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A Product-Service System for Safety Footwear

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Abstract
This paper proposes that safety footwear manufacture shifts towards a sustainable Product-Service System (PSS). The PSS consists of seven stages from identification of requirements through to disposal or replacement. Through this, designers and manufacturers can realise safety footwear that is customised to end user sizing, function, industry and aesthetic requirements. For end users, this PSS leads to the creation of more comfortable and practicable footwear, addressing the underlying level of acceptance of uncomfortable safety footwear, reducing waste and providing sex specific offerings.

Keywords: mass customisation, product-service systems (PSS), design automation, safety footwear

1. Introduction

Conventional off-the-shelf safety footwear is used throughout many industrial sectors and in different operational environments to ensure worker safety. In 2019, the safety shoe market was worth over 9 billion USD and continues to experience a compound annual growth rate of 7.5% .

Safety footwear, despite being a growing market, endures problems regarding user perception around comfort, fit and style (Janson et al., 2021), is technologically restricted, having a significant environmental impact and suffers from vast gender bias. These issues all serve as drivers to change and move away from the current mass production approach to design and manufacturing. Whilst including extended findings from a 2019 survey of safety footwear users (Janson et al., 2021), this paper presents the current broadly adopted outline manufacturing process, followed by a proposal for the future view – the Product Service System (PSS). The proposed PSS would provide customised safety footwear to the end user, designed and tested within a virtual environment. Each stage of the PSS is discussed, followed by the potential comfort, functional, societal, environmental impacts, barriers to implementation, as well as cost implications.

2. Research Methodology

In order to develop the proposed PSS, elements derived from a "Comprehensive DS-1" (Blessing & Chakrabarti, 2009) research methodology were utilised, with the Research Clarification and Descriptive Study stages being the key sources.

2.1. Research Clarification

There are several objectives associated with this stage of the methodology. The first establishes the current "as is" status of the product and its supply - the "Initial Reference Model". This is outlined in section 3. Secondly, the intended ideal outcome of the study, the PSS, is formed - the "Initial Impact Model" as illustrated in section 5. Finally, impacts of and barriers to successful implementation are assessed in section 6.

2.2. Descriptive Study

The objectives associated with this stage of the methodology are focused around improving knowledge and understanding of the product and which components impact its success. Factors that can be used to judge whether the implementation of the PSS are discussed in terms of "motivators" in section 4.

3. Current Safety Footwear Lifecycle

When retailing Safety Footwear, generally products are simply grouped and manufactured by size, style and safety classification (and occasionally gender/sex); across the board, products are not usually customised in line with a refined set of customer requirements such as industry or function. Manufacture takes place under a "push" regime in response to expected consumer demand (Tsigkas, 2013). This traditional "push" model involves companies working on a mass production basis producing relatively standardised products. Figure 1 presents a simplified life cycle of safety footwear from the "End-User" and "Design and Manufacturing" process perspective. This illustrates the very loose connection between the manufacturing and end-user requirements in the exiting mass production environment. Figure 1 represents the "Initial Reference Model" outlined in the Research Methodology.

