Manufacturing custom-contoured wheelchair seating: A state of the art review

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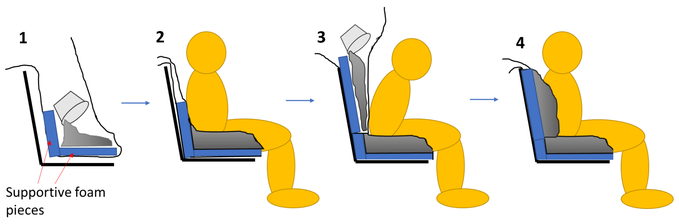
What is custom-contoured wheelchair seating?

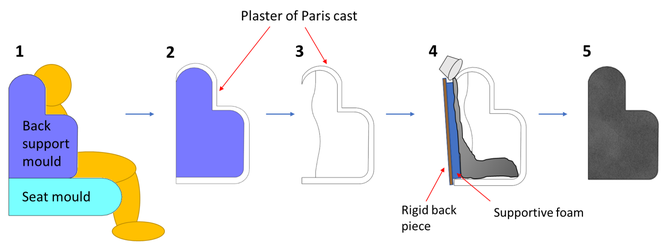
Custom-contoured wheelchair seating typically comprises a seat cushion or back support cushion (or a set of both cushions) with integrated supports that closely match the contours of a person's body. Such a seating system is prescribed by a clinician in order to: prevent, accommodate, or correct skeletal deformities; optimise the seat-body interface pressure; provide trunk stability and limit spasticity; and to enhance autonomic nervous system functions, such as breathing, swallowing, and digestion.

Current Manufacturing Methods

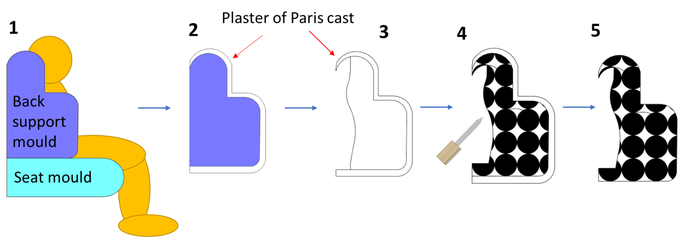
Foam-in-Place Seating (FIPS)



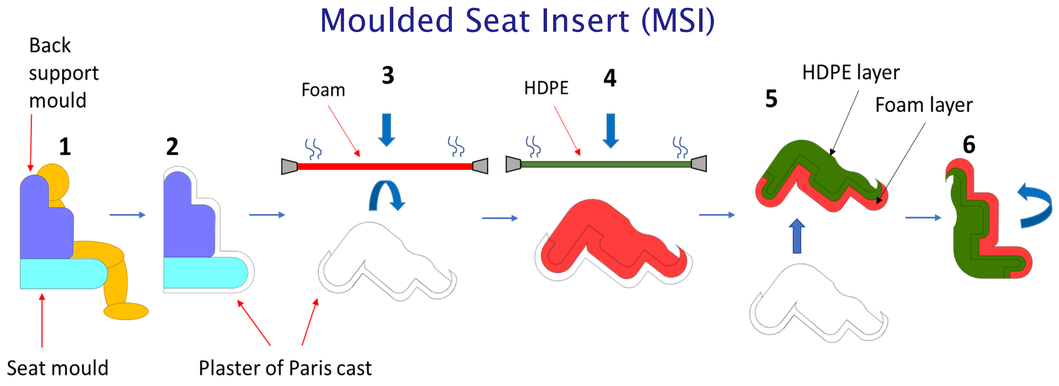
Plaster Moulding



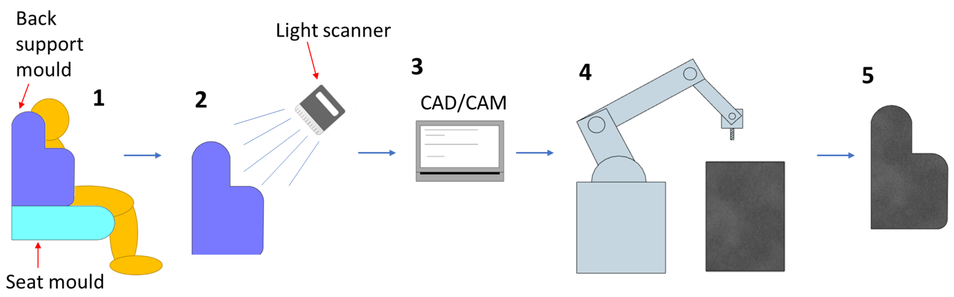
Adjustable Micro-Modular Seating (AMMS)



