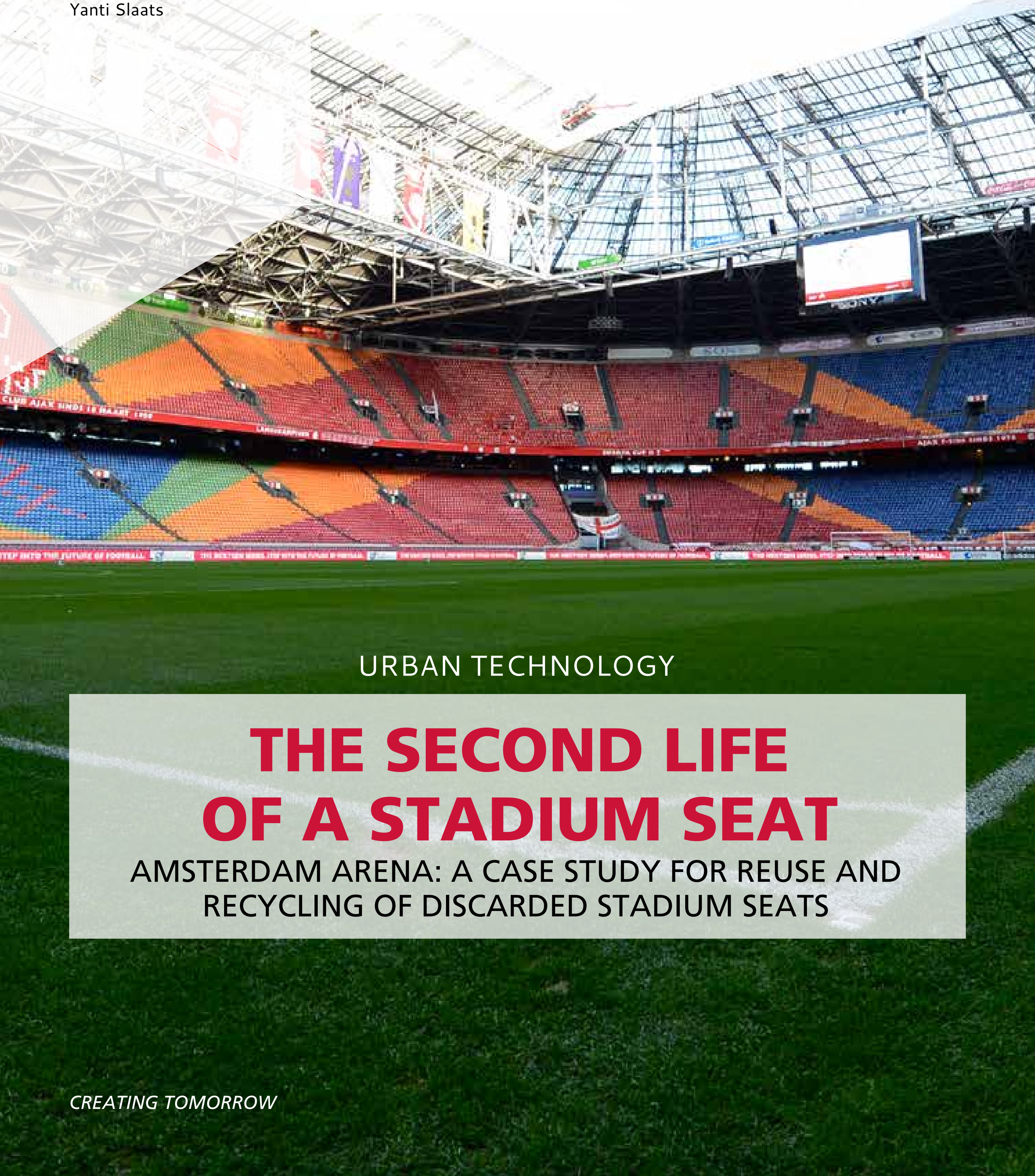
Liselotte van Dijk
Erno Langenberg
Marta Malé-Alemany
Inge Oskam
Yanti Slaats

Amsterdam University of Applied Sciences



URBAN TECHNOLOGY

THE SECOND LIFE OF A STADIUM SEAT

AMSTERDAM ARENA: A CASE STUDY FOR REUSE AND RECYCLING OF DISCARDED STADIUM SEATS

CREATING TOMORROW

INTRODUCTION

Confronted by more and more global sustainability-related challenges, society is increasingly aiming for a circular economy. Wouldn't it be ideal if we could contribute to an economic model with closed loops, where products and materials that are at the end of their functional life are reused in new products and systems? As the Netherlands aims to have a fully circular economy (i.e., zero net waste) by 2050, circularity is also a critical theme for the Amsterdam Metropolitan Area.

'Circular City' is one of the main urban challenges of the Urban Technology research programme of the Amsterdam University of Applied Sciences (AUAS). Its chair of Circular Design & Business and its research group on Digital Production collaborate with companies, lecturers and students on a range of applied research projects in order to advance the knowledge around circular design and business model strategies making use of digital production to encourage the local reuse of discarded urban materials.

