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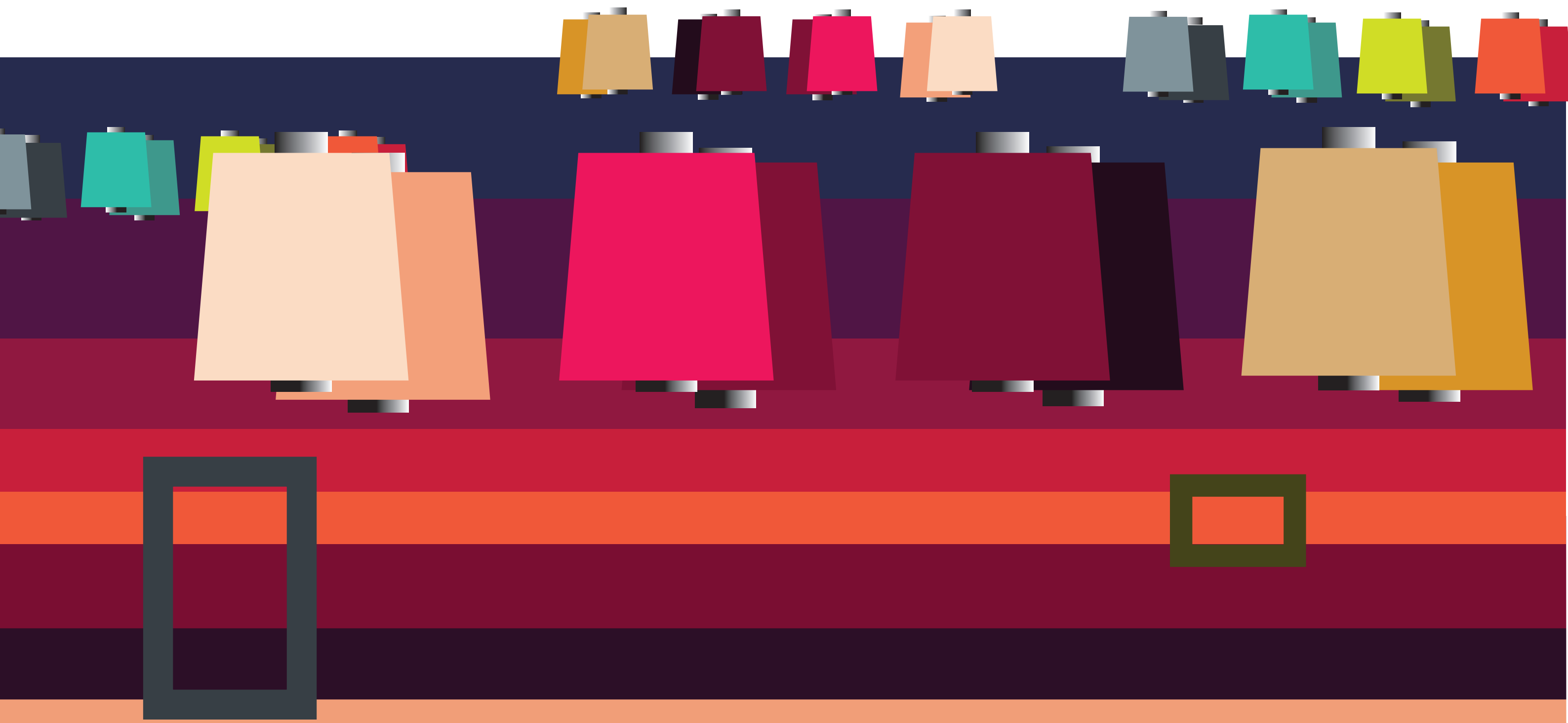
ICT-TEX
ICT IN TEXTILE AND CLOTHING
HIGHER EDUCATION AND BUSINESS



DEVELOPING REQUIREMENTS OF TCI TECHNOLOGIES

Report

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REPORT

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ICT IN TEXTILE AND CLOTHING HIGHER EDUCATION AND BUSINESS (ICT - TEX)

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DISCLAIMER

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TABLE OF CONTENTS

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KNOWLEDGE ALLIANCE ICT-TEX ICT IN TEXTILE AND CLOTHING HIGHER EDUCATION AND BUSINESS

TABLE OF CONTENTS

FIELD RESEARCH

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PROJECT CONTEXT AND OBJECTIVES

The textile industry is a tradition for Europe, with a centuries-old history, it is a leading EU sector offering high quality and innovative products. According to EURATEX Annual report 2017, the EU-28 is the world's largest market for textile and clothing products with household consumption of € 511 billion, a 181 billion turnover and 1.7 million workers employed. The EU Textile and Clothing industry (TCI) consists of 176,400 companies, 99% of which are small and medium-sized niche players focusing on quality, innovation, creativity and outstanding customer service.

The development of the necessary competences and skills for existing workforce and the attraction of qualified young experts has become a priority for companies. TCI is facing important challenges due to the changes in the working processes determined by different factors:

- technological development lead by new environmental protection and Corporate Social Responsibility requirements;
- evolution within manufacturing techniques with introduction of automatic cutting systems, advances in IT supporting product design and manufacture, and growing robotization of tasks;
- increasing introduction of Information and Communications Technology (ICT) ;
- innovation in materials with the rise of technical and smart textiles.

The impact of the above mentioned factors on the requirements for skills is enlarging the area of expertise to drive forward the innovation and ensure Textile and Clothing (T&C) products meet the aims of the industry, as well as the abilities needed to master both existing and new equipment and techniques.

Additionally, the successful professional realization of the specialists of the sector will require knowledge in the field of entrepreneurship.

The existing University curricula do not always meet the needs for ICT, digital and entrepreneurial education. Thus, the current bachelor's and master's engineering degrees are not fully adapted to the business needs. The study standards have to be moved up onto the next level according to both EU and business priorities, technical and technological development and the new approaches for digital and smart specialization.

Following the main recommendation of ESSC, a framework for a rapid response to the current evolution in business models, processes and sales strategies, in terms of continuous training and competences provision, needs to be established.

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PROJECT CONTEXT AND OBJECTIVES

With the aim to strengthen T&C Europe's innovation capacity and foster innovation in higher education, the project main objectives are:

- Develop innovative and multidisciplinary approaches to teaching and learning, developing ad hoc curricula and syllabuses in cooperation between universities and business;
- Stimulate entrepreneurship and entrepreneurial skills of higher education teaching staff and company staff;
- Facilitate the exchange, flow and co-creation of knowledge;
- Outline special requirements for training and education of specialists suitable for TCI producers, incl. technical, digital and entrepreneurial skills provision;
- Introduce innovative schemes for transversal skills training and enhancement throughout higher education programmes, developed in cooperation with enterprises and aimed at strengthening employability, creativity and new professional paths.

The planned activities and expected results of ICT-TEX project are shaped to address the outlined needs of the target groups (students, trainers, academics and textile SMEs) and to meet the ambitious objectives established. The project will develop a set of innovative tools based on a knowledge transfer dynamic approach. These tools will include:

- Gap analysis resulting in the "Report on developing requirements of TCI technologies"
- "Map of ICT technologies in TCI" Report
- "Map of innovation models and entrepreneurial skills in TCI" Report
- The curriculum "Application of ICT in Design of Textile and Clothing" that meet the requirements (resp. digital and entrepreneurial competencies) of the TCI business.

At least 7 validated Study programmes (syllabuses) for technical, digital and entrepreneurial education complying with the latest company requirements; practically oriented and interactive; remotely usable. The syllabuses will be developed following specific topics:

- ICT technologies and digital skills
- Design and production of knitwear
- Design and production of technical, smart and intelligent textiles
- Finishing printing and functionalization.
- Entrepreneurial and innovation skills
- Design and production of woven fabrics
- Industrial engineering, quality control and management

All the above mentioned e-tools will be available for consultation from the project web-platform.

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DESK RESEARCH

AIMS AND STRUCTURE OF THE DESK RESEARCH

The desk research is aimed to highlight the following key information related to T&C sector and its recent developments:

1. Overview about the technology changes T&C European enterprises go thorough during the recent years (i.e. introduction of new processes and new materials determining the adoption of new technologies);

   The Overview will provide:

- A picture of the current composition of TCI in Europe using both qualitative and quantitative data
- An historical analysis of the technology changes experienced by the sector

2. Description of the current technological processes in the TCI on the basis of the product specialisation: woven fabrics, apparel, knitwear, technical and smart textiles, finishing and functionalization analysing the opportunities offered by the upcoming innovative technologies. For each different specialisation will be provided a description of the production process investigating the main technologies implied at its different stages. This will be also important in order to define the requirements of the TCI enterprises in term of skills, competences and knowledge needed for the success of the sector,
3. Identification of Best practices related to technological innovations introduced within T&C companies and development of innovative learning methodologies to update the technological skills of the staff. The innovation capacity of companies, especially SMEs is a key topic for Europe's competitiveness and growth. In order to underline the advantages brought by the adoption and exploitation of new technological solutions allowed by employees constant training, the report will present excellent cases studies focusing both on the company perspective and EU successful projects.

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I. OVERVIEW OF THE TECHNOLOGICAL CHANGES IN THE TCI SECTOR

On a yearly basis EURATEX, the European Apparel and Textile Federation, publishes facts & figures about the situation of the Textile & Clothing industry in Europe (EU27). This report is an interesting source of information and covers many aspects of the sector, such as the general profile, figures on trade, data on sustainability and information about the newest innovations in the T&C sector. Some of the key figures are summarized in this document.

According to the latest report covering 2019, EURATEX estimates the turnover of the textile and clothing industry in the EU-27 to be €162 billion. Investments amount to €5 billion, which represents an increase of 2.7% compared to 2018. Though the number of companies slightly decreased to 160,000, EU external trade continues to be dynamic and to grow each year. In 2019, the T&C industry exported €61 billion in products, an increase of 4.8%. The majority of the 160.000 companies are micro (0-9 employees), small and medium sized (10-249 employees) enterprises and employ about 1.5 million people, thus playing a crucial role in the economy and social well-being of many European regions. Less than 0.2% are large companies, with more than 250 employees. This small size explains why the EU companies principally trade in the internal market. When breaking up the companies into the two sectors clothing and textiles the representation is: 67% of the 160.000 enterprises are clothing companies and 33% are textile companies. Overall, 75% of the world consumption on textiles is clothing consumption.

Fig: Evolution of EU28 textile exports. Copyright: Euratex

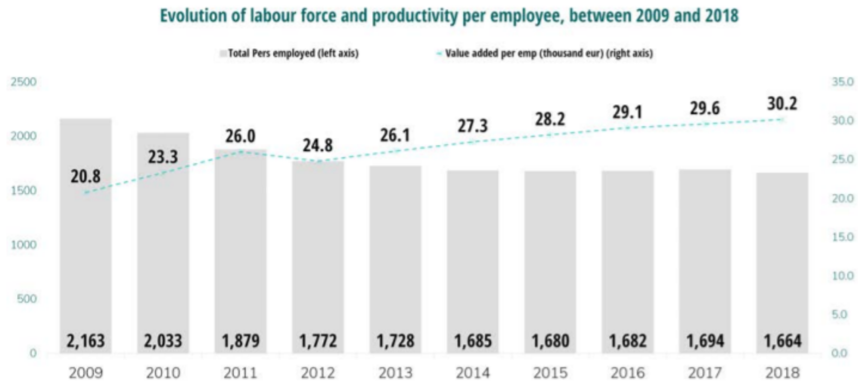

Fig: Evolution of EU28 textile labor force. Copyright: Euratex

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Since 2015 the labour force is mostly stable, but there are difference from country to country. Taking 2015 as reference years (100), situation in 2019 according to Eurostat is as in the following figure:

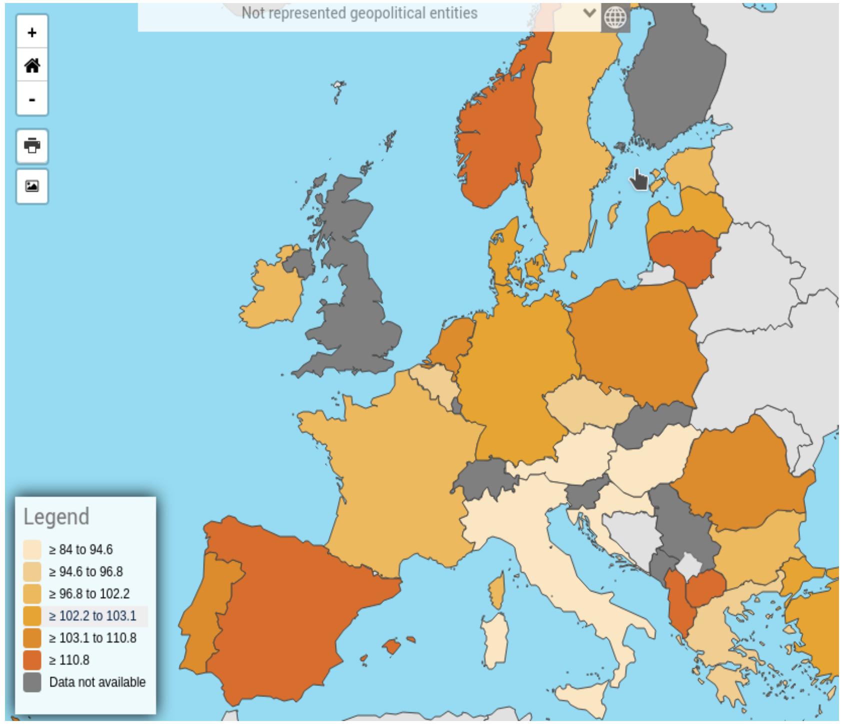


Fig: Number of people employed 2019 against reference year 2015 (=100)

Some interesting figures to highlight in this document is the importance of textile research, innovation and higher education in Europe. There are 40 textile research and technology centers that carry out applied and collaborative research. There are 50 textile departments at technical universities, training bachelor, master and PhD students. Moreover, there are 80 universities of applied sciences and fashion colleges which engage in applied research and training activities. Finally, in 2019 there are 15 Textile innovation clusters active in the EU27, offering technology transfer, business development, promotion and training services. These clusters are important to create a network effect in Europe, as well as worldwide.

To highlight some of these, we have for example:

AUTEX: the association of universities for textiles. This network is no longer limited to European textile universities but has several international universities amongst its members

TextraNet: the European network of textile research organizations

There are constant changes in the TCI as this is a sector with heavy international competition, requiring continuous innovation. Key innovations for the T&C Industry, according to the EURATEX report, are situated in the areas of:

- Smart high-performance materials and products
- Digital manufacturing and supply chains
- Bio-based materials & processing

Furthermore, it is stated that the Smart Textiles area (electronic textiles and smart wearables) is booming. The EU smart textiles' market is expected to reach € 1.5 billion in 2025!

Of great importance for the health of the EU27 TCI, is a good European regulatory framework. This relates also to standardization requirements, to establish the right balance between high-quality, strong European standards and the industry's needs. In 2020 The Textile ETP (European Technology Platform) also became operational, in time for the start of the new EU programmes for the 2021-2027 period. Strategic programmes that were chosen were Circular Economy and Bio-based Fibres.

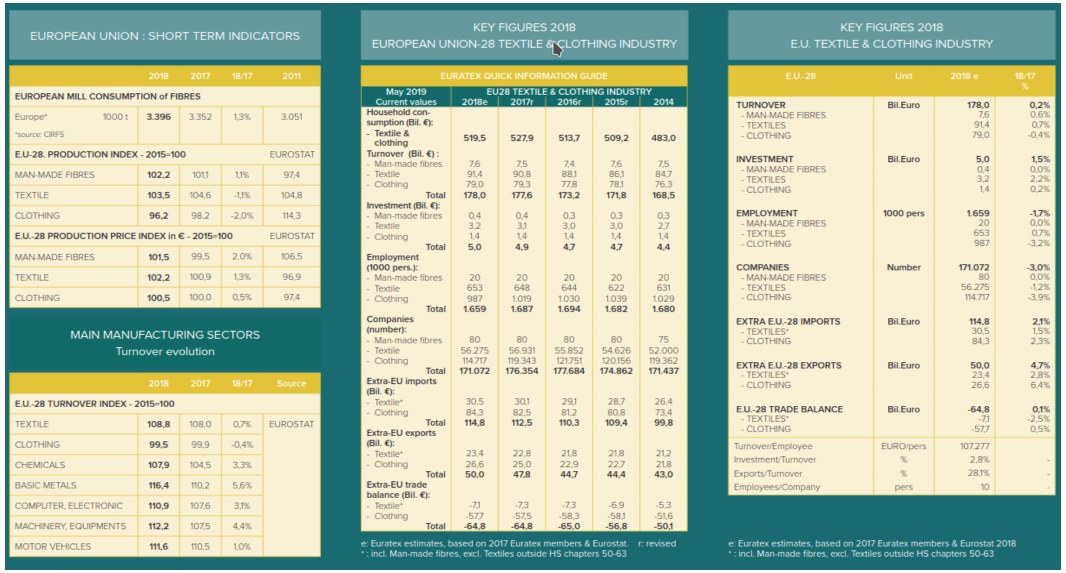
Fig: Strategic Programmes started in 2020

In 2021 a review will happen on the other 5 proposed strategic programmes. Among these, Smart Textiles and Digital Fashion Manufacturing also received a significant number of subscriptions, indicating their importance for the European TCI. The remaining 3 are Sustainable Chemistry, High performance technical textiles, and digital textile production.

From all of this, it is clear that digital evolutions will play a great role in how the TCI industry further evolves. In the near future, the IoT (Internet of Things) revolution will totally change how the production machines operate, while gathering data on all processes will cement big data in the decision making on all levels. At the same time, the design within the fashion manufacturing and within the technical textiles sector moves to a complete digital process, allowing fast simulation of the created products to evaluate their effectiveness before they are actually produced.

The move to online, personalized, shopping is gaining momentum requiring or a very fast optimized logistics chain, or a local manufacturing capacity. It is clear that the future for textile graduates is bright and digital, and that they need to be trained to be able to handle the many changes that are expected the coming decennium.

Update of key statistics over Skills4Smart data, with the data of 2018:



EUROPEAN UNION : SHORT TERM INDICATORS

		2018	2017	18/17	2011
EUROPEAN MILL CONSUMPTION of FIBRES					
Europe* *source: CIRFS	1000 t	**3.396**	3.352	1,3%	3.051
E.U-28. PRODUCTION INDEX - 2015=100					EUROSTAT
MAN-MADE FIBRES		**102,2**	101,1	1,1%	97,4
TEXTILE		**103,5**	104,6	-1,1%	104,8
CLOTHING		**96,2**	98,2	-2,0%	114,3
E.U.-28 PRODUCTION PRICE INDEX in € - 2015=100					EUROSTAT
MAN-MADE FIBRES		**101,5**	99,5	2,0%	106,5
TEXTILE		**102,2**	100,9	1,3%	96,9
CLOTHING		**100,5**	100,0	0,5%	97,4

MAIN MANUFACTURING SECTORS
Turnover evolution

	2018	2017	18/17	Source
E.U.-28 TURNOVER INDEX - 2015=100				
TEXTILE	**108,8**	108,0	0,7%	EUROSTAT
CLOTHING	**99,5**	99,9	-0,4%	
CHEMICALS	**107,9**	104,5	3,3%	
BASIC METALS	**116,4**	110,2	5,6%	
COMPUTER, ELECTRONIC	**110,9**	107,6	3,1%	
MACHINERY, EQUIPMENTS	**112,2**	107,5	4,4%	
MOTOR VEHICLES	**111,6**	110,5	1,0%	

KEY FIGURES 2018
EUROPEAN UNION-28 TEXTILE & CLOTHING INDUSTRY

EURATEX QUICK INFORMATION GUIDE

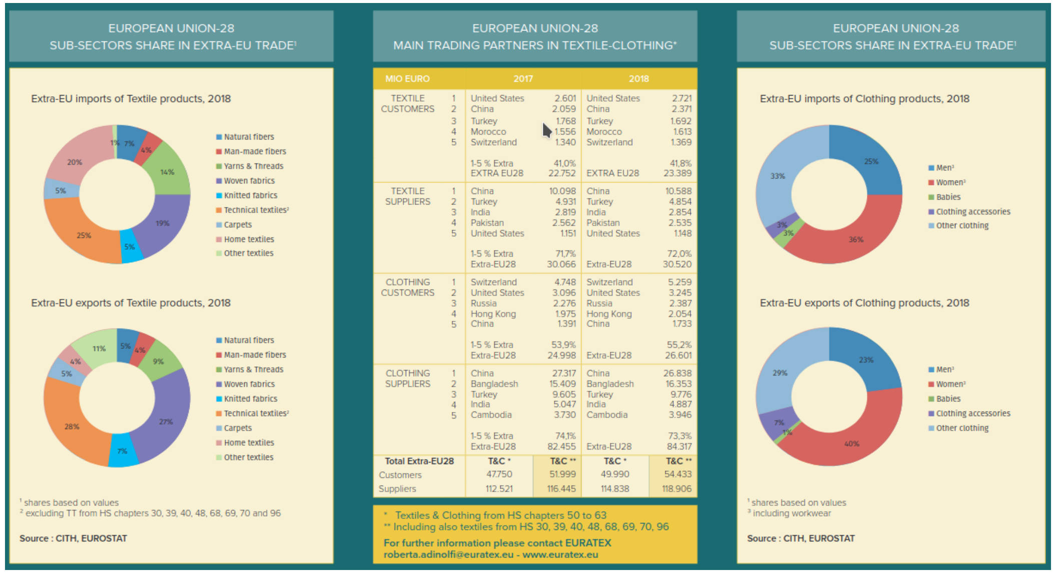
May 2019 Current values	EU28 TEXTILE & CLOTHING INDUSTRY 2018e	2017r	2016r	2015r	2014
Household consumption (Bil. €):					
- Textile & clothing	**519,5**	**527,9**	**513,7**	**509,2**	**483,0**
Turnover (Bil. €):					
- Man-made fibres	7,6	7,5	7,4	7,6	7,5
- Textile	91,4	90,8	88,1	86,1	84,7
- Clothing	79,0	79,3	77,8	78,1	76,3
Total	**178,0**	**177,6**	**173,2**	**171,8**	**168,5**
Investment (Bil. €):					
- Man-made fibres	0,4	0,4	0,3	0,3	0,3
- Textile	3,2	3,1	3,0	3,0	2,7
- Clothing	1,4	1,4	1,4	1,4	1,4
Total	**5,0**	**4,9**	**4,7**	**4,7**	**4,4**
Employment (1000 pers.):					
- Man-made fibres	20	20	20	20	20
- Textile	653	648	644	622	631
- Clothing	987	1.019	1.030	1.039	1.029
Total	**1.659**	**1.687**	**1.694**	**1.682**	**1.680**
Companies (number):					
- Man-made fibres	80	80	80	80	75
- Textile	56.275	56.931	55.852	54.626	52.000
- Clothing	114.717	119.343	121.751	120.156	119.362
Total	**171.072**	**176.354**	**177.684**	**174.862**	**171.437**
Extra-EU imports (Bil. €):					
- Textile*	30,5	30,1	29,1	28,7	26,4
- Clothing	84,3	82,5	81,2	80,8	73,4
Total	**114,8**	**112,5**	**110,3**	**109,4**	**99,8**
Extra-EU exports (Bil. €):					
- Textile*	23,4	22,8	21,8	21,8	21,2
- Clothing	26,6	25,0	22,9	22,7	21,8
Total	**50,0**	**47,8**	**44,7**	**44,4**	**43,0**
Extra-EU trade balance (Bil. €):					
- Textile*	-7,1	-7,3	-7,3	-6,9	-5,3
- Clothing	-57,7	-57,5	-58,3	-58,1	-51,6
Total	**-64,8**	**-64,8**	**-65,0**	**-56,8**	**-50,1**

e: Euratex estimates, based on 2017 Euratex members & Eurostat. r: revised
* : incl. Man-made fibres, excl. Textiles outside HS chapters 50-63

KEY FIGURES 2018
E.U. TEXTILE & CLOTHING INDUSTRY

E.U.-28	Unit	2018 e	18/17 %
TURNOVER	**Bil.Euro**	**178,0**	**0,2%**
- MAN-MADE FIBRES		7,6	0,6%
- TEXTILES		91,4	0,7%
- CLOTHING		79,0	-0,4%
INVESTMENT	**Bil.Euro**	**5,0**	**1,5%**
- MAN-MADE FIBRES		0,4	0,0%
- TEXTILES		3,2	2,2%
- CLOTHING		1,4	0,2%
EMPLOYMENT	**1000 pers**	**1.659**	**-1,7%**
- MAN-MADE FIBRES		20	0,0%
- TEXTILES		653	0,7%
- CLOTHING		987	-3,2%
COMPANIES	**Number**	**171.072**	**-3,0%**
- MAN-MADE FIBRES		80	0,0%
- TEXTILES		56.275	-1,2%
- CLOTHING		114.717	-3,9%
EXTRA E.U.-28 IMPORTS	**Bil.Euro**	**114,8**	**2,1%**
- TEXTILES*		30,5	1,5%
- CLOTHING		84,3	2,3%
EXTRA E.U.-28 EXPORTS	**Bil.Euro**	**50,0**	**4,7%**
- TEXTILES*		23,4	2,8%
- CLOTHING		26,6	6,4%
E.U.-28 TRADE BALANCE	**Bil.Euro**	**-64,8**	**0,1%**
- TEXTILES*		-7,1	-2,5%
- CLOTHING		-57,7	0,5%
Turnover/Employee	EURO/pers	107.277	
Investment/Turnover	%	2,8%	-
Exports/Turnover	%	28,1%	-
Employees/Company	pers	10	-

e: Euratex estimates, based on 2017 Euratex members & Eurostat 2018
* : incl. Man-made fibres, excl. Textiles outside HS chapters 50-63



EUROPEAN UNION-28
MAIN TRADING PARTNERS IN TEXTILE-CLOTHING*

MIO EURO		2017		2018	
TEXTILE CUSTOMERS	1	United States	2.601	United States	2.721
	2	China	2.059	China	2.371
	3	Turkey	1.768	Turkey	1.692
	4	Morocco	1.556	Morocco	1.613
	5	Switzerland	1.340	Switzerland	1.369
		1-5 % Extra	41,0%		41,8%
		EXTRA EU28	22.752	EXTRA EU28	23.389
TEXTILE SUPPLIERS	1	China	10.098	China	10.588
	2	Turkey	4.931	Turkey	4.854
	3	India	2.819	India	2.854
	4	Pakistan	2.562	Pakistan	2.535
	5	United States	1.151	United States	1.148
		1-5 % Extra	71,7%		72,0%
		Extra-EU28	30.066	Extra-EU28	30.520
CLOTHING CUSTOMERS	1	Switzerland	4.748	Switzerland	5.259
	2	United States	3.096	United States	3.245
	3	Russia	2.276	Russia	2.387
	4	Hong Kong	1.975	Hong Kong	2.054
	5	China	1.391	China	1.733
		1-5 % Extra	53,9%		55,2%
		Extra-EU28	24.998	Extra-EU28	26.601
CLOTHING SUPPLIERS	1	China	27.317	China	26.838
	2	Bangladesh	15.409	Bangladesh	16.353
	3	Turkey	9.605	Turkey	9.776
	4	India	5.047	India	4.887
	5	Cambodia	3.730	Cambodia	3.946
		1-5 % Extra	74,1%		73,3%
		Extra-EU28	82.455	Extra-EU28	84.317
Total Extra-EU28		**T&C ***	**T&C ****	**T&C ***	**T&C ****
Customers		47.750	51.999	49.990	54.433
Suppliers		112.521	116.445	114.838	118.906

* Textiles & Clothing from HS chapters 50 to 63
** Including also textiles from HS 30, 39, 40, 48, 68, 69, 70, 96
For further information please contact EURATEX
roberta.adinolfi@euratex.eu - www.euratex.eu

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1.1 Analysis of the technological changes experienced by the sector in the last 20 years

Technology has always had a very close relation with the textile sector. Producing fibers, yarns, fabrics and clothing has in all civilizations been one of the main industries. Producing all these was, and often is, a very labour-intensive process. Technological changes that could reduce the cost of the production haves hence always had a great influence on the market, leading to fierce competition and ending nowadays with large research budgets in order to keep an edge in the market.

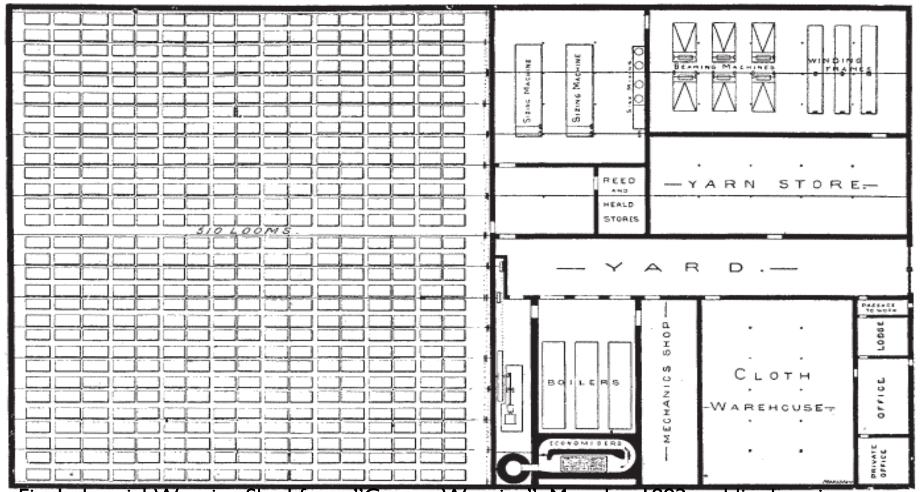

Fig: Industrial Weaving Shed from "Cotton Weaving", Marsden 1892, public domain.

Every time new technologies came on the market this had a big influence on the textile and clothing industry. Weaving already occurred in 5000 BC, and in 700 AD horizontal and vertical looms were widespread. In the 12th century, the hands could operate the shuttle, while the feet could operate the heddles, increasing production. Nevertheless, fabric and clothing production remained small scale, distributed over many households.

This all changed with the industrial revolution in the 18th century, which switched many manual production processes to powered machines, and several technological changes that had huge repercussions on the textile industry: the cotton gin (1793) made cotton much more viable as a mass product fiber, the jacquard loom (1803) allowed fast industrialized weaving, the sewing machine became generally available (1829) transforming the apparel production process.


Fig: Punchingcards on a Jacquard loom, copyright wikimedia

The Jacquard loom can be seen as the start of computational engineering, as punching cards were used to determine the weave pattern, suddenly allowing the production of woven structures with very complex patterns. This had a great influence on Charles Babbage who later invented the concept of a digital programmable computer.

