after normalization.

| Main criteria | Filtration efficiency | Breathability | Environmental impact index |
|---------------|-----------------------|---------------|-----------------------------|
| Filtration efficiency | $1/1.8 = 0.55$ | 0.60 | 0.50 |
| Breathability | $0.3/1.8 = 0.18$ | 0.20 | 0.25 |
| Environmental impact index | $0.5/1.8 = 0.27$ | 0.20 | 0.25 | 0.24 |
The RI value for \( n = 3 \) is 0.58.

Since the value of CR for the initial criteria was 0.0158 or 1.58%, the matrix was considered to be consistent, because it was less than 10%. Furthermore, the priority results for the main criteria were justified following this order: Filtration Efficiency > Environmental Impact index > Breathability, as shown in Fig. S.1. This implies that Filtration Efficiency has a 55% relative weight value to the total objective.

**Step 4.** This step repeated the sequence in step 3 for level 3 in the hierarchy, which was carried out to evaluate the material alternatives with some considerations to the criteria presented. The comparison matrix of various material alternatives (level 3) were calculated for each criterion separately following the sequence in step 3. In respect to the value in comparison matrix, the material properties data was considered in Table 1 above. The value for data was determined following the rules as shown in Table S.4. Furthermore, the value for the comparison was determined by the difference between the two alternative values. The priority results from Step 4 for each material alternative with the considerations to the criterion are separately shown in Table 4.

**Step 5.** This step determined the best material alternative arrangement following the order in the global priority ranking by summing the multiplication of the priority of each criterion by its material alternative. The calculation process for the global priority for each material alternative is shown in Fig. S.2.

**Step 6.** This step selected the best material decision. The best material alternatives were selected according to the results of the calculation of global priority, as shown in Fig. 2.

Therefore, Analytic Hierarchy Process (AHP) was able to specify that the material **Quilt** (C10) and **Cotton 600 TPI** (C11) are most appropriate for the environmentally friendly non-medical mask if all main criteria are considered, with the weight value for both material of 0.0675. From these results, both materials were considered to have the best quality for the filtration and breathability of masks and the lowest environmental impact.

The recommendation for the use of masks by World Health Organization (2020) explained that individuals in specific conditions and close contact or potential close contact with others were recommended to use non-medical masks with the filtration of the cloth fabrics varying between 0.7% and 60%, breathability below 100 Pa, minimum of three layers depending on the fabric and combination of material used to gain a better filtration efficiency and mask shapes designed to fit closely over the nose, cheeks and chin. Based on these recommendations, both Quilt and Cotton 600 TPI material fulfilled the requirement.

**Table 4** Priority result for material alternative with criterion separately.

| Material | Filtration efficiency | Breathability | Environmental impact |
|----------|-----------------------|---------------|-----------------------|
| L1       | 0.0345                | 0.0238        | 0.0917                |
| L2       | 0.0093                | 0.0551        | 0.0917                |
| C1       | 0.0181                | 0.0551        | 0.0515                |
| C2       | 0.0094                | 0.0052        | 0.0515                |
| C3       | 0.0743                | 0.0554        | 0.0515                |
| C4       | 0.0094                | 0.0061        | 0.0515                |
| C5       | 0.0368                | 0.0254        | 0.0515                |
| C6       | 0.0059                | 0.0139        | 0.0515                |
| C7       | 0.0098                | 0.0139        | 0.0515                |
| C8       | 0.0199                | 0.0574        | 0.0515                |
| C9       | 0.0381                | 0.0574        | 0.0515                |
| C10      | 0.0785                | 0.0574        | 0.0515                |
| C11      | 0.0785                | 0.0574        | 0.0515                |
| C12      | 0.1011                | 0.0574        | 0.0515                |
| C13      | 0.0208                | 0.0282        | 0.0515                |
| W1       | 0.0795                | 0.0584        | 0.0267                |
| PE1      | 0.0408                | 0.0286        | 0.0137                |
| PE2      | 0.0809                | 0.0056        | 0.0137                |
| PE3      | 0.0214                | 0.0089        | 0.0137                |
| PE4      | 0.0214                | 0.0155        | 0.0137                |
| PE5      | 0.0824                | 0.0605        | 0.0137                |
| PE6      | 0.0824                | 0.0605        | 0.0137                |
| PE7      | 0.0217                | 0.0605        | 0.0137                |
| PP1      | 0.0831                | 0.0605        | 0.0082                |
| PP2      | 0.0219                | 0.0605        | 0.0082                |
| PP3      | 0.0112                | 0.0093        | 0.0082                |

\[ \lambda_{max} = 26.573 \quad \lambda_{max} = 26.531 \quad \lambda_{max} = 26.097 \quad \lambda_{max} = 26.097 \]

CR 1.37% CR 1.27% CR 0.23%

**Fig. 2.** Global priority result for each material alternative.
The Quilt (C10) material had a characteristic of filtration efficiency 96.1% and breathability 2.7 Pa, while Cotton 600 TPI (C11) materials had characteristic of filtration efficiency 98.4% and breathability 2.5 Pa. As an additional requirement in this study, both materials also had adequate Environmental Impact index.

