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Building the fashion's future.

How turn textiles' wastes into ecological building products

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Abstract. The textile system is one of the most influential production activities at a global level from an environmental point of view, both in relation to the processes that characterize the supply chain and in relation to pre and post-consumer waste. It produces million tons of global greenhouse gas emissions per year and it consumes millions of litres of water; it uses million tons of chemical products. Furthermore, millions of tones of special textile wastes are yearly landfilled in upstream process as well as in downstream process. Less of 1% of materials used to produce clothes becomes part of a closed-loop recycling and less of 2% are recycled in other industrial activities. Changing the textile industrial linear model in a circular one according to Systemic Design principles is advisable, starting from wastes and by-products. As proved in the working paper wastes, due to their properties, can assumed as inputs of new production systems. Particularly the scientific contribution deals with some research activities carried out within a project titled EDILTEX - Innovation for reusing in textile companies. The achievements are described, showing that construction and fashion are fields only apparently far from each other. They can - on the contrary - developing powerful synergies and products with interesting technological and physical performances.

Keywords: recycling and reusing textile wastes, Secondary Raw Materials, ecological building products, textile recycling scenarios.

1. Introduction

The textile plays a crucial role in the third economic sector in several European Countries. The fashion industry is considered as a benchmark of excellence in Italy and Italian fashion revenues are remarkable (Crivelli, 2017). But at the same time the textile system is one of the most influential production activities at a global level from an environmental point of view, both in relation to the processes that characterize the supply chain and in relation to pre and post-consumer waste. The textile sector produces about 3.4 million tons of global greenhouse gas emissions per year and, due to the dyeing, printing and fixing processes, it consumes an average of 7.5 million litres of water and it uses 6 million tons of chemical products (Sistema Moda Italia, 2016). Special wastes are landfilled (Wicker, 2016) both in upstream process (afterwards the production and the delivering) as well as in downstream process (once the textile is used). Less of 1% of materials used to produce clothes becomes part of a closed-loop recycling and less of 2% are recycled in other industrial activities. This is likely due to the currently manufacturing system that operates through an almost linear way (MacArthur, 2017).

Although the framework highlighted, some good practices have been already carried out, showing how it's possible use textile wastes in several sectors, including the building one. Building sector is only apparently far away from the fashion industry. An example of open loop recycling of fashion wastes used in construction is the California Academy of Sciences in Golden Gate Park in San Francisco designed by Renzo Piano Building Workshop. The thermal insulation materials have been made with over 200.000 pairs of discarded jeans.

Transforming the textile industry according to Systemic Design principles is therefore thinkable, proposing a well-known but fundamentally change: wastes and by-products due their properties might be assumed as inputs of new production systems. Such methodological approach makes it possible to meet the circular economy goals set out in current European Directive (EU Directive 2018/851).

2. EDILTEX – Innovation for reusing in textile companies

The project titled EDILTEX (Carbonaro et al, 2018) – Innovation for reusing in textile companies – is a research aimed at meeting needs to reducing environmental impacts of Small Medium Enterprises, in two textile and fashion districts (Tuscany and Lombardy). DAD's research team of Politecnico di Torino was partner of the project dealing with some aspects related to reuse and recycling processes. The research was developed with the economic support of *Fondimpresa* inter-professional fund. On the whole commitment and collaboration were implemented sharing knowledge, analysing the production systems and defining different waste disposal opportunities.

The main normative framework aimed at defining objectives, methodology and activities was the Communication "Towards a Circular Economy: Programme for a Zero Waste Europe" [COM(2015)

614] (European Commission, 2015). The European Commission, by introducing the Circular Economy issue into the European public debate, establishes the importance and priority of identifying methods, tools and solutions to recycling by-products and wastes into Secondary Raw Materials (SRM). Besides, it plans an approach to the development of products and processes fully coherent to Systemic Design.