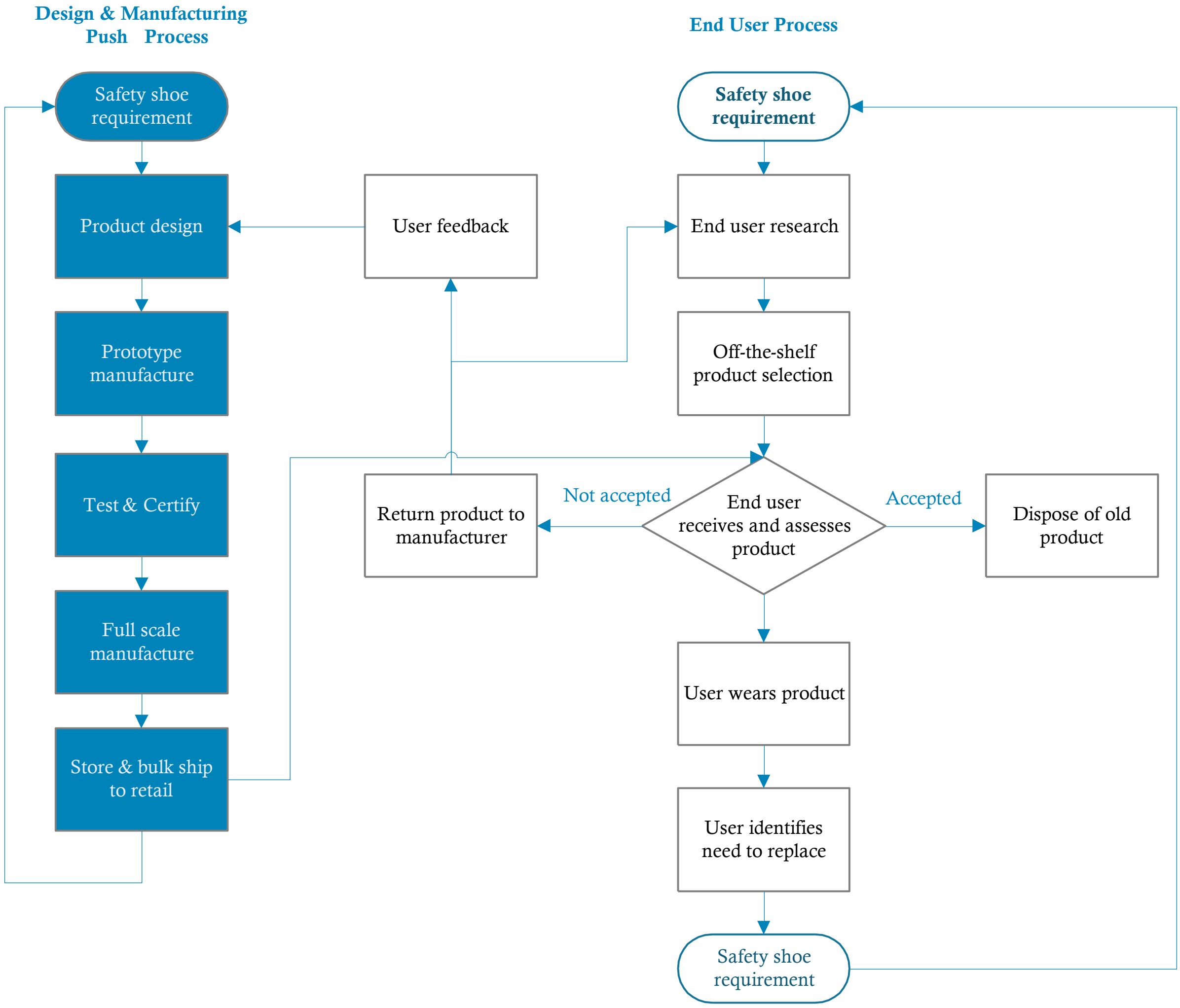

Figure 1. The Life Cycle of Safety Footwear

3.1. Design and Manufacturing Perspective

Under a traditional "push" design and manufacturing system, designs are fixed, based on a set of criteria (including feedback from the end user). For safety footwear, development cycles include prototyping and testing regimes before moving to full scale manufacture. Safety footwear is

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manufactured according to forecast demand from retailers. Finished goods are then stored and shipped in bulk to retailers.

3.2. End User Perspective

In most cases, safety footwear is bought by the end user "off-the-shelf" from a trade or workwear shop (37%), online (31%), or via a workplace catalogue (21%) (Janson et al., 2021), with over half of end users not even trying the footwear before making a purchase, and those that do try on, only for a short period of time. Once in receipt of their footwear, if the user deems that the product fits and is acceptable, this is worn until a replacement is necessary (motivations for replacement are discussed in section 5.7), else returned to the retailer for substitution or refund, then the cycle resumes.

4. Motivation to Change

This section highlights why the safety footwear industry needs to change in order to address the needs of an increasingly demanding customer base and environmental and regulatory requirements.

4.1. Comfort and Fit in Safety Footwear

Wearing safety footwear is legislated and vital for foot protection in many workplaces, from building sites to production lines. However, their use can lead to other outcomes such as muscular problems (Goto & Abe, 2017), altered gait (Ochsmann et al., 2016) and feelings of discomfort (Benjamin et al., 2017). In 1993, a survey of Australian workers wearing safety footwear incorporating a steel toecap found "91% of subjects reported one or more [verified] foot problems… and most considered that the safety footwear either caused the problem or adversely affected an existing foot condition" (Marr & Quine, 1993). In addition, a 2017 study indicated that 81% of participants had at least one problem with their safety footwear (Mancuso et al., 2017). In 2019, a survey by Janson et al., 46% of users indicated that compared to their "everyday" shoes, they found their safety footwear to be uncomfortable to some degree with only 33% experiencing no discomfort. Figure 2 illustrates previously undisclosed results, showing the breakdown of areas where discomfort was felt for the remainder of users.

