The Study of Sustainable Strategy in Design of Protective Clothing and Accessories After Coronavirus (COVID-19) Outbreak

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Abstract. During the COVID-19 pandemic, the coronavirus frontline healthcare workers and the public have generated a great demand for personal protective equipment (PPE). According to the assessment of risk level, PPE such as medical masks, protective suits and face shields should be given priority to the healthcare workers and other medical first responders for use. The risk of the public to exposure is much lower than that of healthcare workers, and there is no need to wear such high-risk protective clothing and accessories. In the face of the general shortage of personal protective equipment due to increased demand, panic buying, hoarding and abuse, the public should look for alternative protection solutions when they are at home or going out. In the view of the problems above, this paper refers to the analysis of the current status of sustainable strategies in the design of protective clothing and accessories. It proposes a design method for the upcycle of abandoned clothing and daily objects. From the perspective of functional protection, demountable and modular design, it also provides methods and means for the sustainable optimal design of PPE, such as multi-functional protective hood, demountable design details, multi-pocket hidden design, internally seamed elastic strap structure, strengthened tightening design of the clothing opening. It is designed to help prevent the spread of transmissible viruses and bacteria, thereby protecting self and preventing others from infecting while alleviating the growing demand for PPE during the COVID-19 pandemic.

1. Introduction
At the beginning of 2020, the whole world was shrouded in the shadow of the COVID-19, which had a significant impact on people's lives and work. During this period, the coronavirus frontline healthcare workers and the public have generated a great demand for personal protective equipment such as protective clothing and masks. The World Health Organization (WHO) estimated that 89 million medical masks are required for the COVID-19 response each month, along with 76 million examination gloves and 1.6 million medical goggles [1]. The lack of proper masks, protective clothing and goggles will weaken the ability of healthcare workers to resist the COVID-19 and put their lives at risk. According to the risk level assessment, medical masks and protective clothing should be given priority to the frontline healthcare workers and patients. The risk of public exposure is much lower than that of healthcare workers, and there is no need to wear such high-risk protective clothing and accessories. In the face of the general shortage of personal protective equipment due to increased
demand, panic buying, hoarding and abuse, the public should look for alternative protection solutions that can be temporarily solved when they are at home or going out. This article proposes a sustainable strategy study in the design of protective clothing and accessories. It is designed to help prevent the spread of transmissible viruses and bacteria, thereby protecting itself and preventing others from infecting, while alleviating the growing demand for personal protective equipment during the COVID-19 pandemic.

2. Protective clothing and sustainable design

The development of sustainable design concepts runs through the entire clothing life cycle. In the apparel field, energy consumption and environmental pollution are involved in fiber selection, clothes processing, design, sales, washing care and waste recycling, etc. Among them, the design stage plays a very important role, and the abstract thinking and skill requirements it produces the development of the green fashion industry. Sustainable clothing design is mainly divided into zero-waste design, recycled design, slow fashion design, and emotional design. [2]. This article mainly focuses on the strategy of recycled clothing design, through upcycling to make abandoned clothing have a specific protective use-value. Upcycle is to improve the function or design of products that are generally recyclable, meaning to upgrade the current status [3]. Specifically, the upcycle is based on the idea of closed-loop production, which gives new value to materials through the creative design of designers, turning the waste material eliminated in one product cycle into the raw material needed in another product cycle, and forming a closed production cycle system [4]. There is no need to change the properties of materials through incineration and melting.

Protective clothing is overalls to protect the human body from physical, chemical, biological and other external factors damage [5]. Wearing protective clothing and accessories during the COVID-19 pandemic is to block biological factors such as bacteria and viruses. At present, medical protective clothing is mostly used in response to the COVID-19 pandemic; the style is mainly one-piece. The protective accessories mainly include goggles, masks, face shields, hair cover, gloves, leg covers, booties and so on. Applying sustainable design concepts to the transformation of protective clothing and accessories, on the one hand, it can alleviate the serious shortage of personal protective equipment, on the other hand, it reduces the impact on resource utilization, energy consumption and environmental pollution, and extends the life cycle of clothing. According to relevant data, clothing recycling activities save 90%-95% of the energy required to manufacture new products [6].

3. Analysis of the current status of sustainable strategies in protective clothing design

3.1. Upcycling the abandoned clothing for protective clothing production

The materials, energy, and labor required to produce a piece of clothing can repeatedly meet design creativity and business needs. In some cases, these resources can even be recycled [6]. Old clothes transformation is to combine the personal design concept to give a new life to the discarded, damaged or old-fashioned clothes, which is to redesign and remake the existing clothes [7]. Abroad, due to the shortage of personal protective clothing and accessories during the COVID-19 pandemic, the British government and relevant agencies have issued documents to guide the public on how to use abandoned clothing as raw materials to make cotton masks. As shown in Figure 1, cut a part from old clothes and hollow out the rectangle, make the fabric fit snugly but comfortably against the side of the face, and fix it on the ear with a tie or ear loops to make a simple mask. German designer Max Siedentopf used worn or disposed female bra as a mask replacement (Figure 2). The Sunst Studio redesigned the abandoned Nike jerseys to create the graphic, protective masks (Figure 3), not only fashionable but also conveying the concept of green environmental protection.
3.2. Using the waste materials to redesign into protective clothing