Therefore, bearing in mind the Systemic Design as methodological reference the research was split-up into stages: *Needs finding; Ideation and Prototyping; Monitoring; Business Strategy* (see figure 1).

Each of the items listed above is described in the following paragraphs.

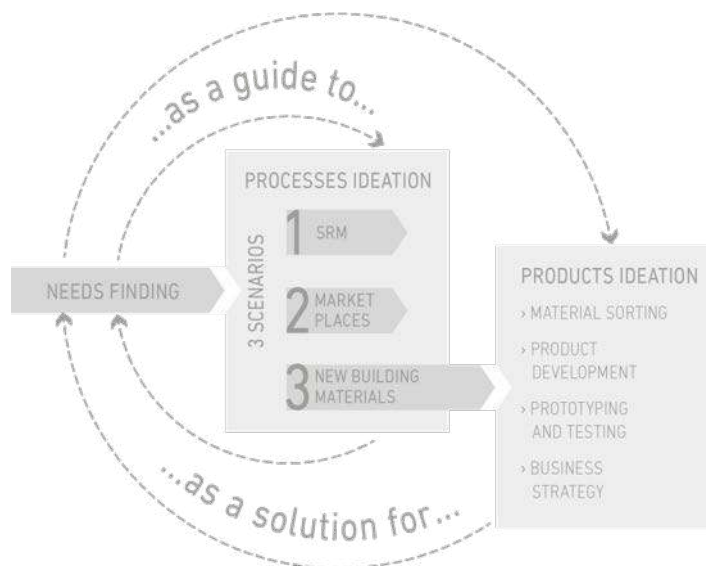


Figure 1. Ediltex project at a glance.

2.1. Needs finding

Needs were pursued through environmental audits in order to point out the most important manufacturing findings and in order to characterise the wastes proprieties and how they could be reused and recycled. Based on the wastes characterisation, some applications for the building sector were identified starting from a study on some international database and several scientific achievements.

For instance, the international MATREC database (matrec, 2019) - allows the search for circular, sustainable and advanced materials for the building and eco-design sectors and covers environmental and technical information. The database includes 21 products from the recycling of textile waste and 37 from leather waste. With regards to building sector, they are mainly used for thermal insulation and acoustic panels and to a lesser extent for wall and floor coverings.

Some interesting studies were found in the international scientific literature. Textile waste was used in addition as thermal insulation blanket (Briga-Sa et al, 2013); researches also include the use of waste fibrous materials in reinforced mortars (Gonilho-Pereira, 2013; Bendjillali et al, 2011; Fantilli, Sicardi, & Dotti, 2017). Scientific paper points out the potentiality of recycling cotton waste as additive in brick manufacturing in order to improve its thermal performance (Rajput et al, 2012). With regard to leather waste, there are interesting applications concerning the utilization as fine aggregate in concrete (Sathish & Vijayaravind, 2015), or eventually in the production of bricks (Aguar et al, 2001).

Furthermore, on the basis of the territorial analysis carried out, particularly at a local scale, it was made possible to identify stakeholders (private and public) such as: enterprises interested in recovering and recycling processes (e.g. Maiano); enterprises enable to building-up machinery to recycle textile wastes and to transform them into Secondary Raw Materials (e.g. Cormatex); research bodies focused on innovation in the textile sector (e.g. Next Technology, Material Recycling); public consortia engaged in textile collection and recovery; chambers of commerce in order to develop business opportunities.

2.2. Ideation and prototyping

Matching the information collected, in the *ideation* stage three scenarios were outlined. The first scenario was focused to enhancing textile wastes as Secondary Raw Materials and/or by-products in existing recycling companies. Some opportunities were investigated such as existing enterprises that manufacturing floor mat materials from recycled textile wastes.

The second scenario was addressed to the valorisation of textile wastes in on-line markets (market places). Within such the reuse or recycling chances are not predetermined. They depend on the supply-demand balance.