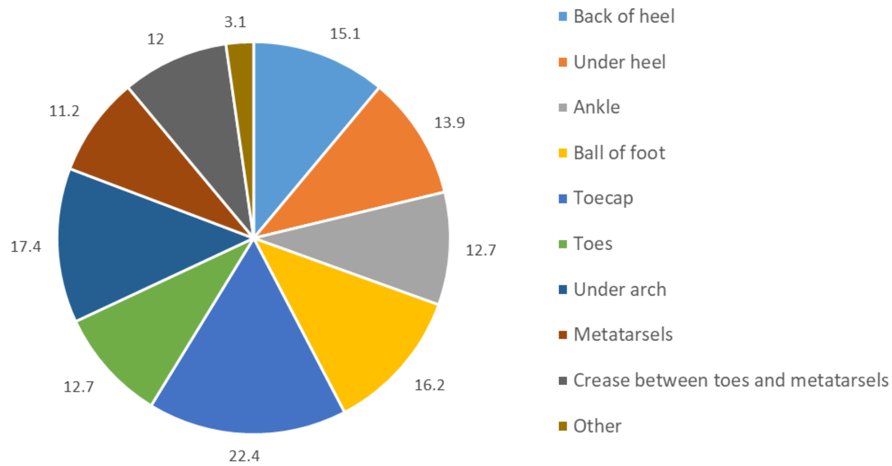

Figure 2. Areas of discomfort by % (not exclusive) for end users.

Despite most end users disclosing some level of discomfort or dissatisfaction with their safety footwear, wearers generally have reached a level of acceptance with the current standard of comfort. In the 2019 survey of those that indicated that their safety footwear was at least as comfortable as their regular footwear, 77% of women and 67% of men were still able to highlight at least one area of discomfort or pain (Janson et al., 2021). The implication is it has become accepted that safety footwear is uncomfortable to some degree; it is this expectation that is challenged by the approach introduced in this proposal. Additionally, intuitively, poorly fitting, uncomfortable footwear must surely impact negatively on productivity of the wearer. There is a paucity of evidence in this area to date.

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4.2. Functionality

Since their inception, safety footwear has experienced few technology advancements. Tweaks in materials, fit and style have been introduced, but to date, safety shoes do not match the level of comfort or technology provided by a non-safety equivalent, especially when compared with sports shoes. Current safety footwear standards centre around EN 20345 which defines a level of protection afforded by safety footwear, however, these definitions are in no way industry specific.

4.3. Environment Considerations

Currently, safety footwear is replaced for one of several reasons. For example, 59% of users cite that it is a resultant of wear and tear, 28% cite damage and around 10% indicate that their organisation's safety wear policy dictates that footwear must be updated (Janson et al., 2021). More industry specific footwear would lead to less wear and tear or damage where this has resulted from inappropriate use. Company policies could also be reviewed to avoid replacing footwear that remained fit for purpose.

4.4. Societal Impacts

Research has shown that women have more problems with their safety footwear than men in terms of fit, comfort and availability. When asked what they would improve about safety footwear, women opted for range, fit and aesthetics, whilst men were more concerned with durability comfort and fit (Janson et al., 2021), with the differences presumably because the range for men is vast when compared with that for women. Given that most safety footwear has historically been designed around a man's footshape, and that many of the offerings for women are simply re-badged men's shoes or boots, this does not promote a sense of belonging for women in environments dominated by men (PLH, 2017).

5. Proposed Product-Service System

Current approaches as described in Figure 2, present a linear view for a typical off-the-shelf mass consumer safety shoe that rarely fits the customer's requirements. To change this, a new approach is presented that takes into considerations that involve the end user in the design process. This transforms the traditional manufacturing "push" model used in the design and manufactured of safety footwear towards a flexible and partially automatable "pull" model, capable of producing customised products (Canadian Manufacturers and Exporters, 2005). The manufacturing, design and user selection processes can be seen as merging to form a single pathway, giving a cohesive and sustainable customised safety footwear product that is fit for purpose. This new approach, presented as a "Product Oriented" Type 1 PSS (Tukker, 2004) can be configured such that all steps up to product assembly are performed automatically and are outlined below in sections 4.1-4.7. This is consistent with similar processes which have been adopted across other industries, for example, tailored shirts (*Bespoke & Custom Tailored Shirts Online ITailor*, n.d.) and Nike sports shoes (Nike, 2021). In line with Tukker and Tischner's definition, the PSS presented aligns the provision of "tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific customer needs" (Tukker & Tischner, 2006). Figure 3 forms the basis of the "Initial Impact Model" outlined in the Research Methodology.