The mask management advice by World Health Organization (2020) explained that mask should only be used by one person and washed frequently. Both Quilt and Cotton 600 TPI material for non-medical mask can be washed repeatedly and immediately discarded if the mask material has been damaged. Since the SARS-CoV-2 can survive on different surface of the material for several days, the mask maintenance and discarded mask should follow certain rules. SARS-CoV-2 can survive for long periods up to 7 days on the surface of COVID-waste, therefore need to handled appropriately, such as microwave disinfection to sanitize the recycled and reused PPE and cloths (Ilyas et al., 2020).

3.1. Sensitivity analysis

Sensitivity analysis was carried out by utilizing various scenarios. A total of 9 scenarios were generated with different value of coefficient $\alpha$ which was the relative weights for criteria, as shown in Table 5. It was observed that the breathability and environmental impact had the same value, which showed that both criteria had the same priority after filtration efficiency, as shown in Fig. S.3.

The results of the sensitivity analysis for the different scenarios describe the influence of various relative weight of each criterion on the priority of each material, as shown in Fig. S.4, for Linen (A), Cotton (B), Wool (C), Polyester (D) and Polypropylene (E) materials.

From Fig. S.4, it is seen that the influence of relative weight value of criteria had a different effect on the priority of each material alternative. Briefly, a more dominant value on a criterion would affect the convergence of the priority of an alternative material.

The shifting of global priority of each material alternative with the consideration of scenario of coefficient $\alpha$ variants was described in Fig. 3. When a scenario was defined for the range value of relative weights of filtration efficiency criteria from 33% to 82% towards the same value for breathability and environmental impact, it was discovered that Quilt (C10) and Cotton 600 TPI (C11) had constant global priority results. There were also other materials with constant global priority results, such as Quilting cotton (C3), Polycotton (PE4) and Polypropylene fabric 1 (PP3).

The results of sensitivity analysis of AHP described several potential materials for the production of an appropriate environmentally friendly non-medical mask. Furthermore, those results were highly support the several efforts for meeting supply chain shortages on mask product development during this pandemic, as discussed on the articles, to support the policymakers for guiding on how masks should be used (Howard et al., 2020; World Health Organization, 2020) and for sustaining the supply of PPE (Chua et al., 2020; Derraik et al., 2020; Ilyas et al., 2020; Rowan and Laffey, 2020, 2021; Zhao et al., 2020).

4. Conclusion

AHP has become a suitable method and selection tool of material alternatives for making non-medical mask. It succeeded in determining material alternative priority, as evidenced by being able to present a ranking of 26 material alternatives. The results of the analysis showed that Quilt (C10) and Cotton 600 TPI (C11) are appropriate cloth from cotton material for making non-medical mask with the highest quality of filtration efficiency and breathability, while having the lowest environmental impact. The weight value for both materials was 0.0675 and fulfilled the material characteristics required by WHO. The sensitivity analysis proved that both materials have the highest priority in various scenarios of relative weights of criteria.

Furthermore, Quilting cotton (C3) with woven structure was considered to be an alternative material for the third priority, with weight value of 0.0648 for all materials. The sensitivity analysis proved that different scenario of relative weight criteria generated same priority for this material. Other results showed that Polypropylene fabric 1 (PP3) was the worst material for making non-medical mask, with weight value of 0.01 for all materials. Both material properties quality and environmental impact had the lowest value and the least prioritized material.
In this study, a general sustainable ecological measuring instrument was used for fabric in the initial phase, which implies that environmental impact which was derived from the process of production of non-medical mask was not considered. For future studies, the environmental impact on the production process, supply chain, and other factors need to be measured.

Masks as PPE need to be redesigned in order to reduce environmental impact. This study will be of assistance to individual and small enterprise to decide the best material in the production of environmentally friendly non-medical masks using locally available materials, and to support the efforts for meeting supply chain shortages on mask production during this pandemic.

CRediT authorship contribution statement

Broto Widya Hartanto: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft. Dyah Sapti Mayasari: Data curation, Validation, Writing – review & editing.

Declaration of competing interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2020.144143.

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