Amsterdam ArenA, home base of the Ajax football team and a major concert and events venue, is replacing all stadium seats in the run-up to the European Football Championship in 2020 (UEFA Euro 2020), and wishes to do so in a socially responsible manner. With that purpose, Amsterdam ArenA engaged the expertise of the Urban Technology research programme at the AUAS to study the viability reusing the old seats in a circular manner. The research started from the assumption that these discarded seats not only form a large and relatively homogeneous waste stream, but also have an emotional value that can potentially raise their economic value, beyond that of the material alone.

For the AUAS this was an important case study, because the Amsterdam ArenA aspires to be a stage for sustainable innovations, reduce its environmental impact and stimulate the local economy. This project could serve as an example for other stadiums and public buildings with substantial waste streams on how to handle discarded products, and rethink how they can prevent waste in the future. With this mission, the AUAS lined up a team of experts on circular design, digital production, business modelling and impact studies to carry out a comprehensive multi-disciplinary study.

Different scenarios

When Amsterdam ArenA commissioned the replacement of its stadium chairs, no reuse had been prospected for the old seats or the material they are made of. For that reason, the agreed baseline scenario for this research was that the stadium seats were to be treated as waste. This meant that the steel frames could be sold to metal manufacturers for recycling, while the seats could end up being partly 'downcycled' and partly incinerated by plastic recyclers.

Based on this initial assumption, would it be possible to explore alternative scenarios to give stadium seats a second life? AUAS and Amsterdam ArenA decided to explore the viability of three options:

- Scenario 1: Redistribution of seats for reuse in other stadiums
- Scenario 2: Upcycling of stadium seats to consumer chairs
- Scenario 3: Recycling the raw material of stadium seats for various applications

In scenario 1 the stadium seats, including the frames, are disassembled, transported and installed in other stadiums. This scenario was explored by Amsterdam ArenA, by redistributing smaller parts of the gallery to amateur stadiums in various parts of the world. For instance, 2500 seats have been sent to Curaçao, 2700 to Surinam and up to 2000 seats are already committed to football fields across the Netherlands. In terms of promoting the reuse of the seats this is definitively a helpful strategy, because the receiving amateur stadiums have very limited means to build or upgrade their current galleries with new seats. Nonetheless, the strategy is debatable in terms of its environmental impact because the seats are transported across enormous distances.

For the AUAS, it was thus crucial to study scenarios 2 and 3 for potential solutions to stimulate a local circular economy. They were explored in two specific research projects, together with a complementary study which concentrated on mapping the economic, environmental and social impacts of scenarios 1, 2 and 3. The approach, outcomes and concluding insights are summarised in this publication.

The physical 'waste' of old seats from Amsterdam ArenA consists of 48,000 hard plastic chairs on metal frames, plus 5,000 or so luxury upholstered chairs from the sky boxes and the main stand. In figures, this residual stream amounts to about 50,000 kg of plastic (PP) and 150,000 kg of steel.

SCENARIO 2:
Upcycling of stadium seats to consumer chairs

The AUAS research team explored the upcycling of the stadium seats based on the principles of the circular economy and with due regard for Amsterdam Arena's requirements – responding to the wishes of fans, generating local employment and ensuring a cost neutral project. This project resulted in a collection of chair designs and corresponding prototypes made with the original seats. In consultation with potential producers, these physical prototypes were assessed in terms of their economic and technical viability.

The designs and prototypes that were made can be divided in four groups:

A. Chair designs reusing the original steel frames
B. Chair designs incorporating other, existing frames
C. Chair designs with a customised frame
D. Chair designs with a digitally produced frame

Early prototype reusing original steel frame, designed by Amsterdam ArenA

A. Chair designs reusing the original steel frames
Without a doubt, the preferred option from a circular economy perspective is to reuse as much material as possible from the existing seats. The AUAS brought Amsterdam ArenA into contact with several furniture manufacturers and production companies that were able to consider this option and make a viable product, to be sold via the Ajax Fan Shop.

The selected version of this chair is made of the existing frame and plastic parts of the original seat, mounted onto a newly built base. The base is prepared to connect a single chair to others into a row of seats of any desired length. This chair will be produced and assembled in a sheltered workshop, which gives em-ployment to people with risk for social exclusion.

Prototype of a single chair connectable to others, made by Ahrend

B. Chair designs incorporating other existing frames
Another desirable option that has been explored is that of mounting the plastic stadium seats onto an existing, preferably reused, chair frame. Upcycling existing frames helps reduce the environmental impact and yield considerable cost savings, as making new ones is no longer necessary. Nonetheless, the geometry of the existing old seats is so specific that it proved hard to find suitable frames to perfectly fit and mount them on. In fact, several options were tested but all needed significant adjustments to fit the plastic parts, implying labour and materials. Another risk is that there may not be enough existing frames to meet people's demand for upcycled chairs. The AUAS concluded that this approach was probably not a viable business option for Amsterdam ArenA.