5.1. Identifying a New Safety Footwear Requirement

A requirement for new (as opposed to replacement) safety footwear can originate from several sources, not necessarily the end user. Organisations (for example, manufacturing or construction businesses) will often specify that personnel in given roles must wear safety footwear (amongst other personal protective equipment – PPE) in order to protect them from particular risks within their role. Other sources of the requirement may be contractual – e.g. for builders working within a construction environment, a level of PPE may be required to enter the construction site. A requirement for replacement safety footwear comes about for a variety of reasons and is discussed in section 4.7

5.2. End User Requirements

The new PSS aligns well with a mass customisation approach detailed by Piller et al. (Piller et al., 2007) which sets out a detailed strategy and proposal for mass customisation across the typical men's and women's footwear industry. The PSS also supports elements of Shang et al.'s (Shang et al., 2018) "Social Manufacturing System" for footwear. For safety footwear in particular, a number of aspects have been identified and are discussed below.

5.2.1. Sizing

There are many aspects of end user requirements that are not currently widely available when considering procuring safety footwear. One of the main aspects that must be considered is sizing. It is proposed that all users would be able to supply a rudimentary footscan using an accessible technique via a mobile phone. The resulting scan is then used to enable accurate sizing of the virtual "last". The last, once designed and manufactured, is at the core of shoe fit. In the proposed PSS a virtual last can either be adapted or custom-made to give a significantly better than nominal fit.

5.2.2. Physiological Considerations

In addition to handling the varying sizes of feet, offering size and shape specific footwear can also serve to accommodate medical conditions such as bunions or minor foot anomalies.

5.2.3. Industry and Role Specific Customisations

At present, except for a few professions such as the fire service, safety footwear is not particularly customised to a given industry; builders and manufacturing operatives will commonly share the same types of footwear. More needs to be done to tailor footwear to specific industries; this PSS, if implemented with the right tools has the potential to facilitate these changes. From the authors' experience, examples of industry specific customisations include:

- Enhanced ladder grips for roofers
- Flexibility across the toes and increased scuff resistant toe region for those who spend a lot of time kneeling
- Improved underfoot comfort (e.g. via specific orthotics) for generally stationary machine operatives
- Clog-free fasteners for builders (wearers in some industries are prone to clogging around lace hook-eyelets)
- Additional temperature regulation for those working in extremes of temperature (via insulation or ventilation)

5.2.4. Safety Classifications

At present, a range of safety options available to end users; this choice could be maintained as part of the new approach though it is proposed via this PSS that an increase in safety classifications would be possible. A modular specification could be developed based on role requirements. For example, a user may require a toecap that is solely crush resistant and not resistant to high impact. A safety classification such as this would ultimately require a policy change to continue to be classified as "safety footwear" as they would no longer pass the existing tests under ISO Standard 20345:2011 (BS EN ISO 20345:2011 Personal Protective Equipment - Safety Footwear, 2014).

5.2.5. User Specific Customisations

In terms of specific product aspects of the PSS, further customisations can be made available to end users in the form of aesthetics, for example stitching colour, materials, self-branding, heel height.

5.3. Virtual Product Design & Testing

Once the user requirements have been identified and the user has selected a base design, the requirements can be applied and a shoe or boot design created. At this point, in the existing process, a design would be prototyped and some preliminary testing carried out. At the heart of safety footwear lies

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a set of standards (BS EN ISO 20345:2011 Personal Protective Equipment - Safety Footwear, 2014). Every new shoe design is subject to a range of tests within these standards including a toecap impact test and toecap crush test. However, with a fully customisable range of safety footwear, it is proposed that these tests be replaced by simulated tests, using physical test data to validate and enrich the model. Finite Element Analysis (FEA) models would be created up front for all base designs to simulate the range of tests. Once user requirements and customisations are applied, the tests can be re-run to ensure certification can be achieved and physical testing on bespoke footwear would not be required on a continuous basis.

5.4. Customer Approval

Following selection of requirements and successful testing using FEA (if required), the customer is presented with a proof of their shoe design ready for approval. Acceptance of this design triggers the manufacture to order process.