Material recycling is the use of modern fiber material separation technology to extract regenerated fiber from abandoned clothing, which can be used to remake clothing or other textiles [8]. Material recycling design not only covers the reuse of traditional waste fiber, but also includes the development and innovation of new-typed recycled materials [8]. Sportswear company Adidas released a protective mask called Face Cover after the COVID-19 outbreak. It is made from a breathable recycled material - Adidas’ Primegreen, which it describes as a high-performance recycled fabric free from virgin plastic. The mask is designed to be reused, and the label "Wash. Dry. Reuse" is printed on it (Figure 4).

3.3. Recycling the daily objects to redesign into protective clothing

Using daily objects to reshape, cut and sew into protective clothing and accessories, combining creativity and practicality. It provides a convenient solution for the public, showing the possibility that daily objects are used as protective clothing. As shown in Figure 5, the mmm design studio has come up with an inventive response called the ‘ANYTHING’ face shield, from used pasta bags to candy bags that can be invented as mask replacements. When the shielding layer is damaged or contaminated, people can quickly replace the new transparent material on the frame. Some people use plastic wrap and plastic garbage bags to wrap their body in any possible way, or combine a transparent plastic board, staples and black foam strips into a face shield, and fixed with a headband as temporary personal protective equipment (Figure 6,7).

3.4. Renovating the scrap to redesign into protective clothing
Garment fabrics, residual materials, old fabrics and decorative materials are used as protective clothing and accessories through recycling and restoration. New Balance has been quick to react to the growing demand for personal protective equipment. As shown in Figure 8, it reuses the materials on hand at its US factory, using shoelaces and sneaker foam, focusing on medically approved fit and filterability to make protective masks. Nike leveraging its resources in the form of a face shield, and the footwear materials will be repurposed as part of the complete product, including padding and soles(Figure 9). As shown in Figure 10, the original wasted fabrics and belts are reused, and they are renovated into non-medical masks by splicing, dyeing, weaving and so on. This method will not only provide the public with sustainable and environmentally friendly solutions, but also test the brand's product innovation capabilities. This rapid transformation shows how brands can optimize local manufacturing and resources to adapt to changing green development needs.

4. Sustainable optimization strategy in protective clothing design
The sustainable design of existing protective clothing has opened a new way to recycle used clothes and daily objects. However, in the process of example transformation, problems such as overly fragmented protection methods and failure to achieve overall protection were also revealed. Therefore, this article will optimize the sustainable strategies in the design of protective clothing, through deconstruction and reorganization, to achieve the upcycle of abandoned clothing and daily objects, and provide a safe and sustainable alternative to prevent the infection of COVID-19. In order to prevent the penetration of virus-bearing droplets and saliva into the surface of the clothing, the garments selected in this redesign are all worn or disposed clothing with waterproof performance, have a kind of water-repellent paint on the surface of the fabric such as waterproof raincoat, trench coat and parka. The main reason for being abandoned is damaged, dirty or old-fashioned. According to the different needs for personal protective clothing during the COVID-19 pandemic, the following five points of sustainable optimization design suggestions are proposed.

4.1. Multi-functional protective hood
Because COVID-19 is mainly spread through the respiratory droplets and close contact [9], the droplets can enter the susceptible mucosal surface through a certain distance (generally 1 m) [10]. When the distance is close, the droplets will fall on the mucosa of the other party through sneezing, coughing and talking. It is very easy to get infections when there is no barrier on the face, so special attention should be paid to the protective design of the face.

Renovated with discarded, damaged or soiled clothing, and extended to design a detachable multi-functional hood to solve the special protection above the neck. As shown in Figure 11, the overall shape refers to the structure of the fake collar, combined with the underarm strap fastener for size adjustment. The hood adopts a demountable brim to splice the transparent visible area and uses the discarded plastic bottle body to make the face shield part. The tiling design is easy to disassemble for wiping and disinfecting, effectively separating droplets and dust, while not blocking the view. The mask part is spliced and stitched with abandoned clothing, non-woven bags or scrap fabrics. There is a socket inside the mask to replace the inner core, which is convenient for recycling. The replacement inner core can be made of daily materials with certain water absorption and breathability such as cotton tissues or paper diapers. Remove the used coffee bag sealing strips to make the nose clip on the top of the mask. Enlarge the proportions by splicing the fabric to increase the height of the collar and
create a protective throat loop. Drawstrings are added behind the hood and around the face to adjust
the shape of the hat and the fit of the head to achieve better protection. Usually worn inside a coat, it
can also be mixed with other items to create personalized accessories that can be worn independently,
providing more choices for wearing during the COVID-19 pandemic. After the epidemic is over, the
brim part can be removed from the hood separately, and only the fake collar part is worn daily. The
detachable design provides a variety of wearing options for the hood fake collar while further
upgrading to a fashionable accessory that can be worn independently.