C. Chair designs with a customised frame
The fact that the original stadium seat consists of two separate plastic parts (which have a specific shape to fit a precise metal structure) implies that a customised frame will be required to connect them to make a chair. For this same reason, selling loose plastic parts of the seats – as they are when removed from the stadium – is not the preferred option.

The AUAS thus explored the option of producing a customised frame, as a means to avoid the risk of not finding enough existing frames to upcycle for all the seats, while simultaneously yielding other benefits like low volume, local production and the possibility of personalisation. In this domain, several directions were explored.

The first customised new chair frame is made by hand at a sheltered workshop in Amsterdam, using recycled wood from industrial pallets. This can be a good solution for producing the designed chair in a limited edition. However, scaling up production to larger quantities would not really be possible considering the limitations associated with the fabrication method and the required labour.

Prototype of chair with existing tube frame, made by AUAS

Prototype with customised frame using reclaimed wood, designed by AUAS and made by Pantar

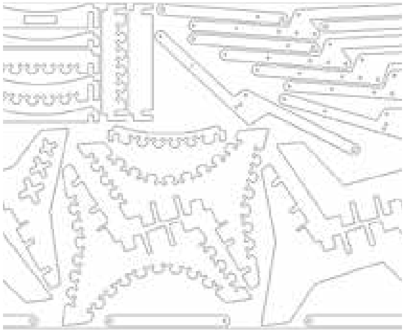
D. Chair designs with a digitally produced frame
Other directions which were explored were done by means of digital production (which includes digital design and manufacturing), using a computer to make and execute a design file on a numerically-controlled (CNC) machine. The advantage of cutting materials (i.e. wood) with a CNC machine that can mill along any given design contour in a Computer Aided Design (CAD) environment is that there are no limitations in terms of the shapes one can produce. This makes it easy to create complex shapes that are customised to fit the specific outline of the plastic seats. Moreover, this can be done any number of times (in small series) without the limitations of standardised industrial production, and by adjusting the cutting outline with unique features, also offer the opportunity to personalise every single chair.

In this realm of digitally produced and customised solutions for the stadium seats, a good option would be a flat pack frame: a set of separate flat wooden pieces that can be assembled by the costumer to create the structure of the chair. The set is produced by CNC milling a single standard wooden plate, perfectly suitable for packing and shipping to the final customer.

Using a similar method, it is also possible to produce a folding chair. This version offers even more advantages, because the structure of the chair is designed with thin, minimal wood components. Consequently, it is possible to nest a higher number of cutting outlines in a single wooden plate, to optimise the use of material and reduce production time and costs.

Besides CNC milling, there are other digital manufacturing processes that are suitable for creating customised frames for the seats. The AUAS team explored 3D Printing to create a unique plastic connector -not available in the market- to interconnect standard tubular profiles (metal tubes, broomsticks or other) into a suitable chair frame. This option -taking into account the current advent of 3D Printing and its role in enabling the democratisation of production- could also help to reduce transport costs. One could send the file to be 3D printed at home or at a local printshop, after adjusting the geometry of the connectors online to exactly fit the profiles acquired by each costumer.

Prototype of foldable chair by AUAS

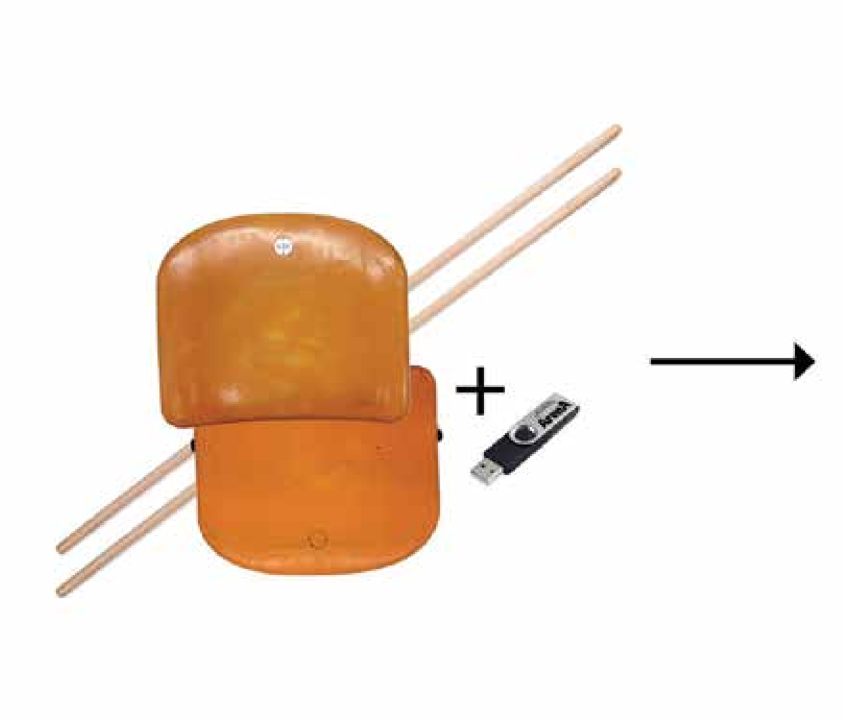


Designs and protoypes by AUAS with digitally produced frame that can easily by customised.
The frame can be sold as flat pack, to be assembled by the customer.

