

5th PLATE 2023 Conference

Espoo, Finland - 31 May - 2 June 2023

Squaring the Circle on PPE: a Systemic Approach to Designing and Repurposing Gowns

Katherine Townsend^(a), Tom Dawson^(b), Eloise Salter^(a), Karen Harrigan^(a), Sonja Šterman^(c)

a) Nottingham Trent University, United Kingdom

b) University of Exeter, United Kingdom

c) University of Maribor, Slovenia

Keywords: Circular System; Design for Reuse; Reusable PPE; Repurposing; Net Zero.

Abstract: The lack of a systemic approach to the provision and servicing of reusable personal protective equipment (PPE) currently limits possibilities for extended use. The paper documents the research and development of a reusable PPE isolation gown and its' integration within a virtuous, circular system, which tackles the human and environmental issues caused by single-use products, through a holistic design for reuse approach. The dual aim of the research is to enhance the design of PPE gowns to improve user experience while decreasing medical plastic waste, in line with net zero targets. The collaborative design of a reusable PPE/surgical gown is the outcome of empirical research supported by a distributed manufacturing network, comprising partnerships between academia and local specialist textile, gown and laundry suppliers and a company focused on enabling fully circular textile systems. The co-design methodology has been implemented through engagement with the industry partners, by analyzing the PPE needs of the active healthcare user, and through wearer trials with NHS trusts in the UK. Following interactions with all stakeholders in the supply and value chain, we have devised a Circular PPE System that addresses the significant barriers relating to the longevity of reusable gowns. The model is based on developing net zero processes, such as fibre-to-fibre recycling, zero waste pattern cutting, design for reuse tactics, low environmental impact decontamination hubs, medical and creative repurposing strategies to extend the functional life of the garment and its materials.

Introduction

The issues associated with single-use personal protective equipment (PPE)¹ and the plastic waste generated by healthcare organizations were exacerbated by the coronavirus pandemic, leading to a call by United Kingdom Research & Innovation for the development of 'reusable products to meet net zero targets' (UKRI, 2020).

In response, the dual aims of this empirical investigation were to design a fit-for-purpose reusable PPE isolation gown and reduce the amount of single use gowns being disposed of (UKRI/ AHRC, 2021). By early 2022 we had developed a reusable gown prototype that met the prerequisite 'EN 13795 industry standards'

for CE/ UKCA marking and the 'research through design' aims of the brief (Townsend et al. 2022). The resolution and testing of the gown, aligned with product longevity and closed material loops was enabled through a 'distributed manufacturing' and servicing network (Kohtala, 2015).

Research by Circular and Sustainable Textiles and Clothing (CISUTAC, 2022) is focused on how northern European societies can replace the current fast fashion model, including workwear and PPE and active wear, with zero waste, circular alternatives. The four key areas that need to be addressed within a 'virtuous system' are defined by Zero Waste Europe (2023) as:

¹ PPE refers to Personal Protective Equipment though technically in the medical context what are commonly referred to as PPE are regulated medical textiles and covered under the Medical Device regulations and standards rather than the PPE or health and safety

regulations and standards. Reference to PPE in this document will be the equivalent of referring to Regulated Medical Textiles including masks, aprons, isolation, surgeons' gowns and surgical drapes.

1. Design for physical and emotional durability
2. Demand-driven production to phase out unsolds and discounts
3. Full supply chain transparency and traceability post-sale
4. Extending the use-phase after first ownership.

We address similar criteria in the development of a reusable PPE gown, using design as a vehicle to mediate between multiple stakeholders in the distribution network, towards a circular textile system (Zaplata et al., 2022). The core aim is to minimize the environmental impact of PPE, by developing a sustainable, novel and inclusive value chain (CISUTAC, 2022).