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It is clear that technology and the TCI industry go hand in hand, and this has continued unabated. Focusing on the last 20 years, from 2000 to 2020, many further technological changes occurred, of which the breakthrough of Information Technology (IT) in textile production, was an important one. IT is the use of computers, storage, networking and other physical devices, infrastructure and processes to create, process, store, secure and exchange all forms of electronic data. Since the mid-20th century, computing capability has continuously advanced while device cost and energy consumption decreased.

The key features of information and communication technology (ICT) are speed and capacity to store and process data. It facilitates the process of manufacturing and dispatching, speeds up the process of analysing the demand and supply, helps in human resource management, and drastically reduces the time needed by operators. It contributes largely to global trade, data mining and data ware housing.

With ICT, colours are matched to the design, dyes are weighed and dispensed, and fabric is printed automatically; companies transmit information between plants and manufacture on a global scale; designs are sent electronically to the print manufacturer and stored on computer to ease repeat printing orders; the just-in-time (JIT) ordering of materials and components is facilitated so they arrive at the factory as they are needed.

1.1.1 Latest technological innovations

Computational Engineering and Simulation

An important part if ICT is simulation-based engineering, especially for technical textiles, where new fabric assemblies are simulated virtually and undergo virtual testing before production. Nowadays, this can go very far, in all levels of the textile industry. First, there are the polymers used for man-made fibers. Molecular modelling allows to optimize polymers for specific needs and accelerates the development of new bio-degradable fibers.

The second level are the fibers. Here there are advancements in fiber testing, with automated tests, and lab management systems to keep an overview. Fibers for specific conditions can be selected making use of neural networks, while all historical information is stored in data bases, allowing for the use of big data techniques. Fibers properties themselves are modelled to fully understand their reaction to external stimuli.

The third level is the yarn. Several new fancy yarns appeared on the market allowing new applications. From the yarn, or from fibers, the fourth level, fabrics and textile assemblies, are made. ICT is used for all aspects of fabrics: in the design and for the simulation of the behaviour, for the calculation and the transfer of machine settings, in the development of complex 2D and 3D structures, and for the integration of complex parts such as heaters and sensors.

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The development of sophisticated numerical simulation models such as CFD codes using detailed 3D human geometry models (eg. coupling CFD with mathematical human thermoregulatory models) is necessary for simulating various complex processes under real-world conditions, such as coupled thermal manikins with "physiological intelligence", dynamic thermal comfort simulation of cars, and simulations of directional IR-radiation scenarios. Recent developments are focused on monitoring and warning systems for real-time risk assessment with wearable sensors to predict noninvasively inner T stress levels in hot industrial environments.

In developing highly productive manufacturing processes, it is vital also to attain sufficient observability and controllability of important process states such that the product quality is achieved, diagnosed, and maintained. On-line process simulations have been implemented to receive information from process sensors, such as pressure, temperature, and flow rate, and predict and control product quality attributes in real time, such as part weight and dimensions.

Apart from modelling, several new production technologies broke through since 2000, requiring complex tools for their designs and to guide the production machines. We give here a short overview.

3D Weaving

One such technology is 3D weaving. Woven fabrics have been used as one of the main types of materials for fashion and domestic uses, as well as in meeting the high-performance demands for technical applications. 3D structures have been used in various industries such as aerospace for some time. 3D fabrics, usually with through thickness direction linkages, are important forms of reinforcements and preforms for textile-based composite materials. Many of the 3D structures are created by weaving, braiding, knitting, filament winding, and pultrusion, among other methods. In relation to woven 3D fabrics, both the conventional weaving machines and purpose-made weaving devices are used.

With the help of 3D weaving, complex preforms with much better mechanical properties can be produced, the manufacturing time is minimal, and the production cost reduced. Moreover, since no plying, cutting, and stitching are needed, minimum machining is required to shape and size them.

As is clear, computer-based modelling plays an important part in all these. This has been ongoing since the invention of the computer, and its importance keeps on increasing. It is very important for accurate predictions, better design and integration and development of complex smart clothing designs. Time and money could be saved if products are accurately pre-screened for a specific application.

Development of mathematical models of the textile and clothing assembly and coupling them with human thermophysiological and environmental models is ongoing. They are necessary tools for designing advanced smart, complex clothing systems with proper feedback algorithms.

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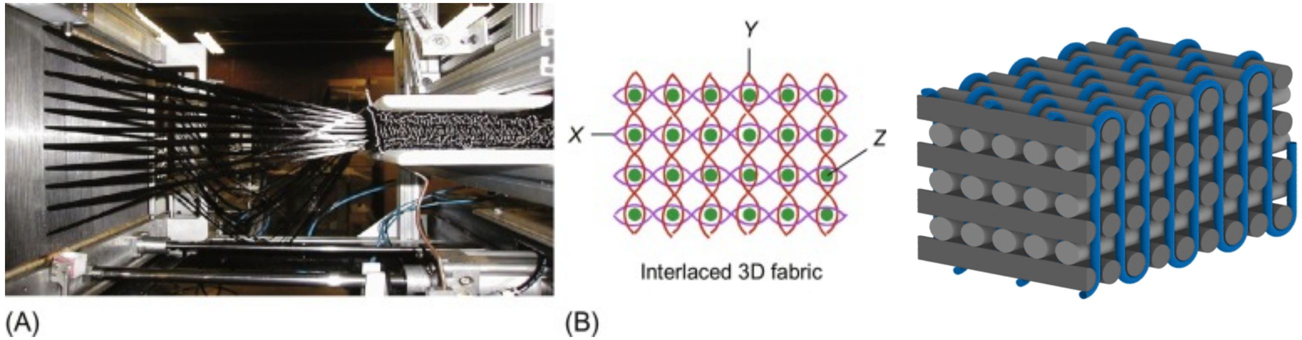

Fig Left: Purpose-made 3D weaving technology and 3D structure. (A) 3D weaving principle used by Mohamed (B) 3D woven structure created by Khokar. (Source: https://www.sciencedirect.com/science/article/pii/B9780081009048000043). Right: A 3D woven fabric by 3D weaving process. (Source: https://textilelearner.blogspot.com/2011/08/3d-weaving-manufacturing-process-of-3d.html)

The Dual-Directional Shedding System first launched in 1997 advanced the technology of weaving to a new dimension. 3D preforms were first used in place of expensive high temperature metal alloys in aircrafts in the early 1970's. 30 years of continuous research and development in 3D woven fabrics has led to production of superior counterparts with advanced properties.

3D woven preforms have various applications from composite reinforcement in various infrastructures, in ligaments, vascular prosthetics, filters, ballistic protection, scaffolds for medical purposes, high performance sports products etc. Commercial applications include military and police helmets, bra cups, car body liners, female body armours, parachutes, sail cloths and in innovative fashion and clothing.

From the machine point of view, electronic control and computerization are expected to continue. This would lead to automatic loom setting for fabrics to weave based on the specification of raw materials and the expected features of the fabric. CAD/CAE/CAM will make the future weaving more efficient and accurate. The ability to handle technical yarns will be enhanced on looms so that the looms will be able to make fabrics with wider range of raw materials for high quality. The further development of the fiber composite industry will stimulate more purpose-made weaving devices/machines to be engineered in order to create large-scale 3D textile structures as preforms and reinforcements. 2D and 3D woven structures will continue to find bionic and medical applications.

Smart Textiles

Another recent new development is the integration of electronics into textiles. The interaction of the two, the electronics and the textile, opens new frontiers in the human factor fields. The interaction between them defines the materials as active, passive and very smart. Passive smart materials are only capable of sensing (optical fibres, conductive materials, thermocouples), while active materials have a sensing and actuation functions, which means they can react to the stimuli (chromatic materials, shape memory materials, phase change materials, hydrogels and membranes, luminescent materials, photovoltaics and electric textile). Very smart materials can sense, react, and adapt themselves accordingly (space suits, thermoregulating clothing and health monitoring apparel).

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Smart clothing with implemented electronic components (sensors, actuators and other functional parts) can largely assist the human performance. Making use of real-time monitoring of the physiological state based on textile sensors, the clothing could smartly adapt to provide the optimal heat balance. Such systems have been researched extensively since the 90s, by attaching hard electronics within the clothing, and have now advanced to fully-fiber based smart textiles.

One example from the EU is the PROeTEX (Protection, eTextiles: Micro Nano Structured Fiber systems for Emergency-Disaster Wear) project. In this, a wearable system is constructed consisting of T-shirt, jacket and boots. It is designed to detect the physiological health status (HR, breathing rate, T, blood oxygen saturation, position, activity, posture) of emergency intervention personnel, and environmental properties (T, toxic gases, heat flux through garments), having the option to give alerts.

Fiber production technologies

The textile industry has kept pace and technology today can provide fabrics that go well beyond the best that nature has to offer. There has been rapid growth in polymer, material, information, and biological sciences and through an interdisciplinary approach many advancements have been made in the past decades. In the next millennium it is expected that textiles will provide superior functionality for emerging economic sectors from space to super conductivity, agriculture, and geo-textile, by implementing, through modern business strategies and highly efficient environmentally friendly production schemes, precisely specified molecules for new textile platforms.

Fibers that have ease of care and natural-like aesthetics have been major themes in recent decades, with high performance and specialty fiber staking on particular significance. The fiber may have polymer modifications, contain additives, or be altered on the surface. Nowadays, fibers are used in all industries as they can replace even metals, so enormous developments are done in the fiber field.

The focus is placed on ecological production. In the future fiber molecules will be designed, engineered, and produced more efficiently than ever before due to advances in combinatorial chemistry, robotics, nanotechnology, bioinformatics, spectroscopy, and high-throughput screening. High performance fibers are of specific interest, and Carbon Nano Tubes (CNT) promises to open up new frontiers in fiber technology.

An important trend is the move towards a circular economy. Awareness on recycling is therefore particularly important going forward. For example, most polyester is currently mechanically recycled. The market share of chemically or biologically recycled polyester is still very low. With new operations starting the commercial production of chemically recycled polyester and further companies in the research and development phase, the market share of chemically recycled polyester is expected to grow in the coming years. The market share of recycled polyester increased from around 9 percent of the world PET fiber production in 2009 to around 14 percent in 2019.

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Electrospinning

Electrospinning was patented as a feasible technique in 1934 by Formhals. Research groups of Lim et al. (2004) and Yang et al. (2005) made considerable contributions to the development of electrospinning. In the last 20 years material scientists have put intensive research efforts to optimize the electrospinning process and the resulting nanofiber's properties. Solvent electrospinning is the most popular nano fibrous production method: it is not limited to thermoplastic polymers, offers scalability and versatility, and can form various nanofiber morphologies. Nano fibrous structures can be produced by electrospinning of various natural, synthetic, or composite polymers, metals, inorganic materials, or combinations.

Nanofibers are ultrafine fibers with diameter sizes within a scale of a billionth of the reference unit (10-9 meters). The interconnected Nano fibrous structures formed by electrospinning are characterized with huge surface to volume ratio, high porosity and small pores which allows unique performances which can't be achieved by other processes. The structure offers a wide range of surface functionalization possibilities, such as loading with sensorial molecules, drugs, or cells.

Moreover, the simplicity of production and low cost of the products are another reason for their preference over other substrate types. Electro spun nanofibers have opened many new possibilities and have been commercialized for many industries, such as for filtration. The applications range from electronics, catalysis, high performance filtration, water absorption, sensors, drug and gene delivery, tissue engineering to wound treatment. However, some technological and biological safety challenges including the optimization of the structure and function are yet to be solved to push future commercialization of their products for clinical practices.

Embroidery technology

The use of embroidery as a joining technology has been investigated over the last decade for example, for utilization in smart textile systems, such as developing a fully Integrated EKG Shirt based on embroidered electrical interconnections with conductive yarn and flexible Electronics.

In the 20s, embroidery technology in which thread direction can be arranged at almost any angle, has elicited great interests in the design and fabrication of tissue-engineered scaffolds. There are various machine configurations available, including up to 11 parallel embroidery heads for TFP and more than 56 parallel heads for standard embroidery.

Fig: A matrix of electronic modules integrated onto textiles by embroidery and soldering (ITA, RWTH Aachen).

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Because of this performance productivity, embroidery technology has decent efficiency when configured with other multi-head machineries. Potential applications of the technology range from decorative embroidery in carpeting or tablecloths to TFP embroidery for resistive automotive seat-heating systems.

Due to these established embroidery applications, embroidery technology is poised to further functionalize textiles as a versatile joining technology. The future of embroidery is in improving double-sided embroidery technology which could have a radical impact on the ability to create new products in various textile markets.

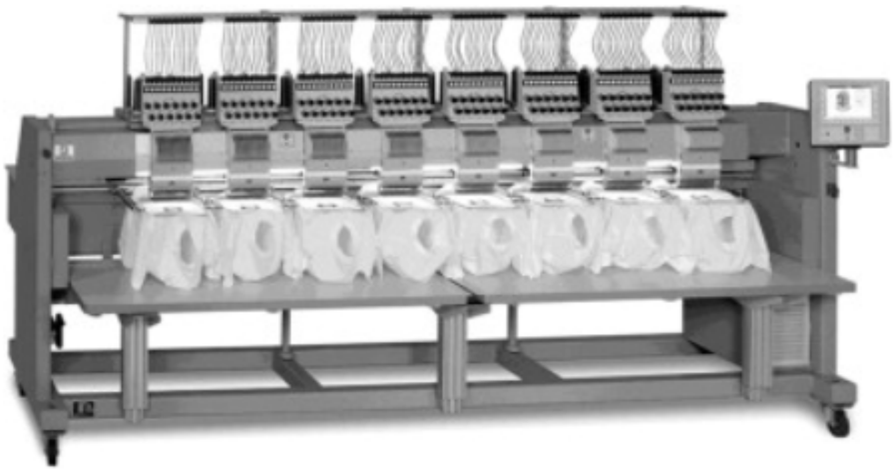

Fig: Tubular embroidery machine with eight heads (ZSK Stickmaschinen GmbH, Krefeld, Germany)

Additive manufacturing (3D printing)

Additive Manufacturing or 3D Printing covers all processes that can form a 3D product by means of adding material, also referred to as rapid prototyping (RP). It can be used to manufacture the product of the prototype easily, rapidly, and inexpensive and is increasingly used in many sectors such as space, automobile, medical, architecture, education, and fashion.

Textile engineering research explored the possibilities of combining 3D printing technology and textile weaves as well as the practical potential for the theoretical collaboration of these two quite different technologies. Plenty of 3D printed clothing prototypes have been designed. Though today's wearable 3D printed applications are more like exoskeletons and armours than textiles and clothing, RP technologies are still remarkable in textile engineering research since it provides the opportunity to produce finished, ready-to-wear clothing directly from raw materials in a single manufacturing operation.

Coloration and finishing

With the help of molecular modelling, a predictive tool of the dye behaviour in different environments is possible. It can stimulate the dye-polymer interactions, using their molecular structures, and the effects of the chromophore substituents on the halo chromic effect. Familiar or hypothetical dyes with the same chromophore can be stimulated and also there is a possibility to develop specifically tailored dyes.

Advances in digital inkjet printing technology during the 1990s and early 2000s have enabled machines to be built that can cost-effectively produce small print-runs on textiles. Designs can be transferred directly from a computer and printed onto fabric in almost the same way as a word document is printed onto paper. The flexibility of the technology allows samples and short runs to be produced easily without the costs of setting up screens and wasted ink.

Clothing technology

Whole body scanning now allows for an accurate digital copy of human bodies for increasingly lower costs. 3D scan collection will eventually lead to large databases of different user populations, optimizing the garment sizing systems. This digital copy or body scan can be combined with clothing patterns to provide made-to-measure garments. The individually adapted digitized clothing patterns can be further processed, for instance, by automated grading and cutting. The 3D scans imported into dedicated software enable virtual fit of garments. However there remains a need for more detailed model validation, and the simulation of material properties.

3D scanners can derive 1D body dimensions, replacing manual measurement. The greater potential lies in human shape processing of human shapes. PCA offers a nice technique to evaluate the differences between humans in a certain population. Several organizations (ISO, NATO, IEEE) have started expert groups to establish standards on 3D body scanning and scan processing. It is expected that the future clothing shopping may be that a customer can get a 3D view of the product virtually fitted onto his body, by uploading his/her 3D scan to the web retail shop and may be also able to customize the design and materials. In this, virtual and augmented reality systems might play a role.

The intricate approaches to simulate and animate clothing started in the nineties with several new techniques, which addressed the cloth mechanical properties and the interaction with the environment, such as Lagrange equations of motions and elastic surface energy, mesh-to-mesh collision detection and response including several layers, and the mass-spring modelling to speed up the simulation of complex clothing to name some of them. The greatest advantage of this kind of software is twofold: (1) the realistic body shape either as dimensioned avatar or direct 3D scan can be used for garment fitting, and (2) in some software packages, the pattern design changes in 2D construction model are updated simultaneously in the 3D simulated virtual stitched garment.

Also, the newest developments include software systems that generate 3D models from photographs. When an object is photographed from different angles with some overlap, the software can recalculate this to a 3D image. Several companies offer apps on a smartphone or tablet that make photos from which body dimensions can be deducted. This technology promises to solve fit problems, for instance by generating accurate data for the development of size charts, enabling a pragmatic approach to the offer of mass customisation, and facilitating virtual model fit trials that enhance online clothing shopping experiences. Consumers have become savvier than ever and as the demand for well-fitted garments is increasing, 3D body scanning technology is being viewed as a significant bridge between craftsmanship and computer-aided design technologies.

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Knitting advancements: whole garment knitting

CAD/CAM technology replaced the mechanical shaping and patterning devices on machines with electronic controls. New designs could be set up using CAD and instantly produced on the CAM machine. Early systems were expensive and only the major companies could afford them. In the 1980s and 1990s CAD/CAM fell in price and small and medium sized companies invested in the new technology. The introduction of computerised technology enabled companies to work globally.

Creating garments by cutting fabric into shapes and sewing the pieces together is being replaced by whole garment manufacturing. From the 1970s companies researched more efficient technologies for garment production such as avoiding the sewing step. 'Wholegarment' technology was further developed in the 1990s by Shima Seiki of Japan and others. The process allows quick garment production and zero fabric loss. Wholegarment clothes made by such seamless technologies are proven to provide greater comfort, better fit and stretch more easily. Wholegarment machines are also capable of producing complex designs. 2D fabric is replaced by 3D knitwear shaped and pleated as required.

Other knitting developments are warp-knitted fabrics made from high performance fiber materials; spacer fabrics for fiber-reinforced composites; and multiaxial warp knitting technology.

Fig: Whole garment knitting with Shima Seiki's machine. https://about.newenergyfinance.com/blog/these-hi-tech-knitting-machines-will-soon-be-making-car-parts/

1.2. Value chain

ICTs offer the scope for the creation of virtual supply chains linking producers within countries or regions. It has an important role for developing countries adjusting to the new era by getting access to parts of the supply chain (other than basic manufacturing and processing) for example for companies to move into higher-value activities such as design and logistics, or to access niche markets. First, it can mean that for the first time a developing country firm can offer an integrated "total package" garment solution for increasingly demanding (mostly large-scale) global retailers. ICT, as a general-purpose technology, can improve business practices and increase the efficiency and competitiveness of developing country firms.

Secondly, ICT is the main driver that shifts value along the value chain, enabling new business models, disaggregating production chains, and creating new opportunities for developing countries in the global supply chain such as custom design or custom production. The global textile and garment sector have been in a state of flux since 2005, when almost four decades of restrictions on trade formally came to an end with the demise of the Multi-Fibre Arrangement (MFA) quota system. Many developing countries now face increasing competition and downward pressure on prices as the global garment industry consolidates around a relatively small number of winners. The textile and garments sector is highly globalized, but its structure has for decades primarily been determined by trade restrictions. Whereas Chinese manufacturers have focused on serving major retailers through mass production and speed-to-market, other examples show companies elsewhere adopting a strategy of moving into fashion design and specialized fabrics or raw materials, or alternatively identifying niche markets that do not demand large-scale production. While countries such as Mauritius and Bangladesh are unlikely to be able to match Chinese garments producers in terms of speed-to-market for very large-scale orders, they can nevertheless use ICT to specialize in other aspects such as innovative fabrics or design.

Within a company, ICT can provide a detailed tracking mechanism so that the progress of an order through the production line is accessible in real-time. It can provide an integrated "full package" service, but it also offers new opportunities in the value chain, such as already exciting applications of advanced Computer Aided Design (CAD) and virtual prototyping packages, to the online handling of routine customs and export bureaucracy.

1.2.1 Trends in the value chain

The value chain in the textile and garments industry stretches from raw material production, yarn spinning, fabric production, dyeing and finishing, garment assembly, labelling, packaging, and delivery all geographically dispersed, involving many partners. During the past decade, several key trends have emerged and changed the industry, such as:

- **Geographical shifts.** In garment manufacturing from developed to low-cost countries, China taking the largest market share. While lower wage costs were often the initial reason for shifting location, other factors have also played a significant part. The goal of shorter lead-times could be achieved by situating production nearer the final markets. Turkey, North Africa (Tunisia and Morocco) and various former Eastern European countries offer quicker access to the EU markets which is why they are now preferred as suppliers. Each supplying country has its own profile. For example, Turkey is a "full-package" supplier with vertically integrated textile and apparel companies, North African countries assemble apparel for firms in France and Italy and Eastern Europe do both mentioned services. Manufacturing companies, or buying agents, may be headquartered in Hong Kong or Taiwan, for example, but will have outsourced most production across the region. With this type of disaggregated supply chain, coordination and communication becomes vital for controlling the network of companies involved in the production of just one product line. ICT technologies have brought considerable benefits in this regard.
- **Transnational Corporations** (TNCs). The rise of large international retailers has come to dominate the global textiles and garments industry, and in the post-quota environment have shifted towards sourcing in larger product amounts from fewer countries.

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- **Lean retailing.** The retailer nowadays wants to concentrate on selling garments, so the supplier has to offer a "full package" service even the responsibility for monitoring the retailer's stocks and placing replenishment orders. In developing countries, the shift towards a full package service can be challenging. It demands a high-level integration, management systems and information technologies.

- **Speed-to-market**. In the past it was common that seasonal products are ordered up to 10 months in advance, delivered in bulk to large warehouses, and lead to large amount of unsold goods. In today's environment this is solved by the electronic point-of-sale barcode technology to collect and process large amount of data on customer purchases based on which a fast reaction can be given. This strategy is optimized by garment retailers, for fast turnover in styles and fashion trends, leading to a short product lifespan. In a business, the supply chain must be highly integrated in terms of information and efficiency, while often being geographically highly disintegrated.

1.2.2 Fast fashion, sustainability, reverse logistics and ICT

Fast fashion and over consumption within the textile industry have seriously threatened natural resources. Innovative solutions for production and consumption must be researched and developed to sustain future generations and many EU research projects are focused on development of sustainable solutions in the clothing and textile sector. A full textile supply chain, from the raw material, production to user and disposal or reuse of the textile product is quite complex involving many actors. One solution for decreasing production as well as textile waste management is the proper collection, recycling, reuse, or disposal of used textile products.

Reverse supply chains are one of the solutions - it is important to develop proper infrastructures for textile recollection, which is the first point of a reverse supply chain but the most problematic for logistics costs. The first mile problem is the issues and overall cost related to returning used textiles from their end of use with a consumer back to collection points. These issues include the cost of transportation, energy, natural resources, and time. When the supply chain is directly reversed the point of recollection is then the point containing the most actors therefore the most cost. Moreover, managing the total cost of the supply chain and the composite value of the components is essential to cost reduction and financial survival. The early days of Reverse Logistics were measured by convenience and customer accommodations. The stock return soon became a standard business practice between retailers, manufacturers, and distribution channels. The evolution of reverse logistics for manufactured products is developing in direct proportion to the rapid advancements in technology, mass production and rapid launch of new products. Therefore, it is demanded to have a fast response - an infrastructure with real time intelligent analysis and disposition based on changes in cost, resale value, spare parts, repair and overall demand, and only companies that collaborate, integrate, and optimize date exchange can succeed.

ICT is crucial in this regard as well as in dealing with the first mile problem in the collection of garments through apps. A digital infrastructure for collecting used garments can be used to optimize locations for collection points therefore, minimizing the first mile problem of reverse logistics in the textile industry. For example, an app from Swedish developers, known as the Cirqle App, has been made to serve as a bridge between individual consumers and both retail and textile recollection agencies.

1.3 ICT in Industrial Engineering, Quality Control and Management

Information and Communication Technology (ICT) as a general-purpose technology can improve business practice, increase the efficiency and competitiveness of industries, as well as having a profound impact on our everyday life. ICT helps optimise industrial processes, improving performance, sales management and contact between clients and suppliers as well as providing better data management tools to aid the decision-making process. It is a main driver that shifts value along the value chain, enabling new business models, disaggregating production chains, and creating new opportunities for developing countries in the global supply chain. With ICT implemented, the developing countries can improve business practices and increase the efficiency and competitiveness of their firms.

Without the ICT, the industries of those countries would probably be left behind in term of technological advancement and competition. The global textile and garment sector has been in a state of flux since 2005, when almost four decades of restrictions on trade formally came to an end with the demise of the Multi-Fibre Arrangement (MFA) quota system. Many developing countries now face increasing competition and downward pressure on prices as the global garment industry consolidates around a relatively small number of winners [22, 23].

ICT technology is crucial for development and depend about the type of technology needed. Whereas Chinese manufacturers have been focused on serving major retailers through large scale production and speed-to-market through an emphasis on logistics, other examples show companies elsewhere adopting a strategy of moving into fashion design and specialized fabrics or raw materials, or alternatively identifying niche markets that do not demand large-scale production.

ICT empowers organizations to get to substantial measure of data at an exceptionally fast rate. ICT likewise helps organizations to extend their range to faraway areas, offer new products and services, reshape employments and work processes, and change the way they direct business. An organization's ICT infrastructure consists of: ICT resources, ICT services and ICT management. These serve as a wide diagram for securing, creating, actualizing and incorporating ICT in a way that it backs the business capacities and methodologies of an organization. Utilization of ICT permits the flow of information that ties together the textile and clothing production network, and ICT is the way to accomplish effective data sharing. Innovative technology can empower a provider to enhance business practices, increase productivity and competitiveness, and to meet the ever-shorter lead times required [25].

ICT programme technology is used at various stages of the design process together with CAD and CAM. Presently, it is rapidly changing the textile industry. Initial design proposals are generated, developed, modelled and communicated using ICT and CAD software. Latest technological development such as using the 3-D body scanner, beyond the preciseness of measurement, ensures the analysis of data which could be used for diverse needs in the clothing industry including made-to-measure, customisation, fit trials, developing standardized size for specific targets, creating niches, efficient communication during manufacturing processes, efficient and rapid prototyping and online shopping [25].

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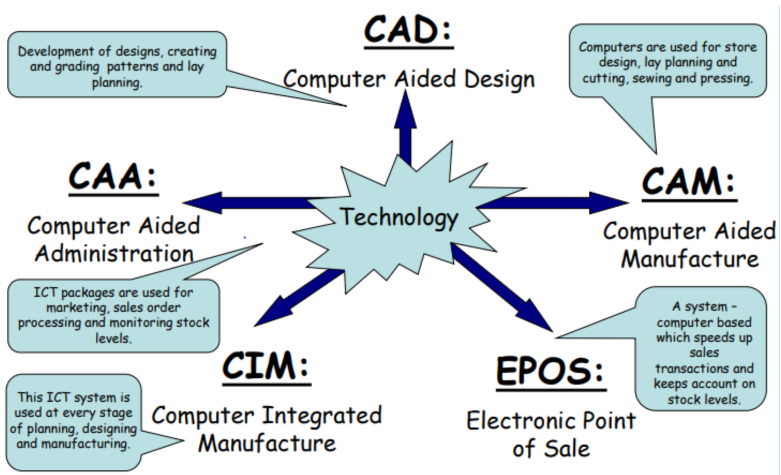

CAD/CAM (computer-aided design and computer-aided manufacturing) is described as the computer software used for design and manufacture prototypes, finished products and for automated production management. CAD is the utilization of computer technology for design and design documentation. CAM uses the models and assemblies made in CAD programming software to create ways that move the machines that transforms the designs into physical parts. CAD and CAM work together as a system, utilizing both - product design and fabricating processes, particularly, computer numerical control (CNC) machining. Computer aided designing software not just give the possibility to accelerate the way of putting another model into production and enhance the quality of the materials, but also to decrease material expenses and work power, guaranteeing a flexible change of the collection. The vast majority systems are made by the module rule in which isolate garment designing stages are executed [24].

A schematic representation shows the 5 main examples of computers systems used in the Textile Industry [33].

In recent decades, T&A companies have faced fierce competition in the era of Industry 4.0. All players of the industry are facing the same challenges, such as shortened order lead time and rising material and labour costs with reduced profit margins.

T&A industry tried hard to harmonize with logistics warehouses, inventories of stores, and supply chains according to customer demand as well as with manufacturing/production plans. In today's smart manufacturing environment, the textile and apparel (T&A) industry faces challenges such as efficiency, sustainability and quick response to clients' dynamic requirements as well as product quality and regulatory compliance, which ascertain its survival. In addition, the industrial ecosystem, global sustainable business trends and consumer-driven economy put pressure on industries to become more sustainable, innovative and agile because consumers, especially generation Z consumers, are more eco-aware and willing to pay for eco-friendly products. To date, much research on corporate sustainability has focused on consumers' willingness to support and buy sustainable products, which are identified by service, quality and price [34].

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As good practice, it could be mentioned Textile Research Institute AITEX that develops projects to create Smart textiles and ICT solutions for the textile industry and is also closely involved in new technology assessment and the transfer of new technologies to companies. Among the many advantages of the industrial applications provided by information and communication technology, ICT helps optimise industrial processes, improving performance, sales management and contact between clients and suppliers as well as providing better data management tools to aid the decision-making process. The Institute is working on the following research and development lines, as follows:

- using Artificial Vision as tool for acquiring, processing and analysing images captured during high-speed, repetitive processes which would be impossible with the naked eye. In that context they develop new image-capturing and processing techniques to develop automatic default-detection systems for the textile manufacturing line, provide analysis of the critical points in the weaving process using high-speed cameras and analytical studies of the impact of a bullet on bulletproof panels using high-speed cameras.
- using the Radio Frequency Identification improves the traceability of products through the supply chain and optimises stock control, speeds up order processing and reduces picking errors. In such context projects are related to the development of smart ID and tracking systems for in-store clothing stock; the development of emitting antennae integrated into a garment and integrating antennae into a PPE to track the wearer.
- using the strategy way of Industria 4.0 - the introduction of digital technology into industry to allow devices and systems to interact and modify or adapt processes, products and business models. Such approach could help to textile companies looking to introduce innovative digital systems in the following fields: business solutions, smart solutions and control (Big Data & Analytics), collaborative platforms, cyber security, computing and the cloud, connectivity and mobility, 3D printing, advanced robotics and embedded sensors and systems.