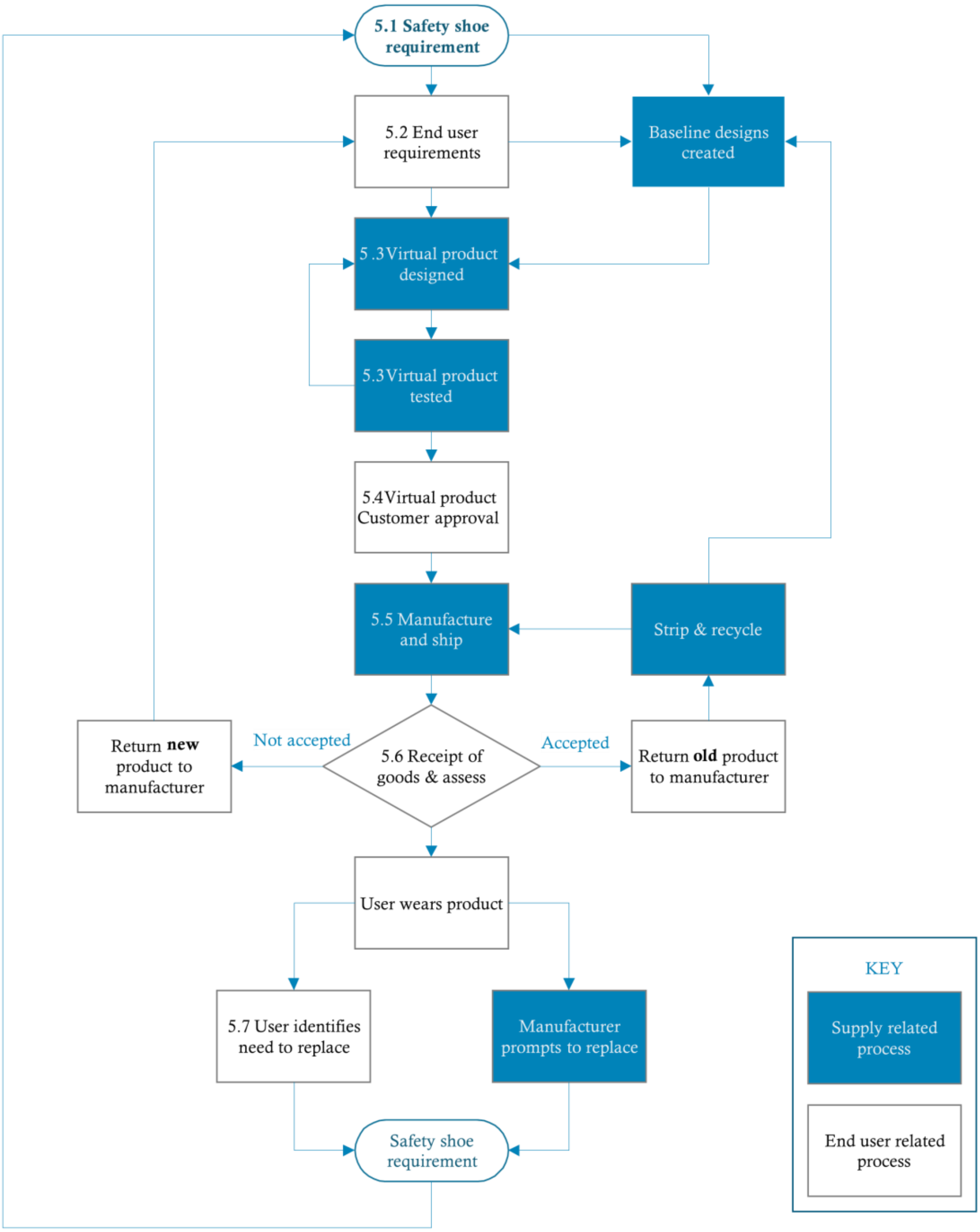

Figure 3. Proposed "Pull" Product Service System for the Supply of Safety Footwear.

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5.5. Manufacturing & Shipping

Adopting the new PSS would give manufacturers the opportunity to operate a true "pull" process, incorporating Lean and Just-in-Time manufacturing processes. Safety footwear would be made to order at the point of acceptance and shipped directly to the end user. It would be relatively simple to introduce this PSS as a pilot alongside existing manufacturing processes and grow the range of base footwear over time. New manufacturing methods would be needed in some areas, with examples including:

- Lasts – (upon which the shoes are manufactured) become modifiable or recyclable and as such would be bespoke to suit user requirements (though ultimately, a core set of common sizes could be maintained).
- Soles – additively manufactured, machined or moulded to order from their nearest match in terms of size, colours and feature; it is likely that a single size of sole could accommodate a range of sizing requirements.
- Uppers – fabric / leather cut to nearest size match following pattern specification from the bespoke design (proofed by the user).
- Toe caps – using new materials, such as lattice structures, and processes such as additive manufacturing used to ensure most appropriate design / best fit for the end user.