The paper describes the methodology employed to develop the PPE gown prototype, drawing upon the active users' requirements, literature and gown reviews. We explain how we established links with a distributed manufacturing network and circular textile systems provider and how the positive improvements of the gown were counter-balanced by perceptions of negative environmental issues linked to disposal strategies. Finally, we discuss how we responded to these issues by developing a Circular PPE System to address current barriers to meeting net zero targets.

Designing a Reusable PPE Gown with Active Users

The methodology drew on the teams' experience of conducting 'participatory research through clothing design' with overlooked fashion demographics (Townsend & Sadkowska, 2020). This earlier work combined the principles of 'co-design' (Sanders and Strappers, 2008) with insights into the 'lived experience' (Eatough & Smith, 2017) of the 'active user' (Kohtala, Hyysalao & Whalen, 2020).

PPE gowns are paradoxical items of clothing; a medical product designed to protect the healthcare worker and patient *and* a generic item procured en masse, placing the recipient in the 'passive user' domain (Strappers, 2006 cited in Kohtala et al. 2020). Following a literature review and interviews with

procurement and medical leads in 2020 we identified nurses, particularly women, as being active users of PPE by vocalising issues and customising the one-size gowns they were often allocated. In a reversal of Manzini's concept of "diffuse" and "expert design", the nurses' diffuse experiences of wearing PPE made them the experts (Manzini 2015, p.37).

Survey and gown review

While it was crucial for nurses to be part of our network, direct access was unfeasible due to Covid-19 restrictions. Using our initial findings we devised an online questionnaire addressing key aspects of isolation gown design and use (Šterman et al. 2022). The PPE Gown Survey (2022) was circulated via healthcare partners in the East Midlands, UK. Analysis of the 130 responses reinforced issues with sizing, fabrication and heat stress (e.g. McQuerry et al. 2021). Providing space for additional feedback elicited commentary on nurses' 'person-product relationships' (Niinimäki & Karell, 2019).

A gown review of 30 disposable and reusable products enabled the team to collate garment specifications, fibre content and design details. The technical measurements provided quantitative data, complemented by the qualitative insights from the survey and through sensorial impressions noted by trying the gowns on. By studying this information, the team devised a medium-sized pattern block and sourced a fluid repellent, breathable textile, similar to the more comfortable, reusable gowns. Garment toiles were created incorporating multiple cuff, neckline and fastening solutions.

Developing the Distributed Network: fabrication, production and servicing

Following 9 months research and development of the Style 1 gown prototype, the original named manufacturer failed to support the sampling/ testing process. This was one many "challenges encountered when confronting the theoretical framework of new circular economy business models with the material reality of design collaboration and prototyping." (Earley & Forst, 2019, p.1). We sought a replacement manufacturer through the Textile Services Association, who had made the case for

'reusable over single-use gowns' during the pandemic (TSA, 2021). The TSA connected us with local fabrication, manufacturing and laundry providers situated within a 30-mile radius, as follows.

Toray Textiles Europe Ltd (TTEL, 2020) are producers of polyester and nylon woven textiles for a variety of protective clothing contexts, notably DWR (durable water repellent) carbon coated polyester PPE gown fabric. TTEL hold OEKO-TEX® certification, have been ISO14001 accredited since 1998, and maintain an environmental management system to support their customers to use / re-use / re-cycle and dispose of its fabric and packaging in an environmentally responsible manner.

Anze Ltd UK (2022) are a manufacturer of sustainable healthcare apparel, with over 25-years of experience of producing and supplying reusable surgical gowns and drapes to the NHS. The company was involved in drawing up EU-wide standards which have shaped the reusable PPE industry, and are seeking smarter, greener solutions with a variety of partners.

Synergy LMS (2020) offer a range of linen services tailored to the needs of healthcare providers in the UK, including rental service of reusable PPE (washed at 71° C) and surgical gowns (sterilization at 134° C) to a total linen management solution encompassing the distribution and collection of ethically sourced products to and from medical wards.