Survey among Ajax-fans

Along with the design process of upcycled seats, the social interest in acquiring either the separate loose parts of an old stadium seat or an eventual new chair made from its parts or recycled materials was explored in an online questionnaire, which yielded 222 responses from certificate holders. Presented with preliminary designs for five chairs and two benches, the respondents answered specific questions concerning their own interest in buying a chair, their appreciation for the various designs, and their notion of an acceptable price.

The results of the survey show that half of the respondents are interested in a chair made out of an old stadium seat, suggesting that the seats have a clear emotional value for many Ajax fans. The results also indicate the fans' favourite designs. For these designs, the AUAS examined which of these designs could be realised in large numbers, and at what production cost. Based on these outcomes, Amsterdam ArenA began talks with producers who could actually manufacture, supply and sell the chairs through the Ajax Fan Shop.

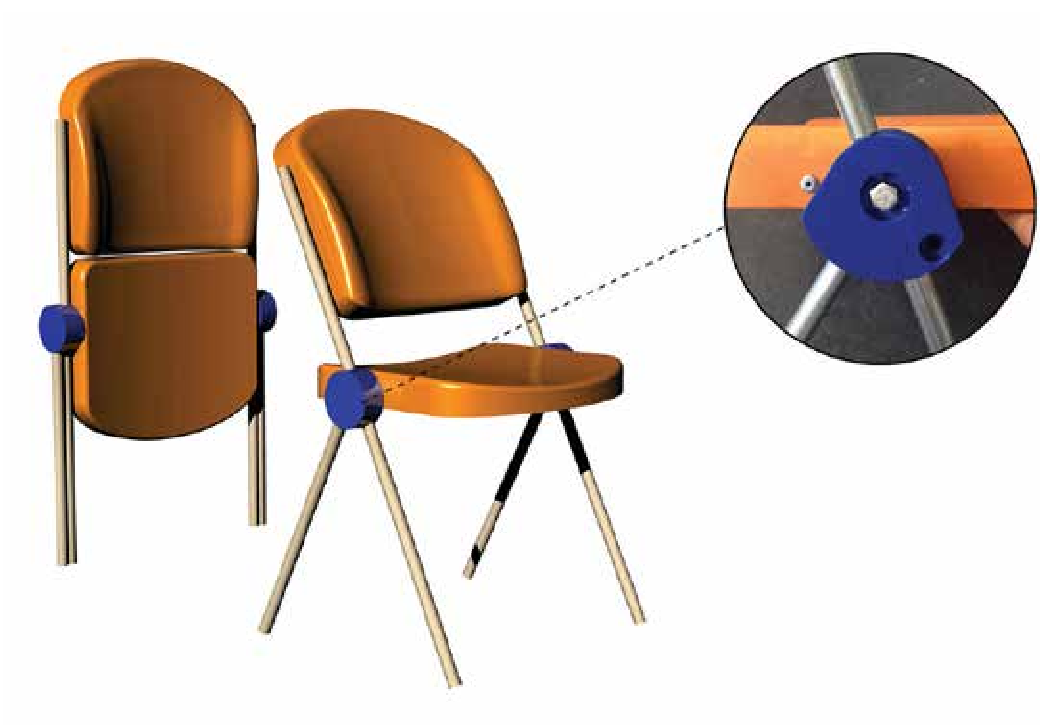


Creating a chair using a 3D printed node

Conclusions on upcycling stadium seats to consumer chairs

The AUAS research demonstrates that the 'upcycling of stadium seats to consumer chairs' (scenario 2) is a viable scenario for Amsterdam ArenA to give the old stadium seats a new destination. In cooperation with furniture manufacturers (Desko, Pantar and Ahrend), several viable designs (to be produced in the short term) have been prototyped. The survey among Ajax fans has revealed that there is interest in different models of chairs, and suggests that the selling price could be higher the more the chair's design is elaborated and personalised. Moreover, manufacturing in small series – by hand or with digital production methods – would enable designers / entrepreneurs to market special editions.

Shortly, this research shows that the life of a material can be substantially prolonged, and that by giving it a new application its economic value can also increase. It can even create the opportunity to capture precious memories and become a collector item for fans. Thus the Amsterdam ArenA case study illustrates that when the right scenarios and business models are in place, circularity can be made visible and reach a wide audience.



RECYCLING THE RAW MATERIAL FOR VARIOUS APPLICATIONS

It is obvious that not all 50,000 stadium seats will be suitable for reuse through redistribution or upcycling. Some old seats are broken, and those located on the first tier at the east side of the stadium are more degraded than others because of their greater exposure to solar radiation. To envision a circular future for all these remaining plastic parts, the AUAS research team examined recycling options at material level: can the old seats also be used as a 'new' raw material to make products? And, most importantly, could those products be of use to Amsterdam ArenA or other parties in its immediate surroundings, to further strengthen the notion of circularity?