Finally, the third scenario was aimed at developing new building materials, basically through two activities: the *material sorting* process and afterward the *product development*.

In particular, the research was focused on waste used mainly in wadding manufacturing. These are polyester fibres (PET) and polyurethane foams PUR. PET and PUR were chosen in relation to:

- chemical-physical characteristics of wastes, both obtained from non-renewable raw materials with a high environmental impact, as consequence it is priority to develop reusing and recycling strategies;
- absence – for the time taken into account (year 2017 and 18) - of a recovery chain;
- quantities to be disposed by the companies, on average higher than other types of waste.

As is well known, a building product in order to be used in construction must be able to fulfil a large number of requirements. This occurs both in the case of new raw materials and in the case of Secondary Raw Materials. Crucial in the material sorting is the comparison among properties of

wastes and by-products with similar products made up with raw materials (e.g. wool was assumed as benchmark since its properties and since it is usually classified as an ecological material). A correlation was then made (through database and software) between the density value, used as a constant reference parameter (kg/m^3), with the following properties: mechanical; chemical; environmental; physical; thermal; acoustic.

Particularly, the correlation between the density of wastes made with PUR and PET with the absorption coefficient (see figure 2) shows that both wastes - although featured by different specific weights - are characterized by excellent performances to be used as sound absorbing materials.

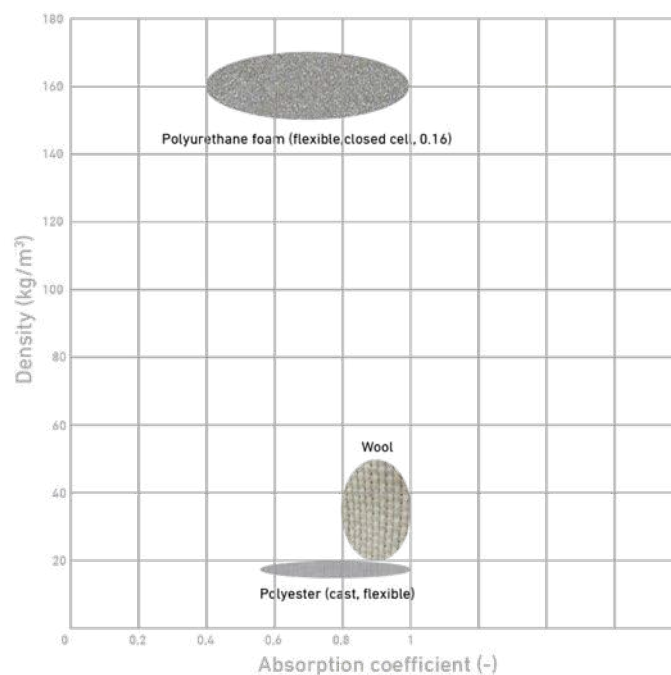


Figure 2. Correlation between density [kg/m^3] and absorption coefficient [-] of PUR and PET in comparison with wool (benchmark material).

The absorption coefficient was ranked between 0.6 and 1, according to PUR or PET chemical-physical compound. Such outcome has influenced the subsequent activities. The research was thus addressed towards the design and developing a product that can improve the indoor acoustic comfort.

As already mentioned, a product to be classified as a building product has to meet different kinds of requirements. The product development was therefore influenced by the current regulatory framework for acoustic comfort. In particular, a technical standard (UNI 11532-1:2018) was taken into account, which states guidelines for the acoustic design of offices, schools and restaurants.

Figure 3 shows the conceptual proposal. In accordance with the acoustic technical standard guide lines, it was decided to *develop a product* featured by overlapped layers. According to absorption coefficient expected, its inner part was made up mostly with PET wastes. The use of such waste is due to the fact that was decided to give firstly priority to waste at a lower mass. A Medium Density

Fireboard (MDF) framework was designed to stiffen the product. However, other scenarios were considered, e.g. by combining the PET and PUR wadding wastes with thermo-formable materials (for instance in case of furniture solutions). An outer fabric, made of leatherwork waste was proposed since leather is an easy maintaining material and overall it has self fire extinguishing characteristics. The product development was completed with the proposal of assembling the layers and sewing them together. As highlighted in figure 4 the product might be implemented both as an internal finishing and as a furnishing element.