Manufacturing the gown

On comparing our Style 1 prototype with Anze's PPE gown we found many similarities, including the 97.3% Polyester/ 0.7% Carbon fabrication (by TTEL), general style and dimensions. Anze's gown was supplied to healthcare providers nationwide and throughout Western Europe. The company offered us the opportunity to integrate our design modifications with their tried and tested model which included the following:

- Reshaping the front/back neckline
- Reshaping the sleeve head
- Shortening the sleeve
- Reducing the number of fastenings
- Introducing an XS size
- Recalculating the grade rule (XS-5XL).



Figure 1: Anze/NTU/Revolution-ZERO reusable PPE isolation gown prototype, 2022.

Anze Ltd sampled the prototypes in EN 13975 certified conditions and provided access to their CAD/CAM system, enabling us to adjust the pattern blocks, nest and lay plan. During this time, the company formalised a collaborative partnership with Revolution-ZERO which included the Anze/NTU gown (Figure 1). Revolution-ZERO (2023) has a mission to displace single use medical textiles with reusable alternatives that are more effective, economic and sustainable. To do so they work with partners to provide technology enabled solutions for net zero circular economy, or cradle-to-cradle medical textiles and PPE.

Wearer trials and key findings

With the support of Synergy LMS two wearer trials were conducted in 2022 with 24 participants working in ICU wards at the University Hospitals of Derby and Burton NHS Foundation Trust, and 12 participants at Nottingham University Hospital Trust. In addition, Revolution-ZERO coordinated a third trial with short-sleeved variation of the gown with 10 ICU staff in St Helens and Knowsley NHS Trust and a fourth trial at Royal Cornwall Hospital Trust, for 14 participants.

Feedback from the trials was positive, with the comfort and fit of the reusable gowns

outperforming single-use products. Commentary from wearers evidenced 'improved comfort' based on 'cooler fabrication', 'better fit' and the desire to wear reusable PPE as being 'more sustainable'. Suggestions were also made for minor modifications to 'cuff depth' and 'gown length'.

The main finding was that the development of such a high quality, durable gown could potentially create an additional environmental problem, relating to what happens when it reaches its maximum-use threshold? We discovered how post-laundry practices include shipping used gowns offshore to be used by medical charities in developing economies or sending them to landfill. This limited approach to reuse and disposal led us to review the original aims of the project and extend it by 6-months to facilitate research into repurposing strategies.

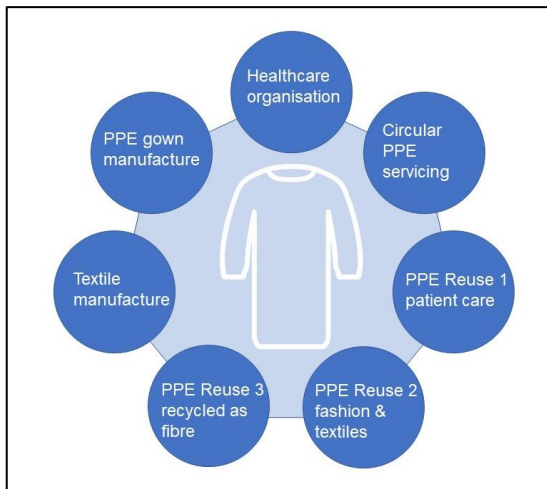


Figure 2: Circular PPE Gown System, Townsend et al. 2023.

Circular PPE Gown System: design, use and repurposing

Undertaking wearer trials of the gown highlighted the problems associated with "a linear model that is characterized by low rates of use, reuse, repair and fibre-to-fibre recycling of textiles..." (European Union, 2022).

