Sand chair: Improving access to Cornish beaches through sustainable design

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A collaborative design opportunity

Cornwall Mobility (CM) are a charity based in Truro which provides advice and support for people with physical disabilities and mobility difficulties. They work with adults and children to evaluate their specific needs and offer a large range of assistive technology and mobility products to support independent living. In particular, activities such as washing, cooking, dressing, undressing, and getting around the home, are key areas where support is provided (Cornwall Mobility 2016). CM are also responsible for the management and delivery of beach wheelchairs, or 'sand chairs' at coastal locations across Cornwall.

Falmouth University (FU), located 10 miles from CM, is positioned as the UK's Number One Arts University in the Sunday Times league table 2017 (Falmouth University 2016). The university's Centre for Smart Design addresses, *"societal grand challenges such as climate change, energy security, an ageing society, and health and wellbeing"* (Benjamin 2016). CM and FU have collaborated to develop a new type of sand chair for use on Cornish beaches. This collaboration is part of the Centre's initiative to develop partnerships to jointly research and develop new products and services for global markets. *"These initiatives aim to deliver social benefits, economic growth and knowledge based employment in Cornwall and beyond"* (Benjamin 2016).

Current sand chair provision in Cornwall

CM identified that access to sand chairs in Cornwall could be improved in terms of increasing the number of beach locations where they operate, increasing the number of sand chairs available at those locations, and improving the usability and design of sand chairs more generally. Sand chairs are frequently used by locals and visitors to Cornwall, including children and adults who are physically disabled through disease or injury, and elderly people who struggle with mobility. The sand chairs are needed because conventional wheelchairs are unsuitable for traversing sandy and/or stony beaches. When deployed users of sand chairs may transfer from their usual wheelchair which is on firm ground, or may take the few steps necessary to move from a car to sit on the sand chair. Adjacency, the ability to provide a stable braking system and a comfortable support surface are all part of a design brief. So too is the ease of pushing and manoeuvring the sand chair over variable terrain. This is of particular importance when the carer is elderly or infirm.

The sand chairs available for public use in Cornwall are managed by CM and are available at nine locations across the county. Two types of wheelchair are currently used: a product called Landeez™ and another called DeBug™. Both wheelchairs are imported from the USA, are expensive and subject to import duty. Furthermore, a number of known faults and design improvements were recognised by CM with both products before the project began.

Health and wellbeing benefits

The health and wellbeing benefits of being by the sea have long been acknowledged anecdotally. However, a recent study used small-area census data for the population of England to determine that good health is more prevalent the closer one lives to the coast (Wheeler et al 2012). The authors also noted that, "*the positive effects of coastal proximity may be greater amongst more socio-economically deprived communities".* Cornwall has one of the highest levels of economic deprivation in the UK

(Eurostat 2014), and nationally, substantially more people who live in families with disabled members live in poverty, compared to individuals who live in families where no one is disabled (Gov.uk 2014). This highlights the need to consider how Cornish beaches can be made more accessible to people with physical disabilities and mobility difficulties, enabling them to enjoy the physiological and psychological benefits that being by the sea can bring. The findings would of course be generalizable to other coastal communities. An adequate provision of sand chairs could impact positively on the tourist industry as well as the local population, wherever they're made available. As an example, CM has recently received a letter from a happy visitor from London thanking them for enabling him, by using a sand chair, to paddle in the sea for the first time in years.

Human centred design approach

The project demonstrates how a charity, such as CM, can be empowered through design, to provide improved access to products and services for their clients. Through FU's Centre for Smart Design, support has been provided in the form of high value research and access to prototyping and development facilities. CM has supported important primary research activities in this product sector combining its knowledge of assistive technologies and its advisory role to a large client base. The collaboration has allowed us to engage with CM clients using human centred design methods – guided by the requirements of ISO 9241-171 (2008)[1] – to strategically inform the design development.

Existing Product review

Analysis of an existing sand chair provided some clear indicators for areas of improvement. The Landeez™ product was tested on Perranporth beach in Cornwall with three members of the CM team. Areas examined included: ease of getting into the chair; comfort whilst seated; manoeuvrability of the chair over different sand conditions; and ease of getting out of the chair, together with perceptions of comfort and security. Although the testing team are all able-bodied, the evaluation was a useful exercise to establish design opportunities to improve the sand chair for 'active users', i.e. people who do not permanently rely on a wheelchair but have some limited mobility.