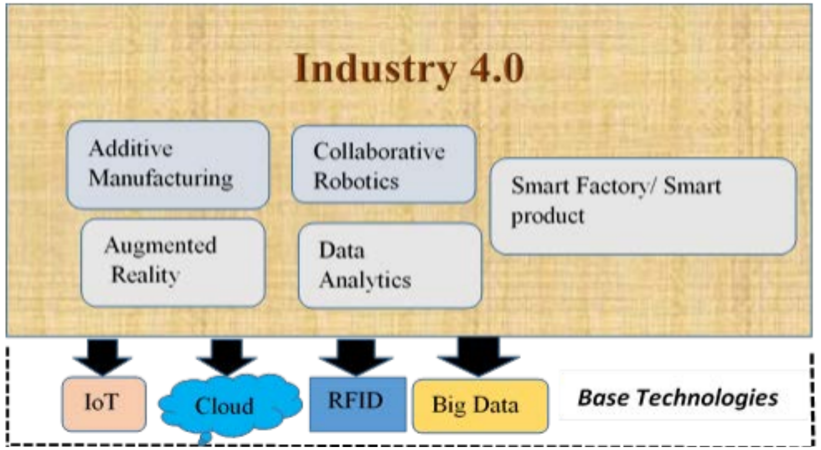

Figure 1. Industry 4.0 framework with base technologies [32]

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- developing of emotional interactive commerce – studies the development of neuromarketing and emotional engineering tools to analyse the evolution of consumer tastes and preferences with respect to different brands and services and interact with social media, and
- developing Information systems and e-business - the above systems help to improve productivity and process control and optimise resource management [23].

The use of present-day ICT tools over the world in the textile industry cannot be overemphasized as it has make it easy to pass information across and communicate effectively and efficiently in a very short time. The use of various ICT tools in the textile industry also aid the design and manufacturing of high quality products, providing the high flexibility, reducing the time for product getting to market, monitoring the flow of raw materials all the way to the end users and helping to increase the competitiveness at global market, to yield the required consumer relationship and financial gains. Studies show that IT has the characteristics that may optimize organizational performance [26-29]. However, IT business size and worth and the effects of IT can be based on several factors such as IT capability, IT resources, IT infrastructure, management practice, and the competitive environment [30].

The textile industry is distinguished by extreme global competition, mostly in nations that has easy laws in doing business, which makes factors such as quality, efficiency, and innovative capabilities significant for business sustenance [28]. In the great innovation of clothing design utilizing industrial framework, the essential patterns are intended for bodies that make up the dimensional typology display for a given populace. The largely use in the garments industry of CAD systems to configure designs alongside database coming from 3D scanning innovation of the human body, are prerequisites to amplify virtual displaying of the dimensional correspondence body-dress in the work of concluding the 2D designs after the solid body measurements [31].

In order to facilitate improvements for the first mile problem in the textile industry, the use of information communication technology (ICT) has been researched. Using ICT to coordinate the logistics flows of used garments, as well as encouraging the use of available infrastructures by consumers, has opportunities for further development. The authors of this thesis have collaborated with Cirqle, a Swedish based start-up that has created an app to reward individuals for the proper disposal of used garments. One example of the use of ICT in practice is the app developed by Cirqle and discussed. The app serves as a guide to finding places to return textiles, facilitating the process of properly discarding used textiles. In order to provide a background for the problem, the authors have created a definition for the first mile problem as related to textile logistics.

The definition of the first mile problem is the logistical issues and overall cost related to returning used textiles from their end of use with a consumer back to textile collection points. The authors use the definition as a background for understanding how ICT can be used as a support system in reducing the effects of the first mile problem. The purpose of this thesis is to explore how a digital infrastructure for collecting used garments, such as the Cirqle App, can be used to optimize location's for collection points; therefore minimizing the first mile problem of reverse logistics in the textile industry [32].

Investment in ICT is unlikely to be the sole decisive factor governing the future of the garments industry in any country. But well-informed decisions about ICT can improve the chances of competitive success.

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1.4 Best Practices – New technologies and training methodologies for quality control and sustainable management

Name of good practice	The impact of the textile industry on sustainable water management (within the project Natura 2000)
Type	Adoption of innovative technologies
Topic	Sustainability
Description (Objectives, results etc.)	The project provides the stakeholders with technical tools and approaches that allow for reuse and recycle of “alternative” sources of water or a better treatment of difficult wastewater locally, while at the same time assessing social acceptability and the effect over the whole system and the local community.
Evidence of success	• innovative water treatment technologies and control systems • interfacing decision making platforms • an overall consultative and participatory approach
Funding sources	Total Project Costs for beneficiary & third parties: 10.489.553, 75 EUR Max. EU Contribution: 9.261.272,38 EUR
Year	2018 - 2022
Contact (address, email)	Galeb, Omiš, Punta 6, Croatia galeb@galeb.hr
Responsible person	Josip Aračić, president
Web site	http://galeb.hr/en/galeb-entered-the-consortium-to-participate-in-h2020-project-project-o/
Key Relevant information for ICT-TEX project	Galeb serves as a demonstration site for the implementation of photocatalytic module that should treat organic, non-biodegradable pollutants left in the water after wastewater treatment plant.

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Name of good practice	Scientific annual symposium – "Textile Science and Economy"
Type	Technology transfer promotion
Topic	Sustainability
Description (Objectives, results etc.)	The initiative to launch a scientific-professional conference "Textile Science and Economy" starts in 2007. The idea was to design a scientific - professional platform focused on textile topics that will interest scientists, educators and entrepreneurs in the field of textiles, clothing and footwear. The purpose of the Conference is to synergistically connect educational and scientific - research resources of the University of Zagreb Faculty of Textile Technology and other related higher education institutions with economic entities, business and creative incubators and participants in other, complementary areas.
Evidence of success	Through carefully selected lectures and interactive workshops, members of the scientific research community in the field of textile science and technology present the latest achievements and propose innovative solutions aimed at the growth and development of the textile manufacturing sector. The selection of topics for all the Conferences held so far is aimed at encouraging cooperation with the EU, as well as encouraging regional cooperation, emphasizing the importance of using scientific and research resources in the function of improving and developing production. As a result and a key dissemination tool of the conference, a Proceedings of scientific and professional papers is published every year, which represents professional literature of key importance for the textile sector.
Funding sources	University of Zagreb Faculty of Textile Technology and Croatian Chamber of Economy
Year	Since 2007
Contact (address, email)	tzg2020@ttf.unizg.hr
Responsible person	Dean of the University of Zagreb Faculty of Textile Technology
Web site	http://tzg.ttf.unizg.hr/
Key Relevant information for ICT-TEX project	The 13-year experience of holding a Textile Science and Economy scientific-professional symposium reflects a significant impact on the manufacturing sector, not only in terms of contributing to the availability of information on technological research and development but also in directing and strengthening communication between the research community and the manufacturing sector.

Name of good practice	ENTeR (CE 1136) – Expert Network on Textile Recycling Project
Type	Technological and training innovation
Topic	Waste management systems promoting circular economy
Description (Objectives, results etc.)	ENTeR project main objective was to improve sustainable links among industrial textile areas fostering closer cooperation on waste management and circular economy. The aim is to demonstrate the benefit of an operational collaborative model amongst research and business partners, based on an online tool and shared skills focused on waste eco design and resource efficiency. The ten partners of the ENTeR project identified five areas of action: **Legal and Policy:** to monitor local and community policies in order to constantly orient the Strategic Agenda; **Waste management**: to develop specialized databases and a platform for the exchange of information, materials and technologies. **Research and technological trends:** to develop technologies that integrate and optimize the product life cycle; **Communication:** to favor a secondary materials market and encourage the reuse of waste; **Educational:** to highlight the training needs of companies identifying circular models favor conditions.
Evidence of success	Through a Check-Up Tool application developed by ERGO Sant'Anna it was possible to measure the level of "circularity" of the production processes of 5 textile companies in the province of Varese. The Tool analyzes strengths and weaknesses emerging from the measurement seizing the opportunities for internal circular economy practices improvement. The project promoted a joint offer of innovative services developed by the main local research centers and business associations (“virtual center”), involving public stakeholders in defining an action plan to drive circular economy strategic actions.
Funding sources	European funds – Interreg
Year	2017 - 2020
Responsible person	Roberto Vannucci
Web site	https://www.interreg-central.eu/Content.Node/3.html
Key Relevant information for ICT-TEX project	Development of technologies able to optimize the production processes with respect to the product life cycle circular model of economy in textile production according relevant environmental management system and quality management system. promote traceability systems and methods and support the study of a model for waste recovery;

2. DESIGN AND PRODUCTION OF WOVEN FABRICS STATE OF THE ART

2. 1Current technological processes in the weaving industry

“Textiles” is a word coming from the Latin word “textilis” that means “woven”. The European textile and clothing industry involves 176,400 companies with 1.7 million people, 99% of which are SMEs [35]. Every production step from fibres through fabrics to clothing is present within Europe, making this industry a powerful economic sector with a turnover of EUR 181 billion [35]. The EU is the second-largest world exporter of textile and fashion goods after China, with an export value of 66 billion US dollars [36].

The technological processes for the manufacturing of woven textiles are based on products, which are gradually formed and converted from fibres into yarns and from yarns into a wide range of fabrics.

The modern weaving technology is based on the following processes:

- Winding: the process aims to check and omit the yarn imperfections, creating a suitable for warping yarn packages.
- Warping: the process aims to prepare the warp set of threads (on the warp beam), suitable for the production of the required fabric design.
- Sizing: the process aims to increase the strength of the warp set of threads, preparing it for the action of the forces during the formation of the shed on the weaving machine.
- Looming: the process involves the drawing-in and tying of the warp set, aiming to prepare the threads correctly for the weaving and to assure unimpeded weaving performance.
- Weaving: the process involves the fabric formation on the weaving loom, involving all weaving machine’s mechanisms and aiming to form the grey fabric.

The production of woven textiles is a very complicated process that involves several steps with many unforeseen problems and appearance of obstacles, which depend on the input materials (threads, chemicals for sizing), machinery, settings of the production processes, labor forces, and management. The design of the fabric is also critical, the multicolored patterns, jacquard fabrics and 3D fabrics being among the most problematic ones. At the same time, developments as quick stale change, multiphase weaving and CAN-bus systems are supporting the nowadays fast production of high-quality fabrics with different applications.

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2.1.1 CAD/CAM systems in woven textiles design

The CAD/CAM systems help the designer to create in an easy way and quickly test different colour designs. They allow the virtual creation of designs in an economical way, facilitating the production process and minimising the efforts in the pre-production stage. The creation of databases of warp and weft compositions, colour palettes and machine settings allows the CAD systems to show the appearance of the fabric and to allow fast adjusting of the machine parameters, needed for the sample weaving. The virtual simulation of the fabric is also possible in the design stage. Besides, the CAM systems allow fast setting of the weaving machine parameters and data storage that is necessary for permanent optimization of the production parameters.

2.1.2 Multi-coloured designs

The colour transfer from the CAD system to the real woven fabric is especially important in the design of jacquard fabrics, where the colour of the threads is already fixed. However, it is quite difficult to transfer the same colours and shadows form the CAD system to the fabric, despite the significant modernisation and automation of the dyeing technologies [37]. The yarn's properties (twist, material) could influence the colour appearance. The threads interlacing in the fabric formation and their tension could lead to differences between the desired colour shadow and the final colour. The multi-coloured designs are also very sensitive to weft distortion, which is almost invisible in the case of single coloured fabrics [38]. In this case, the weft distortion could appear due to the yarn characteristics (unevenness, twist), structural characteristics of the fabrics (warp and weft density, weave pattern), machine settings during weaving (warp and weft tension, shed formation). There is still a demand for investigation and solutions of this particular challenge in the woven textiles production.

2.1.3 3D shapes weaving

The weaving of 3D shapes is mostly related to composite materials. The advantages of these woven structures are related to greater delamination resistance, because of the z-binder application, increased impact performance, enhanced "out-of-plane" properties and many others [39]. The use of 3D woven composites grows continuously in industrial applications, related to loading transfer (T-joints, curved beams). They have been successfully applied in the automotive industry [40] and for replacement of high-strength steel beams [41].

The 3D fabrics are woven using modified weaving mechanisms: multi-eye heddles for creation of the layers, differential feeding, etc. The introduction of stitching yarns assures the join of the layers. The development of the technology goes together with the demand of the industries, especially these that are using composite materials, but also from medicine and agriculture. Therefore, it is expected that more 3D solutions be available for intended applications.

2.1.4 Quick style change

The quick style change system assures change of the fabric style in less than 30 min. The weaving loom' producers have developed their own systems for splitting the back side of the frame of the weaving machine from the warp beam to the reed. The advantages of the quick style change systems are related to increased productivity, due to lower loom downtime, elimination of interference losses because of concurrent stops, and reduced labor costs due to decreased workers in the weaving room.

2.1.5 Electronic controls

The modern weaving machines use multiprocessor architecture, which allows data transfer between several subunits. Controller Area Network (CAN-bus) system is used for internal and external data exchange [42]. The advantages of the application of the CAN-bus systems are related to achieving a high quality of the fabrics, irrespective of loom speed; troubleshooting problems help; microprocessor controlled lubrication; storage of the production efficiency data; control and report of the style change time, etc.

2.1.6 Multiphase weaving

Multiphase weaving is related to the formation of multiple sheds simultaneously, and several weft threads are inserted into the sheds. Two different principles are applied:

- Shed formation, weft insertion and beat-up occur in the direction of the weft set;
- Shed formation, weft insertion and beat-up occur in the direction of the warp set.

After the shuttle looms and shuttles looms, multiphase weaving machines are considered to be the third generation of looms.

2.2 Best Practices – New technologies and training methodologies in the Woven Fabrics sector

Name of good practice	Academy
Type	Innovative training methodology coping with the sector technological innovation
Topic	Woven Fabrics
Description (Objectives, results etc.)	In collaboration with the Accademia di Belle Arti Aldo Galli – IED Como the project aim to the development of exploratory paths that link Italian art, culture, know-how and fabrics with an experience, for the young participants, within the corporate ecosystem: from knowledge of yarns and weaving techniques to product design, prototyping up to the economic aspects related to marketing.
Evidence of success	• The discovery and enhancement of new talents has brought a new concept of technological and commercial development, making Attilio Imperiali weaving facrory a leader in the marketing of its RASO SETA LAMÈ, also bringing new and important developments for a sustainable and low environmental impact production. • 30 youth every year since 2014 approach in the weaving and fabric production sector thanks to the Academy project and the know how acquired directly from the factory.
Funding sources	Private
Year	Since 2014
Contact (address, email)	luca@attilioimperiali.it
Responsible person	Viviani Luca
Web site	http://www.attilioimperiali.it/aziende/storia/
Key Relevant information for ICT-TEX project	The direct approach that Attilio Imperiali weaving factory does in the training program of young possible new staff members gives them the opportunity to be in contact with the classic and innovative weaving technologies giving life to a know-how of direct skills of the textile sector.

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Name of good practice	BCF yarns (Bulky Continuous Filaments), directly from PET flakes
Type	Application of new materials
Topic	Woven Fabrics
Description (Objectives, results etc.)	Truetztschler Man-Made Fibres developed a line for production of carpet yarns using recycled waste from water-bottles. The yarns, called Bulky Continuous Filament's (BCF), are used for weaving of PET carpets. The production stages involve polymer recycling, production of polymer granules, extrusion, spinning, blowing, texturing, winding, wrap and weft threads preparation and weaving. Carpets and carpet back sides can be produced from the adopted recycled technology.
Evidence of success	The adopted technology leads to decrement of the investments for fibres, as well as increases the value of the company in the production chain.
Funding sources	Private
Contact (address, email)	nonwovens(at)truetzschler.de
Responsible person	Eva Trenz
Web site	https://www.truetzschler.com/en/
Key Relevant information for ICT-TEX project	The use of new materials also require the use of appropriate machines. Introducing this kind of material Truetztschler payed attention to chooses related to shortened processes, optimised raw material utilisation, durable machine components and machines that significantly improve the recycling process.

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Name of good practice	PosiJet
Type	Application of new technologies
Topic	Woven Fabrics
Description (Objectives, results etc.)	Terry Plus-i is a new jacquard weaving machine of Picanol. A novelty in the technology is PosiJet – the main nozzle, which is now available in a 4-channel version. PosiJet is the new, revolutionary main nozzle set-up. Positioning the main nozzle tubes in the best possible position for inserting the filling yarn, while the machine is running.
Evidence of success	The advantage of using this nozzle on the machine is that the reed no longer needs to have conical entrance. This is a big and immediate cost saving. Besides, all four nozzles are set with only one setting, which saves time. The smaller weft channel dependency leads to a decrement of the overall stops and the loom is overall more stable with fewer interventions needed for its fine tuning.
Funding sources	Private
Contact (address, email)	info@picanol.be
Web site	https://www.picanol.be/machines-features/features/posijet
Key Relevant information for ICT-TEX project	The use of new materials also require the use of appropriate machines. Introducing this kind of material Truetztschler payed attention to chooses related to shortened processes, optimised raw material utilisation, durable machine components and machines that significantly improve the recycling process.

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3. DESIGN AND PRODUCTION OF APPAREL STATE OF THE ART

3. 1 Technological processes in Apparel Design and Production

Clothing production has doubled in the last two decades, driven by the growing middle-class population across the globe and due to fast fashion. Due to quicker style changes and increased number of collections per year and often at a lower price, the clothing industry is showing growth in terms of sales. The technological process of conventional apparel design and production processes can be divided mainly into two parts. The first one is the design part and the second involves the production of clothing.

3.1.1 Apparel Design

The anthropometric data of human beings differ from each other. Therefore, while designing apparel for mass production, it is important to know for which market the apparel product is supposed to be designed. The size medium in Germany is different from the size medium in China. Human body proportions are different between different populations. Therefore, there is no universal size, which fits all. There are various sizing systems in the apparel industry that are used by apparel brands to launch into respective markets.

The main aim of the sizing system is to establish a standard size chart system that can be applied to the pattern design methodology to be used in the construction of garments. [43]. These sizing systems are the result of statistical data collected over time and are used for the sizing systems for example the size Germany is the representative result of measurements of Germany's population.[44]

The clothing industry increasingly prefers to use computer-aided design (CAD) techniques for both fashion design and pattern creation as it offers greater efficiency and time-saving solutions to many complicated tasks as well as facilitating Internet-based communication amongst designers, manufactures, and retailers. Specialized 2D CAD software, including packages such as *cad.assyst* (Assyst), *Modaris* (Lectra), *Accumark 2D* (Gerber), *Master Pattern Design* (PAD System), *TUKAcad* (Tukatech), *GRAFIS* (Software Dr. K. Friedrich), *Audaces Apparel* (Audaces), *COAT* (COAT- EDV-Systeme) and *Fashion CAD* (Cad Cam Solutions), support geometrical pattern drafting from first principles using only anthropometric measurements of the target size and shape. In the apparel industry, the designs are made in digital form with the help of CAD software [45]. To check if the fit of the pattern designed the prototyping on that basis is done to check if the product is suitable for bulk production. It is usually an iterative work, which is performed until the desired results are achieved.

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An increasingly used alternative is the 3D fit simulation where the fabric properties are given to material in a software environment and 2D patterns are digitally sewn and draped on an avatar. In this way, the prototyping work is reduced to save time and resources. Modern 3D CAD software also offers 3D simulation during motion which makes the product realization even more realistic during the design phase. [46] There several 3D CAD solutions providers in the market, but Clo3D, Modaris v8, Tuka3D, and 3D Vidya are mostly used.

3.1.2 Apparel production

The apparel production starts from getting prepared for cutting fabric layers. The process of cutting starts from the lay planning for cutting. The cutting lay plan or commonly known as a marker is generated in a way that maximum efficiency of fabric lay is achieved to reduce the fabric wastage as much as possible. During the laying of cut parts on a marker, the grainline of the cut part must have to be considered. This cutting lay planning is carried out in combination with 2D CAD software which was prior used to design pattern pieces. The cutting department receives the fabric from the processing department or some outsource vendors. The fabric inspection of the fabric must have to be performed before the fabric is layered for cutting and this process takes place in the folding/inspection department of fabric processing. The fabric inspection takes place according to the following used pointing systems.

- 10-point system
- 4-point system

Each fabric roles received by the cutting department also receives information about the faults of fabric roll. The faults are also made visible by some sort of identification and temporary mark at fault locations. This information is required during lay spreading. As these faults are not allowed to be visible on the finished garment. Therefore, the faults are removed during spreading and fabric ends are overlapped on predetermined ‘splice lines’ on fabric lay. In clothing production, the lay length is decided based on the number of garments required from a cut and the efficiency of the marker to keep fabric wastage to a minimum. After the lay planning has been done the fabric spreading is carried out. There are four spreading methods of fabric are known as zigzag. Left/left, right/right, and stepwise spreading. [47] The spreading is performed manually as well as with automatic spreading machines. Manual spreading is a physically demanding job. Computerized spreading can be performed by one operator. In computerized spreading famous technologies are from Gerber, Lectra, Assyst bullmer, and Tukatech. One of the main advantages of computerized spreading is the tensionless spreading of a wide variety of materials. The cutting is performed either manually or computerized in apparel production. The efficiency and accuracy of computerized cutting are much more than manual cutting. The following important cutting technologies are in practice in cutting departments of apparel production.

1. Manual
    a. Straight knife
    b. Round knife
    c. Band Knife
    d. Die to cut

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2. Computerized
   a. Knife cutting
   b. Laser beam
   c. Waterjet
   d. Plasma

The use of manual or computerized technologies depends on factors like required garment production, the complexity of cut parts, type of material, labor costs and return on investment of technology acquisition. In the case of manual cutting, the marker printed on a paper by the plotter is fixed on the top surface of lay to serve as a guideline for manual cutting. An experienced worker follows the lines with the cutter and cut the fabric lays. In the case of manual cutting, the small particles of fibers fly in the air and have health concerns for the workers. The manual cutters of Eastman are considered quite reliable in the apparel industry. Band knives are usually used to cut small parts of garments like zipper flies, waistbands, etc.

Apparel companies with larger production volumes usually prefer computerized cutting. The computerized cutting is performed on a special cutting surface, which has a suction function that keeps the whole lay of fabric firm at its place while the cutting function is performed, and sucks the small particles of fibers produced during cutting. In the apparel industry usually, knife cutters are used to perform CNC cutting. Famous CNC cutting technology suppliers are Lectra, Gerber, Tukatech, and IMA. It has been observed that lately Chinese companies are also getting a good share in automatic cutting in the Asian apparel industry due to their price competitiveness as compared to European and American suppliers. Other cutting technologies like laser, waterjet, plasma are used for special materials. After the cutting has been performed, the cut parts are grouped according to their sizes and labeled accordingly for the sewing process.

In case if there are embroidery on any particular cut part e.g. a logo or any other design, the particular cut parts are sent to the embroidery section where multi-head embroidery machines are used to do this process. Famous embroidery machines in the apparel industry are from Tajima Group which offers single head and multi-needle/head machines (up to 40 heads).

The sewing department in apparel production involves most of the human resources than any other department of clothing production. There are three different production systems in practice in apparel production known as progressive bundle system, unit production system, and modular production system [48]. In the apparel industry is however progressive bundle system and unit production system is mostly in practice. In the progressive bundle system, the cut parts are moved in form of a bundle system from the work station to work station. A simple T-shirt has 4-5 simple sewing operations to complete it but a relatively complex product e.g. five-pocket jeans may at least 25-30 sewing operations before it is sewn. For an efficient production line, the idle time of the sewing operator must have to be avoided. This means that every sewing operator at every operation is required to have enough amount of work at his/her operation. Therefore, the line balancing in the bundle system is very critical and difficult [49]. Here the time studies are important to avoid operational bottlenecks. In comparison to the bundle system, the unit production system works on the principle that the cut parts of a single garment move in the production line as one entity. There is an overhead system that is either moved with the help of a computer-controlled system and manually also. Each time the sewing operator has to take the relevant cut part from the chain, stitch it and hang it again for its movement to the next operation.

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These two systems have their advantages and disadvantages. In the bundle system, the inventory costs are much higher as a large amount of work in process (WIP) moves into the production line as compared to the unit production system. Therefore, a particular garment piece requires much greater time to finish from start to the end of the sewing production line. The lead time of production is much quicker than in bundle systems. This helps also to improve quality control by quick identification of faults at any production stage. The bundle system is preferred due to its cost and where style changes in production lines not very frequent. In a unit production system, the garment moves quickly between operation to operation and product lead-time is less than in a bundle production system. The system is computer-controlled. If there is a machine lockdown at any sewing operation due to any reason, its computer system will automatically divert the workload to other operators to maintain a smooth production flow. The rectification of any production problem at a quality check is also efficient because it is identified quickly due to faster movement production between operations. The data generated is used to make reports, transparent production status, and operator salaries too. The main disadvantage of the unit production system is that it is expensive to install because it requires a hanger system with chips and sensors, a push button system at every workstation, and software. An especially trained workforce is required which can efficiently deal with the infrastructure. Proper preventive maintenance of equipment is required to keep the system running. Famous unit production systems are Eton, SmartMRT, Euratex, and Tuka INA.

Types of sewing machines in sewing production depend upon the type of product being produced in the sewing industry. There are automatic sewing operations are performed in the sewing industry for the reproducibility of sewing operations to realize mass production. These sewing machine automation are usually performed on operations like:

- Pocket setter
- Pattern seamer
- Bartacks machines
- Buttonholes machines
- J-stitch (on zipper fly)
- Leather patches seamers
- Belt Loop attaching machines
- Bottom hems

It has been observed that in the woven clothing like formal shirts, pants, etc the use of lockstitch (class 300) sewing technology is more than other stitch types (chain stitch, cover seam, overedge). In knitwear, the use of chain stitch is relatively more than lockstitch. It can be attributed to the nature of the fabric used in knitwear because it is usually stretchable and needs a stitch type which is also flexible. In sewing production, the machine features like needle positioning during and after sewing operation, automatic thread trimmers, and the location of sewing at the seam start and end are also important for production efficiency, because it can reduce the later work in apparel finishing. The sewing machinery manufacturers are presenting universal robots in combination of machines and man. Sewing machinery manufacturers are presenting their concepts sewing stations where a universal robot is working with a machine operator side by side and feeding multiple machines. This is a tendence which can be observed in future due to decreasing prices of robot technology and increasing labor costs. [50]

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After the sewing has been finished, the garment goes to the finishing department where it is prepared for final shipment. The use of automatic universal finisher for shirts and pants are used to perform pressing. The use of simple pressing with steam function leaves burn/shiny marks on the fabric surface, which are more visible on fabrics with darker shades. With automatic finisher, different programs can be chosen according to the type of material and finish required. The company Veit GmbH is a market leader in finishing technology. Its latest version of the "Shirt Finisher" can finish a shirt in 10 to 15 seconds which can replace manual tasks and improve production and labour costs. Despite the advantages of automatic finishers on manual pressing, the comparison of the price is also important. A simple pressing station is way cheaper than the automatic finisher. Factors like labor cost and energy conservation are chosen while choosing between the technologies usage.

Certain types of finishes are applied on sewn garments which are termed as garment wet processing. In this process, garments are given a worn look (e.g. in jeans) by desizing, enzyme treatments, overdyeing, tinting, stone washing, resin finishing and softening. This production stage involves a lot of water in apparel production which raises questions on the environmental impacts of clothing supply chain. The machinery manufacturers are bringing new technologies like Tonello laser blaze technology which can give the garment an aged look by laser and key brands like Levis are introducing their Water Less Program to make their garments more environmentally sustainable.

All the dirt marks, hanging thread has to be removed before the garments are finally pressed. The buyer's packaging instructions, barcodes, price tags, and accessories are attached to the garment before the final quality check. After the final packaging, the garment pieces are packed into carton as per the buyer's instruction. The final inspection is carried out either internally or by the buyer's quality team which performs the final quality audit. After the clearance from the final inspection, the product is ready for shipment.

Digitalization in the apparel industry is taking place. To keep the sewing production line in full view, German sewing machine manufacturer Dürkopp Adler has presented its Qondac system, which keeps the record of each stage of the production stage and its efficiency in real-time. The productivity of sewing machines and their status can be analyzed and machines can also be maintained virtually. The interface can be connected with the ERP system of the organization e.g. SAP to exchange the status of production to other relative departments. [51]

3.2 Best Practices – New technologies and training methodologies in the Apparel sector

Name of good practice	Efficient use of resources, productivity increase
Type	Application of new technologies
Topic	Safety garments
Description (Objectives, results etc.)	UVEX Group which specializes and safety clothing and equipment has been a success story about how manufacturing can stay in Europe and make good business. The innovation idea and use of state of the art technology for their manufacturing in Ellefeld, Germany has let the UVEX Group show on the average annual growth of 5 % in the last 3 years.
Evidence of success	At their Ellefeld location, a state-of-the-art cutter and an automatic spreading machine with two twenty-meter-long conveyor spreading lines were put into operation. Through this measure and a CAD layer optimization, the fabric is used much more efficiently. The cutter does not need a gap between cut parts (zero millimeters), the layer optimization nested the cut parts optimally for the least possible waste of the fabrics for personal protective equipment and workwear fabrics. The long laying lanes also increase efficiency. According to the company statement, the latest cut technology, which has been in use in Ellefeld since October 2017, has saved tens of thousands of meters of fabric a year that no longer has to be produced (and purchased). The sustainability balance is now significantly improved. Besides, after the cut, only the finished cut pieces (without waste) are sent, there are no further CO2 emissions during transport. The measure will also relocate jobs back to the manufacturing site in Germany
Funding sources	Private
Contact (address, email)	serviceteam@uvex.de
Web site	https://www.uvex-safety.com/de/uvex-safety-group/wie-wir-arbeiten/umweltfreundlich/#c180707
Key Relevant information for ICT-TEX project	The use of the latest technology can result in apparel production save a lot of resources in the longer term. The use of latest technology is long term investment in company processes and maybe a financial burden on company books but this best practice example shows that how by using the latest cutting technology help save the UVEX group thousands of meter of fabric which just get wasted in the cutting process. The fabric used for safety clothing is very expensive as compared to conventional clothing. Therefore, the rational approach by UVEX Group to invest in the latest cutting technology resulted in them to save their financial resources. They made also created a good impact on the environment by waste reduction.