Because of the special character of this case study – involving potential buyers with a proven attachment to the old seats – the study focused on the possibilities to recycle the material as a unique, separate waste stream, as opposed to the common approach of mixing waste streams and treating them in large quantities. The intention was to keep the plastic as close to the original material as possible (in colour and feel) so as to preserve its emotional value.

Granulate from old plastic seats

Material composition

The initial and crucial step towards reusing a plastic waste stream (like the seats) as a raw material for making new products is to determine the exact composition of the material. This will determine its possible applications and help to identify any legal restrictions involved.

The Amsterdam ArenA seats are 20 years old. They were produced at a time when different rules and regulations applied to what was allowed (or not) to be made in various plastics. In principle, treating the seats as a separate waste stream makes it easier to determine the composition of the material. However, this waste stream is not as homogeneous as it looks at a first glance: the seats were produced in three different batches and in different years, by two manufacturers in two different countries, and in five different colours, all of which possibly differ in exact material composition. From this perspective, recycling presents a lot more challenges than initially estimated.

Considering the potential diversity in material composition between the different seat models, this study helps to frame a key issue for recycling: when using this raw material to make any designed product, material tests will need to be performed before it can be launched on the market.

Additives

As the first step in determining the composition of the seats, it was decided to examine the largest batch, which is also the oldest one. The manufacturer was asked to provide details of the original compound, but after 20 years this information was no longer available. For that reason, further research was conducted through XRF / FTIR scans and other processes. The seats were found to consist of polypropylene (PP) with a number of additives for coloration, colour protection and fire retardation.

The XRF scans also revealed the presence of bromide, which could indicate that a brominated flame retardant (BFR) was used in the plastic to ensure fire safety in large public stadiums. This specific component could prevent or limit its potential reuse, as some types of BFRs are now prohibited by European regulations. Nonetheless, additional testing of one of the samples (a first-generation red seat) found no banned brominated flame retardant in the material, thus ensuring broader possibilities for its reuse. Currently, further research is in progress to find out the exact source of the bromide.

Processing 20-year-old plastic seats

Given the wish to keep the raw material of the seats as close to the original as possible, the research included testing different processing techniques, as well as the quality of the samples, to determine possible applications. The tests included two common production processes for plastic – pressure and injection moulding – and one experimental technique, 3D Printing.

Before using any forming technique, the plastic chairs had to be de-mounted, cleaned and ground to form a roughly homogeneous granulate. These steps presented a challenge because of the relatively small scale of the test case; the recycling industry usually works on the basis of large quantities and small margins. This could be different if there is more demand for locally processed recycled raw material or business margins increase. In the case of Amsterdam ArenA finding an application of high value, combined with the emotional value associated to the material, can indeed result in a much higher margin.

The granulate was subjected to initial tests to validate the processes of pressure and injection moulding. The raw material of the seats proved as effective as virgin polypropylene. The samples were subsequently tested to determine their specific properties (i.e. tensile strength, elasticity and density), with promising results: they demonstrated good material performance, slightly inferior to virgin new material yet certainly sufficient for processing in objects of different sizes and applications.