[1] Although this standard relates to human-computer interaction, it embraces the definitions of both Human Centred Design and User Experience. The four stage generalised model includes (i) understanding and specifying the context of use, (ii) specifying the user requirements, (iii) producing design solutions and finally (iv) evaluating the designs against requirements.

Figure 1: Landeez™ front wheels snagging in the sand

Some specific issues were identified in relation to getting in and out of the chair and the wheel arrangement over certain terrain:

(i) The leg rest makes it difficult to back into the chair from a standing position and sit down on it in an intuitive way.

(ii) The over-sized tyres at the rear make it difficult to access the seat from the side (this would also make transferring from a wheelchair to the sand chair almost impossible as the two chairs cannot be placed close enough to each other for safety).

(iii) The small wheels at the front had a tendency to snag in deeper sand (see figure 1).

This exercise helped to establish a Product Design Specification (PDS) to benchmark the sand chair concepts that developed.

Early prototyping and feedback

A focus group consisting of eight CM clients and staff members participated in a review of an early sand chair prototype, comparing it to the Landeez™ and DeBug™ products. Clients with mobility ranging from severe arthritis to paralysis were involved with the testing with one staff member with experience in prosthetics simulating the problems encountered by a lower limb amputee. Particular focus was placed on the ease of getting in and out of the chair and the relative comfort and feeling of security when seated. The feedback identified that although the prototype was comparatively easier to get in and out of, the stability of the product during this transition needed to be improved. The requirement for longer, more substantial, arm rests for grip and a greater feeling of security in the chair was identified as a positive area of improvement. The back and seat shape and padding were also areas where user testing established opportunities for further development to improve comfort.

The participant feedback informed further development and later sand chair prototypes. The geometry of the chair was adjusted to position the front axle further forward creating a more stable arrangement. The testing helped to ratify the wheel arrangement, with large wheels at the front and two smaller, swivelling wheels at the rear. This circumvented the problem of smaller wheels snagging in deeper sand but still allowed a wheelchair user to position themselves close to the seat to transfer to the sand chair.

Figure 2: Testing the sand chair prototype for ease of transfer to a wheelchair

The seat and back shape were derived from ergonomic research relating to *easy chair* design by Grandjean (1988) who used an adjustable test rig to determine the preferred seat profiles across a range of participants. Pheasant (1996) discusses the work stating that, "*a seat that enables the user to adopt a semi-reclined position and has a backrest that is contoured to the shape of the lumbar spine will both minimize the mechanical loading on the lumbar spine and maximise the overall levels of reported comfort."*

Although a standard design for the seat and back shape was developed, the sand chair concept offers flexibility in manufacture to accommodate different profiles to suit people with spinal deformity. Additional supporting elements, such as a head rest, could also be developed to integrate with the chair structure. The sand chair has been designed for adults, but the concept could easily be scaled to provide a paediatric chair later.

Sustainable design strategies

Existing sand chairs provided an opportunity to benchmark the quality of user experience in relation to function and aesthetics. However, they also provided a useful starting point for comparison when considering the life cycle and environmental impacts of the new concept. The existing products reviewed rely on a tubular, fabricated frame construction, typically using marine grade stainless steel. The project presented an opportunity to challenge this approach and disrupt the current model for sand chair design, exploiting sustainable design strategies.

In an attempt to make the product more inclusive, the emerging design concepts sought to establish a new visual language with styling associated with deck chairs and sun loungers as opposed to the archetypal wheelchair (see figure 3). Using layered profiles, cut from plastic sheet material, the design allows for body contouring, providing comfort and body support in an ergonomic way.

Figure 3: CAD visualisation of sand chair concept with styling associated with a striped deck chair

Distributed manufacturing

The advantages of using CNC machined[2], sheet material over other materials and production processes were explored early on in the project. The use of plastic was investigated as an alternative to metal components to avoid corrosion in the outdoor environment. However, plastic moulded components typically require expensive tooling to be made. The use of sheet plastic material negates the need for bespoke tooling as the parts can be produced on a CNC router using industry standard cutting tools. It is also suitable for low volume production which is appropriate to the current size of the market for sand chairs. However, as production increases, this method would also lend itself to a distributed manufacturing model, potentially allowing the key component parts to be produced locally to where the product would be sold and used, thus reducing energy and emissions associated with transportation. In addition to improving sustainability, distributed manufacturing could significantly reduce supply chain costs, and support tailoring of products to the needs of consumers (Srai et al 2016).