Name of good practice	**European Clothing Action Plan**
Type	Technology transfer promotion
Topic	Sustainable clothing
Description (Objectives, results etc.)	The European Clothing Action Plan (ECAP) was an exciting project bringing environmental and economic benefits to the clothing sector. It was one of the first EU LIFE funded projects to address clothing sustainability. The project used the strategies of design for longevity, influencing sustainable action plans. The project was inspired to create consumer awareness of buying practices and used textile collection. As a result, Retailers reduced the environmental footprint of garments they sell by implementing sustainable fiber strategies, reducing certain fibers' emission factors, and changing high-level fiber compositions. Workwear retailers and brands worked alongside organizations in the textiles production chain to trial pilot fiber-2-fiber schemes, to increase the amount of recycled fibers in their clothing collections for recycling and re-use were increased by campaign activity and work with collectors and municipalities.
Evidence of success	Nine companies started an innovative pilot to recover fibres and turn them into new garments. Few successful examples are: Asos: denim jeans made with 17-20 per cent recycled cotton; Blycolin Group International: bedsheets made from fibres of recycled cotton-15 per cent post-consumer, 35 per cent industrial cotton waste, 30 per cent cotton and 20 per cent polyester; HAVEP: workwear aprons made from 10 per cent post-consumer recycled cotton, 10 per cent industrial cotton waste and 55 per cent recycled PET and 25 per cent cotton; JBC: denim made from 20 per cent postconsumer jeans, 79 per cent bio cotton and 1 per cent elasthan; Moodstreet: trials with jackets taken into full production which included polyester made with 43 per cent post-consumer and 57 per cent virgin material; Schijvens Corporate Fashion: workwear t-shirts, polo shirts and blouses made from 30 per cent
Funding sources	EU – LIFE program
Year	2015 -2019
Contact (address, email)	ecap@wrap.org.uk
Web site	http://www.ecap.eu.com
Key Relevant information for ICT-TEX project	The outcomes of the results are in accordance with the sustainability aspects of the project. The practices used by industries to utilize the waste into their production department not just saved valuable resources but also contributed to the environment at a very considerable rate. It is also very interesting how the project partners engaged the younger generation in the project via different campaigns. ICT-TEX project is aimed to engage the younger generation in the field of clothing and textile. The strategies used by ECAP can provide incredible insight into how young people have interacted and how they participated in the project.

4. DESIGN AND PRODUCTION OF KNITWEAR STATE OF THE ART

4.1 Technological processes in Knitwear Design and Production

The Textile and Clothing industry is among the largest industrial branch in the EU. The industry accounts for some 5% of employment and 9% of companies in the total EU manufacturing sector, as well as over 4% of total merchandises' exports [52]. The country with the largest production in the EU is Italy and more than half of the EU employment is concentrated in Romania, Poland and Portugal. Five EU countries have increased their exports of knitwear to Russia within 18-49% in 2018 [51]. At €20.3 billion in value, knitwear is the largest apparel product category imported into the EU, accounting for 12.1% of all apparel imports [53]. Active sportswear, fashion sportswear, swimwear and dresses are the fastest growing product categories by import value (import value grew on average by 13,8% each year).

Knitting as one of the methods for forming a textile structure ranks second after weaving. The skeleton of fabric construction is composed by loops intertwined with each other. In some groups of machines, working on the weft principle of knitting, one thread is enough to form a knitted structure. Except loops with modern knitting automats could be knit and other structural elements such as floats, tucks, split stitches, as well as transferring loops from one needle to another.

The ability to transfer stitches by flat knitting machine allows creation of structural effects in the fabric like aran and cables, and also getting cut details and fully knitted 3D products directly. Both technologies, 2D shaped fabric knitting technology and 3D knitting technology lead to short production process, high knitting efficiency and material waste reduction. Only by fully fashion technology there is a lack of sewing threads on the fabric surface. The 3D knitting technology could also be applied to other groups of knitting machines.

The production cycle of knitwear goes through the steps [54] underlined in the Figure 1.

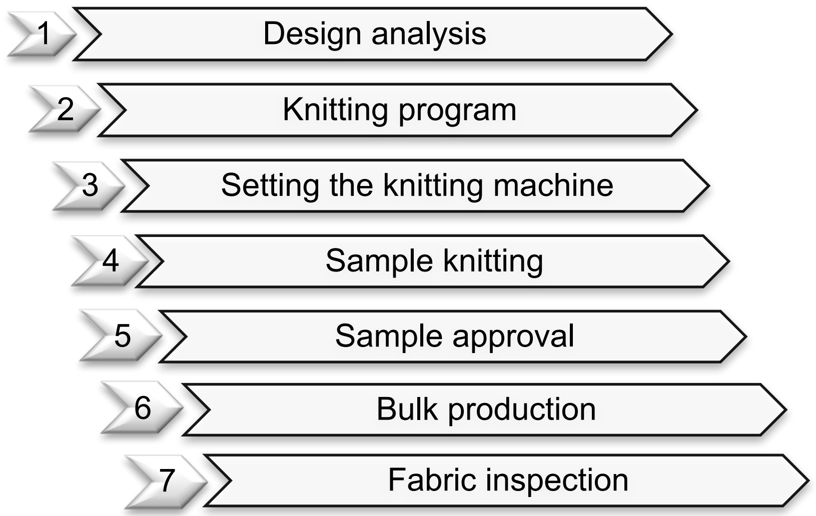

Fig. 1 Process flow of knitting section

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In the first step of the production process are defined the cut of the product and the knits within each zones. In the presence of a sample to work on should be done a design analysis and the parameters of the loop structure should also be determined. In some cases, there is only a sketch of the designer. Then this step is significantly more difficult to perform, as the technologist must “read” the idea of the designer. In the second step, the program for controlling the knitting machine is made using the data from the previous step. According to several authors the technical developments in the knitting sector have been hampered by two factors: the skills of programmers and technical knowledge of designers [55-59]. This gap appears to widen with the advent of more complex technology. Taylor and Townsend [58] concluded that advancements in technology have led to a wider skill gap between the knitwear designers and the technology.

Furthermore, it is reported that even after 20 years of complete weft-knitted garment machines, the technology is not being used to its full commercial potential [58]. The challenge is to create new epistemologies in terms of effective processes in design development for knitwear; increasing the technical knowledge of the designer and the programming skills of the technician will ultimately result in an increase in innovative functional design in both apparel and beyond. The German company Stoll has proposed partially solution to this problem by including additional functionalities in the software of the designers, suggesting the limitations that must be observed (for example, the maximum number of colours that can be used in knitting intarsia or jacquard).

In the third step, the yarn is loaded on the machine and the necessary machine settings are made. A test sample is then knitted to establish the exact knitting parameters. The experience of the technologist is of great importance here. The author in [55] defines this as a second problem in knitwear production: the time factor. In most cases, it is needed to knit more than one sample, which requires a lot of machine time.

After approval of the sample, the bulk production is started. Then only the technical problems in the machines are monitored, which should be removed timely, as they are directly related to the knitted fabric defects. Finally, the quality control of the finished products is done.

4.2 Best Practices – New technologies and training methodologies in the Knitwear Sector

Name of good practice	OPIC 2014-2020 "Introduction of energy efficient production equipment".
Type	Application of new technologies
Topic	Knitwear
Description (Objectives, results etc.)	Many examples of good practices applied in Bulgarian knitting companies could be cited. In this type of textile production they are constantly renewal of the machine park and maintaining the latest versions of software products, as the development of innovative technologies is directly related to them. For instance, "Brod Luky Ltd" EOOD specializes in the production of outerwear (sweaters, cardigans) implements the project OPIC 2014-2020 "Introduction of energy efficient production equipment". **"BROD LUKY" LTd** is equipped with modern machines including 40 Shima Seikiknitting machines - 5/7 and 12/14 gg, ready-made machinery of the leading companies Juki, Comp1ett, KMF, Duerkopp,Rimoldi, Brother,ironing and finishing machines NepiOtello, andPrimus.160 employees are engaged.
Evidence of success	Not only the production capacity is expanded, but also the energy efficiency and the quality of the products are increased, the costs per unit of product are reduced and the economic efficiency and the competitiveness of the enterprise are increased.
Funding sources	EU Fund – OPIC program
Web site	http://www.brod-co.com/c/en/about-brodco/about-us/
Key Relevant information for ICT-TEX project	The introduction of new machinery and the ability to get access to public funds are important strategical aspects to assure a better company positioning in the market.

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5. DESIGN AND PRODUCTION OF TECHNICAL TEXTILES STATE OF THE ART

5. 1 Technical and Smart Textiles industry

Technical and smart textiles are textiles that are created for a specific functional need, and hence have a non-aesthetic purpose. Technical textiles include textiles aimed for use in healthcare, automotive, geo-technical applications, agriculture, and protective clothing. They require specialized production machines and chemistry.

Following sectors are distinguished within technical textiles [60,61]:

- Buildtech - Construction textiles
- Agrotech - Textiles used in agriculture
- Clothtech - Technical textiles for clothing applications
- Geotech - These are used in reinforcement of embankments or in constructional work
- Hometech - Textiles used in a domestic environment - interior decoration and furniture, carpeting, protection against the sun etc.
- Indutech - Textiles used for chemical and electrical applications and textiles related to mechanical engineering
- Medtech - Manufacturing and application of medical and hygienic textiles
- Mobiltech - Textiles used in the construction of automobiles, railways, ships, aircrafts and spacecrafts
- Oekotech – Textiles for environmental protection applications
- Packtech - Packaging, silos, containers, bags, lashing straps, canvas covers, marquee tents
- Protech - Technical protective fabrics to improve people's safety in the workplaces
- Sporttech - Textiles for shoes, sports equipment

They target high volume markets as well as niche applications. Products consist of finished textiles such as clothes, uniforms, bags, belts but also yarns, ropes and fabrics.

As a special extension, smart textiles embed a further electronics component into the textile, which can be for MedTech, Buildtech, or any of the other technical textiles. Furthermore, they are used in normal apparel.

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Smart textiles may include 5 functions: sensors, actuators, data processing, energy supply and communication. These functions may be ensured by miniaturised electronic devices, flexible or stretchable electronic devices, or made entirely from fibre structures. Several generations of smart and functional materials and smart textiles are distinguished [60]:

- First generation: textiles with added functionalities, which make them smarter and are always active (e.g. antibacterial, UV PPEs, plasma treatment, conductive, stain resistant, ..)
- Second generation: passive smart textiles, able to perceive data on condition or stimuli of the environment, such types of textiles contain only sensors; include e.g. PCM, colour change materials, shape memory
- Third generation: active smart textiles (comprise both sensors and actuators), e.g. temperature regulating, bioreading (heart rate, oxygen, muscle tension, …), light emitting, antenna, ...
- Fourth generation: ultra-smart textiles (able to sense disparate data types and forecast and feed external conditions without preliminary tuning), e.g. space suit, musical jackets, …

Technical textiles are an ever increasing part of the EU textiles production, taking 22% in 2011, which increased to 26% in 2017 [62]. Most technical textiles are produced in Italy and Germany (more than 4.5 billion Euro each), with France a distant third at 2 billion Euro. These three contain 60% of the EU production of technical textiles, worth, 24 Bn Euro [63]. The long term trend of technical textiles is positive in most EU countries. Overall, the TechTex sector is a major contributor to the EU textile industry, with 27% of the textile industry turnover. Although Italy and Germany are the leading producers in the EU, TechTex is gaining importance all over Europe, and it has a leading role among the EU textiles exports. In this, medical textiles and non-wovens are the main TechTex exports of the EU.

As technical textiles and smart textiles are so diverse, no unified history of it can be sketched. Mostly, as chemical understanding of polymers and technical production processes increased, technical textiles were a logical consequence, with ultra strong fibers, heat resistant fibers, conductive fibers, carbon fibers and other high-tech fibers as trailblazers for the TechTex applications.

In order to work with TechTex, several important skills must be present:

- Ability to simulate the effect of the specialized fibers, yarns and fabrics for the use case at hand
- Ability to verify the properties of the resulting textile product
- Ability to construct the end products
- Ability to program the smart textiles
- All of these require specialized skills. Digital tools are very worthwhile in the design process: concept, materials to be used, textile structure, position of the smart devices. For wearables, comfort and fit may be additional features.

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5.2 Technological processes in Technical and Smart Textiles Design and Production

5.2.1 Simulate the effect of the specialized fibers, yarns and fabrics for the use case at hand

In order to understand the effect of the TechTex in the engineering application at hand, physical simulation is performed. Tools like Abaqus, OpenFoam, Fluent, SolidWorks, TexGen, MatLab, Python, …. are used to investigate the interaction between the textile and the engineering application. For example:

A geotextile used in a waste disposal site must help maintain the structural stability and must have a low water permeability. Interaction at the waste disposal site is studied to determine thickness and construction of the geotextile needed.

A fire protection layer and water absorption layer for use in a fireman suit is modelled to determine the effect of a fire at 4 m distance, to determine the thickness of the layers and their placement in the suit to offer an optimal protection to the fireman.

A conductive yarn/fabric used in a patch antenna constructed from textile materials is modelled to obtain the correct size to allow the highest possible bandwidth with these materials

The properties to be designed may be very broad, as illustrated by the examples above. Overall very few standard software is available. Most of it has been developed by researchers, causing it to be very specific for a given functionality, not very transparent nor user friendly, requiring high calculation times and several often expensive licenses.

5.2.2 Verify the properties of the TechTex product

Technical textiles are created for their function. They hence have to satisfy strict regulations, rules and standards. Standard testing and certification is required, with quality assurance. Good understanding of statistical tools and software packages is required to interpret the results of the testing. As for statistics, the data analysis tool in spreadsheets (e.g. Excel) will do in many cases.

5.2.3 Construct the end product

The skills required in construction of technical textiles and smart textiles corresponds mainly with the tools arising in standard apparel: CAD software to perform and simulate the weaving / knitting / embroidery needed for the construction, as well as 3D product design and 2D pattern generation. An extra complication for technical textiles are the many different binding techniques that arise in these products: gluing, lamination, sonic bonding, thermal bonding, sewing, soldering, … [64].

A good grasp of these binding techniques is required.

5.2.4 Programming of smart textiles

The smart textiles on the other hand, also require programming to capture the output of the sensors, and use this to determine the reaction required. This can be via actuators like light, buzzers, motors, …, but also via communication of the results through an embedded antenna to the cloud. Textiles engineers need to master the concepts of programming (Arduino IDE, C++, python) in order to unlock the full potential of smart textiles.

Extensive training of the future textile engineer is required in order to fully enable the potential of technical textiles, not only in the development of new technical textile fibers and coatings, but also in the use of modelling tools to determine the effect of the TechTex on the final product, the use of CAD software to construct and visualize the product, the use of statistical software to test the efficacy and do the quality assurance of the products, and the use of programming tools to program the function of the smart textiles. At UGent, the master in Master of Science in Sustainable Materials Engineering contains the major Polymers and Fibre Structures, were students are trained to perform the role of the future textile engineer as described in this section [65].

For SME's in house digital design is often very challenging. Therefore it is important for universities to provide them support in this respect.

5.3 Best Practices – New technologies and training methodologies in the Technical and Smart Textile Fabrics sector

Name of good practice	TPU Evolution
Type	Application of new technologies
Topic	Technical and Smart Textiles
Description (Objectives, results etc.)	TPU Evolution is a solution for the creation of bags, shoes, tapes, suitcases, technical fabrics and fabrics for personal protection, outerwear, knitwear, indoor and outdoor furniture and unique accessories of superior quality. Depending on the type of finishing, one single product allows for different effects on the fabric. Fabrics created with this product have an incredible peach hand feel, softness, lightness, rubber effect and elasticity. By increasing the application temperature it is possible to obtain a rubber or lamination effect. TPU gives excellent resistance to abrasion, impact, germs, chemical agents, oils and fats and hydrolysis. TPU Evolution has also anti microbial properties, UV stability and extraordinary color solidity. All of this gives incredibile performances to the products.
Evidence of success	Evolution Mask is the first filtrating face mask made with the innovative polyurethane yarn TPU Evolution, in combination with the high performance bacterio-static poliammide 6.6 Qskin by Fulgar with silver ions inserted during spinning, making the yarn bacteriostatic. Thanks to their innovative TPU Evolution technology Coatyarn is became the leader company in Europe for production of bacterio-static fabric for mask thus obtaining greater earnings and creating a new business department in their company.
Funding sources	Private
Year	2020
Contact (address, email)	info@coatyarn.com
Web site	https://en.coatyarn.com/evolution-mask
Key Relevant information for ICT-TEX project	Yarn and Smart and Tech textile Innovation, quality and potential of its products. The perfect use of their machine park, made up of machines with finenesses between 18 and 3.

Name of good practice	AI-Textiles TOP DOWN CLUSTER PROJECT
Type	Innovative training methodology coping with the sector technological innovation
Topic	IntelligentTextiles
Description (Objectives, results etc.)	The goal of the AI-Textiles project is to lay the foundations so that companies belonging to the cluster can develop specific skills e advanced in the field of intelligent fabrics and AI technologies, starting from which ideas, solutions, and innovative products can develop in response to the growing ones market demands. The project aims to train the companies involved with an approach of "learning by doing" for the development of new products and for the improvement of processes already in place, so that companies belonging to the cluster can, through innovation, increase its competitiveness and access new markets. 1. on the potential offered by smart fabrics for the development of goods / services; 2. on Italian and / or European success stories in the field of sensors wearable and not; 3. on the potential offered by artificial intelligence for the analysis of the data collected by the sensors embedded
Evidence of success	10 online webinar produced, 13 enterprises that since the beginning of the project are involved directly on the Ai-textile project training programs, 8 public events promoted
Funding sources	Sardegna Ricerche POR FESR 2014/2020 Cluster programme
Year	ongoing
Contact (address, email)	luca.piras@diee.unica.it
Web site	https://ai-textiles.diee.unica.it/
Key Relevant information for ICT-TEX project	a) information, training and awareness raising of participating companies on potential offered by artificial intelligence applied to sensor networks on fabrics (woven and non-woven) and the combination of data, through the organization of seminar and training events; b) definition of scenarios and business models in order to make one available series of information on the applications and use of smart fabrics in real projects and potential market opportunities: • analysis of the products and services created through the application of a network sensors in fabrics in the rest of the world; • analysis of business models. c) transfer of knowledge and skills through the conception and realization of prototypes of innovative projects and products.

Name of good practice	Company: Bekaert Deslee
Type	Application of new technologies
Topic	Technical and Smart Textiles –BD Cloud
Description (Objectives, results etc.)	The online BD Cloud is your selection platform for BekaertDeslee fabric designs and bed concepts. The tool reveals a virtual showroom with all BekaertDeslee fabric designs, a concept library that inspires with trendy mattress concepts, an overview of all our brands and innovations, and so much more. Through this platform, fabrics like Vitalize® is available, which is a mattress textile with incorporated Far Infrared Technology. This high tech yarn is made from polyester fibers, permanently linked with ceramic mineral crystals. Vitalize® textiles have the ability to reflect Far Infrared Rays back to the body that generated them. Other specialized fabrics are Coolmax, Mosquito Protection, and more.
Evidence of success	Through the online BD Cloud, Bekaert Deslee can optimize collaboration with their Business customers. It forms the next level of doing B2B. is also a co-creation platform, where you can easily collaborate with our Sales and Designers. The integration of different design and manufacturing steps into one application in the cloud helps to streamline the design process and save both time and money. The 3D configurator in the BD Cloud allows to configure any bed concept, save the configurations and refine them afterwards - just in a few simple clicks. The greatest advantage of this tool is that it is available in the cloud and can be reached from anywhere in the world. New features are being added all the time, like a pillow customizer, improved manuals, … .They have 2500+ employees.
Funding sources	Private
Year	2018
Contact (address, email)	https://www.bekaertdeslee.com/en/contactinfo@bekaertdeslee.com
Web site	https://www.bekaertdeslee.com/en/home
Key Relevant information for ICT-TEX project	Bekaert Deslee is an example of a business that takes innovation seriously. BD Cloud is an example of the future of interaction between a technical textile company and its customers. They also founded an Innovation & Design Center (IDC) in Belgium which houses a 'pool of talent' that makes co-creation a reality through the BekaertDeslee Academy, in a new 3.575 m² building . In 2020 they won the Bizon Award with their collaboration with https://manual.to on a project on digitization of work instructions. This offers a new way of providing technical manuals, in order to translate the tasks of the workers into instructional online resources, allowing to transfer knowledge between workers.

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Name of good practice	Company: Ohmatex
Type	Application of new technologies
Topic	Technical and Smart Textiles - Ohmatex washable connector.
Description (Objectives, results etc.)	Ohmatex wants to standardize smart textile connectors, to bridge the textile components with detachable electronics parts, typically the microprocessor. It consists of a male part that can be integrated in a textile through soldering to an Ohmatex conductive ribbon, and a female part which can be fitted with a customized PCB, and fixed to a fabric.
Evidence of success	This connector formed the basis for the launch of the thinnest textile micro USB cable. In 2019, the company obtained with their technology a large space contract with the ESA. Under the project name GAIN (Garments for Advanced Insights), ESA has signed a contract for 1.04 million EUR. The project focus is the development of training tights with integrated sensors and wearable computing that can help astronauts to train effectively. The training tights are scheduled to fly to the International Space Station around 2021.
Funding sources	Private
Year	2014
Contact (address, email)	koe@ohmatex.dk
Responsible person	CEO Klaus Østergaard
Web site	https://www.ohmatex.dk
Key Relevant information for ICT-TEX project	Standardization of smart textile connectors is an important part going forward, if we want smart textiles to fully penetrate the market. Ohmatex is very active in this important area. They mainly operate as a consulting form for companies wanting to put smart textile in the market

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Name of good practice	Smartx – European smart textiles accelerator
Type	Technology transfer promotion
Topic	Technical and Smart Textiles – SmartX EU project
Description (Objectives, results etc.)	SmartX is boosts smart textiles innovation to develop an end-to-end smart textiles manufacturing value chain in Europe and help drive promising prototypes faster to market. Building a strong sustainable community will be the underlying long term objective of the Programme, to foster interaction and collaboration within the European smart textile industry. During the 3-year programme 3 calls for funding will help support up to 40 individual projects with a total budget of €2.4 million. SmartX unites eight clusters two Research and Technology Organisations (for specific technological assistance) and three innovation support entities (for professional project initiation, implementation and follow-up): together they will reach out to over 60,000 SMEs all over Europe to build a dedicated community around SmartX.
Evidence of success	3 calls to SMEs , last in November 2020 18 events, in location and online Web based collaboration platform.
Funding sources	EU – Horizon 2020 programme
Year	Started 2019 ongoing
Contact (address, email)	lutz.walter@textile-platform.euhello@smartx-europe.eu
Responsible person	Lutz Walter, ETP Secretary General
Web site	https://www.smartx-europe.eu
Key Relevant information for ICT-TEX project	a) Information and training to companies working in smart textiles. This to share knowledge and prepare companies for the calls for projects. b) Support given to the SMEs from one of the 13 partners: Textile ETP (Belgium), Euramaterials (France), Citta Studi Spa (Italy), Högskolan I Boras (Sweden), TEXFOR (Spain), CITEVE (Portugal), DSP Valley (Belgium), CITC EuraRFID (France), Deutsche Institute Fur Textile (Germany), CENTEXBEL (Belgium), Steinbeis Innovation (Germany), Institute Français de la Mode (France), Sourcebook (Germany) c) transfer of knowledge and skills through the conception and realization of prototypes of innovative projects and products

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6. FINISHING, PRINTING AND FUNCTIONALIZATION PROCESSES STATE OF THE ART

6.1 Finishing and Printing Textile Processes

The textile industry belongs to one of the most complicated industrial chains in the manufacturing industry. It is a fragmented and heterogeneous sector dominated by SMEs, with a demand mainly driven by three dominant end-uses: clothing, home furnishing and industrial use. Description of the textile production is complex because of the wide variety of substrates, processes, machinery and components used, and finishing steps undertaken. Different types of fibers or yarns, methods of fabric production, and finishing processes (preparation, printing, dyeing, chemical/mechanical finishing, and coating), all interrelate in producing a finished fabric [66].

6.1.1 Wet processing

Wet processing includes several steps that involve dyeing and printing of fiber, yarn or fabric, along with a variety of finishing steps that provide desired characteristics to the final product (for example woven fabric).

The textile industry uses large quantities of electricity and fuels. In spun yarn spinning, electricity is the dominant energy source, whereas in wet processing the major energy source are fuels, meaning that the *energy efficiency is an important component of a company's environmental strategy*. Such strategy include energy-efficiency methods for process optimization as well as complete replacement of current machinery with state-of-the-art new technology. Although the introduction of new technology in the beginning requires greater financial investment, if all the benefits of the new technologies, such as water savings, material saving, less waste, less wastewater, less redoing, higher product quality, etc. are taken into account; in long term the new technologies are more justifiable economically [66].

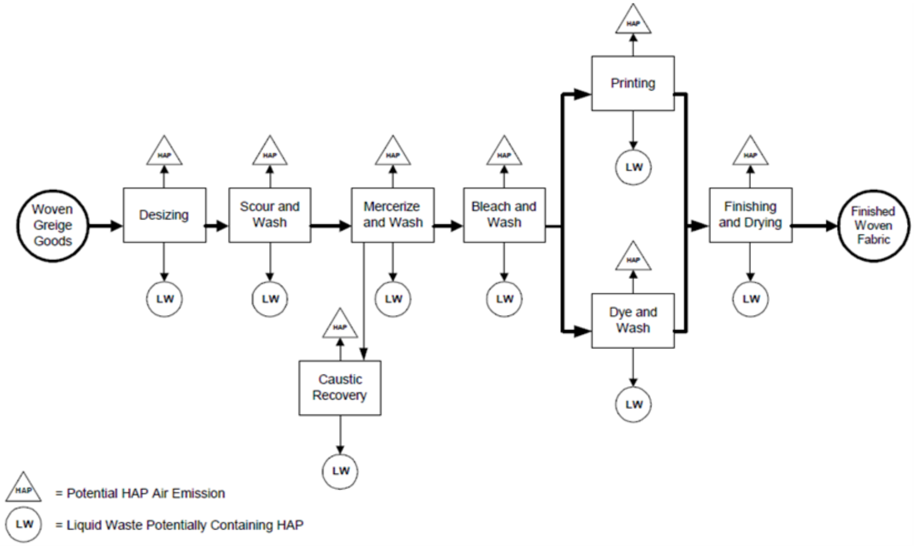

Figure 2 Schematic of Woven Fabric Wet-Processing Operations

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6.1.2 Preparatory processes

Prior to dyeing/printing the fabric pass different preparation processes: heat-setting, desizing (woven only), singeing, scouring, bleaching, and mercerization (cotton only), using different types of equipment and chemicals. Desizing, scouring, and bleaching operations involve the removal of impurities and can be done on various types of washers and steamers. Mercerization is a process on cotton fabrics, done for various purposes such as improving dye affinity/uptake, improving strength, brilliance, etc. Drying operations are generally done using ovens, cylinder dryers or stenter frames [67].

Desizing, scouring with strong alkali and bleaching are typical pre-treatment steps in cotton finishing plants. Scouring and bleaching steps are often combined. With the use of enzymes the alkaline scouring process can be replaced. Due to the better bleaching ability of enzyme, scoured textiles bleaching can be done with reduced amounts of bleaching chemicals and auxiliaries. With *enzymatic scouring*, sodium hydroxide used in common scouring is not necessary. In term of quality, the enzymatic scouring will achieve good reproducibility, reduced fiber damages, good dimensional stability of fabrics, increased colour yield, and a soft fabric texture. The rinsing water consumption for scouring can be reduced to 20% of traditional techniques. If the enzymatic scouring is combined with bleaching with reduced concentrations of peroxide alkali, the rinsing water consumption can be reduced to 50% of traditional techniques; hence saving energy. This method can be applied to cellulosic fibers and their blends (woven and knitted goods) in continuous and discontinuous processes. Existing machines (jets, overflows, winches, pad batches, pad steamers and pad rollers) can be used for this purpose. This method is applied world-wide, especially in German finishing plants. The method offers savings in water, time, chemical auxiliaries and energy, depending on on-site conditions [68].

For removal hydrogen peroxide after bleaching *special enzymes (peroxides)* which catalyze the reduction of hydrogen peroxide to oxygen and water may be used. No side reactions with the substrate or with dyestuffs occur. Peroxides are completely biodegradable. Rinsing steps after peroxide bleaching can be reduced with enzymatic peroxide removal and its application is possible in a discontinuous, semi-continuous, and continuous production methods, in new and existing installations. Savings in water and energy consumption can be in the range of 6-8% of production costs [69]. The Skjern Tricotage-Farveri textile plant in Denmark implemented this measure and achieved 2,780 GJ/year in energy savings and 13500 kl/year in water savings.

The *cold-pad-batch method* can be used for pre-treatment in dyeing and finishing plants. In this method, alkali/hydrogen peroxide is embedded into the fabric using a padder, and the fabric is then stored to allow complete reaction between the fabric and chemicals prior to rinse. As much as 50% of the water and electricity, and 38% of the steam used in pre-treatment can be reduced with this method. However, cold-pad-batch technology is limited to woven cotton fabrics [70].

6.1.3 Dyeing and printing process

In *Cold-pad-batch dyeing* method energy consumption can be reduced from about 20.9 MJ/kg of dyed fabric for winch dyeing to under 4.6 MJ/kg of dyed fabric for cold-pad-batch dyeing with beam washing (a reduction of over 350%). Chemicals reduced due to the implementation of cold-pad-batch dyeing are salts, lubricants, levelling agents, antimigrants, fixatives, and defoamers.

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Other benefits associated with such dyeing include savings on water and labour. Water consumption for pad-batch dyeing with beam wash-off is only 10% of the amount used to dye fabrics using winch machines (a 90% reduction). Although it is a cost-effective way for facilities to apply reactive dyes to cotton and rayon, this method may not achieve the desired final fabric properties for all cottons. Cold-pad-batch dyeing is also not appropriate for dyeing synthetic fabrics.

Microwave dyeing equipment employs microwaves for rapid, efficient and energy-saving dispersion and penetration of dyes and chemicals into fabric. Since microwave irradiation generates heat through dielectric losses, the heat is absorbed by objects having large losses, and thus fabric containing moisture is heated without heating of the surrounding air and equipment itself. Furthermore, in contrast to the case of moisture (dyeing solution) penetrating the fabric, the fabric itself becomes a steam generator through internal heating, and penetration and dispersion of dyes and chemicals occurs rapidly and uniformly, ensuring suitability for continuous dyeing in mass production. The capital cost including the construction cost is about US$450,000 [71].

Automatic dye machine controllers, which are based on microprocessors, allow control of process parameters such as pH, colour, and temperature. They control the dye cycle, including the amount of water utilized in the process, and hence the amount of water and pollutants discharged as effluent. Automatic host controllers include dye program management and reporting systems, on line scheduling, recipe management, and costs analysis (energy, dyes, and chemicals, etc.). Dye machine controllers have the potential to reduce the volume of industry effluents by up to 4.3%. A U.S. textile company, Amital, automated dyebath flow and temperature control in a new acrylic yarn production facility. This resulted in clean exhausted dyebath and, therefore, eliminated the need for post-rinsing. Hence, water, energy and chemical use were reduced. Another example is instrument upgrading from manual to computer control for a dyeing process implemented at Bloomsburg plants in the U.S. Since washing time after dyeing was controlled more precisely with automated instrumentation, water use fell by 28% and energy consumption was reduced by 16% [72].