Following the coronavirus pandemic, when reliance on offshore suppliers and unsuitable PPE exacerbated the crisis for nursing staff, there were calls for a local approach to PPE manufacture linked to the need for extended product use (Henshall, 2023). As illustrated in

Figure 2, the working model for our Circular PPE System focuses on increasing the current use phase by the Healthcare organization, to encompass three stages of Reuse. The model echoes the textile sectors' aspirations for Workwear and PPE through "implementing a fully circular value chain, incorporating cost efficient dismantling, sustainable and circular designs, and approval from public authorities." (CISUTAC, 2022).

The seven stages within the system begin with Textile manufacture and continue in a clockwise direction to PPE Reuse 3. Further research is being undertaken to support the functionality of the system, employing understanding of textile design, manufacture, and re/use to support value creation at each stage (Zaplata et al., 2022).

Textile manufacture and PPE Reuse 3: recycled as fibre

Toray Textiles Europe Ltd, recognizes how "the growing demand for textiles is fueling the inefficient use of non-renewable resources, including the production of synthetic fibres from fossil-fuels." (European Union, 2022). TTEL utilise 100% recycled polyester fibre and recycle 60% of the water used in their weaving production. They aim to remove the DWR carbon coating from their textiles to recycle the 100% polyester to fibre and yarn, at scale. "The ultimate goal is to produce a biodegradable PPE textile" (Else, 2023).

Gown manufacture

Anze Ltd continue to facilitate minor modifications to the Anze/NTU/Revolution-ZERO gown and to produce bespoke specifications for specific customers based on demand driven production. They plan to develop a Petite range (XS-3XS) and offer reusable PPE accessories such as headwear to accommodate nursing staff from ethnically diverse groups. Anze's goal is for the circular PPE system to facilitate a "gown-to-gown" model, with the product being recycled and remade, in lieu of a compostable, garment (Lamb, 2023).

Healthcare organization

In October 2020, the NHS became the first national healthcare system worldwide to set "a carbon net zero goal" with an aim to reach net zero in direct emissions by 2040, and then in

July 2022 the first to embed this target into legislation (NHS England, 2022). This creates the conditions and will for a rapid and large-scale shift towards circular medical textiles, but it is a complex task – the NHS and its supply chain accounts for “10 per cent of UK GDP and employs £1.4 million people” (UKRI, 2022) Consequently, “a move from linear to circular PPE requires new ways of thinking and operating, involving cross-sector collaboration mixing clinical, industrial, commercial, scientific, and academic expertise” (Dawson, 2023).

Circular PPE servicing

In April 2023 Revolution-ZERO will trial a ZER-DECON unit to reprocess and supply surgical textiles for orthopaedic theatres at St Michael’s Hospital, Cornwall, UK (Henshall, 2023). The PPE servicing process will integrate Net Zero focused washers, dryers and reporting sensors and will include low temperature decontamination and reusable sterile packaging. The servicing model echoes the full supply chain transparency of the PPE circular system. Since setting up Revolution-ZERO in 2020, the company have secured interest from 150 NHS Trusts and have so far supplied more than 15 Trusts with reusable products and services.

PPE Reuse 1: patient care

There are numerous viable pathways for the proposed transition from a PPE gown to be used in patient care, including as an endoscopy or another health screening procedure. Some minor design interventions may be required to customize or prepare used gowns to be aesthetic and functional for outpatient and inpatient care, depending upon the specific context.

PPE Reuse 2: fashion and textiles

Synergy LMS are providing the research team with used gowns, including our own models from the wearer trials. This waste stream is being experimented with in PPE Repurposing Workshops at NTU by undergraduate, postgraduate students and staff from the Fashion, Textile & Knitwear department in the School of Art & Design. The gowns are being deconstructed and upcycled as innovative, ‘intentional’ fashion and textile design concepts (Niinimäki & Karell, 2019) (Figure 3). The lightweight, fluid repellent properties of the end-of-life garments are also being explored as

outerwear for use by homeless members of the local community, by designing for physical and emotional durability (Townsend et al. 2023).