With time, the manufacturing process can become increasingly efficient and lean. Process learning can take place utilising and refining the set of customer choices on offer, for example, reducing colour offerings over time or capitalise on a superior level of service to customers for "premium" requirements.

5.6. Receipt of Goods

Once the user has received their custom-made safety footwear, they can choose to accept (and wear) their product, or return it to the manufacturer. If returning the footwear, this invokes a feedback loop to ensure that the reasons for rejection are captured and lessons learnt are built into future customisations. The footwear could also be modified or further customised and returned to the customer to ensure customer satisfaction.

5.7. Replacing Safety Footwear

Safety footwear is generally replaced for one of two reasons:
Time Based Replacement: In order to mitigate any litigation-based risks, organisations and individuals will specify a period after which, safety shoes must or should be replaced. This is regardless of level of use, damage or whether the footwear remains fit for purpose. It is difficult to estimate the number of pairs of safety footwear that are disposed of each year that remain fit for purpose, but it is suggested that a large number in a corporate environment follow this route. Indeed, 90% of all shoes end up in landfill (The Guardian, n.d.) and can take over 1,000 years to decompose.
Fitness Based Replacement: Clearly if safety footwear is damaged or worn out it may no longer be fit for purpose and it is common sense to replace it. However, the frequency of replacement is a burden borne by the purchaser. In the new PSS, sensors are to be incorporated into safety footwear to establish not only wear time but whether a given set of safety characteristics remained fit for purpose, this would lead to an increase in "Time in Use" – the number of days (or months) between receiving safety footwear and identifying the need to replace. Subsequently, "Cost in Use" is also reduced (see below).

6. Impacts of Implementation of the PSS

The clear impact of successful implementation of a Type 1 product oriented PSS is the resulting increase in customer loyalty. This stems from the improvement to both tangible and intangible values that are likely to be perceived by those customers (Tukker, 2004).
Improving the level of comfort, fit, the ability to accommodate foot anomalies, and aesthetics of safety footwear would lead to greater productivity in industrial environments. If safety footwear did not

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worsen the foot problems of wearers, less working time would be lost due to illness. Furthermore, a study in the US (Stewart et al., 2007) found that whilst pain conditions lead to a loss in production time, the majority of pain related lost time led to a reduction in performance at work; ultimately, discomfort causes distraction. Through implementation of this proposed PSS, there is significant potential to reduce the level of wastage from over-production. Manufacturing errors or poor setting of customer requirements may cause waste at product launch, but will decrease over time as the design process becomes refined through better specification, customer feedback and the returns process.

Waste will likely be reduced through the specification and provision of industry or function specific safety footwear, reducing damage and wear and tear that results from inappropriate use or environments. In the ideal scenario, all used footwear should be returned to the manufacturer for inspection, strip/survey and recycling such that (for example) soles can be manufactured from recycled footwear. No element of the footwear should be destined for landfill. This can be achieved via a buy-back service or other incentive schemes. In terms of shipping, manufacturing organisations may be set up "in country" to ensure a fast turnaround. Other than for raw material shipping, transportation is reduced and in turn the overall environmental impact is reduced, consistent with the incremental reduction associated with Tukker's type 1 PSS (Tukker, 2004).

Implementation of this new PSS for safety footwear brings about significant societal impacts. As previously asserted, safety shoe or boot wearers have reached a level of acceptance with a degree of discomfort when wearing safety footwear; uncomfortable work boots are the status quo. Until a different option is made available, these poorly fitting solutions will continue to be offered. When considering a non-industrial environment where safety footwear is not required or dictated, under no circumstances would it be acceptable to wear uncomfortable footwear throughout the working day. Employers can further take advantage of this new approach to safety footwear by instilling a perception of care towards their employees giving potential improvements in morale. Individuals are more confident and prepared if they have the correct safety footwear, ensuring safety but also providing comfort, fit and style.