3D Printing filament from old plastic seats

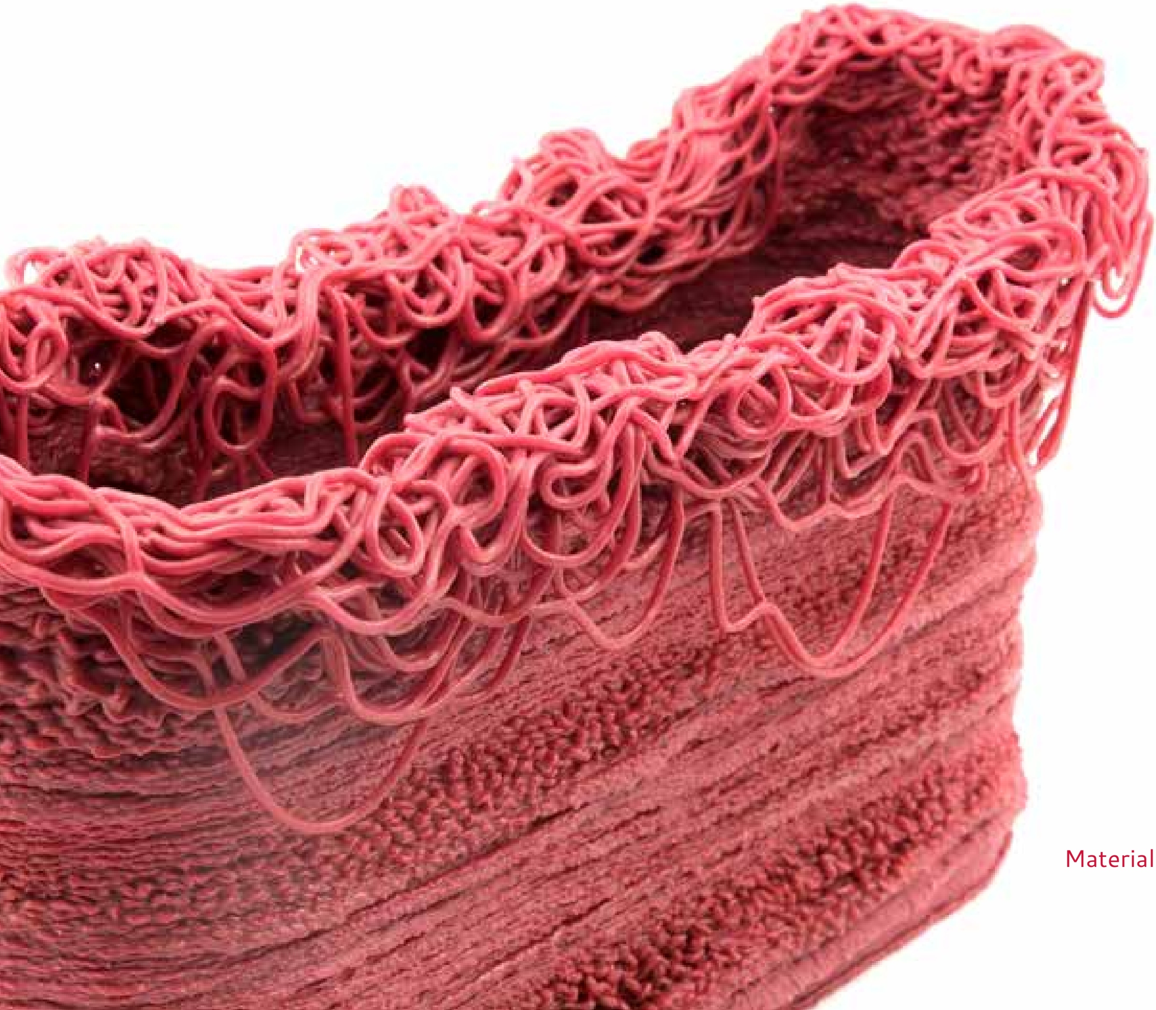
Tensile test bars for material testing

The potential of 3D Printing

3D Printing was also explored as a potential production technique. As opposed to common industrial processes, this digital production technology enables non-standard manufacturing in small batches. Thus it provides opportunities to create bespoke objects on demand, with the advantage that small, locally produced, personalized editions are therefore possible, based on the raw material that is available. Moreover, 3D printing can also contribute to circularity by printing with recycled plastics. In the Amsterdam ArenA case study, these opportunities could unlock a creative potential, a social connection and an environmentally positive impact that are truly worth investigating.

In the AUAS research, two scales of printing were examined: desktop scale (for home printers) with rolls of filament made with the plastic of the recycled seats, and large-scale 3D Printing with a robotic arm, using a granulate version of the same plastic. In both cases, printing with the recycled material without any additives proved a challenge. Yet the printing process greatly improved when adding glass fibers, as it became a lot more consistent and controllable, yielding stronger printed results.

However, the quality of 3D prints not only depends on the material but also on the printer scale (desktop, robotic or other), the printing head, the chosen deposition pattern and, ultimately, the shape of the desired object. Given all these factors -and keeping in mind the extensive opportunities for applications that it can offer- the option of large-scale 3D printing with recycled plastic should be further examined.



Material experimentation

Conclusions on recycling stadium seats

As seen in this case study, the precise composition of a plastic waste stream inevitably determines its possibilities for recycling, the processing method and its potential applications. Yet, in practice, it can be quite difficult to find out exactly what the waste material consists of, if only because years later the original manufacturer may have lost the relevant information. Extensive research is thus needed to trace the exact additives.

When the seats are ground into a 'new' raw material and formed into granules, basically any product that is normally made from a similar type of plastic can be produced from them. With due regard for the additives present in the plastic itself, and their specific restrictions, it is possible to find interesting applications for Amsterdam ArenA, using any common production method such as pressure or injection moulding.

3D Printing with recycled plastic implies higher costs (when compared to virgin plastic) because the plastic needs to be previously cleaned, processed for printing, and eventually mixed with other materials like fibres. Thus interesting applications need to be explored in domains that privilege the emotional value of the original raw material. These opportunities can be found in and around Amsterdam ArenA: for example, the material can be used to make interior design elements or temporary event furniture for the new extended concourses of the stadium, to build small pavilions in the public space around the stadium, or to fabricate any support prop needed for public events hosted at the stadium.

Large scale 3D Printing with an industrial robotic arm.

EVALUATION OF ECONOMIC, ECOLOGICAL AND SOCIAL IMPACT

Alongside the study on the viability and design possibilities for upcycling and recycling the plastic stadium seats, the AUAS also engaged in assessing the economic,ecological and social impacts of all three initial scenarios to give the stadium seats a second life (redistribution for reuse, upcycling to consumer chairs and recycling the raw material for various applications).

Approach

This endeavour proved to be quite challenging, because a literature search (on existing methods and tools that can be used to assess impact) revealed that a tool that combines the assessment of economic, ecological and social impacts (Triple Bottom Line) of circular solutions is not readily available. Consequently, quick scanning methods were chosen to evaluate each impact category separately.