[2] Computer Numerical Controlled (CNC) machining allows for multiple components to be cut from a single sheet of manufactured board, such as plywood or HDPE.

Mass Customisation

The potential for design detailing through sheet material construction evolved in four stages (see figure 4). Through scale model making and prototyping design concepts using sheet materials, the ease in which CAD software and digital manufacturing processes[3] can accommodate incremental changes to the design were well exploited. This same principle could be applied within a production context where the inherent modularity of the design is further enhanced through the ability to customise individual component parts on a chair-by-chair basis. This presents the opportunity for a multitude of product variations, tailored to specific customer needs, with no further investment required in tooling or manufacturing capability. To offer this extent of flexibility would be very costly to achieve using tube bending and welding manufacturing processes, as adopted by other sand chair products The notion that the product could be adapted or upgraded later during its life time, provides the means to significantly extend the life span of the sand chair. Furthermore, this customisable design approach will also cater for severely disabled people, as well as the majority who are less disabled, making the product more inclusive.

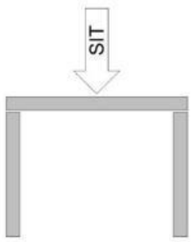
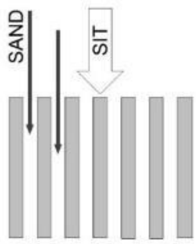
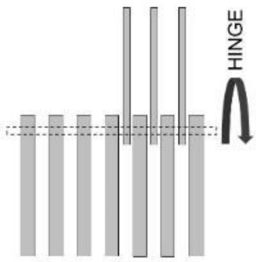
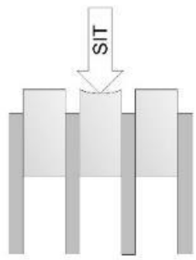
Stage 1: Initial concepts explored using sheet material typically in a box construction format. The face of the sheet became the surface to sit on.		Stage 2: More developed concepts considered a seat surface formed from the edges of multiple sheets spaced apart. Sand and water can drain between the gaps.	
Stage 3: This arrangement became an efficient method to hinge potentially adjustable parts of the sand chair, such as the arm rests.		Stage 4: Interspaced sheet profiles were replaced with protruding medium density foam to reduce weight and provide a cushioned surface to sit on.	

Figure 4: Four stages of design evolution using sheet material

Design for disassembly

In a later iteration of the concept, the main body of the sand chair – consisting of the seat, back rest and mounting points for the front axle and rear castors – was constructed from rigid sheet profiles, interspaced with medium density foam profiles. This sandwich construction is held in compression using threaded stainless steel bar at spaced intervals through the seat and back rest portions (see figure 5), with nuts at each end of the bars, tightened against the face of the outermost rigid sheet profiles. The foam profiles provide three key functions: the extent that they compress under pressure helps to keep tension on the threaded bars, keeping the assembly rigid; secondly, the foam, which sits proud of the rigid sheet profiles, provides a cushioned surface for the seat and backrest; finally, the wider spacing

[3] Such as laser cutting card and foam and CNC machining plywood and HDPE sheet plastic.

created by the foam means fewer rigid sheet profiles are required, drastically reducing the weight of the sand chair.

Figure 5: Plywood and EVA foam prototype partially assembled

Recycling is a key aspect of sustainability, but "*in order to be effective, products need to be easily disassembled into component parts and separated by material. If this is difficult, these products simply end up in landfill instead"* (Shedroff 2009). The foam and rigid sheet lamination is analogous to the structural insulation panels (SIPs) found in the construction industry. However, with the sand chair concept the panels are not bonded to each other with adhesive so they can be easily separated at the end of the product's life.

This strategy is extended to all of the components of the sand chair where all parts are fixed through means of slotted profiles in the sheet material, or mechanical fixings. This allows for re-use, repair or remanufacturing using serviceable components, or for individual parts to be sent to appropriate recycling streams. In this respect the product embraces the notion of a circular economy and attempts to follow Cradle to Cradle (McDonough and Braungart 2002) design principles.