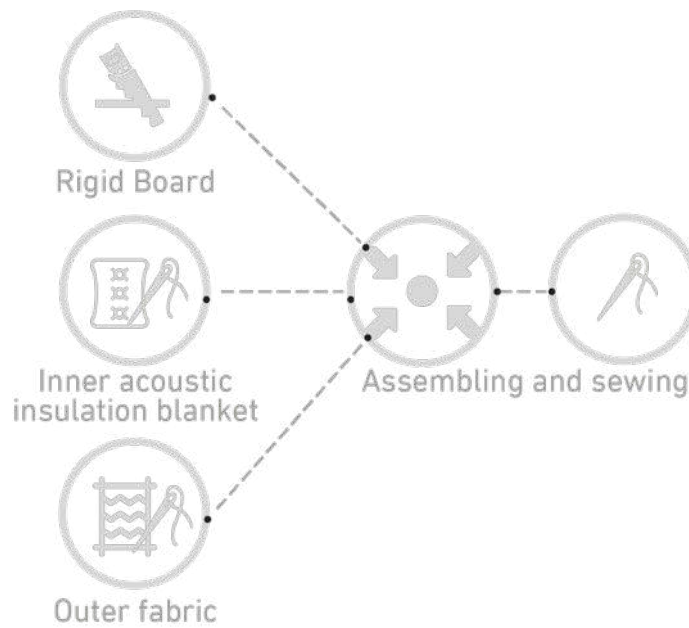


Figure 3. The insulation acoustic product. The proposed materials and assembling.

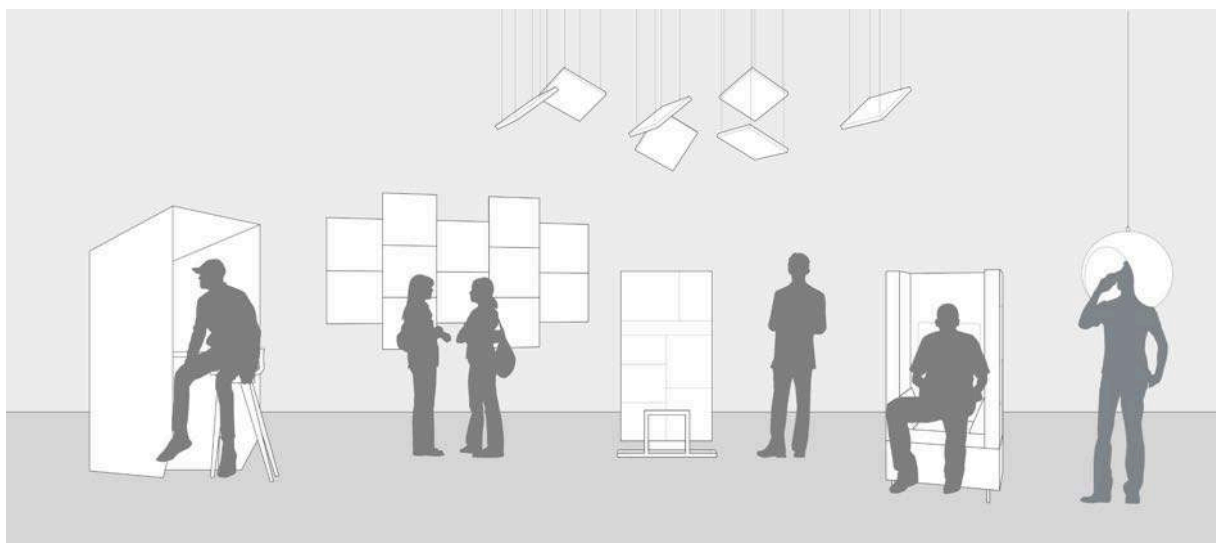


Figure 4. Potential scenarios use of the acoustic insulation product. From left to right: 1) focus area 2) panels; 3) mobile partitioning; 4) think-tank armchair; 5) phone-boot.