A far-reaching societal impact lies in the improvement of safety footwear for women. There is current lack of an adequate range of comfortable, fitting, fit-for-purpose and stylish safety footwear for women when compared with their male peers. It is suggested that this is a contributing factor towards women entering industrial work environments. However, to date, there is little other than anecdotal evidence to support this supposition. Lack of appropriate safety footwear can lead to feelings of exclusion; this can occur early in the careers of females in industrial environments. For example, often, when visiting factories personnel are required to don safety footwear. However, women can find that the offering is available in sizes, fits and styles only suitable for men. Anecdotal reports indicate that this has the effect of making those individuals (albeit potentially subconsciously) feel unwelcome or that they do not 'fit in'.

Ultimately, whilst the motivations to change, outlined in section 4, are somewhat unrecognised, more comfortable, fitting, attractive, role-appropriate and safer footwear will inevitably attract end-users towards the products resulting from this PSS.

6.1. Barriers to Implementation

The PSS outlined in this paper demands a major cultural shift in how safety shoes are manufactured and supplied. There are some significant barriers to overcome in order for this PSS to be adopted.

6.1.1. User Perceptions

It is believed that end users have reached a level of acceptance with their safety footwear; discomfort to some level is to be "expected" and has become normal. Giving end users a better option is key and can be accomplished by delivering a better fitting shoe or boot that is designed specifically for the environment and industry in which it is to be used.

6.1.2. Cost in Use

Introducing new technology, materials and providing an increased level of customization for safety footwear will inevitably mean that an increase in unit price is likely (assuming that increased costs are passed on to the consumer). However, the “Cost in use” is deemed likely to fall. “Cost in use” when applied to safety footwear can be defined as the overall cost of the product over a given time period. In simple terms, footwear outlay may be more expensive for the end user but if it proves more durable, it is likely to be largely better value. So, despite the perception of a cost increase for customised footwear, the overall cost in use is decreased. In organisations that regularly purchase safety footwear for a large numbers of employees, the financial benefits could be significant.

6.1.3. Shareholder Value

The capital expenditure of setting up and production costs of operating such a PSS are likely not insignificant. Tukker et al concede that a type 1 PSS as presented here inevitably leads to an increase in tangible and capital costs for the provider (Tukker, 2004).

6.1.4. Physical Testing versus Simulation

It is appreciated that the policy change to achieve this is not an insignificant undertaking. Collaboration would be necessary with current test houses and standards authorities to validate any simulation methodologies developed and this work would be ongoing. Audit-based spot testing on an ongoing basis is also suggested to instil confidence in the change of policy. A further issue around testing lies in the different skill levels required to perform the analysis. Simulated testing and validation moves from physical test centres back to the designer (though this could also be outsourced). On the contrary, it may also be possible to gain certification using physical testing so long as a pre-defined set of boundary conditions, e.g. toecap size, is not compromised for that range of footwear. It should be noted however, that any reduction in experimental testing taking place not only has environmental benefits due to the reduced number of test pieces required, but timescales to market can be vastly reduced and hence the proposed approach becomes viable.

6.1.5. New Materials

Development of materials and processes for the toecap region will require significant effort and may prove lengthy. In addition, development of processes to accurately model the material properties using theoretical FEA methods may require collaboration with software developers and materials experts in order that the analysis proves sufficiently robust to ultimately replace physical testing.

7. Conclusions

A gap in the market exists for a customisable, comfortable and aesthetically acceptable safety footwear that is industry and environment specific. Changes would ordinarily be end user driven but some work needs to be done to change perceptions and recognise the need to change. Note that this current lack of appreciation of the need to change has led to very little research around this aspect of safety footwear. The contribution of this research aims to highlight the need for change and prompt further research in this arena. Under the proposed Product Service System, having specified their requirements, the end user gains a better fitting, more comfortable safety shoe or boot, tailored to their specific working needs and their aesthetic requirements.

The PSS outlined in this paper for safety footwear was developed using derived stages of a Comprehensive DS-I research methodology. It includes design, simulated testing and validation and manufacture of safety footwear and begins to address different aspects of the product lifecycle. The PSS serves to transform design, manufacture and supply of safety footwear, potentially offering a more sustainable manufacturing process coupled with customised design and positive environmental benefits through reduced disposal of footwear as it remains fit for purpose for longer. Furthermore, societal impacts regarding the provision of safety footwear for women to match their male counterparts starts to bridge the gap and could help to promote diversity and inclusion within industrial environments.

Future work should focus on further developing the PSS using additional stages of Blessing et al's methodology, to take it from an Initial Impact Model to an Impact Model, potentially utilising Penin's blueprint concept (Penin, 2018), and ensuring key success criteria are addressed.