Conclusions

The identified need to link the design and use of PPE products to a circular textile system has informed the specification, production, servicing and reuse of an isolation gown. The circular PPE gown will carry the names of the designers, manufacturers and servicing providers (Anze, NTU & Revolution-ZERO) so that once in commercial production and circulation the customers will be aware that they are buying into a circular product/ system that seeks to minimize waste during, and at the end of the products first lifetime. The ‘gown to gown’, ‘cradle to cradle’ model could be attributed to any PPE textile product, guaranteeing that once an item reaches its legislated use phase it will be returned to the servicing provider (Revolution-ZERO) to be repurposed.



Figure 3: PPE Repurposing Workshop, NTU, March 2023.

By providing sample gowns to healthcare trusts around the UK, we have secured further trials with NHS Highlands for use in dental practice, and for the short-sleeved version of the gown to be tested in an extended wearer trial in the St Helens and Knowsley Hospital Trust Intensive Care Unit. The researchers are seeking follow-on funding to support these trials and continue their design investigations into repurposing. For example, in the Reuse 1 phase, there are a plethora of potential uses/ users in patient care, particularly if items could be customised using textile techniques such as printing and embroidery to align items with medical

procedures. As indicated by the ongoing repurposing workshops at NTU, there are multiple repairing, surfacing and construction approaches that fashion and textile designers could adopt in the Reuse 2 phase, by using gowns as a permanent waste stream.

Acknowledgments

The research led by Nottingham Trent University has been funded by the Arts and Humanities Research Council, UKRI (AH/VO15842/1). The research led by the University of Exeter was funded by SBRI Healthcare an Accelerated Access Collaborative (AAC) initiative, in partnership with the Academic Health Science Networks (AHSNs). The views expressed in the publication are those of the author(s) and not necessarily those of SBRI Healthcare or its stakeholders.