During the *prototyping* several experiments were carried out and some interesting achievements were reached. Among the scenarios outlined the activities were focused on manufacturing samples, sized as flat square panels. The wastes were processed at the LASTIN (Laboratory for Innovative Systems) of the Politecnico di Torino as well as the afterward cutting-off and forming of PET wastes samples. Some PET and PUR wadding wastes were tested and they were chosen those more suitable for shaping modular acoustic screens. The external surface was featured both with leather and textile surpluses. The reuse of different trimmings gave a unique pattern in term of size and colour (see figure 5).



Figure 5. On the left, one of the prototype of insulation acoustic screen manufactured within EDILTEX project. On the right, a list of available textile and leather waste samples.

2.3. Monitoring

The *monitoring* stage was involved mainly the evaluation among technique for measuring sound absorption performance. Generally speaking, it is possible to carry out a sound absorption test in three ways:

- 1) measurement of resistivity to the flow of single materials;
- 2) measurement of the sound absorption coefficient from normal incidence (sound wave orthogonal to the surface), through the use of Kundt's pipe;
- 3) measurement of the sound absorption coefficient by random incidence (acoustic wave from all directions) in reverberation chamber.

With regards to the specific characteristics of the prototype, with the support and the scientific collaboration of INRIM (National Institute of Metrological Research), it was recognized that the measurement in reverberation chamber was the most appropriate. The reverberation chamber is an “environment” specifically designed to have no parallel surfaces and it is built-up from hard and reflective materials. Inside, a diffuse field is generated in which the incidence of the sound wave produced by a source is totally random. This type of measurement is the one that allows to have a

sound absorption coefficient closer to the real conditions of use. Furthermore, the reverberation chamber test allows to verify the actual acoustic behaviour of the prototype and to outline the absorption curve at different frequencies.

The first monitoring carried out show that some acoustic requirements were met, demonstrating that the characteristics of the selected materials since the pores size and pores disposition are suitable as acoustic screen. This shows the potentiality to develop a building product from a certain quantity of PET and PUR wastes promoting a systemic and symbiotic processes between only apparently disparate industrial sectors.

2.4. Business strategy

Finally, the *business strategy* definition was focused on two main activities: on the one hand side, activities aimed at analysing the technical feasibility; on the one other, activities aimed at assessing the economic viability. Both are still in progress.

The technical feasibility is addressed to developing, prototyping and experimenting the other mentioned scenarios (focus area; mobile partitioning; think-tank armchair; phone-boot) in term of: shapes and sizes; connections and fastening; performances, depending on the intended use. Furthermore, it is planned to install and test the solutions in some pilot sites and monitor their efficacy *in situ*.

At the same time, activities focused on the economic viability has been developing in order to: explore the market, in particular perform primary and secondary research to identify market volumes, areas, trends, segments, barriers; identify the best technological proposition for the market; define the value proposition(s); define a go-to-market strategy.

3. Conclusion

The transition from a linear production process to a circular one entails the implementation of current wastes collection and processing systems. As mentioned designing the supply chain is a crucial part of the business strategy shared with the Small Medium Enterprises, thus their wastes can be effectively exploited as Secondary Raw Materials in an other manufacturing systems.

On the whole the outcomes show that new perspectives in textile production are actionable. They are based on the principles of circular economy and in accordance to a systemic approach matching together sectors such as fashion and building. Despite it is required to managing properly situations of complexity and uncertainty - in which there are no simple answers and lot of efforts are still necessary - a systemic addition is however possible: building and fashion makes “building the fashion future”.

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