In conventional rotary printing processes, an automatic dyestuff mixing kitchen for printing can result in savings of US$154,000 per year on wastewater charges, and pigment, energy and water consumption. The investment cost varies between US$23,100 and US$2,308,000, depending on the size and type of the system [73]. But lately, with speeds equalling and some instances surpassing rotary printers, textile inkjet printing holds a competitive advantage because it eliminates the screen preparation process and offers the ability to hold print information in a digital format up until production.

6.1.4 Finishing

Finishing refers to any operation (other than preparation and colouring) that improves the appearance and/or usefulness of fabric after it has been woven or knitted. Finishing encompasses any of several mechanical (e.g., texturing, napping, etc.) and chemical processes (e.g., optical finishes, softeners, urea-formaldehyde resins for crease resistance, etc.) performed on fiber, yarn, or fabric to improve its appearance, texture, or performance. The fabric is usually dried prior to finishing using either convective (hot air) or conductive (cylinder dryers) methods. Chemical finishing can be done on a continuous finishing machine (pads and stenter frames). Figure 3 shows a typical fabric dyeing and finishing process [67].

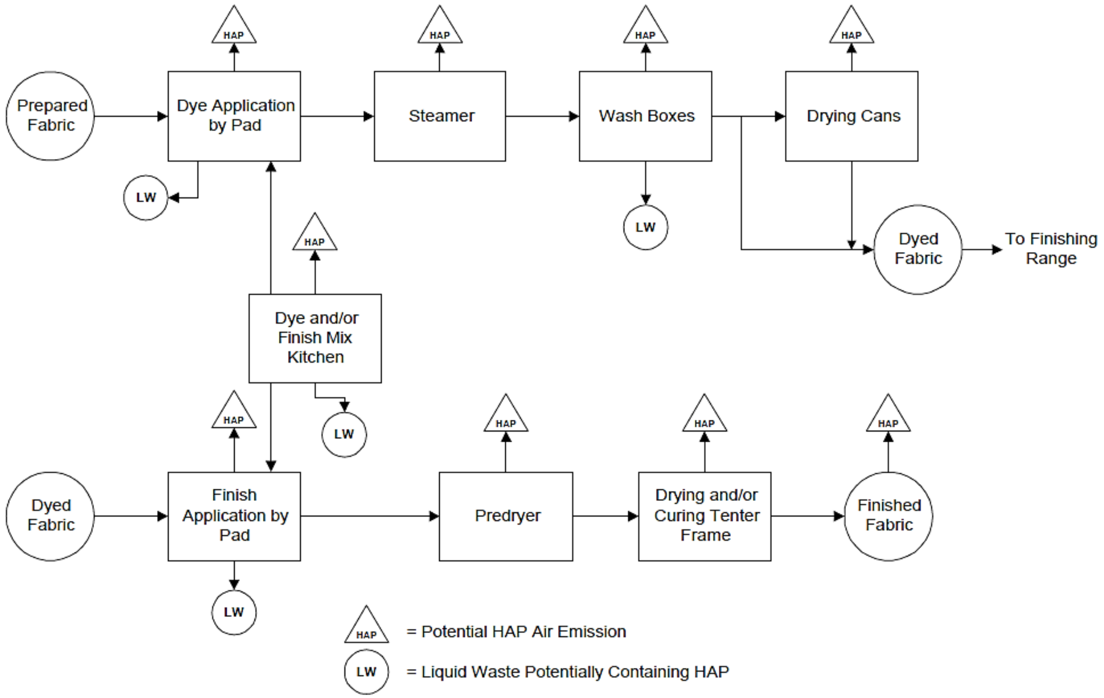


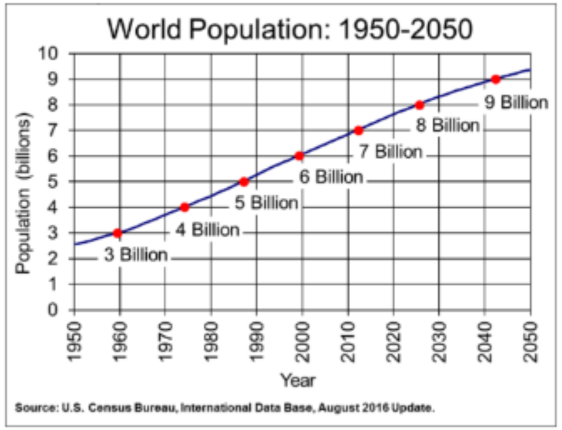
Figure 3 Typical Fabric Dyeing and Finishing Process [66]

In wet-processing there is also used more energy and water, and because of that recovering heat from hot rinse water is imperative. Large amounts of hot (up to 80° Celsius) water is used to rinse fabric or yarn. Plants may discharge a mass of rinse water up to thirty times the weight of the yarn/fabric that is rinsed. The heat from the rinse water can be captured and used for pre-heating the incoming water for the next hot rinse. This option provides the important ancillary benefit of reducing the temperature of the wastewater prior to treatment as well. However, many textile plants around the world are not recovering heat from their hot rinse water. To transfer the heat from the rinse wastewater to the incoming cold freshwater, plate heat exchangers can be used. Simple heat exchangers are sufficient for continuous processes. In discontinuous processes, the heat exchanger would have to be fitted with buffer tanks and process control devices. Based on case-studies in several textile plants in China, NRDC (Natural Resources Defence Council) reported fuel savings of 1.4 – 7.5 GJ/tonne fabric rinsed by the implementation of this measure. The payback period was less than six months in all cases studied by NRDC [70].

Conserving water and mitigating water pollution will also be part of the industry's strategy to make its production processes more environmentally friendly, particularly in parts of the world where water is scarce.

In 2016, the world's population was 7.4 billion; this number is expected to grow to 9.5 billion by 2050. Future population and economic growth will stimulate rapid increases in textile production and consumption, which, in turn, will drive significant increases in the textile industry's absolute energy use, water use, and carbon dioxide (CO2) and other environmentally harmful emissions.

However, today, given the projected continuing increase in absolute textile production, future reductions (e.g., by 2030 or 2050) in absolute energy use and CO2 emissions will require further innovation in this industry.



Innovations will likely include development of different processes and materials for textile production or technologies that can economically capture and store the industry's CO_2 emissions. The development of these emerging technologies and their deployment in the market will be a key factor in the textile industry's mid- and long-term climate change mitigation strategies [74].

Table 1 Emerging energy-efficiency, water efficiency, and GHG emissions reduction technologies for the textile industry [73]

	Man-made fiber production technology	
1	Nanoval technology	Pilot
	Spinning	
2	Vortex spinning and jet spinning	Commercial with very low adoption rate
3	Friction spinning	Commercial with very low adoption rate
	Weaving	
4	Multi-phase loom	Commercial with very low adoption rate
	Wet processing	
5	Enzymatic treatments	Various commercialization stages depending on the application
6	Ultrasonic treatments	Pilot
7	Electron-beam treatment	Development
8	Ozone for bleaching cotton fabrics	Development
9	Advanced cotton fiber pre-treatment to increase dye receptivity	Pilot
10	Super-critical CO_2 in dyeing	Pilot
11	Electrochemical dyeing	Development
12	Ink-jet (digital) printing	Commercial with very low adoption rate
13	Plasma technology	Pilot
14	Foam technology in textile finishing	Commercial with very low adoption rate
15	Microwave energy	Development
16	Alternative textile auxiliaries	Various stages of commercialization depending on the type of auxiliary
	Sensor and control technologies	
17	Fuzzy logic and other expert systems	Various stages of commercialization depending on the application
18	Real-time on-line monitoring systems	Pilot

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6.2 Best Practices – New technologies and training methodologies in the Finishing and Printing Sector

Name of good practice	ECO-INNOVATION - at the heart of European policies
Type	Application of new technologies
Topic	Sustainable dyeing
Description (Objectives, results etc.)	New water treatment facility developed the framework of an EU-backed project, Wasatex
Evidence of success	The implementation of the treatment system has, in the first instance, resulted in about 70% of consumed water being recovered. It is expected that the recovered volume can be increased to 90-100%, with some of the treated water being reused in factory processes, and some feeding a steam boiler. Additional benefits are more uniform quality of water compared to extracted groundwater, and reduced water heating costs. The principal benefits are lied to the dyeing process that it is the more water consuming.
Funding sources	EU project, Wasatex, Budget: €1,700,097 (EU contribution from the Competitiveness and Innovation Framework Programme €850,048.50)
Year	2016
Contact (address, email)	Olimpias Tekstil d.o.o. Vukovarska cesta 219/a, Osijek (Croatia)
Responsible person	Božena Rakitić, president
Web site	www.olimpias.com
Key Relevant information for ICT-TEX project	A wastewater treatment facility of a Croatian textiles factory at Osijek in north-eastern Croatia, could be the first in the European Union to have the capability to recover and reuse up to 100% of the water that the plant consumes.

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Name of good practice	Company: DUPONT
Type	Application of new technologies
Topic	Finishing, printing and functionalization - INTEXAR
Description (Objectives, results etc.)	Light, stretchable, and seamless. DuPont™ Intexar™ Fitness is comfortable, wearable technology that enhances performance clothing. Intexar is an electronic ink and film transforms fabric into smart clothing. It is an electronic ink and film that seamlessly transforms fabric into smart clothing for multiple applications. The technology is embedded directly onto fabric using standard apparel manufacturing processes,
Evidence of success	DuPont had been making flexible circuitry for decades, but manufacturers wanted more: stretching, available to withstand the elements, long life. The introduction of DuPont brand Intexar kicked off a cascade of innovative ideas including fitness gear, heated garments, and wearable health care. An example is the Owlet Band. At the 2019 Consumer Electronics Show (CES), the company introduced an Intexar abdominal band worn by a pregnant woman to monitor her foetus. It won the show's Wearable Technology award..
Funding sources	Private
Year	2017
Contact (address, email)	https://electronics-imaging.dupont.com/intexar-contact-us
Web site	https://electronics-imaging.dupont.com/intexar
Key Relevant information for ICT-TEX project	Intexar is a prime example how smart textile solutions have entered the mainstream. The technology allows to turn most (woven) fabrics into smart textiles.

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ICT-TEX
ICT IN TEXTILE AND CLOTHING HIGHER EDUCATION AND BUSINESS

FIELD RESEARCH

AIMS AND STRUCTURE OF THE QUESTIONNAIRE

The project aims to respond to the tremendous need of textile and clothing engineers, especially those who can work with CAD, CAM, CAE and PLM systems, for higher level of ICT proficiency by developing specialized training courses that will improve digital as well as entrepreneurial competences of the learners as part of the new curriculum "Application of ICT in Design and Production of Textiles and Clothing".

In order to identify the business needs and requirements, the project consortium elaborated a questionnaire to be submitted to the textile and clothing European companies belonging to the project countries.

The analysis of the results obtained will help the partnership to build a flexible training program responding to the current and future qualification requirements in order to unlock the innovation potentials of the industry.

With the scope to design the most complete picture of the sector as possible the questionnaire was structured into different sections:

- **Respondent general information**; gathering important data related to the company's representative participating to the survey, as for example country of origin, age, position, qualification.
- **Company general information;** containing questions related to the company size, innovation propensity, quality operation implemented, sustainability level.
- **Company productive features;** the company was required to indicate its production specialties among the ones analyzed, namely, design and production of woven fabrics, design and production of knitwear, design and production of apparel, design and production of technical and smart textiles, finishing and printing. For each production specialty common information was analyzed i.e. property of the production processes / material and products range treated / technologies, machines and software used / employees skills shortage.
- **Needs for ICT skills:** analyzing the level of maturity of different kind of ICT technologies, their integration in the respondent company and the skills that employees need to develop in order to introduce ICT innovations in the company.
- **Need for Entrepreneurial skills:** analyzing the company arrangement and the main procedures adopted to stimulate an entrepreneurial mindset, as well as the skills mainly required to promote innovation..

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RESPONDENT AND COMPANY GENERAL INFORMATION

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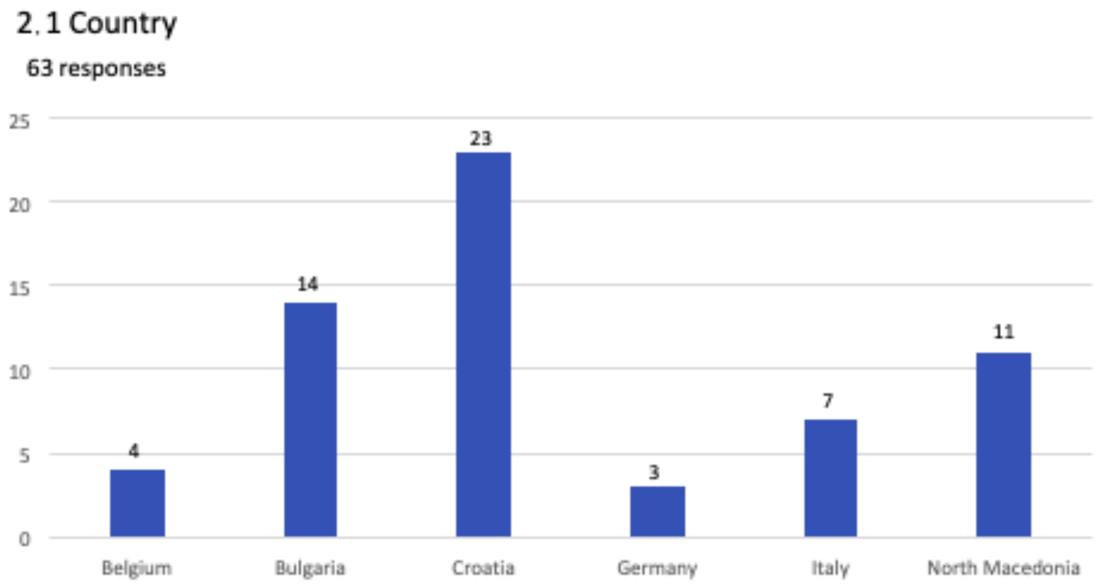
RESPONDENT GENERAL INFORMATION COUNTRY OF ORIGIN

- 6.3% of the participant were from Belgium, (4 Participants)
- 22% From Bulgaria (14 Participants)
- 36.6% From Croatia (23 Participants)
- 4.8% From Germany (3 Participants)
- 11.1% from Italy (7 Participants)
- 17.4% Macedonia (11 Participants)

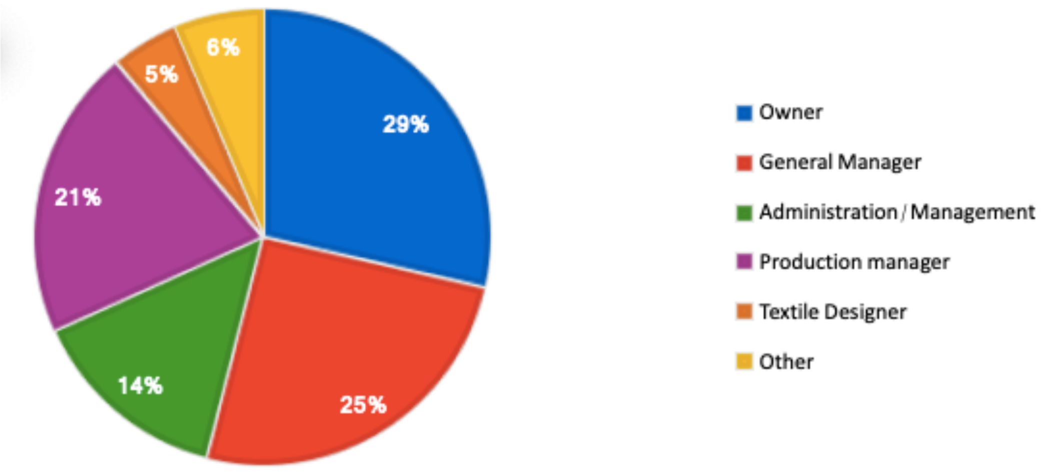


RESPONDENT GENERAL INFORMATION
POSITION IN THE COMPANY

The results of the survey show that for most of the companies that have shown interest in answering the questionnaire, the respondents come directly from the managerial departments, in fact, as can be seen from the graphs 29% of the answers are by companies owners, 25% by general managers, 21% by production managers, 14% by administration managers, 5% by textile designers and the remaining parts from different professional figures as marketing managers, sales managers, technicians and grant experts.

This it justified by the structure of the questionnaire, that requires for the respondents to be in a managerial position in order to have a general vision of the company, know the different company departments, the techniques, procedures, and the machines implied in the different production stages and being able to provide meaningful information for all the questionnaire sections. The respondents composition guarantees the quality and accuracy of the answers provided.

2.2 Your position in the company



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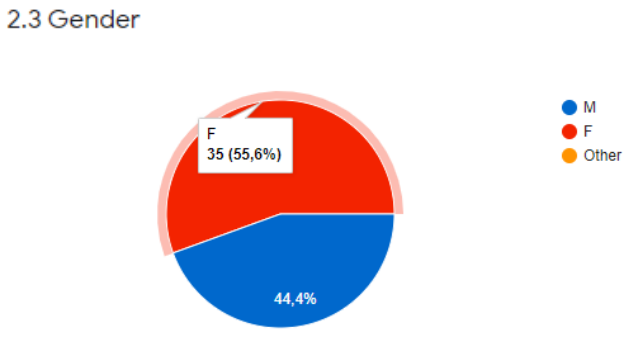
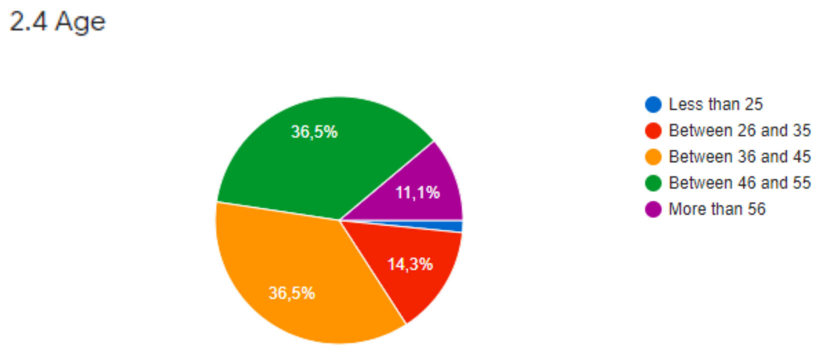
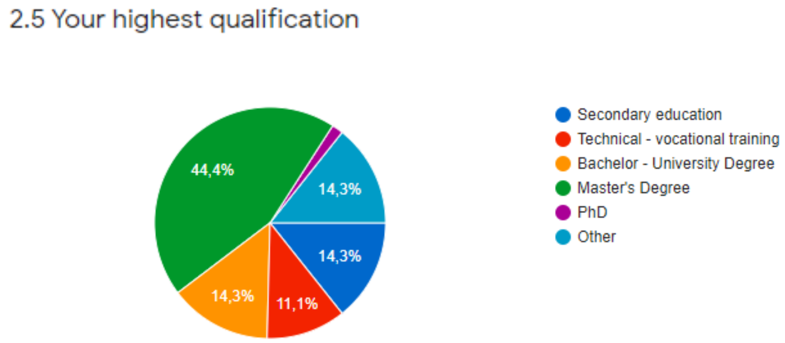
RESPONDENT GENERAL INFORMATION
GENDER, AGE AND QUALIFICATION

From the answers obtained it is clear that a slight majority of responses came from female compared to males. Looking at these data in perspective, it can be understood that the managerial figures within textile companies are well balanced regards to the gender equality. We can also verify that most of the responses come from the 36-45 and 46-55 age group, thus giving a quick insight into what is the today status of entrepreneurship and employment of the textile sector. This is also in line with the respondents position held in the companies. Almost the totally of the people interviewed held a managerial position, generally reached by experienced workers, with a higher instruction level. In fact the answers come for the most part, 44.5%, from highly qualified personnel with a master's degree, 14.3% have an university degrees, with the same percentage 14.3% of the answers come from personnel with a secondary school diploma, only 11% of the answers come from personnel with specialized technical diplomas in the textile sector.







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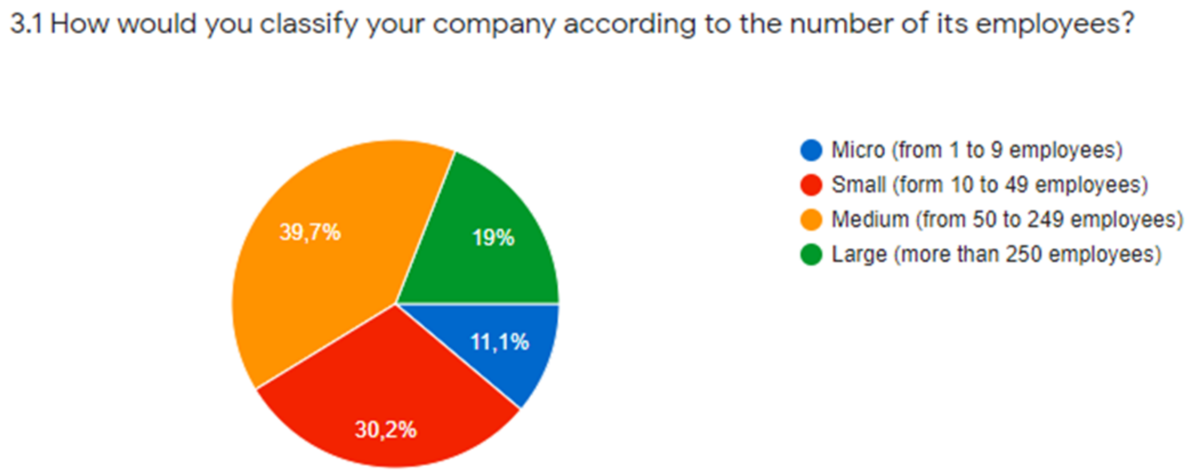
COMPANY INFORMATION
COMPANY SIZE

Checking the responses to the company general information section, it is noted that: together the companies of micro (fewer than 10 employees) and small (10 to 49 employees) size, represent the half of the total questionnaire respondents, exactly 50,8 %. Also the companies of medium size (from 50 to 249 employees) are well represented with a percentage of 39.7%. The last portion 19% is occupied by large companies with more than 250 employees.

We can say that this division well reflects the market composition, dominated by small and medium size enterprises focusing on high quality and innovative products.



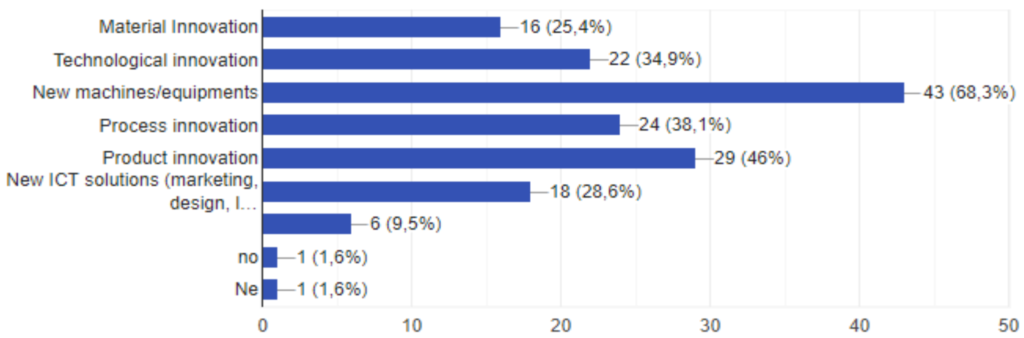
COMPANY INFORMATION
RESEARCH & INNOVATION PROPENSITY

The quality and innovation propensity of the T&C sector is confirmed by the fact that most of the companies that participated in the questionnaire affirmed to have a special research and innovation department with a percentage that stands at 39.7%, while another 19% stated to be in the process of creating one. Anyway the percentage of the companies that do have not a dedicated department for research and innovation, at the moment is still the majority with 41,3% (plus that19% which foreseen to have one in the near future) of the total interviewed , even if 12,7% of this portion recognize the importance of research and innovation declaring to need a R&D department, while no one replied they did not need it.

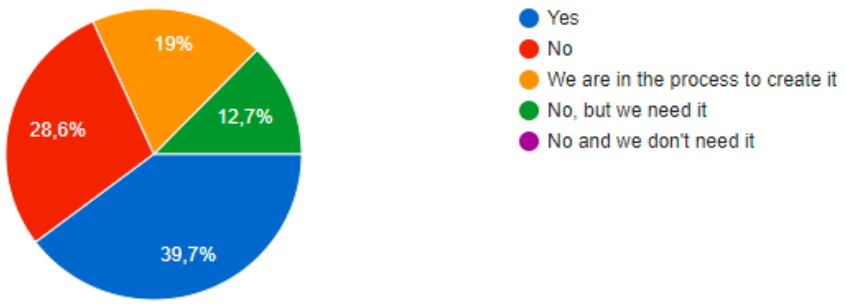
As regards to the type of innovations most adopted by companies in the last 5 years, the most occurring is certainly the one which concerning new equipment and machines with a percentage of 68.3%. Immediately after, with a very remarkable percentage of 46%, we find product innovations. While innovations in production processes are in 3rd place for importance with a percentage of 38.1% and to follow the technological innovations with a percentage of 34.9%.

28.6% of the companies replied that the most adopted innovation in the last 5 years are new ICT solutions and 25.4% material innovations. Only 9.5% of companies in the last 5 years have adopted the principles of circular economy and about 3% of companies have not adopted any innovation.

3.3 During the last 5 years, has your company adopted / developed one or more of the following typologies of innovations?



3.2 Does your enterprise have a department dedicated to research&innovation?



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COMPANY INFORMATION
QUALITY CONTROL

The importance to test their products and to assure quality control all along the production process is well established among the T&C enterprises.

As we can notice from the graphs only 14,3% of the respondents declared not to test their products, meanwhile the other 85,7% replied that they test somehow their products.

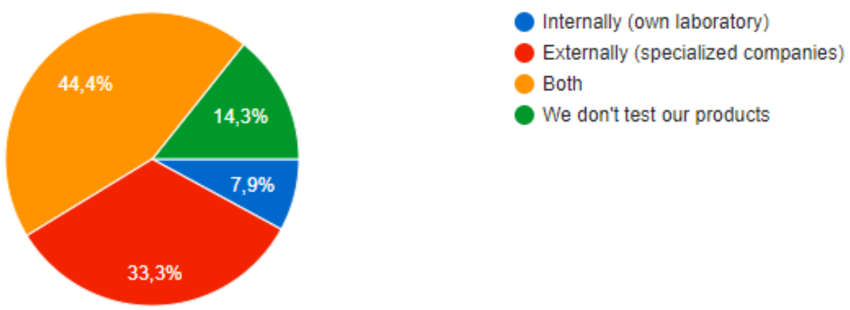
For what concern the method of testing:

- most of the companies 44,4% test their product both internally, in their own laboratories, and externally by the mean of specialized companies
- a considerable percentage 33.3% of companies test their products only externally
- a residual percentage 7.9% test their products only in their own laboratories.

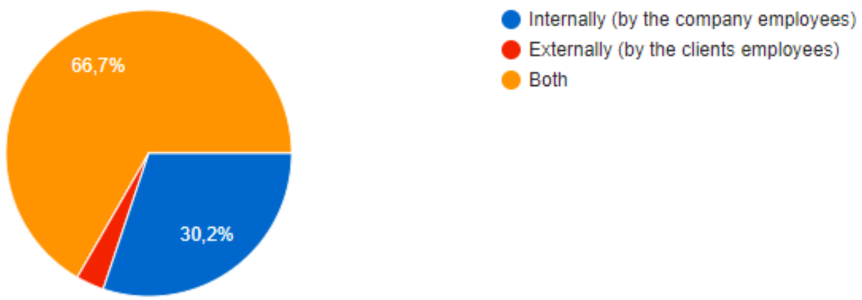
Almost the totally of the interviewed adopt internal quality control procedures. Quality control operations are performed both internally, by their own employees, and externally, by the clients employees, for the majority of the respondents, with a percentage of 66,7%, on the other 30.2% of companies perform the quality control process just internally.

Only 3.2% of companies perform this process completely externally.

3.4 How does your company normally test the produced products?



3.5 How are quality control operations normally done in your company?



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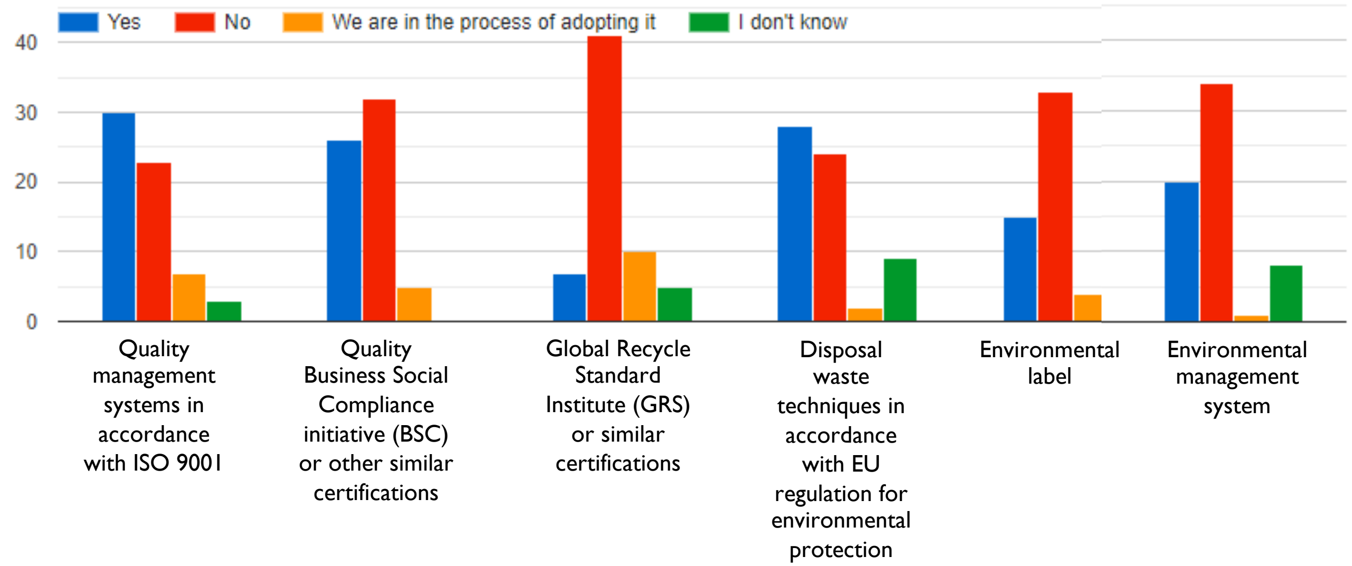
COMPANY INFORMATION
QUALITY AND ENVIRONMENTAL CERTIFICATIONS

Looking at the international certifications, the responses show that out of 63 responses received, 30 companies have adopted the ISO 9001 quality certification. 26 of them have BSCI (Business Social Compliance Initiative) certification, committing themselves to adopt rules for improving working condition.

Considering the environmental commitment only 7 companies have obtained the Global Recycle standard institute certification, 28 companies have applied disposal waste techniques 15 companies have adopted environmental labels and 20 of them have set up an environmental management system.