References

Benjamin, D., Ahram, T., de Ru, E., Choukou, M. A., Abdi, E., Gardan, N., Boyer, F. C., Regnault, P., & Taiar, R. (2017). Comparison of FAP scores with the use of safety footwear and regular walking shoes. Theoretical Issues in Ergonomics Science, 18(6), 631–642. https://doi.org/10.1080/1463922X.2016.1260180

Bespoke & Custom Tailored Shirts Online | iTailor. (n.d.). Retrieved November 20, 2021, from https://www.itailor.co.uk/

Blessing, L. T. M., & Chakrabarti, A. (2009). DRM, a design research methodology. In DRM, a Design Research Methodology. Springer London. https://doi.org/10.1007/978-1-84882-587-1

BS EN ISO 20345:2011 Personal protective equipment - Safety footwear, (2014).

Canadian Manufacturers and Exporters. (2005). Manufacturing 20/20.

Goto, K., & Abe, K. (2017). Gait characteristics in women's safety shoes. Applied Ergonomics, 65, 163–167. https://doi.org/10.1016/j.apergo.2017.06.012

Janson, D., Newman, S. T., & Dhokia, V. (2021). Safety footwear: A survey of end-users. Applied Ergonomics, 92. https://doi.org/10.1016/j.apergo.2020.103333

Mancuso, G., Cavrini, G., Berdondini, R. M., & Mancuso, M. (2017). Skin lesions and other foot problems associated with safety footwear. Giornale Italiano Di Medicina Del Lavoro Ed Ergonomia, 38(4), 261–264. http://www.ncbi.nlm.nih.gov/pubmed/29916607

Marr, S. J., & Quine, S. (1993). Shoe concerns and foot problems of wearers of safety footwear. Journal of Occupational Medicine, 43(2), 73–77. http://occmed.oxfordjournals.org/

Nike. (2021). Nike By You. https://www.nike.com/gb/en_gb/c/nikeid

Ochsmann, E., Noll, U., Ellegast, R., Hermanns, I., & Kraus, T. (2016). Influence of different safety shoes on gait and plantar pressure: a standardized examination of workers in the automotive industry. Journal of Occupational Health, 58(5), 404–412. https://doi.org/10.1539/joh.15-0193-OA

Penin, L. (2018). An Introduction to Service Design: Designing the Invisible. Bloomsberg USA. https://doi.org/10.1080/14606925.2019.1615677

Piller, F. T., Mu¨ller, M., & Mu¨ller, M. (2007). A new marketing approach to mass customisation. International Journal of Computer Integrated Manufacturing, 17(7), 583–593. https://doi.org/10.1080/0951192042000273140

PLH. (2017). Work Boots Aren't Just For Men – Women Need A Great Pair of Safety Footwear Too. PLH Group. https://plhgroupinc.com/womens-safety-footwear/

Shang, X., Shen, Z., Xiong, G., Wang, F. Y., Liu, S., Nyberg, T. R., Wu, H., & Guo, C. (2018). Moving from mass customization to social manufacturing: a footwear industry case study. Https://Doi-Org.Ezproxy1.Bath.Ac.Uk/10.1080/0951192X.2018.1550675, 32(2), 194–205. https://doi.org/10.1080/0951192X.2018.1550675

'Some soles last 1,000 years in landfill': the truth about the sneaker mountain Fashion The Guardian. (n.d.). Retrieved November 22, 2021, from https://www.theguardian.com/fashion/2020/mar/21/some-soles-last-1000-years-in-landfill-the-truth-about-the-sneaker-mountain

Stewart, W. F., Ricci, J. A., Chee, E., Hirsch, A. G., & Brandenburg, N. A. (2007). Lost Productive Time and Cost Due to Common Pain Conditions in the US Workforce. Journal of American Medical Association, 49(6), 672–679.

Tsigkas, A. C. (2013). The Lean Enterprise - From the Mass Economy to the Economy of One. Springer-Verlag Berlin Heidelberg. http://www.springer.com/series/10099

Tukker, A. (2004). Eight types of product-service system: Eight ways to sustainability? Experiences from suspronet. Business Strategy and the Environment, 13(4), 246–260. https://doi.org/10.1002/BSE.414

Tukker, A., & Tischner, U. (2006). Note from the field Product-services as a research field: past, present and future. Reflections from a decade of research. https://doi.org/10.1016/j.jclepro.2006.01.022

https://doi.org/10.1017/pds.2022.105 Published online by Cambridge University Press