Sheet material strategy

The adoption of HDPE sheet material as the main structural element led to a design approach where many of the ancillary components were also developed using the same material. For example, a system was designed that automatically engages a brake pad onto the front wheel when the arm rest is lifted up (see figure 6). This provides an intuitive means of keeping the sand chair steady whilst the user gets in or out of it. The use of bicycle componentry was considered early on when reflecting on inadequate braking systems presented in the existing products. However, the opportunity to maximise the use of the sheet material during production was quickly realised and the brake components were designed using the same material. The CNC cutting paths are arranged as closely as possible on the sheet and the small spaces left between larger components are filled with ancillary elements such as the brake pad parts and linkages to the arm rests. In effect, the brakes are made of waste material.

Figure 6: Sand chair prototype using HDPE plastic (brake assembly circled)

The sand chair design allows for variation in the sheet materials used, and any sheet type that meets appropriate performance specifications[4] could be adopted for production. However, consideration has also been given to the life cycle impacts of the material which will be used. The decision to specify HDPE sheet in the latest iteration of the sand chair was based on a number of factors. Polystone® Play-Tec HDPE is manufactured by Röchling Engineering Plastics and is primarily used for outdoor playground equipment. The material is recyclable, providing a viable alternative to landfill at the end of life of the product, and the performance requirements which make it suitable for playgrounds are ideal for the sand chair. The material has been developed specifically for outdoor use and is highly durable. "*even after 10 years, embrittlement of the material is not to be expected. Even scratches are practically invisible due to the material being homogeneously through-dyed."* (Röchling 2012). The product is also resistant to colour fading from exposure to sunlight, wind and rain, and has been subjected to simulated weathering tests as per ISO 4892-2 (2013)[5]. The durability of this material supports an extended life design strategy for the sand chair.

Similarly, Evazote® foam, made from EVA copolymers, was selected due to its performance specification. It is used in a number of product applications including knee pads, gym mats and boat fenders and is non-toxic, water and chemical resistant (Zotefoams n.d).

Conclusion

The project demonstrates how a charity can be supported by a university to be empowered by design. The client base established by CM provided an excellent means of developing primary research using human centred design strategies. The design development and prototyping was supported by the resources and expertise based at FU. A unique design has been developed which will be protected through UK design registration.

Keates and Clarkson (2004) draw attention to the fact that inclusive design needs not just to reflect the needs of the immediate user, but all individuals involved in the product. These include the installers, carers, those involved in product maintenance and ultimately product recycling and disposal. We would

[4] Including acceptable mechanical strength and rigidity, water resistance, resilience to weathering and sea air, and UV resistance.

[5] The standard specifies methods for exposing test pieces to xenon-arc light in the presence of moisture to reproduce the weathering effects that occur when materials are used in outdoor environments.

endorse this view as a key to this present project has been the intentional and highly successful involvement of both users, carers and equipment managers in the design process. Their feedback was an invaluable tool to help define key priorities and features of the sand chair design. The input provided by participants with significantly different levels of mobility and disability has also demonstrated the need for a product that could be fundamentally adapted in design to meet different user needs. The sand chair design evolved as a modular system that could accommodate bespoke design detailing as part of the manufacturing process, or as a post-manufactured upgrade or alteration.

The sheet material construction of the sand chair underpinned the sustainable design strategies employed. CNC machining production methods potentially offer a distributed manufacturing model for the sand chair, reducing energy and emissions associated with transportation. The digital tools used to manipulate the design also provide the means for mass customisation of the product.

As a *kit of parts,* the sand chair is designed for disassembly, allowing easy separation of components for re-use, repair, or recycling. This will significantly extend the lifespan of the product and reduce the overall environmental impact.

The HDPE component parts are strategically positioned for cutting from the sheet to afford the most efficient use of the material. Ancillary components, such as the brake pad assemblies, have been purposefully designed using the same material and occupy space on the sheet that would otherwise be wasted. Materials such as the Playstone® Play-Tec have been specified for both their technical performance and recyclability.

We have attempted in this project to develop a socially acceptable and sustainable product – and one that the user is happy and content to use without any intervention from professionally qualified personnel. Cooper (1999) has suggested that the only successful products are those that users *want* to use. The feedback received from all our participants has indicated that we are well on the way to achieving this goal.

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