3.6 Does your company have the following?



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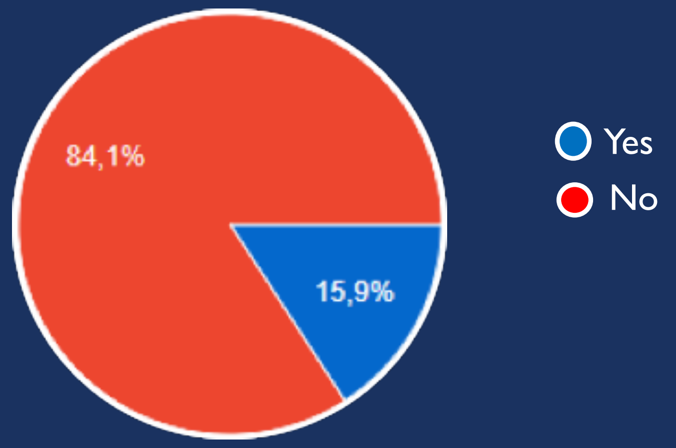
DESIGN AND PRODUCTION OF WOVEN FABRICS

3.7 Does your company design and produce woven fabrics?



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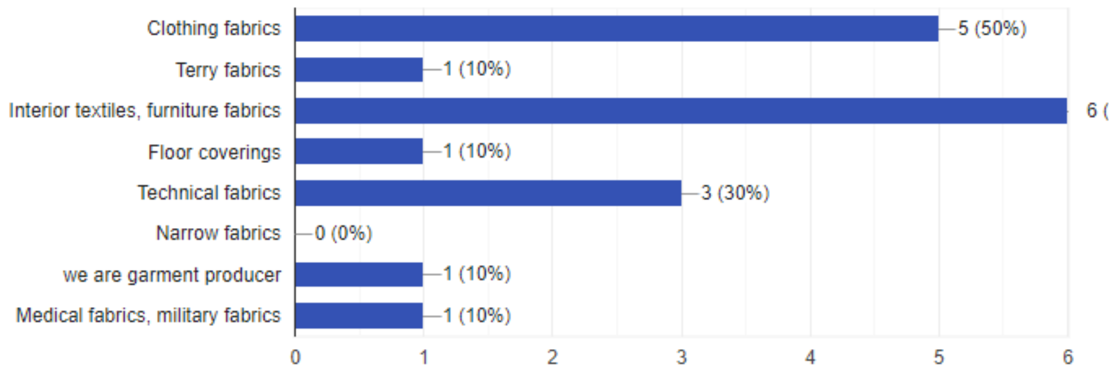
DESIGN AND PRODUCTION OF WOVEN FABRICS MATERIALS AND PRODUCTS RANGE

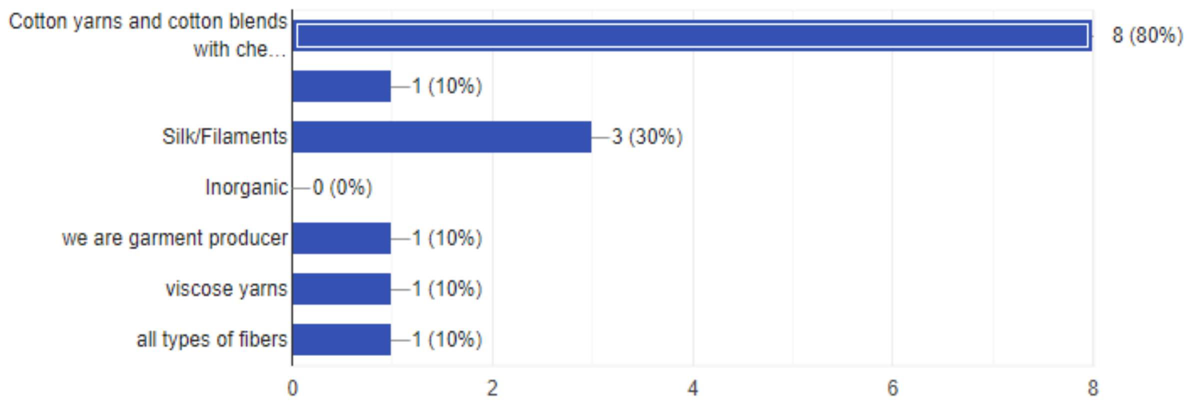
From the answers obtained, we see that 15.9% of the companies that responded to the questionnaire produce woven fabrics. The most used material in the production process, with a percentage of over 80%, is cotton and cotton blends with chemical fibers, 30% of companies use silk. At the same percentage with 10% of answers we find all type or fibers, viscose yarns, wool and woolen yarns blended with chemical fibers. None of the company use inorganic yarns in their productions.

Regarding the range of woven fabrics, most of the factories produce interior textile and furniture fabrics with a percentage of 60%. Following we can find clothing fabrics and technical fabrics producers respectively 50% and 30% of the respondents. With the same percentages, 10% we finally have medical fabrics, terry fabrics and floor coverings producers. None of the factories that replied to the questionnaire produce narrow fabrics.

4.2 What range of woven fabrics does your company produce?



4.1 What materials does your company work with?



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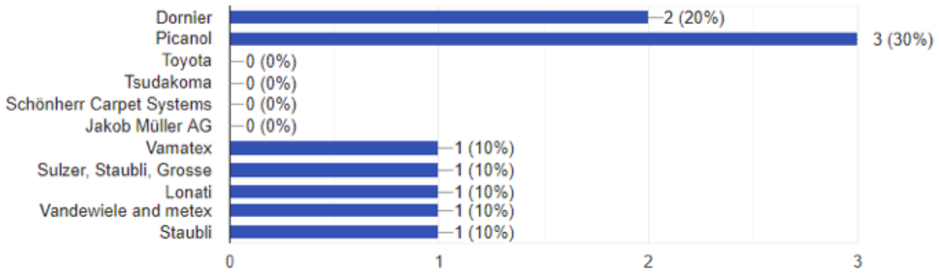
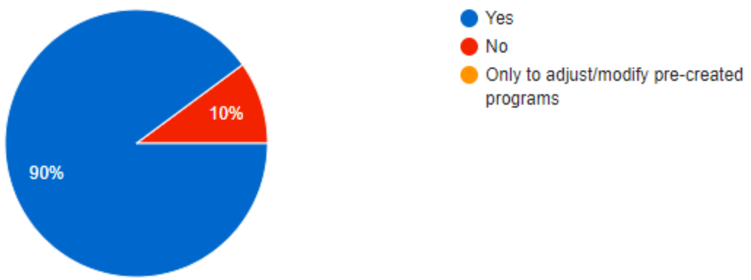
DESIGN AND PRODUCTION OF WOVEN FABRICS TECHNOLOGIES SOFTWARE AND MACHINES

Looking at the type of machine use: 40% of the manufacturers of woven fabrics interviewed have installed air-jet looms machines, 30% have installed rapier looms in their factories and 10% of the companies with the same percentage replied that they have installed: shuttle looms, knitting machine and circular knitting. None of the factories that replied to the questionnaire installed water-jet looms. Concerning the specific kind of weaving machines used, most of the companies replied that they use Picanol with 30% of the answers while another 20% use Dornier. The other respondents adopt other kind of machines : Vamatex, Staubli, Lonati, Vandewiele and Metex. Additionally, the questionnaire shows that none of the companies use Toyota, Tsudakoma, Schonherr Carpet System or Jacob Muller AG.
Entering into the merits of CAD systems, 90% of companies highlight the regular use of CAD systems and only 10% do not use them.

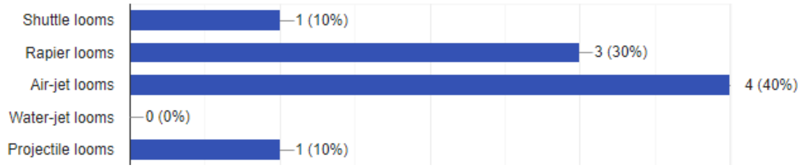
4.4 What kind of weaving machines does your company use?



4.5 Does your company use CAD systems to develop/create products?



4.3 What kind of weaving machines has your company installed?



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DESIGN AND PRODUCTION OF WOVEN FABRICS ANALYSIS OF THE ANSWERS

Analyzing the data coming out from the answers of the questionnaire we note important aspects on the composition of the companies in the various sectors. As regards the design and production of woven fabrics, we can observe that the companies that replied to the questionnaire belong to medium and large companies. The majority of the responses come from medium-high level managerial figures with an age group between 35 and 55 years.

Most of the companies interviewed identify technological innovations as the engine for their production activities improvement, the possibilities attributed to new machineries for this sector are also of great importance. Only 50% of them have invested their commitment for the ISO 9001 quality certification, a trend also confirmed for the BSCI certification, moreover we can note that none of the companies involved in the questionnaire obtained both of them. Concerning the certifications for sustainable environmental development there is still a lot of work to be done as well, in fact only the extreme minority of companies that answered the questionnaire have obtained the Global Recycle Standard Institute (GRS) certification and only one of them is in the process of obtaining it. On the other hand, the compliance with the environmental requirements are assured by the adoption of disposal waste techniques in accordance with EU regulation for environmental protection and Environmental Management Systems, of which 70% of the respondents belonging to this sectors are promoters.

Most of the companies have installed rapier loom and air jet loom for their productions. Rapier machines weave more rapidly than most shuttle machines but more slowly than most other projectile machines. An important advantage of rapier machines is their flexibility, which permits the laying of picks of different colors. They also weave yarns of any type of fiber and can weave fabrics up to 110 inches in width without modification.

Instead the more modern air-jet loom uses a jet of air to propel the weft yarn through the warp shed. It is one of two types of fluid-jet looms, the other being a water-jet loom, which was developed previously. Fluid-jet looms can operate at a faster speed than predecessor looms such as rapier looms, as the survey shows air-ject is most common. The machinery used in fluid-jet weaving consists of a main nozzle, auxiliary nozzles or relay nozzles, and a profile reed.

Air-jet looms are capable of producing standard household and apparel fabrics for items such as shirts, denim, sheets, towels, and sports apparel, as well as industrial products such as printed circuit board cloths. Heavier yarns are more suitable for air-jet looms than lighter yarns. Air-jet looms are capable of weaving plaids, as well as dobby and jacquard fabrics.

Considering the use of CAD and CAM systems for companies in this sector, we note that all of them use these software in support of the design and production process.

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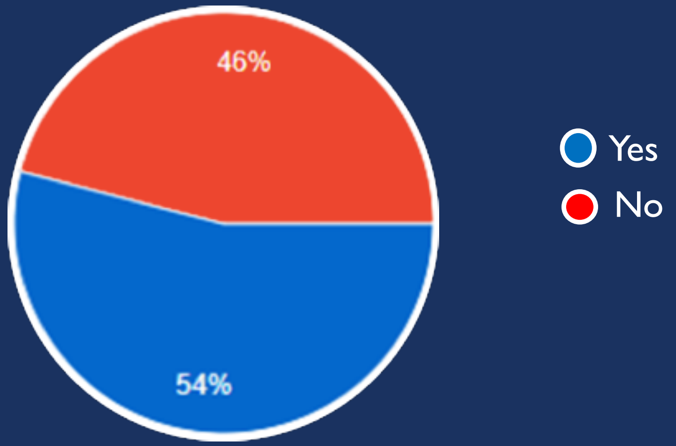
DESIGN AND PRODUCTION OF APPAREL

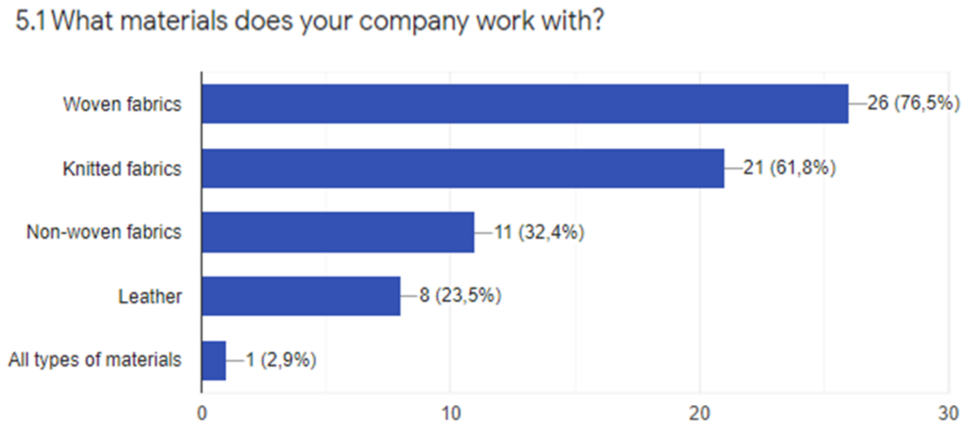
3.7 Does your company design and produce apparel?

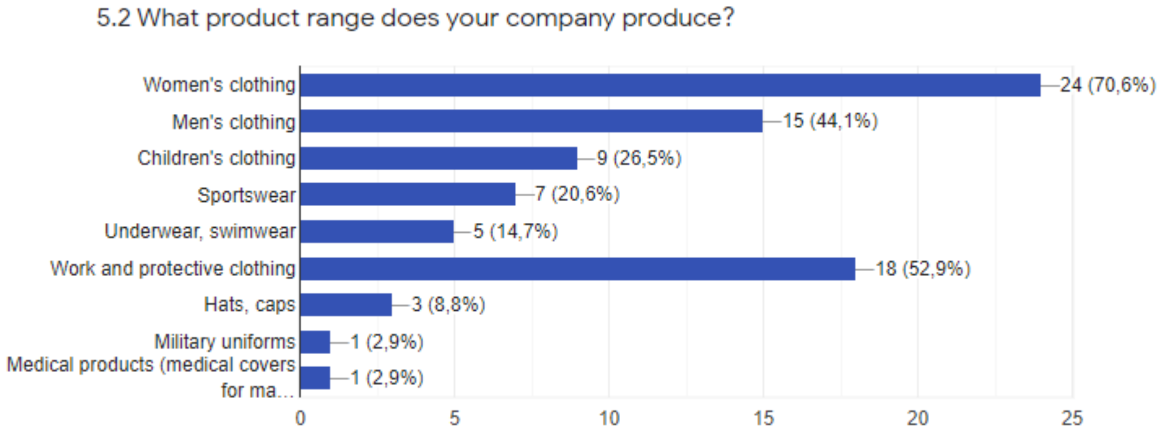


DESIGN AND PRODUCTION OF APPAREL MATERIALS AND PRODUCTS RANGE

From the answers of the questionnaire we can identify that 54% of the companies that participated to the questionnaire are apparel producers. The materials they mainly use are woven fabrics and knitting fabrics counting respectively 76.5% and 61.8% of the answers obtained. 32.4% of companies use non-woven fabrics and 23.5% use leather. 2.9% of companies use all types of materials identified.

The products range most produced are the women's clothing with 70,6% of the answers, then we can find working and protective clothing with a percentage of 52,9% and men clothing for the percentage of 44,1%. 26,5% of respondents produce children clothing, 20.6% Sportswear and14.7% underwear and swimwear. Finally we have hats and caps producers representing 8.8% of the total and fine military uniform and medical covers producers with a percentage of 2.9% each.





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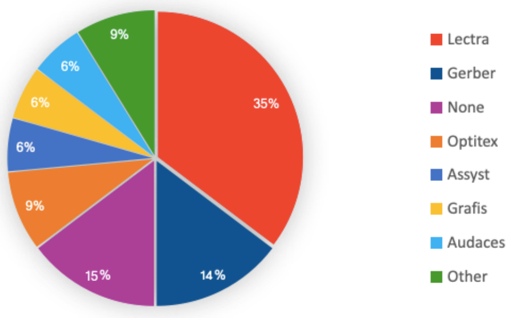
DESIGN AND PRODUCTION OF APPAREL TECHNOLOGIES SOFTWARE AND MACHINES

Regarding the main kind of software used in the production process by the apparel manufacturing companies interviewed, we can see from the graphs that the most used Cad systems are: Lectra and Gerber counting respectively for 35% and14% of the answers. Optitex stands at 9% while Assyst, Grafis and Audances at 6% each. The other respondents are equally distributed among other kind of software (Consult, Gemini, Stoll M1 plus). Moreover we understand that a considerable percentage of the companies don't use Cad systems in their process with a percentage of 15%.

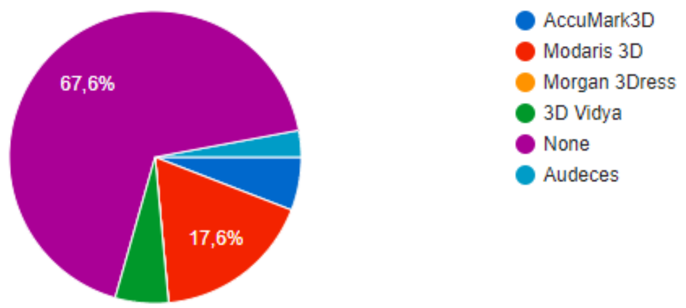
For what concern software for 3D visualization and fit accuracy we see that the great majority of the companies interviewed, as many as 67,6%, do not use them. Among the ones that have introduced this kind of software the most used are: Modaris 3D with17.6%, and Accurmark3D and 3D Vidya with 5,9% each, only one use Audaces.

The same trend is seen with regard to PLM software, in fact 46% replied that they do not use any PLM software, among those who introduce this kind of software the most part 27% of the interviewees, use Lectra PLM (the same seen also for CAD), 9% use Yunique PLM Gerber, Grafis is used for 6% while the remaining respondents use other kind of software, namely Plexis, Programa Consult, Audaces, Centric Fashion PLM.

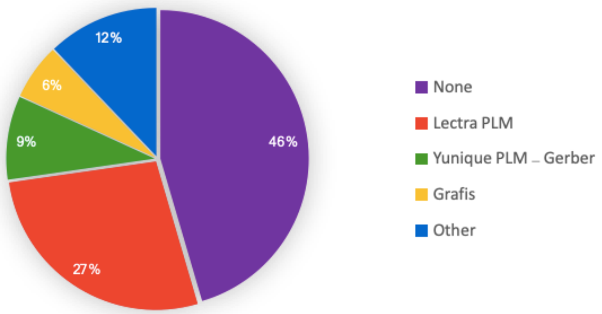
5.3 What CAD system do your company pattern makers work with?



5.6 What 3D visualization and fit accuracy software does your company use?



5.7 What PLM software is used in your company?



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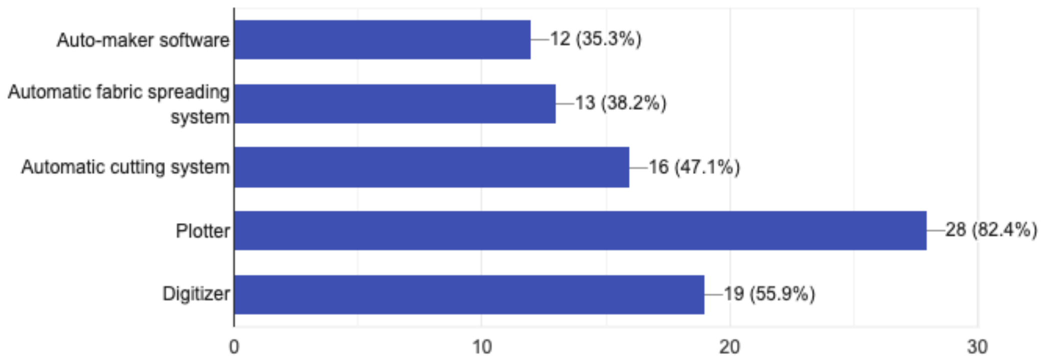
DESIGN AND PRODUCTION OF APPAREL TECHNOLOGIES SOFTWARE AND MACHINES

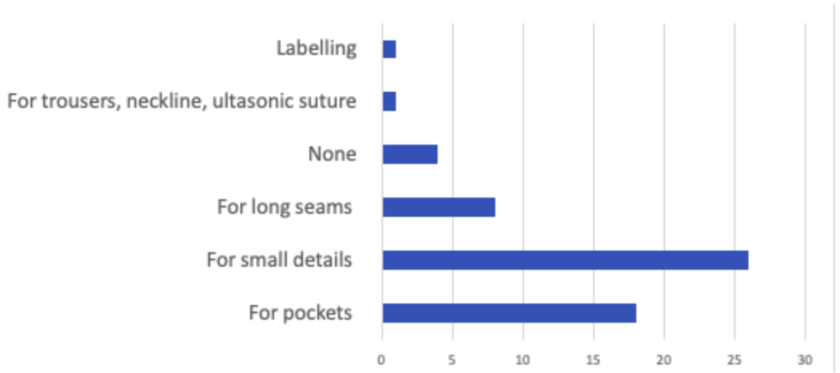
Regarding the technologies most used by apparel manufacturers, we can state that almost the totally of the companies that replied to the questionnaire 82,4% use the Plotter, following with a high percentage we find the Digitizer 55,9% and the Automatic cutting system 47.1%. A minor part use Automatic fabric spreading systems, introduced by 38.2%, of the manufactures and Auto-maker software with a percentage of 35.2%.

Another important data to analyze is the use of automatic industrial sewing applied to the production process, we find that for 76.% of the answers this system is used for small details, for 53% for the pockets and for 24% for long seam, only residually for other kind of processes. Moreover, it should be noted that 12% of the interviewees do not use this technology.

5.8 Which of the following technologies is your company equipped with?



5.9 For which kind of processes, automatic industrial sewing machines are used in your company?



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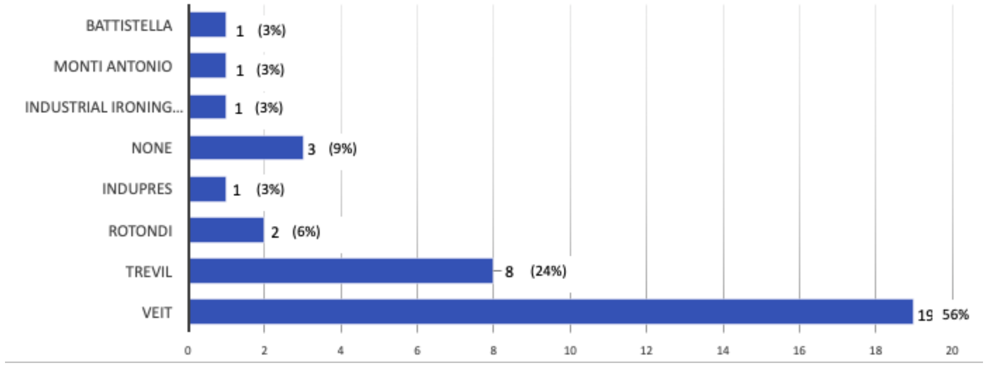
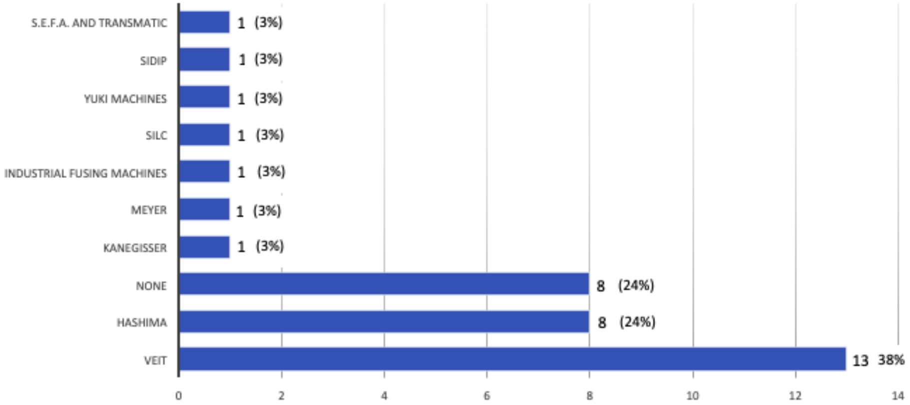
DESIGN AND PRODUCTION OF APPAREL TECHNOLOGIES SOFTWARE AND MACHINES

Going specifically to the production systems we find that the most used ironing machines among the interviewees are the VEIT with a percentage of 56 %, we also find Trevil with a percentage of 24% and Rotondi for a 6%.
Analyzing the data related to the fusing machines, we find that VEIT still in the first position among the companies interviewed also here with a percentage of 38 %, while another 24% use Hashima. It has to be underlined that 24% of the companies do not use fusing machines in their production processes.
Finally for what concern the embroidery machines the most used is Bother with a percentage of 29%, ZSK is used by 21% and Tajima by 12% of the companies interviewed. Other types of machines are equally distributed among the other respondents. Around 41% of the respondents declared not use this kind of machine or to outsource this process to subcontractors.

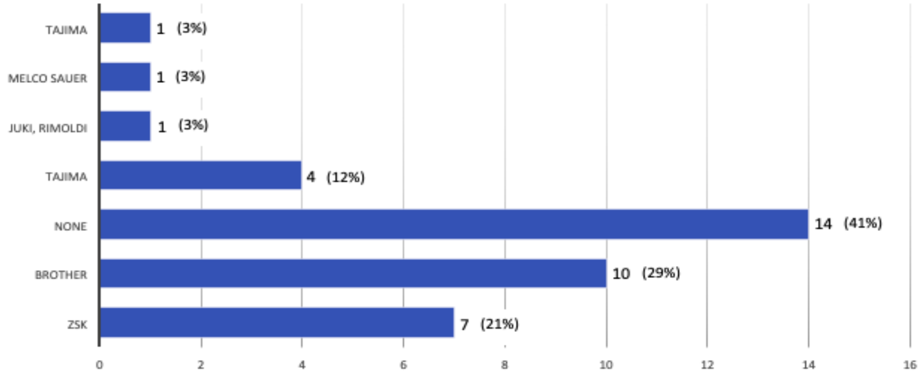
5.10 What kind of ironing machines are used in your company?



5.11 What kind of fusing machines are used in your company?



5.12. What embroidery machines are used in your company?



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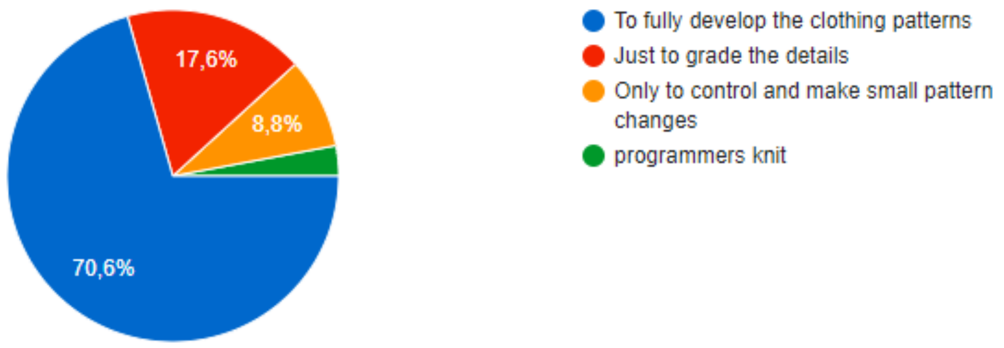
DESIGN AND PRODUCTION OF APPAREL SKILLS NEEDED

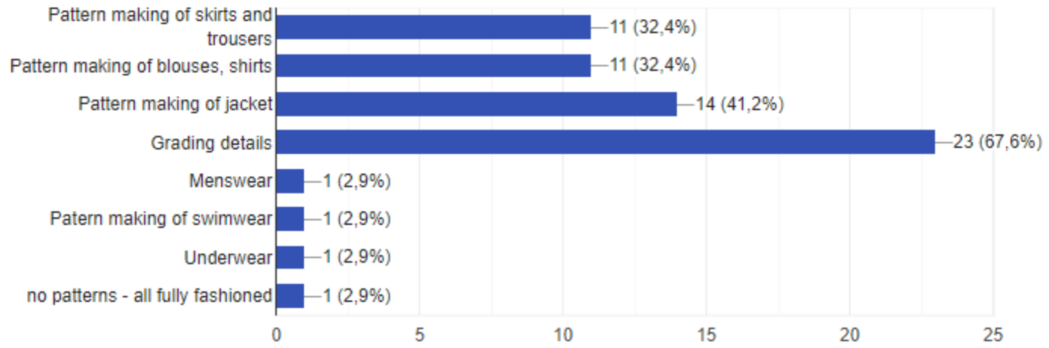
Thanks to the questionnaire, we also identify the skills that clothing manufacturers need most.
We find that the great majority of the companies interviewed 70%, look for professionals able to fully develop the clothing patterns, from the design to the adjustments. On the other hand, for the remaining companies, it is sufficient that their employees are able to grade the details (17,7% of the respondents), or to check for defects and make small changes in the patterns (8,8% of the answers obtained). Only 2.9% of the companies interviewed considers important to know the knitting programs thoroughly.
In reference to the training needs for pattern makers mainly identified by the respondents, according to the specific topics provided we find:

- Ability to grade details, as the main need for knowledge with a percentage of 67.7%;
- Ability to develop patterns for specific kind of clothing. The most needed are for jackets with 41.2%, for blouses and shirts 32.4% and with the same percentages pattern making for skirts and trousers.

5.4 What skills should pattern makers have in your company?



5.5 Can you identify specific topics according which your pattern makers need to be trained for?



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DESIGN AND PRODUCTION OF APPAREL ANALYSIS OF THE ANSWERS

Analyzing the data on the companies operating in the sector of design and production of apparel that have replied to our questionnaire, we realize that most of them, unlike the producers of woven fabrics, are small and medium-sized enterprises. However, there is no shortage of large enterprises which are in any case the minority. The reference age, considering the answers obtained, remains stable between 46 and 55 years as in the woven fabric sector and also in this case we note how the greater importance given to this questionnaire comes from the management departments. As in the case of woven fabric production, also for this sector most of the responses come from Bulgaria and Croatia even if Macedonia and Italy show as well an incidence in the responses received.

In all the cases analyzed, the answers come from highly qualified personnel with university or master degrees. In this sector we can see in a very incisive way, how innovative technologies and production innovations can be important for the market, however also ICT technologies play an important role.

In reference to quality control and compliance with social and environmental standards, most companies process the quality control procedures both internally and externally or in some cases only externally. Most of them have obtained the ISO9001 quality certification, the responses from Italy highlight even more this trend.

Compared to the productive realities of woven fabrics we see in this case more coexistence between ISO9001 and BSCI certifications while the negative trend is maintained for the Global Recycle Standard Institute certification. Disposal waste techniques and environmental labels are well distributed in this sector.

We note that most of the companies that answered to the questionnaire use both woven and knitted fabrics for apparel production, the great majority produce woman's clothing using Cad and Cam software for modeling and pattern making. Pointing out that the most used Cad System by medium-sized companies is the French Lectra. On the other hand 3D and PML software are not largely spread among the respondents.

The skills most required by the companies of this sector are connected to the entire pattern making process. This means that professionals need to be able to manage the pattern process through all the different stages: design, creation, construction engineering, cut and assembly, adjustments.