For the economic impact, the scenarios were assessed with a quick financial calculation. As for the ecological impact, scenarios were evaluated using a Life Cycle Analysis (LCA) quick scan, previously developed by the AUAS, and based on the RECIPE method and the ECO-invent database indicators. To assess the social impact, the study focused on the impact topics described in the Handbook for Social Impact Assessment and the Guidelines for social life cycle assessment of products by the United Nations Environmental Programme. Finally, interviews with experts provided additional information about the use of impact assessments in daily practice.

To evaluate the reuse of parts and materials of the stadium seats, detailed information must be specified before any impact can actually be quantified. In this case, those details were assessed with Amsterdam ArenA and with the furniture manufacturers, producers and material recyclers involved in the process of making the final products.

This communication is crucial: it yields information that quick scanning methods can use to generate insights into the possible impact of the alternative scenarios, as well as to indicate the 'hotspots' that are the most crucial for the impact. By prioritising and valuing these hotspots, Amsterdam ArenA gained insights into the impact of the different strategies, enabling it to identify the scenarios that are the most interesting for the organisation.

Economic impact

The financial calculations together with the outcome of the online survey (where demand for the different upcycled chairs was tested) have shown that with a mix of scenarios the total project can be cost neutral. That means that different scenarios can be implemented. Eventually the number of products sold per scenario will determine its economical value. An expost evaluation is needed to check if the assumptions were correct.

Ecological impact

In theory, the redistribution of stadium seats for use in other stadiums (scenario 1) has the most positive expected ecological impact, because it prevents or postpones production of new stadium seats. Although this redistribution does not replace newly produced seats, it does give stadiums with a tight budget the opportunity to upgrade existing galleries that currently consist of bare concrete or wooden benches.

Considering the expected market share as suggested by responses to the online questionnaire, the highest ecological impact is foreseen for the upcycling of stadium seats to consumer chairs. Within this scenario, the ecological impact between different chair designs does not differ much. However, this impact can be minimised by using a minimum amount of extra materials, and by specifically choosing those materials that have the lowest ecological impact.

Recycling scenarios (scenario 3) rarely yield better results than upcycling scenarios in terms of ecological impact. In the Amsterdam ArenA case, it depends on what type of product would be made with the recycled plastic of the seats. As this has not yet been examined, when considering ecological impact the rule of thumb is to favour products with a long expected life.

Social impact

Social topics that are suggested in the existing guidelines include abolishment of child labour and forced labour, secured fair salary, as well as health and safety at the work floor. Considering that Amsterdam ArenA aims to source all necessary production steps within the greater Amsterdam region, these topics are of no discriminatory value for the comparison of the different scenarios. Unfortunately, the topics that could discriminate between circular production scenarios and traditional linear scenarios -like the emotional value of reusing products (or their parts) and the awareness of end-of-life scenarios, are not represented distinctively enough in the existing guidelines.

In the AUAS research project for upcycling (scenario 2), some designs were specifically generated for production in a sheltered workshop. These designs are to be preferred over solutions which do not make use of this alternative work force. However, all upcycling scenarios could be executed in ways that would optimise social impact, given the multiple strategies by which this can be achieved. In Western countries, the 'hotspots' for optimising social impact include education, engagement and job satisfaction for employees, consumers' well-being, stimulation of production transparency and end-of-life responsibility, and community engagement.

REFLECTIONS FOR OTHER STADIUMS AND FUTURE DIRECTIONS

The AUAS study shows that all three scenarios, 'REDISTRIBUTION OF STADIUM SEATS' (scenario 1), 'UPCYCLING OF STADIUM SEATS TO CONSUMER CHAIRS' (scenario 2) and 'RECYCLING OF THE MATERIAL FOR VARIOUS APPLICATIONS' (scenario 3) are viable scenarios for Amsterdam ArenA to give the old stadium seats a second life.

In any of them, the seats can be given a new destination with a positive ecological impact and can be done in a way that social impact is also optimized. Especially with scenarios 2 and 3 it is possible to retain the emotional value that old stadium seats have for Ajax fans, and create awareness for the transition towards a circular economy.

The analysis of these different scenarios gives a rough estimation of the impact that can be expected, but for future reference certain hotspots should be taken into account when defining each scenario in more detail in order to optimize impact. In the case of Amsterdam ArenA, the research suggests that a combination of scenarios is the most optimal solution to generate the highest impact, in economical, ecological and social terms.

Moreover, the results of this study provide valuable insights for other stadiums, and opportunities for future research and follow-up projects.

Reflections for other stadiums

As seen in the Amsterdam ArenA case, doing this study after commissioning new stadium chairs to a manufacturer is a missed opportunity. There could be ways to fully close material loops and thus substantially contribute to the circular economy. For instance, the AUAS research shows - even if this option was not explicitly prototyped - that it would be possible to grind the plastic of the old seats and use the granulate as a raw material (in pressure, injection moulding or other processes) to produce the new stadium seats.