4.2.  Demountable design details

Because the virus is sensitive to ultraviolet rays and heat [9], it can be washed by high-temperature
water at 60 °C to inactivate pathogens and dirt brought by the outside world effectively. Unlike
disposable protective clothing that is thrown away after use, this type of protective clothing and
accessories needs to be recycled after repeated washing and cleaning. In order to solve this problem,
the required garment pieces are cut from the abandoned clothing, and add demountable design details
to the original clothes, so that facilitate the cleaning and disinfection after separate disassembly. As
shown in Figure 12, the cuffs, trouser legs, armhole or hem are partially disassembled, and the
clothing parts are connected by waterproof zippers. During the pandemic, cuffs and trousers made of
scrap can be used to replace dismantled garment parts. Increasing the frequency of cleaning and
disinfection of this part reduces the survival rate of viruses on clothing. After the COVID-19 pandemic
is over, people can continue to replace the original fabric part for daily wear and use. They can also
adjust its length or style according to seasonal changes. Improve the suitability and utilization rate of
clothing to achieve "one for more." Extend the life cycle of clothing to make the most efficient use of
resources.

4.3.  Multi-pocket hidden design

Multi-pocket concealed design is added to the outside or inside of the garment by dismantling
abandoned backpacks or cross-body bags. It meets the functional requirements for carrying protective
equipment during the epidemic, not only access the convenience for the wearer, but also increase the storage space for single protective products. Masks, disposable hand sanitizer and wipes can be stored inside. As shown in Figure 13 (a), the backpack pocket detached by snap connection on the garment is removed when not in use. Alternatively, it can use the metal buckle that comes with the backpack pocket to hang it on the buckle of the jacket or the hook of the large backpack to achieve a modular split design freely. Remove the zipper compartment inside the abandoned backpack and sew it to the garment to use it as a hidden pocket. As shown in Figure 13 (b), the nylon strap of the used backpack is sewn on the shoulder of the garment, the disassembled pocket is transformed, and the strap on the garment is connected with a buckle. By adjusting the opening and closing of the buckle, it can be converted into a backpack or messenger bag style to achieve a dual-use effect.

![Figure 13. Multi-pocket hidden design. The picture was drawn by the author](image)

### 4.4. Internally seamed elastic strap structure

The elastic straps seamed to the inside of the garment. When the protective clothing needs to be taken off, the coat is carried on the shoulder like a backpack, eliminating the need to handle it, creating a rapid carrying system, and allowing it to be worn at any time during the epidemic period. As shown in Figure 14 (a), the shoulder strap of the abandoned sports backpack can be removed and sewn inside the garment. Alternatively, use discarded ropes or elastic bands, pass through the collar of the coat, and fix the two ends at the positions on both sides of the body and convert it into a simple strap structure (Figure 14 (b)). In the indoor security area, protective clothing can be temporarily taken off and hung behind the body, to alleviate the sultry and discomfort caused by wearing the coat for a long time. People can wear it immediately when they go out or encounter emergencies related to COVID-19.

![Figure 14. Internally seamed elastic strap structure. The picture (a) was drawn by the author, The picture (b) from the Internet.](image)

### 4.5. Strengthened tightening design of the clothing opening


In order to solve the sealing needs of protective clothing and accessories, a new design should be handled starting from the cap section, neckline, front fly, cuffs, trousers, and hem based on the original clothing. The elastic drawstrings and clips, velcro or adjustable snaps removed from the abandoned clothing are used to enhance the tightening design of the clothing opening. It is internally closed and has a warming effect.

5. Conclusion
Although the COVID-19 pandemic has been effectively controlled in China and other regions, it is still spreading in some countries around the world. Due to the appearance of asymptomatic patients, it is very necessary to take active protective measures in public places or group activities. In the case of shortage of resources, personal protective equipment such as medical masks, protective suits and face shields are mainly provided to frontline healthcare workers, and the public is encouraged to use alternative personal protective equipment that can be temporarily solved. Although it does not meet the medical-level protection standards, it can prevent the wearer from being infected with the COVID-19 to a certain extent. The reusable design of this type of protective clothing and accessories facilitates disinfection or clean after each wear, to minimize its limb exposure and optimize the safety and comfort of wearing, while reducing the consumption of new materials when manufacturing new products, thereby decreasing energy consumption, air pollution, water pollution and even greenhouse gas emissions caused by the use of new raw materials [11].

Many disposable masks and protective clothing are made of polymer fibers from fossil raw materials. They are non-renewable materials, and improper treatment after their use will cause environmental pollution. With the rapid rise of the circular economy, we have combined creative thinking with sustainable ideas to realize the upcycle of abandoned clothing and daily objects, and become a substitute for non-eco-friendly clothing. The health anxiety and bacterial fear brought about by this COVID-19 pandemic have an impact on people's dressing style. Functional protection, demountable and modular design provide methods and means for the sustainable design of personal protective equipment, guide and encourage people to accept cycling reuse mode. Based on the public's strengthening of ecological awareness, sustainable clothing design will become increasingly committed to minimizing climate impact and waste, while maximizing value at all stages of the product life cycle.

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