An important fact is represented by the use of automatic industrial sewing machines. Indeed we note that they are mainly used for the creation of small details and pockets, these machines leave ample space for hand-made processing and the skills of the technicians who use them are also of great importance.

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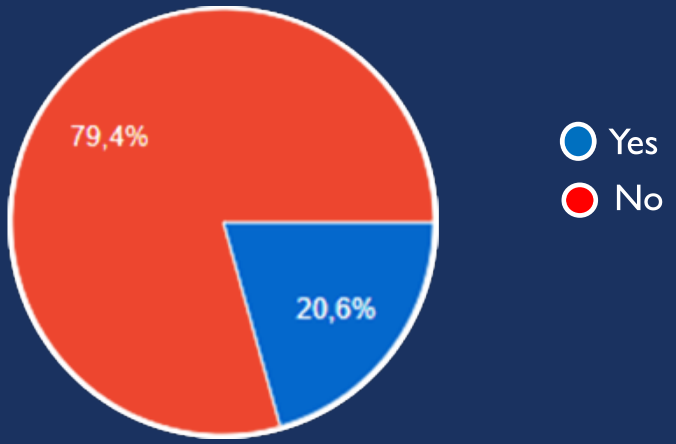
DESIGN AND PRODUCTION OF KNITWEAR

3.7 Does your company design and produce knitwear?



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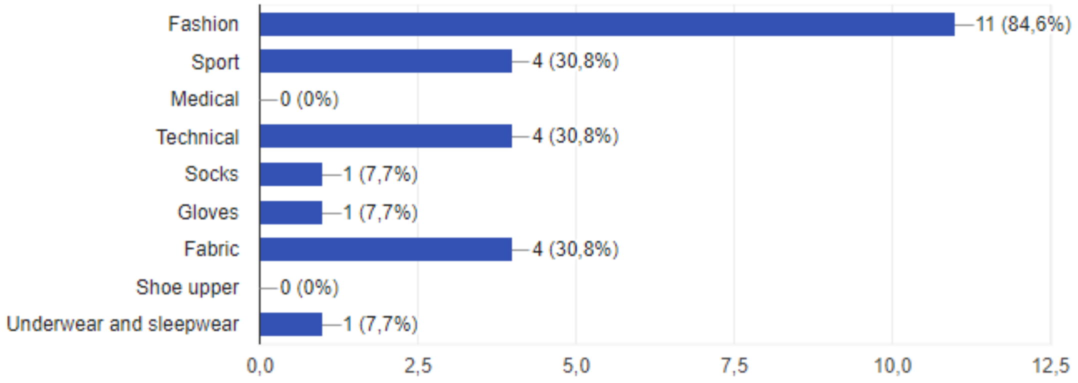
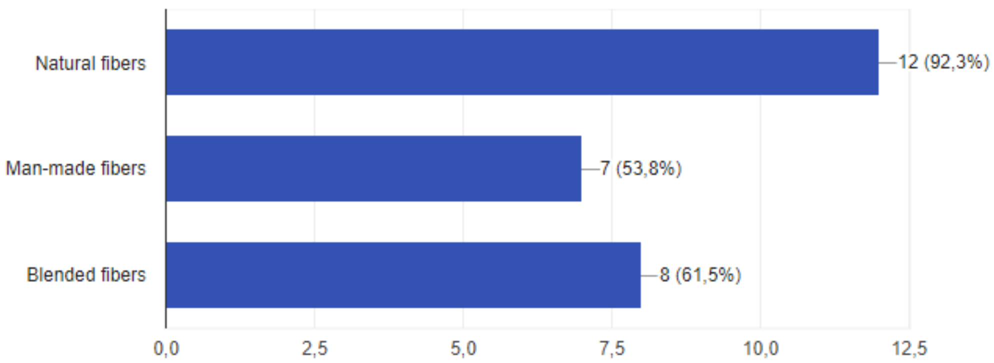
DESIGN AND PRODUCTION OF KNITWEAR MATERIALS AND PRODUCTS RANGE

The incidence of the knitwear productive sector among the companies interviewed is approximately 20% of the total number of responses received.
The great majority of the factories interviewed is focused on the production of fashion garments for a percentage equal to 84.6%. Sports garments, technical garments and fabrics are equally distributed among the companies with a percentage of 30.8% each. Residually we have socks, gloves and underwear producers.
Almost all respondents 92,3% use natural fibers in the production process, blended fibers are normally used for 61,5% of the interviewed, while man-made count for another 53, 8%.

6.2 What kind of knitting is your company production focused on?



6.3 What kind of materials are basically used in your company for the products?



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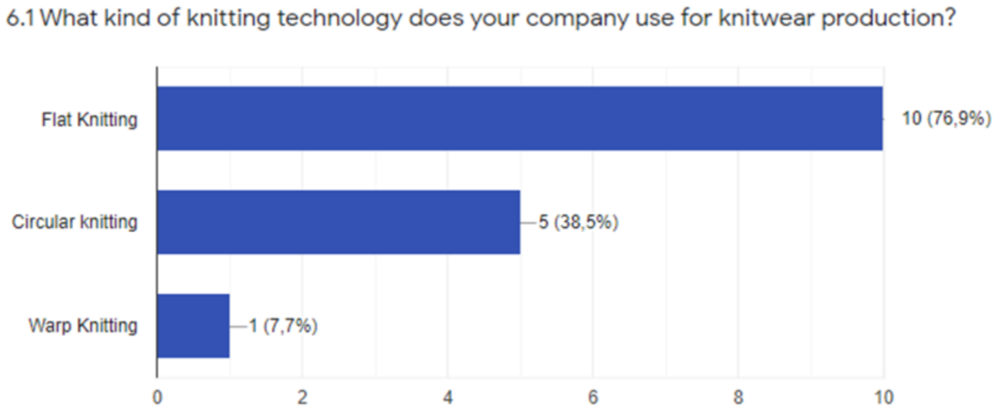
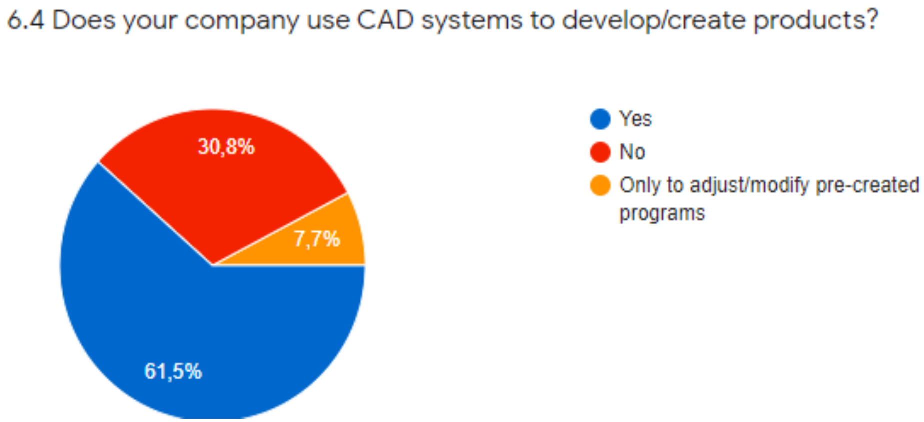
DESIGN AND PRODUCTION OF KNITWEAR TECHNOLOGIES SOFTWARE AND MACHINES

Looking at the kind of technologies and software mainly implied in the production process, we can see that the majority of knitwear companies use flat knitting machines with a total percentage of 76.9%. Circular knitting is used by 38.5% of the companies interviewed, while only one company declared to use wrap knitting machine.
With regard to the application of CAD systems, the majority of companies taking part in the survey use them regularly with a percentage of 61.5%, only 7,7% affirmed to use these systems solely to adjust / modify pre- created programs. A considerable percentage of 30.8% do not use CAD systems in their manufacturing processes.





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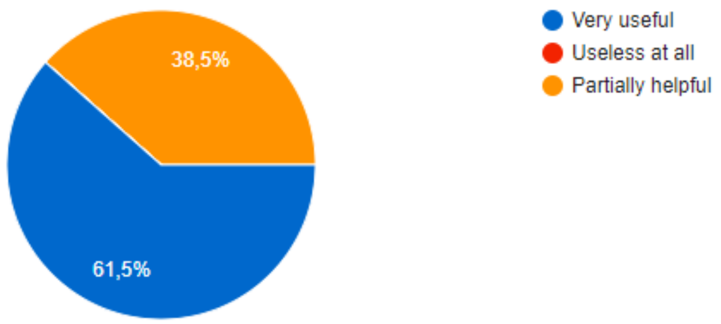
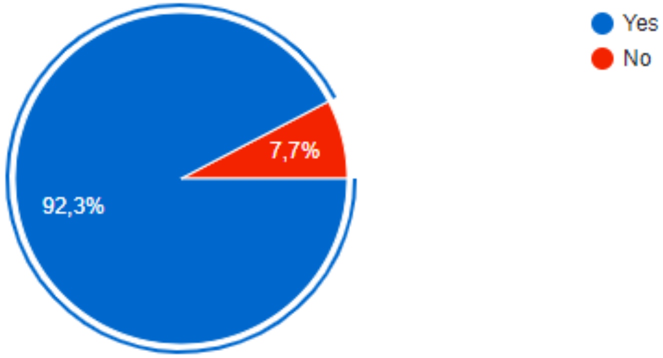
DESIGN AND PRODUCTION OF KNITWEAR TECHNOLOGIES SOFTWARE AND MACHINES

The trend related to the use of CAD systems is also confirmed by the perception of usefulness for 2D and 3D visualization software. The majority of the company interviewed exactly 61.5% consider these kind of systems very useful, while for another 38.5% they are partially helpful, anyway no one replied that these software are useless at all.
An important information is represented by the fact that almost the totally of the companies interviewed use automatic programs to support their production process.

6.5 What is your opinion about 2D/3D visualization of your newly programmed models/patterns?



6.6 Do you use automatic programs?



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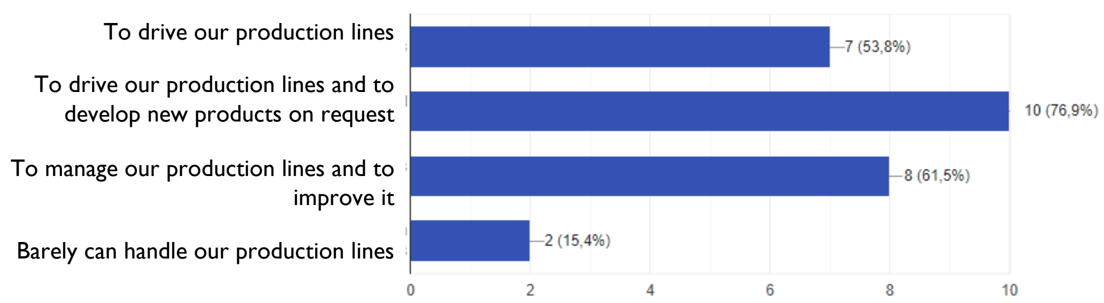
DESIGN AND PRODUCTION OF KNITWEAR SKILLS NEEDED

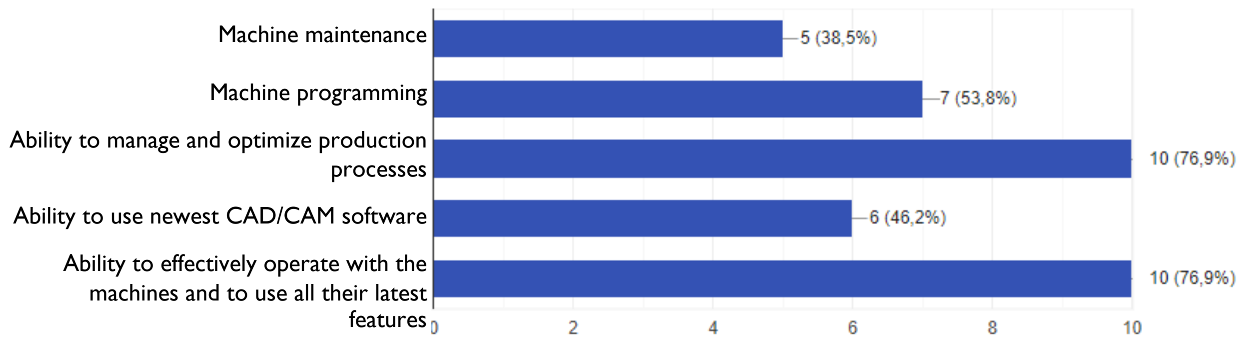
Another important aspect to analyze is related to the skills mostly required by the knitwear sector' employees.
Analyzing the data we can see that the companies interviewed require that their technical and management staff is able not only to drive their production lines, ability sufficient for 53,8% of the respondents, but also to improve it and specially to develop new products, significant respectively for 61.5% and 76.9% of the interviewees.

Furthermore going deeper into the skills shortage among the technicians employed in the sector, we observe that the ones that need to be improved the most are the ability to manage and optimize production product and the ability to effectively operate with the machines installed using all their latest features. These competences are considered very important by the same percentage of companies 76.9%. Immediately to follow we have the ICT skills; machine programming and ability to use the newest CAD/CAM software are indicated approximately by the half of the respondents among the skills that the technical staff need to enhance. Finally with a percentage of 38,5% we have machine maintenance competences.

6.7 What kind of skills has your company technical and management staff?



6.8 What kind of skills does your company technical staff need to improve in your opinion?



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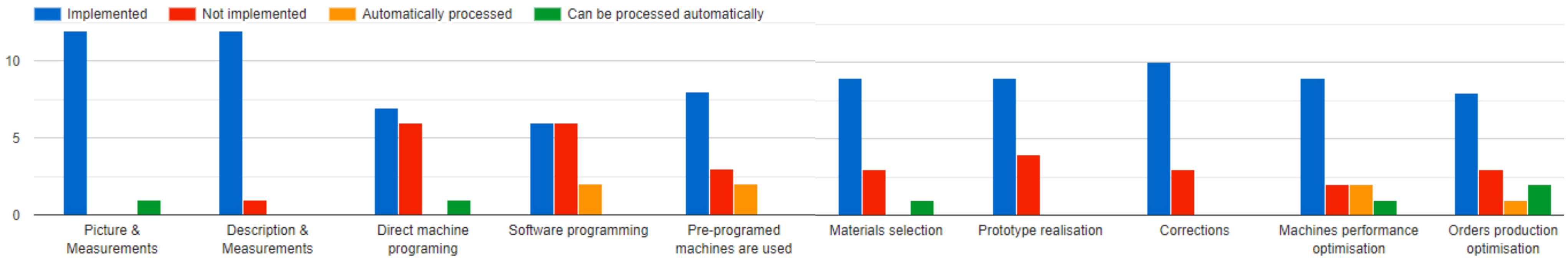
DESIGN AND PRODUCTION OF KNITWEAR PRODUCTION PROCESS

Regarding the production process related to the manufacturing of a single model we note important aspects from the answers collected:

- Picture and measurements together with description and measurements are the only steps implemented by all the companies interviewed;
- Largely spread steps are also the ones related to material selection, prototype realization, correction making and orders and machines performance optimization;
- Pre-programmed machines are preferred to machines and software that need direct programming.

Furthermore we can also deduce that automated systems are not widely applied to the production process in the knitwear sector.

6.9 Please indicate which ones of the following steps are implemented in your company to create a single model and if they are/can processed automatically.



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DESIGN AND PRODUCTION OF KNITWEAR ANALYSIS OF THE ANSWERS

Analyzing the answers coming out from the enterprises operating in the knitwear sector, we notice that only a small percentage of the companies involved in the survey produce knitwear. In this case most of them are Italian but we find a good percentage of companies also from Croatia and Bulgaria.

Also in this case, as in the two sectors previously analyzed, we note that the prevailing age of origin of the answers is the one between 36 and 55 years. We also note that the majority of them are small and medium-sized enterprises, with a slight percentage of large enterprises with more than 250 employees. The majority of the companies interviewed produce in flat knitting giving us an interesting cross-section to analyze. Producing in flat knitting means centralizing one's production on garments for men, women and children such as sweaters, scarves, trousers, skirts, thus excluding accessories such as socks, hats, gloves which in this case represent a small slice of the market occupied to those who produce in circular knitting. This production trend reminds us that most of the circular processing is implemented in countries outside the EU, consequently at a lower production price. Circular knitting is also used when the design requires complete garment clothing, trousers and sweaters with vertical stripes and other clothing especially designed for sports wear that is not possible to produce using the flat knitting machines.

The preeminent use of natural fibers indicates that we are returning, or in some cases we are now developing, a trend that avoids the use of blended fibers by encouraging the normal characteristics such as hand feeling and the natural peeling of the materials. Most of these companies use automatic programs, even if the production stages are mainly managed by the personnel, this means there remains a large benefit to be obtained by better embedding automated systems in the production process. This is is also confirmed by the fact that the percentage of companies that declared not to use CAD systems, or to use them in a limited way, still consistent almost 40%.

Innovation is considered a much important aspect by our interviewees, who indeed require from their employees the ability to improve the production lines and to develop new kind of products. On the other hand they believe that these kind of competences, together with those related to technological and ICT skills are also the ones that the technical staff need to improve the most.

Furthermore we note how most of them, especially companies that are based in Italy, have BSCI and ISO9001 certifications. Also environmental awareness in this sector is rapidly growing, indeed most of the companies participated to the questionnaire have adopted or are adopting systems for the waste management.

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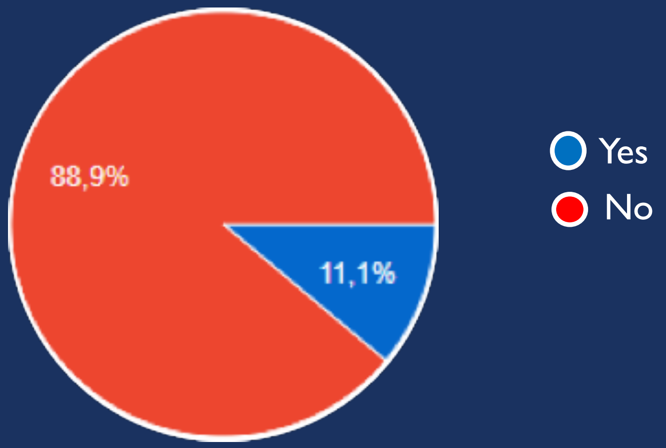
DESIGN AND PRODUCTION OF TECHNICAL AND SMART TEXTILES

3.7 Does your company design and produce technical and smart textiles?



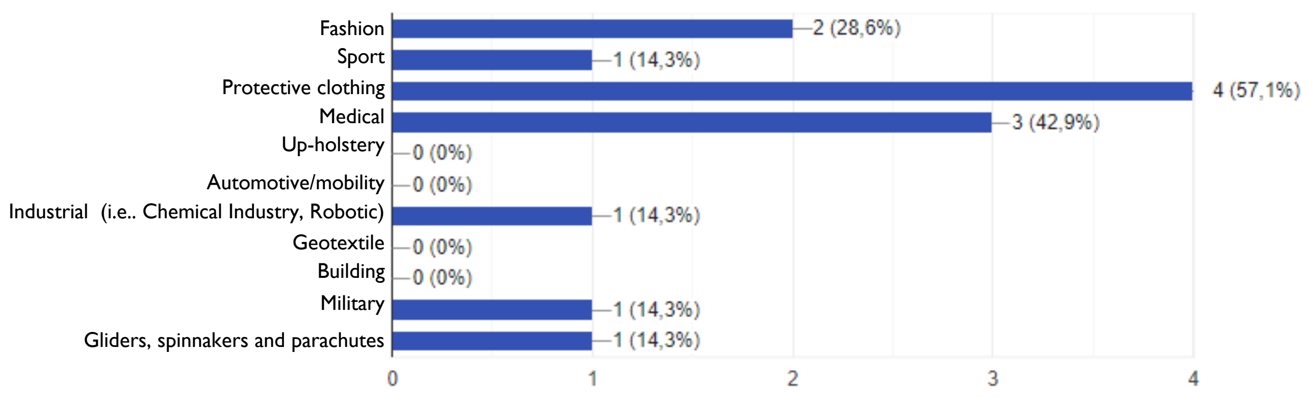
DESIGN AND PRODUCTION OF TECHNICAL AND SMART TEXTILES MATERIALS AND PRODUCTS RANGE

Only 11.1% of the companies interviewed belong to the technical and smart textile category.

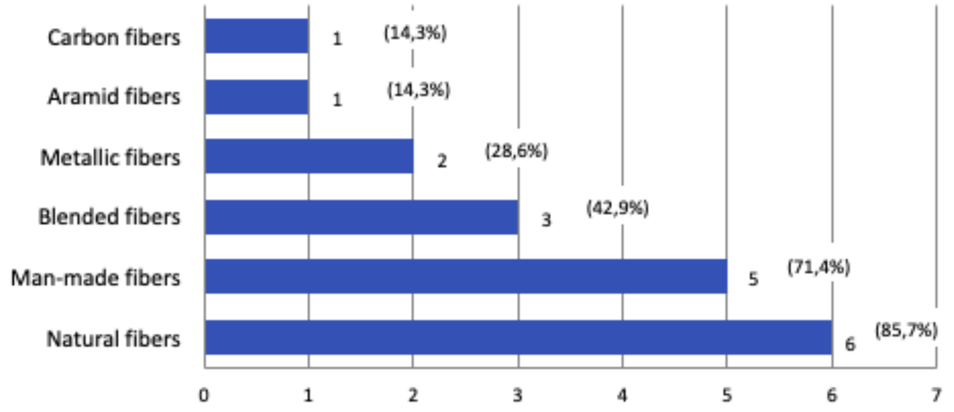
The greater incidence for this production sector is based on the production of protective clothing with a percentage of 57.1% of the total, we also find the production of medical clothing and fashion clothing respectively with the percentage of 42.9% and 28.6%, while sports clothing accounts for 14.3% of the respondents, the same percentage as industrial and military clothing.

The raw materials most used in this sector is the natural fibers with an incidence of 85.7%, then we find the men-made fibers for a percentage of 71.4% and blended fibers for another 42.9%.

7.1 What kind of textile products is your company production focused on?



7.5 What kind of materials are basically used in your company for the products?



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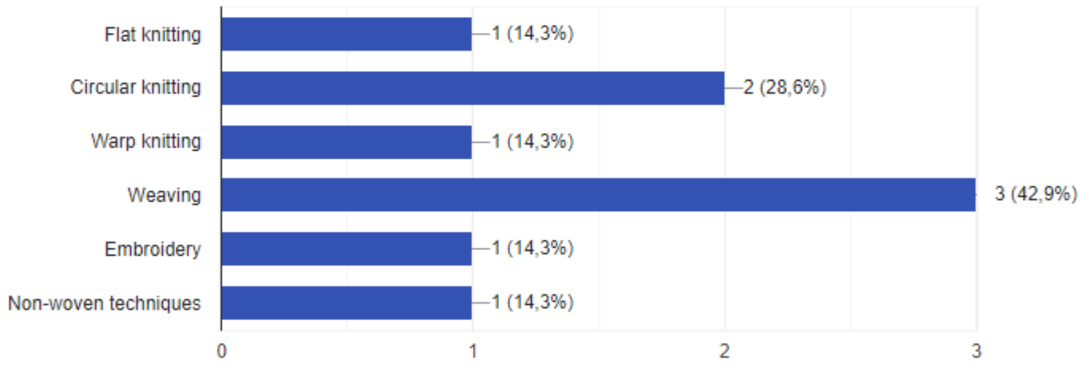
DESIGN AND PRODUCTION OF TECHNICAL AND SMART TEXTILES TECHNOLOGIES SOFTWARE AND MACHINES

By analyzing the production process we understand that the companies interviewed use specific machines and or software mostly for the weaving process with a percentage of 42.9%, and circular knitting with a percentage of 28.6% residually we have specific software / machines applied to other kind of processes, specifically embroidery, non-woven techniques, wrap knitting and flat knitting.

The kind of machines and or software that the companies interviewed declared to utilize for these kind of processes are:

Brother, PE design 11, Ink/stitch, InDesign, Eurolaser, Picanol, Mayer & C, Stoll knitting machines with design pattern generating program M1 +, CAD / CAM Microdor system for pattern making.

7.2 For which of the following items/processes does your company use specific machines/softwares?



7.3 Can you write down the machines brands and the CAM/CAD systems used for the items/processes indicated in the previous question? (Optional)

Stoll knitting machines with design pattern generating program M1+, CAD/CAM Microdor system for pattern making

Brother, PE design 11, ink/stitch, InDesign

Eurolaser

picanol

Mayer&C

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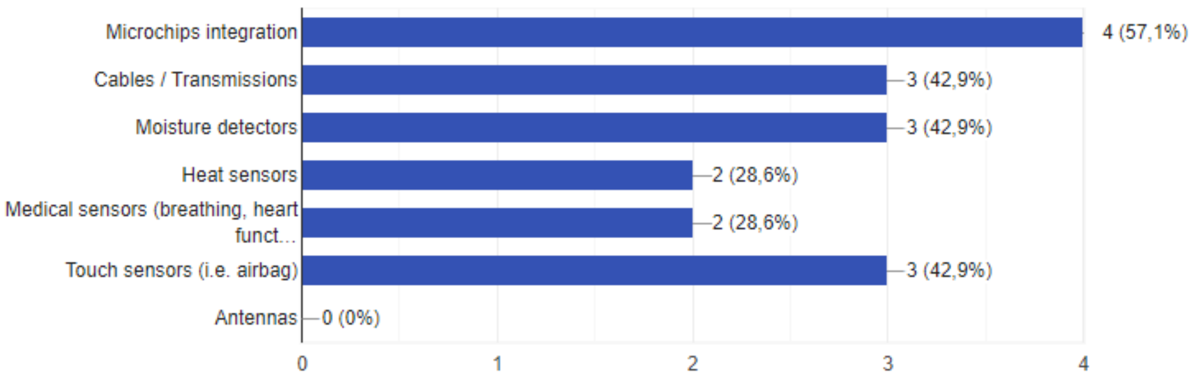
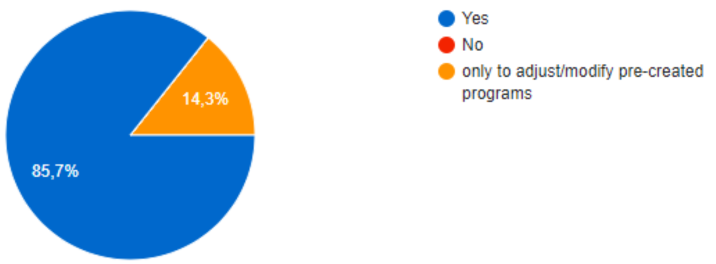
DESIGN AND PRODUCTION OF TECHNICAL AND SMART TEXTILES TECHNOLOGIES SOFTWARE AND MACHINES

Concerning the main kind of electronic components used, the majority of the companies that replied to our questionnaire 57,1% apply microchips elements. Then with a percentage of 41,9% for each element we find cables transmissions, touch sensors and moisture detectors.
Heat sensors and medical sensors are applied by 28,6% of the interviewed.
All the respondents declared to use CAD systems to develop their products, while 2D / 3D visualization software are considered useful at 71.4%, and partially useful at 14.3%, with the same percentage we find those who consider these systems useless.

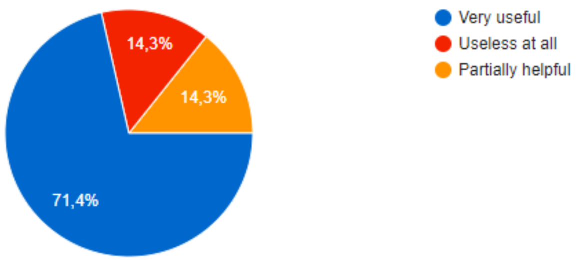
7.4 What kind of electronic components does your company applicate?



7.6 Does your company use CAD systems to develop/create products?



7.7 What is your opinion about 2D/3D visualization of your newly programmed models/patterns?



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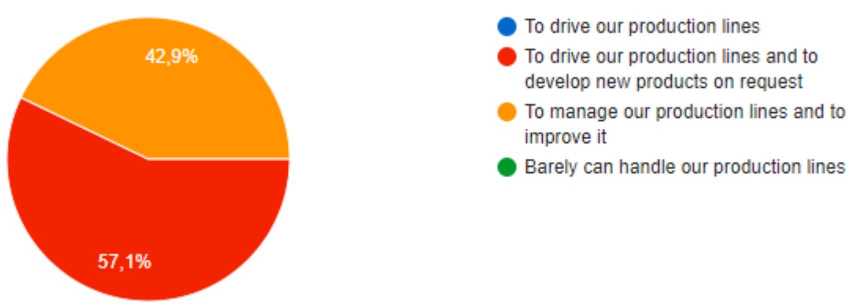
DESIGN AND PRODUCTION OF TECHNICAL AND SMART TEXTILES SKILLS NEEDED

Moving on the skills need analysis for this sector we can observe that the findings are very similar to the ones underlined for knitwear. Like was highlighted for this sector, also the technical and smart textiles companies require to their employees not only the ability to drive the production line, but also to improve it and to develop new product.

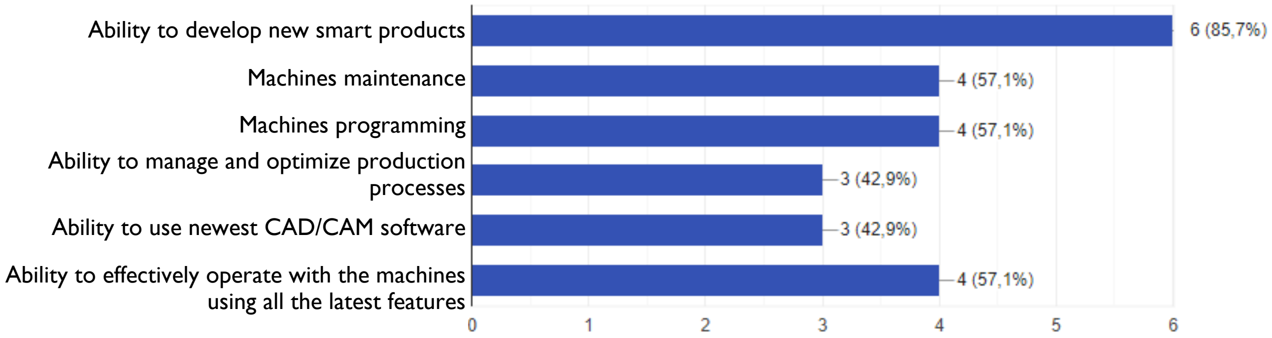
An important aspect that emerge from the answers collected, is that these kind of skills also reflect the ones that technicians need to improve the most according to the interviewees. Namely:

- the ability to develop new smart products with 85.5% of the answers received;
- the ability to effectively operate with the machines installed assuring their maintenance, programming and the correct exploitation of their latest features with 57,1% of the answers received;
- the ability to manage and optimize the production processes and the ability to use newest CAD / CAM software's that count 42,9% of the respondents.