Certainly the Amsterdam Arena is not the only stadium in Europe that will face the question of renovating its seating galleries in the coming years. In fact, the AUAS would argue that all stadiums should include circularity as a leading theme in their procurement procedures. Stadiums ought to consider using plastic waste streams (if possible, their own) for the production of new furniture, the construction of temporal pavilion-like constructions for events or the manu facturing of interior design or architectural elements to improve their facilities, among other applications.

From the AUAS perspective, the making of new seats from old plastic is a key design and production research project to undertake. And when pondered for any other stadium or public facility, this scenario needs timely attention to address the following two recommendations:

A. The material of the existing seats needs careful characterisation. Additives which were accepted in plastics when the old seats were produced may not be permitted today. Also the characteristics of the material may have changed due to intensive use and weather influences (which may require durability tests, adding virgin material or other specific solutions to allow its reuse).

B. The new hypothetical seats –besides being (partly) produced with recycled material- ought to be designed in a true circular fashion. Circular design strategies that are applicable include 'design for product durability' and 'design for upgradability and adaptability'. Additionally, circular business model strategies must be developed to accompany the product designs (considering an access model in which the seat producer stays owner of the products or other similar setups).

The chairs of the Amsterdam ArenA as an example- form a relatively small amount of plastic, which is released in small batches due to the gradual removal of the old seats from the stadium galleries. Processing plastic in this way is not aligned with the current processes of the recycling industry: instead, the industry works with large, often non-homogeneous, amounts of plastic. In consequence, recycling, processing and making new products locally (i.e. new seats) may involve logistical challenges and additional costs that must be taken into account in order to find the most suitable application(s).

Another insight is that often the owner of a waste stream (i.e. the stadium) has little experience in processing the materials, and developing new products following circular strategies and guidelines. Therefore, this type of projects requires collaboration with external parties that can help in estimating the potential of waste streams and creating meaningful visions for the circular economy.

Follow-up projects

The AUAS aims to continue collaborating with Amsterdam ArenA to explore its circular solutions. In this endeavour, it wants to inspire and help seat producers, other stadiums or any public buildings in and outside The Netherlands, which will undergo similar renovation processes in the coming years. In that context, this collaboration can become a great example of applied research, focused on addressing sustainability-related global challenges.

To date, several follow-up projects related to Amsterdam ArenA stadium seats have been started:

- Amsterdam ArenA will produce a number of upcycle chair designs in collaboration with the furniture manufacturers that participated in the initial AUAS research project, involving sheltered workshops and creating local employment. These chairs will soon be available to the public through the online Ajax Fan Shop.

- The AUAS, in collaboration with Amsterdam ArenA and Amsterdam Made, has organised an open design challenge and exhibition to involve professional designers in thinking about creative upcycling and recycling solutions for the stadium seats. The aim of this endeavour is to serve as a reference and a source of inspiration, both in practice and in education.

- At the AUAS, several groups of Industrial Design Engineering students are developing circular design proposals based on the use of the old stadium seats.

For the future, the AUAS Urban Technology research programme plans to involve additional partner companies and undertake -framed within the chair of Circular Design & Business and its research group on Digital Production- the following projects:

- Explore large-scale robotic 3D Printing with recycled plastic from stadium seats, in order to prospect viable and concrete circular applications. As a reference framework, it will consider the production of temporary furniture and interior design elements for the Amsterdam ArenA concourse extension, planned for the UEFA Euro 2020.

- Investigate the design and production of a stadium seat, following circular design and business model strategies. Preferably this research will be done in collaboration with a seat producer and one or more stadiums that are making renovation plans in the future.

- Inquire how a similar approach as the one presented in this publication, can be applicable to other waste streams, both from stadiums or other public buildings.

Idea for using recycled material

Partners

This publication is based on the results of three AUAS applied research projects. They were elaborated within the Urban Technology research programme, with the leadership of the chair of Circular Design & Business and its research group on Digital Production.

These projects were made possible thanks to KIEM-VANG subsidies of **Regieorgaan SIA**. **Amsterdam ArenA** was a partner in all three projects, contributing in its role as a 'client' by supplying the research question, offering relevant information and providing old seats as a test material for physical experimentation and prototyping.

Partners that contribute to the 'Upcyling' project include **Desko**, who made designs and reflected on the survey amongst Ajax fans and impact assessment, **Pantar**, who helped design and build a chair with customised frame and **Ahrend**, who helped design and build one of the prototype chairs with a standard steel frame. All three afforded insights into their manufacturing process. **Fiction Factory** helped in CNC milling customised chair frames in wood.

Partners that contributed to the 'Recycling project include **Emmtec, ICL** and **SGS**, who performed various material research on samples of the existing plastic. **Omefa** grinded the plastic and performed injection moulding tests. **3D4makers** shared their resources and knowledge in plastic processing to make polypropylene granulate and 3D Printing filament from the old plastic seats. **Multi3dprint** helped performing 3D Printing tests and exploring potential applications. Finally, **HB3D** afforded insight into their robotic 3D Printing process with composites, and performed large-scale printing tests.

The students of the AUAS Engineering department who contributed to this research are Willem Jaap Koomen, Nick Ootes en Sjors van der Mark.

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