Moulded Seat Insert (MSI)



Computer Numerical Control (CNC) Carved Foam



Comparison of Manufacturing Methods

Table 1 considers some key characteristics associated with the different custom contoured wheelchair seating manufacturing processes available to SeatTech.

Computer numerical control (CNC) milling of foam exhibits many benefits, and adjustable micro-modular seating systems (AMMS), such as Matrix Seating and Lynx, offer unique solutions for wheelchair users who need alternative options to the traditional foam, such as greater rigidity, enhanced airflow etc.

However, while CNC milling process has generally superseded FIPS and plaster moulding processes, CNC milling requires high capital investment, wastes large amounts of material which is detrimental to the environment, and also presents the same issue around temperature control as the other foam systems. This suggests that further innovation in the manufacturing processes for custom-contoured wheelchair seating is needed, and so the characteristics of additive manufacture/3D printing are considered here also.

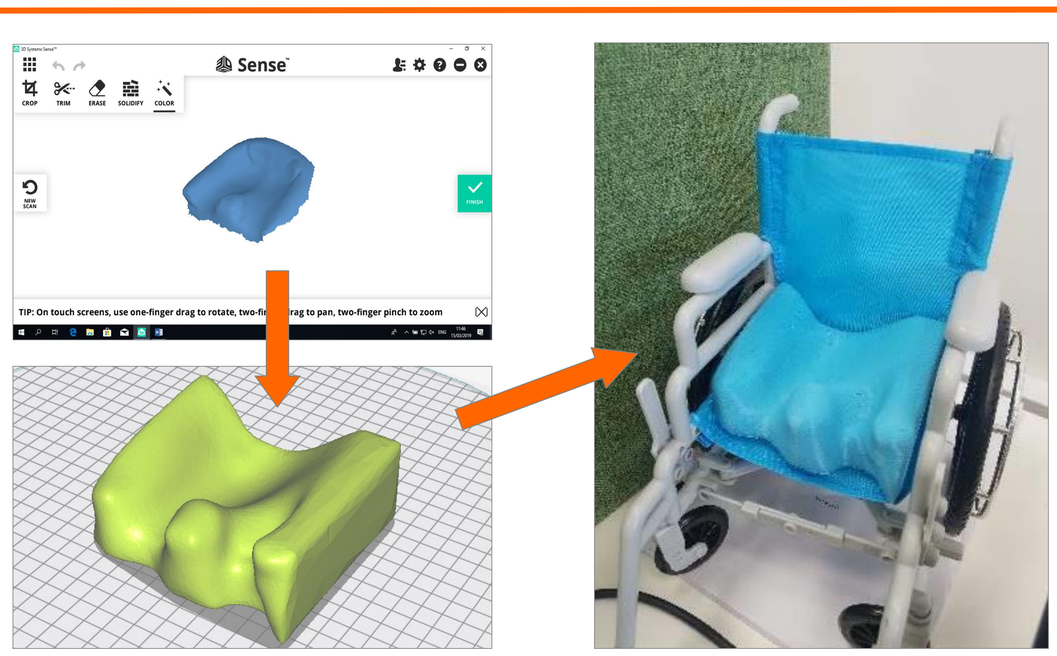
Features	*Current* SeatTech Processes		*Potential* SeatTech Processes	
	Plaster moulding	Adjustable Micro-modular Seating	CNC Foam Carving	3D/Additive Manufacturing
Infrastructure costs	In place	In place	High	Moderate
Materials cost	Moderate	High	Moderate	Low?
Labour Input	High	High	Moderate	Moderate
Airflow – Heat/Moisture transfer	Poor	Good	Poor	Good
Physical storage space	High	High	None	None
Ability to re-produce same	Poor	Poor	Good	Good
Complexity of tight contours achievable	Good	Poor	Good	Good
Ability to offer rigid support	Challenging	Good	Challenging	Good
Hazardous manufacturing process	Yes	No	Yes	No
Hazardous to environment	Yes	No	Yes	No