References

- Anze Ltd UK (2022) <https://anze.co.uk/>
- CISUTAC (2022) Circular and Sustainable Textiles and Clothing, <https://www.cisutac.eu/>, Accessed 28 March 2023.
- Dawson, T. (2023) Making Medical Textiles circular, *Resource: Sharing knowledge to promote waste as a resource*, 21 March, 2023, <https://resource.co/article/making-medical-textiles-circular>
- Eatough, V. & Smith, J. A. (2017) Interpretative phenomenological analysis. In: Willig, C. and Stainton-Rogers, W. (eds.) *Handbook of Qualitative Psychology 2nd Edition*, London, UK: Sage, p. 193-211.
- Else, C. (2023) Private telephone conversation with Sales Manager, Toray Textiles Europe Ltd., Nottingham, 29 March 2023.
- European Union (2022) EU Strategy for Sustainable and Circular Textiles, European Commission, Brussels, 30 March, 2022, <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0141>
- Henshall, A. (2023) How hospitals could avoid future PPE chaos, Business, BBC News, 23 February <https://www.bbc.co.uk/news/business-64718017>, Accessed 28 February 2023.
- Kohtala, C. (2015) Addressing sustainability in research on distributed production: An integrated literature review, *Journal of Cleaner production*, Vol. 106, November 2015, pp. 654 – 668.
- Kohtala, C. Hyysalo, S. & Whalen, J. (2020) A taxonomy of users' active design engagement in the 21st century, *Design Studies*, 67, p. 27–54.
- Lamb, R. (2023) Private conversation with Managing Director of Anze Ltd., Sutton in Ashfield, Nottinghamshire, UK, 15 March 2023.
- Manzini, E. (2015), *Design, When Everybody Designs – An Introduction to Design for Social Innovation*, Cambridge, MA: The MIT Press.
- McQuerry, M., Easter, E., & Cao, A. (2021). Disposable versus reusable medical gowns: A performance comparison. *American Journal of Infection Control*, 49(5), 563–570. <https://doi.org/10.1016/j.ajic.2020.10.013>
- NHS England (2022) Delivering a Net Zero National Health Service, July 2022, <https://www.england.nhs.uk/greenernhs/wp-content/uploads/sites/51/2022/07/B1728-delivering-a-net-zero-nhs-july-2022.pdf>.
- Niinimäki, K. & Karell, E. (2019) Closing the Loop: Intentional Fashion Design Defined by Recycling Technologies. In Vignali, G., Reid, L.F., Ryding, D. & Henninger, C. (Eds.) *Technology-driven Sustainability; Innovation in the Fashion Supply-chain*. Cham, Switzerland: Palgrave Macmillan, p. 7-27.
- PPE Gown Survey (2021) Redesigning PPE: enhancing the comfort and safety of healthcare workers wearing isolation gowns to treat patients with COVID-19, <https://ntusurvey.onlinesurveys.ac.uk/grading-gowns-redesigning-one-size-ppe-to-fit-and-protect>
- Revolution-ZERO (2023) <https://www.revolution-zero.com/>
- Šterman, S., Townsend, K., Salter, E. & Harrigan, K. (2022) Surveying Healthcare Workers to Improve the Design, Wearer Experience and Sustainability of PPE Isolation Gowns, *Strojnicki Vestnik: Journal of Mechanical Engineering*, 68 (4), pp. 252-264. ISSN 0039-2480
- Synergy LMS (2020) <https://www.synergylms.co.uk/>
- Textile Services Association (2021) The Case for Reusable Gowns, <https://tsa-uk.org>
- Townsend, K., Prince, E., Escott, A. & Barker, G. (2023 in print) NTU X Emmanuel House: Developing a responsible design practice with fashion students and service users, *Design, Materials and Making for Social Change*, Eds. R. Earley, & R. Hornbuckle, Routledge.
- Townsend, K., Sadkowska, A. (2020) Re-making fashion experience: a model for 'participatory research through clothing design'. *Journal of Arts and Communities*, 11 (1-2), pp. 13-33. ISSN 1757-1936
- Townsend, K., Šterman, S., Salter, E. & Harrigan, K. (2022) Out of Isolation: designing reusable PPE gowns based on an understanding of healthcare workers' lived experiences. In: D. LOCKTON, S. LENZI, P. HEKKERT, A. OAK, J. SÁDABA and P. LLOYD, eds., *Proceedings of DRS2022: Bilbao, 25th June - 1st July*.
- TTEL (2020) Toray Textiles Europe Ltd, <http://www.ttel.co.uk/>
- UKRI (2020) United Kingdom Research & Innovation, *Rapid Response Call: Ideas to Address Covid*, 31 March, 2020, <https://www.ukri.org/opportunity/get-funding-for-ideas-that-address-covid-19/>



5th PLATE Conference Espoo, Finland, 31 May - 2 June 2023

Townsend, K., Dawson, T., Salter, E., Harrigan, K., & Šterman, S.
Squaring the Circle on PPE: a Systemic Approach to Designing and Repurposing Gowns

[/blog/the-circular-economy-towards-net-zero/](#)

UKRI/ AHRC (2021) *Grading Gowns: Redesigning One-size PPE to fit and protect female health workers more effectively*, Project information at: <https://gtr.ukri.org/projects?ref=AH%2FV015842%2F1#tabOverview>

UKRI (2022) *The circular economy: towards net zero*, Blog, 14 June 2022, <https://www.ukri.org/blog/the-circular-economy-towards-net-zero/>

Zaplata, F., Köppchen, A., Grevinga, T. & Bruggeman, D. (2022) (Co-) Design for Understanding: mediating between processes of multistakeholder value creation towards circular fashion and textiles, *IFFTI 2022: Fashion Reimagined*, 5-8 April, Nottingham Trent University, UK, pp. 416-437, <https://www.iffitixntu22.co.uk/conference-proceedings>

Zero Waste Europe (2023) <https://zerowasteurope.eu/about/about-zero-waste/>