Table 1. Comparison of current manufacturing options for custom contoured seating manufactured at SeatTech

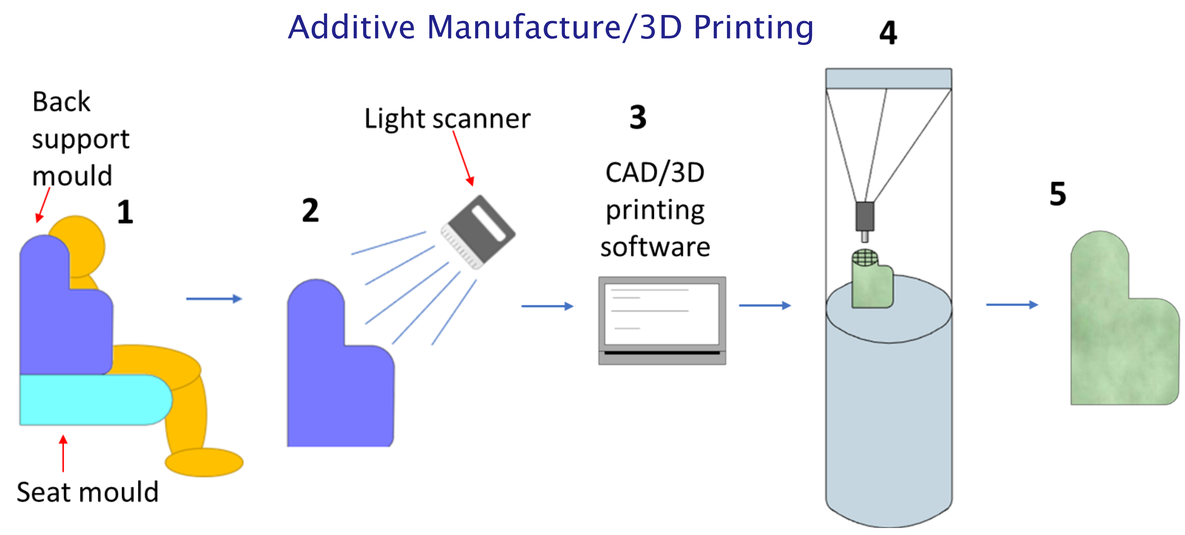
Where to go next: Additive Manufacturing?

With additive manufacturing, material waste, which is an issue with several of the current methods, is minimized. Furthermore, additive manufacturing allows for design changes to be made digitally prior to the physical manufacture of the device, potentially reducing manual labour and production time. This digital manipulation prior to the physical production of a cushion is also achievable through CNC milling, but such alterations are limited due to the use of foam as the constituent material. The digital manipulation and customisation attainable through an additive manufacturing approach could allow for better control of the micro-climate at the user-cushion interface, potentially lowering the risk of pressure injury in users. This presents an advantage over foam seating where the addition of ventilation holes is usually not feasible, since subtracting material from a foam cushion also subtracts postural support and material resilience from the cushion (1).

What appears to be the main limitations of implementing additive manufacturing to produce custom-contoured wheelchair seating systems are *a)* the size of print beds compared to the size of wheelchair cushions and *b)* the time to 3D print a seating system. A majority of 3D printers costing less than €8,000 are desktop-sized, only offering build volumes up to around 250mm by 250mm by 300mm (xyz-axes). The 95th percentile male would require a wheelchair seat cushion with dimensions around 550mm by 540mm by 100mm (depending on the material used to make the cushion) (2). Thus, most affordable printers lack the build-size to print a seat cushion in one piece. One solution to this challenge could be to design a system whereby an effective cushion could be printed in multiple pieces and put together for use on a wheelchair. Additionally, it is anticipated that the size of available and affordable build volumes will increase as 3D printing technology improves. Addressing long print times, which increase the risk of print failure, requires design thinking and further research, but the use of filaments with larger diameters (3.00mm or more) or printing with large pellets instead of small filaments may lower the print time required for large objects like wheelchair seating systems (3).



Additive Manufacture/3D Printing



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