7.8 What kind of skills has your company technical and management staff?



7.9 What kind of skills does your company technical staff need to improve in your opinion?



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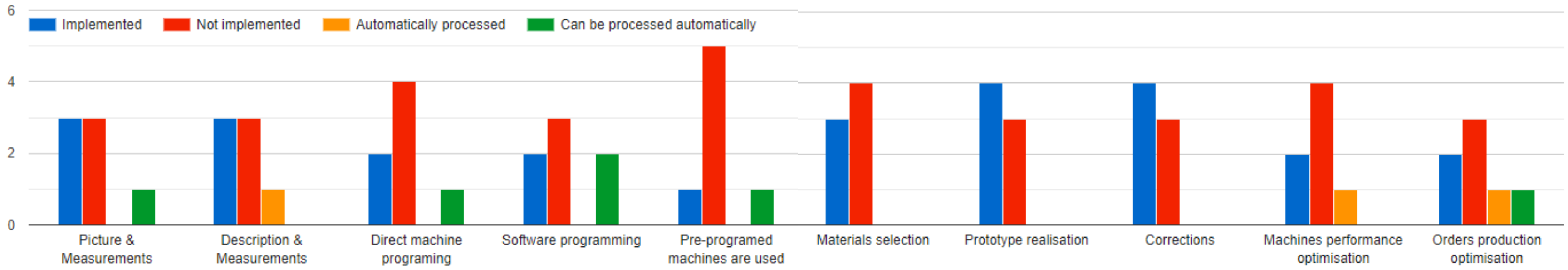
DESIGN AND PRODUCTION OF TECHNICAL AND SMART TEXTILES PRODUCTION PROCESS

If we look at the data relating to the steps implemented for the production of a single model we can note important aspects:

- Only the steps related to prototype realization and correction making are well established among the companies interviewed
- The steps related to picture and measurement, description and measurement and material selection are implemented approximately by 43% of the respondents while the other steps are carried out by a residual part of the companies.

As we noted for the knitwear sector, automated systems are not widely applied neither to the technical and smart textiles manufacturing, even if there is a more incidence of the steps that could be processed automatically.

7.10 Please indicate which ones of the following steps are implemented in your company to create a single model and if they are/can processed automatically.



DESIGN AND PRODUCTION OF TECHNICAL AND SMART TEXTILES ANALYSIS OF THE ANSWERS

From the data collected for the smart textile manufacturing sector we note that the companies size are really different, ranging from micro companies with less than 9 employees up to large factories with over of 250 employees. In this case the respondents usually operate in 2-3 different production sectors so they can also produce woven fabrics or knitwear or both of them while some have internal departments for printing and dyeing finishing also.

The reference age can be identified between 35 and 46 years. In this case as well, the respondents to the questionnaire are highly specialized high-level managers. As we expected the innovations most implemented by these companies are related to new production technologies and new machineries.

The majority of the replies came from Belgium and Croatia. Compared to the other sectors analysed, we note that the product tests are carried out internally, the quality control is carried out both internally and externally and that the majority of companies adopt disposal waste techniques even if they are not in possession of specific certifications.

The range of products mainly produced are protective and medical clothing principally using natural fibers, but also blends and man-made fibers are largely adopted and applying different kind of components as microchips, cables and different kind of sensors.

In general, from the analysed data we can see that CAD systems are largely used and there is a strong common interest in further developing them. 2D - 3D visualization software are strongly integrated in Belgium companies while in Croatia the possibilities of this technology needs to be better understood.

As we have seen for the preview sectors, the skills shortage are mainly linked with the development of new products and the ability to correctly operate with the machines installed exploiting all the possibilities offered by their functionalities.

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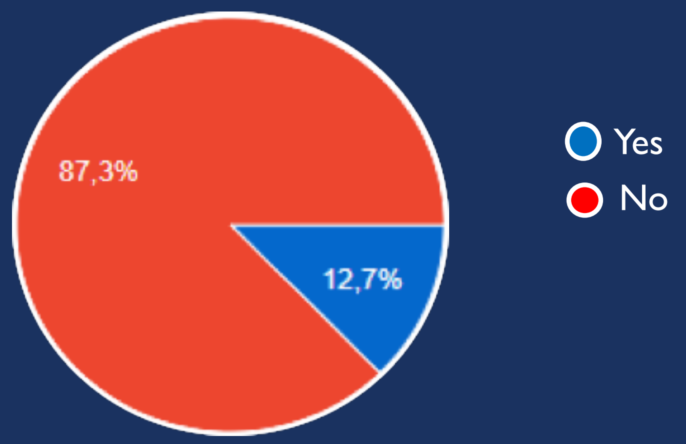
FINISHING / PRINTING SPECIALIZED COMPANIES

3.7 Does your company perform dyeing and/or other finishing treatments?



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FINISHING / PRINTING SPECIALIZED COMPANIES FINISHING PROCESSES

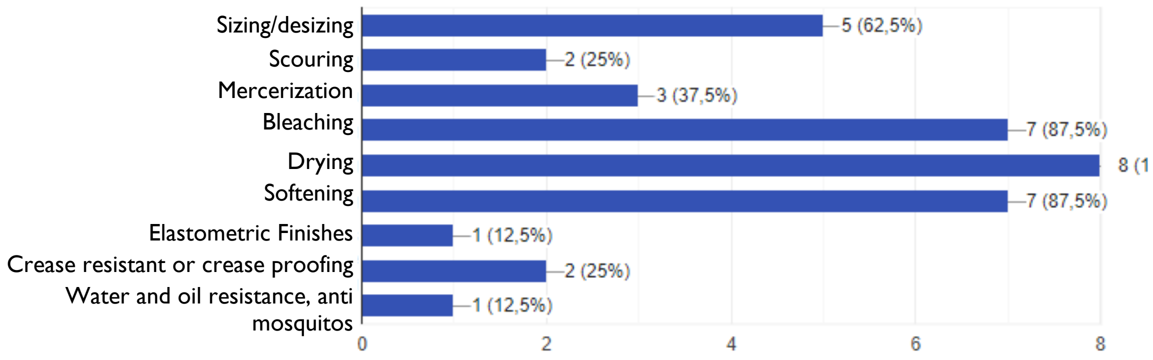
The percentage of responses from companies in the printing and finishing sector represent about 13% of the total number of companies that participated in the questionnaire.
We can observe from the graphs that all of the companies interviewed perform the dying process.

With reference to this kind of process 75% of the companies interviewed can implement continuous dyeing, 72.3% fabrics dyeing and 65% discontinuous dyeing, while garment dyeing and yarn dyeing is implemented by 25% of the respondents.

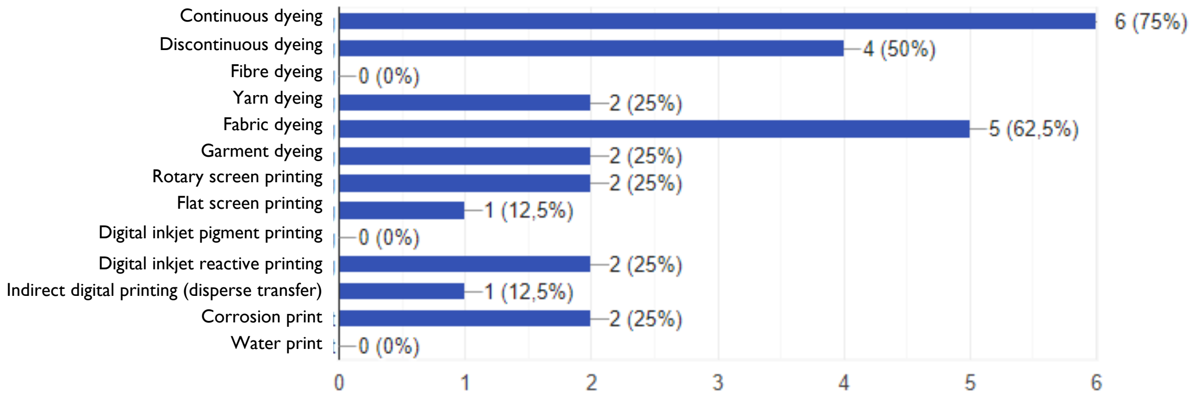
On the other hand the companies specialized in the printing process are lower. Considering the type of printing implemented we find rotatory screen printing, digital inkjet reactive printing and corrosion printing counting for a percentage of 25%, then we find flat screen printing applied by12,5% of the company interviewed whilst water printing is not fulfilled by the companies who replied to the questionnaire.

Concerning the other typologies of finishing processes, the majority of them implement the bleaching and softening processes internally with a percentage of 87.5%, another 62.5% perform sizing and desizing, and with a 25% we have scouring and crease resistant process, residually we find elastomeric finishing and water and oil resistant processes.

8.1 Please indicate which ones of the following finishing processes your company is currently implementing considering the product type:



8.3 Please indicate which ones of the following dyeing/ printing processes your company is currently implementing considering the product type:

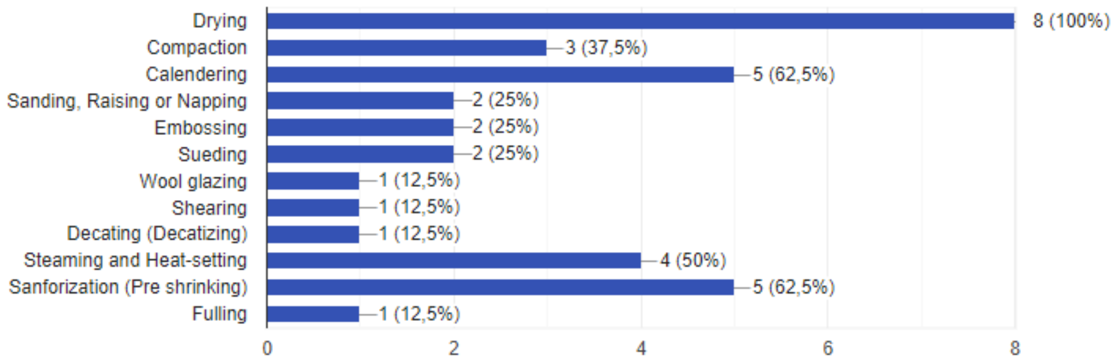


FINISHING / PRINTING SPECIALIZED COMPANIES FINISHING PROCESSES

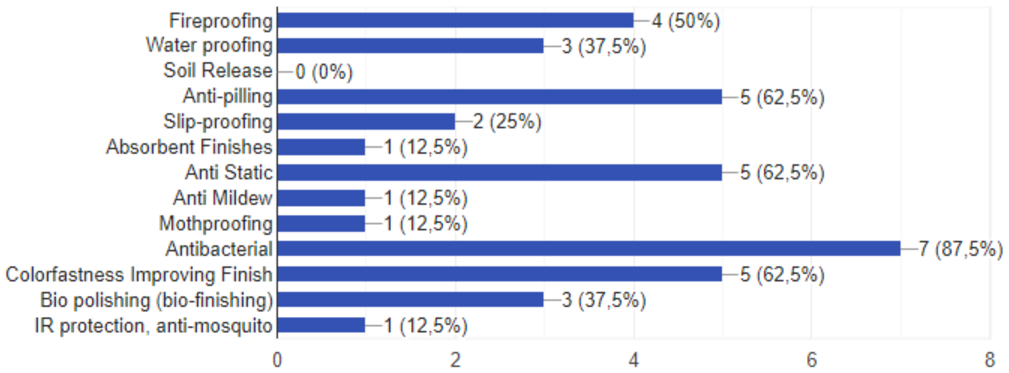
As regards mechanical finishing processes drying process is implemented by the totally of the interviewees, then we have calendering and sanforization with 65%, steaming an heat setting with a percentage of 50% and compaction implemented by 37,5% of the respondents. We find a lower incidence for sanding and raising process, embossing and sueding processes, implemented by 25% of the companies interviewed, residually counting for 12.5% of the responses collected we can find wool glazing, shearing and decating process and fulling.

Checking the finishing processes applied to transfer particular properties to the product realized, the responses highlights a high use of antibacterial processes with a percentage of more than 87%, colorfastness, anti-pilling and anti-static processes are implemented by 62.5% of the companies interviewed. 50% apply fireproofing processes and 37.5% complete water proofing and bio-finishing processes. In addition 25% fulfill the slip-proofing process in their work and 12.5% regularly implement the mothproofing, anti-mosquito, anti-mildew and absorbent finishes process.

8.2 Please indicate which ones of the following "mechanical finishing processes" your company is currently implementing considering the product type:



8.5 Please indicate which ones of the following finishing processes for special purposes (properties) your company is currently implementing considering the product type:



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FINISHING / PRINTING SPECIALIZED COMPANIES SKILLS NEEDED

Going specifically to the employee training needs related to innovative or conventional dyeing/printing processes and technologies the main aspect underlined by the companies interviewed are:

- need for technical education and direct experiences (learning by doing);
- need for training and experience in rotary screen printing technology, raster printing and reactive and pigment dye;
- need for improved skills and knowledge about dyeing chemicals, colorimetric and spectrophotometry;

8.4 If applied, please specify which kind of training the employees need most in order to improve their skills in innovative or conventional dyeing/printing processes and technologies (which is or not listed in the previous questions)

3 risposte

technical education

Rotary screen printing technology, knowlage about dyeing chemicals, raster printing and reactive and pigmet dye, knowlage about colorimetrics and spectrophotometry

Direct experience

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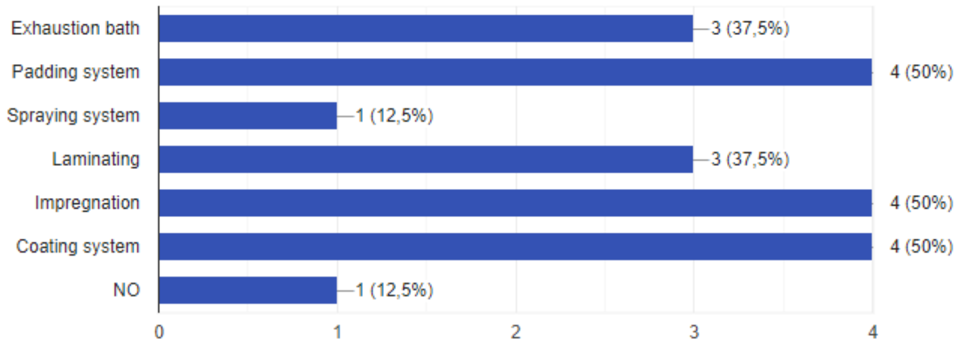
FINISHING / PRINTING SPECIALIZED COMPANIES TECHNOLOGIES

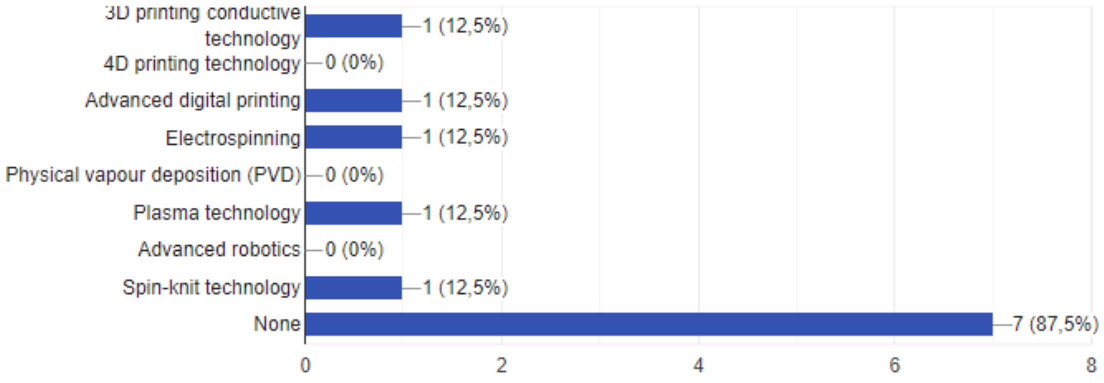
Looking at the data concerning the technological processes adopted, we note that 50% of the companies interviewed are endowed with padding systems, impregnation and coating system. 37.5% use exhaustion bath and laminating. Spraying system is used by the 12.5% of the company interviewed.

We also find a very important data concerning the innovative technologies that the respondents are equipped with. More than 87% of the companies interviewed declared that they do not use any of the listed technological innovations. Consequently we understand that only one of the companies replying to the questionnaire, normally use in its productive process innovative technologies like 3D printing, advanced digital printing, electrospinning, plasma technology and spin-knit technology. No one has introduced advanced innovations as 4D printing, physical vapor deposition and advanced robotics.

8.6 Please indicate which ones of the following technological processes your company is currently implementing considering the product type:



8.7 Is your enterprise using one or more of the following innovative technologies? If yes, which ones?



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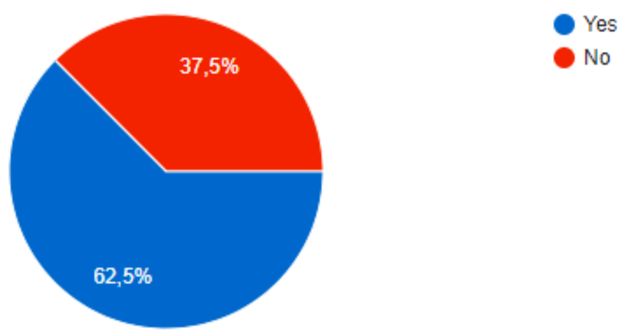
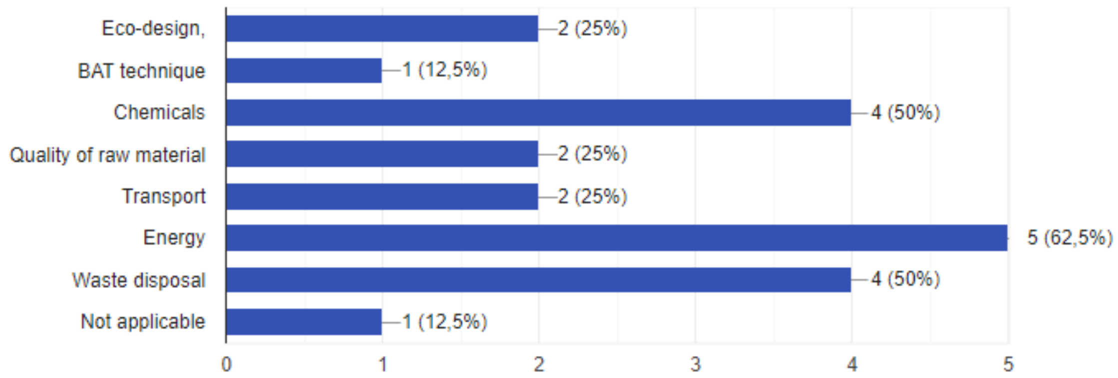
FINISHING / PRINTING SPECIALIZED COMPANIES SUSTAINABILITY

From the replies to the questionnaire we note a very encouraging figure concerning the adoption of environmental sustainability principles, in fact 62.5% of the companies interviewed declared that they are applying sustainable circular model in their production processes. Looking at the kind of practices implemented we see that most of the companies about 62.5%, use energy resources conscientiously, 50% of the companies interviewed apply the principles of productive sustainability for the use of chemical products and waste disposal. 25% of them transport their goods in the most sustainable way possible, use eco raw material and base their market on eco-design. Only 12,5% use BAT techniques.

8.8 Is your company implementing sustainable production circular model (closing a loop) in accordance with your production type?



8.9 If applied, please specify in which production processes has your company implemented sustainable production principles



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KNOWLEDGE ALLIANCE ICT-TEX ICT IN TEXTILE AND CLOTHING HIGHER EDUCATION AND BUSINESS

FINISHING / PRINTING SPECIALIZED COMPANIES ANALYSIS OF THE ANSWERS

Analyzing the companies operating in the finishing and printing sector, we realize that all of the respondent companies perform the dyeing process. Most of them use the Continuous dyeing method because it is a system that allows for fabrics rapid color variations. It is mainly used to dye large quantities of cotton fabrics and its blends with cellulosic artificial fibers, in the same color. The continuous and storage dyes are carried out widely due to the difficulties in the dye penetration and to avoid dead folds or permanent beating. Anyway also discontinues dyeing is widely used. In this process, the dye gets slowly transferred from a comparatively large volume dyebath to the substrate or material that is to be dyed. The time taken is longer. In discontinue dyeing processes, textile substrates can be easily dyed at any stage of their assembly into the desired textile product. This includes fiber, yarn, fabric or garment.

Furthermore we can see that the dyeing process is mainly implemented to the fabrics with a percentage of 62,5%, only 25% of the respondent apply this process on yarns or garments.

Among the other processes mainly applied we also find bleaching, softening and sizing/desizing for the chemical finishing processes while among the mechanical ones we find drying, implemented by all off the companies interviewed, calendaring and sanforization. These processes are meant to support the dyeing procedure from one side and to give to the products a better aspect and improved features to the other side. Finally we can also list the most spread finishing processes fulfilled with the aim to give special properties to the products, they are antibacterial, colorfastness, anti-pilling, anti-static and fireproofing.

From the responses collected we can also highlight the low propensity in the adoption of innovative technologies for the companies in the sector. The main constrains in their introduction are probably due to the initial investments but also to the lack of specialized professionals able to properly operate with them. Indeed we can see that among the skills most needed by the companies of the sector we find technical abilities and special knowledge mainly related to specific dyeing and printing processes, as for example rotary screen printing technology, raster printing, colorimetric and so on.

On the other hand the data concerning the adoption of circular model of production are encouraging, as they indicate an increasing attention to the environmental aspects mainly in reference to the use of chemicals, energy and waste disposal techniques.

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NEED FOR ICT SKILLS

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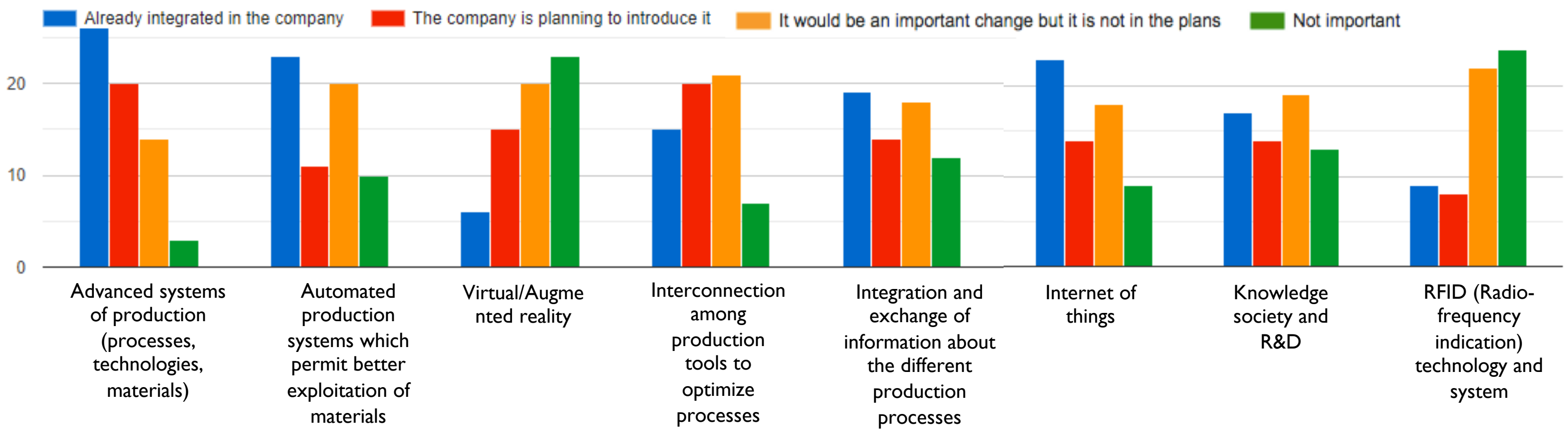
NEED FOR ICT SKILLS
MAIN TECHNOLOGICAL CHANGES ADOPTED

If we analyze the responses received regarding the state of important technological changes relevant for the employees ICT skills we can note important facts:

- Most of the factories, more than 40%, has already introduced advanced systems of production (processes, technologies, materials), automated production systems which permit better exploitation of materials and internet of things are also well implemented with a percentage of 36%, then we find integrated systems for the exchange of information between the different production processes with a percentage of 30% and systems for shared knowledge and R&D counting for around 27% of the companies. For these kind of technological changes also the percentage of companies who are planning to introduce them or considering them really important is considerable.
- Low importance is instead attributed to virtual/augmented reality and RFID (Radio Frequency Indication) technology even if most companies recognize their importance and some of them have already introduce these kind of innovations in their productive reality or are planning to introduce them.

9.1 What is the state of the following technological changes affecting ICT skills in your company?



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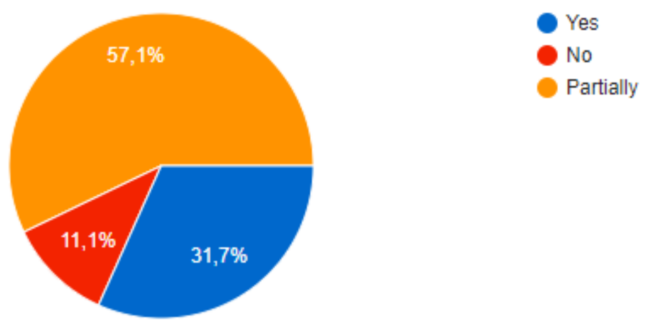
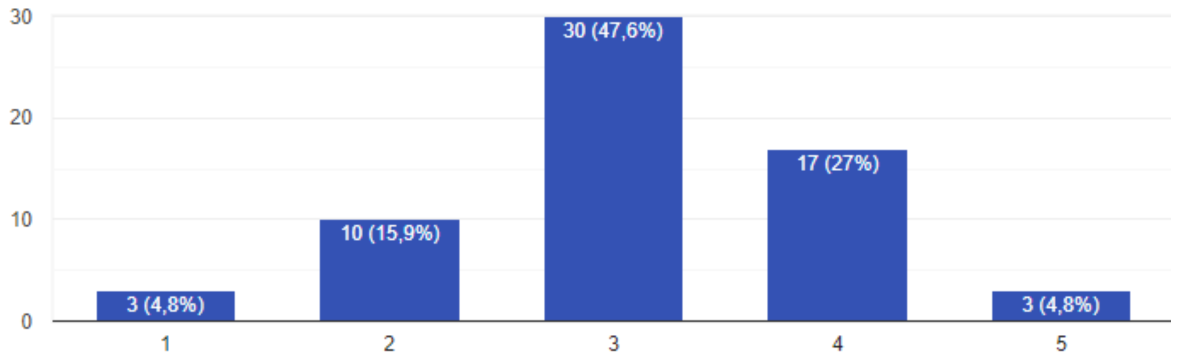
NEED FOR ICT SKILLS
ICT INTEGRATION LEVEL

The majority of the companies interviewed 57,1% indicate that their employees are not completely skilled to introduce the previous listed technological changes, while 31.7% of them consider their employees completely skills and another 11.7% replied that the knowledge and abilities of their employees are not sufficient. In other words, as regards the integration of ICT into the company's production processes, the majority, more than 47%, replied that ICT are on average integrated, 27% of the companies believe that they have a medium-high level of ICT integration and 4.8% very high. On the other side 15.9% of the companies interviewed consider their ICT integration level as medium-low and 4.8% very low.

9.2 Do you think your company employees have the competences needed to introduce these kinds of technologies?



9.3 How high is the level of integration of ICT in your company, in your opinion?



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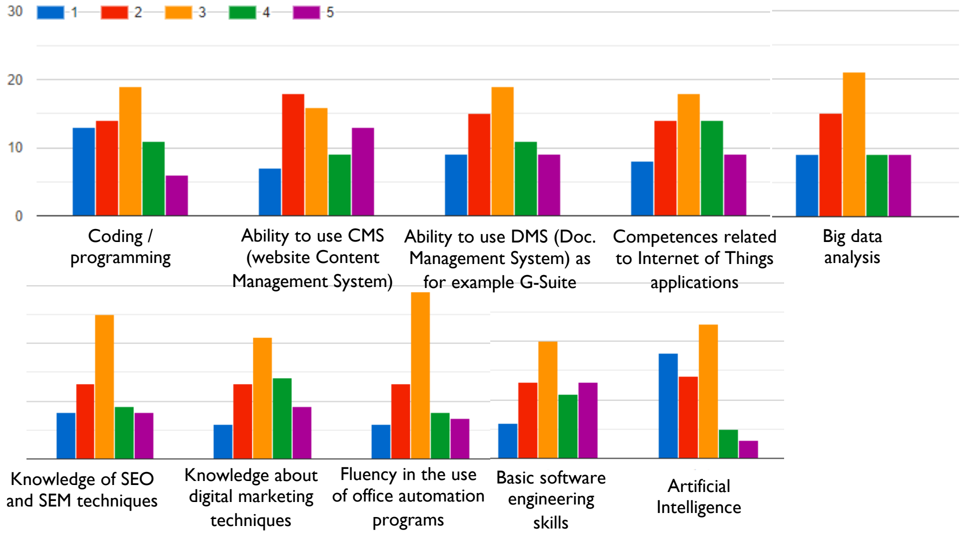
NEED FOR ICT SKILLS
ICT SKILLS PERCEIVED IMPORTANCE

Analysing the perceived relevance of the main ICT skills for the companies replying to our questionnaire, we can observe that in general the majority of them assigned a medium grade of importance. In particular it mainly happens for competences like knowledge of SEO (search engine optimisation) and SEM (search engine marketing) techniques / ability to use office automation programs / artificial intelligence. This last one considered not important at all by a relatively high percentage of respondents. In general this trend is repeated also for the other analysed skills: coding or programming / ability to use CMS (website contents management systems) / ability to use document management systems as for example G-Suite / knowledge about social media and digital marketing techniques and instruments / ability to use internet of things applications / big data analysis / basic software engineering skills. Among the listed skills the ones that the companies believes their employees need to improve mostly are the knowledge about social media / digital marketing instruments and basic software engineering skills, immediately after we have big data analysis and then the use of CMS and office automation programs.

9.4 Please evaluate the relevance of the following ICT skills for your company by assigning a grade between 1 (very low) and 5 (very high)



Variable	Score					Global score
	1	2	3	4	5	
Basic software engineering skills	6	13	20	11	13	201
Knowledge about social media/digital marketing techniques and instruments	6	13	21	14	9	196
Ability to use CMS (website Content Management System)	7	18	16	9	13	192
Competences related to Internet of Things applications	8	14	18	14	9	191
Fluency in the use of office automation programs	6	13	29	8	7	186
Ability to use DMS (Document Management System) as for example G-Suite	9	15	19	11	9	185
Knowledge of Search Engine Optimization and Search engine marketing techniques	8	13	25	9	8	185
Big data analysis	9	15	21	9	9	183
Coding / programming	13	14	19	11	6	172
Artificial Intelligence	18	14	23	5	3	150

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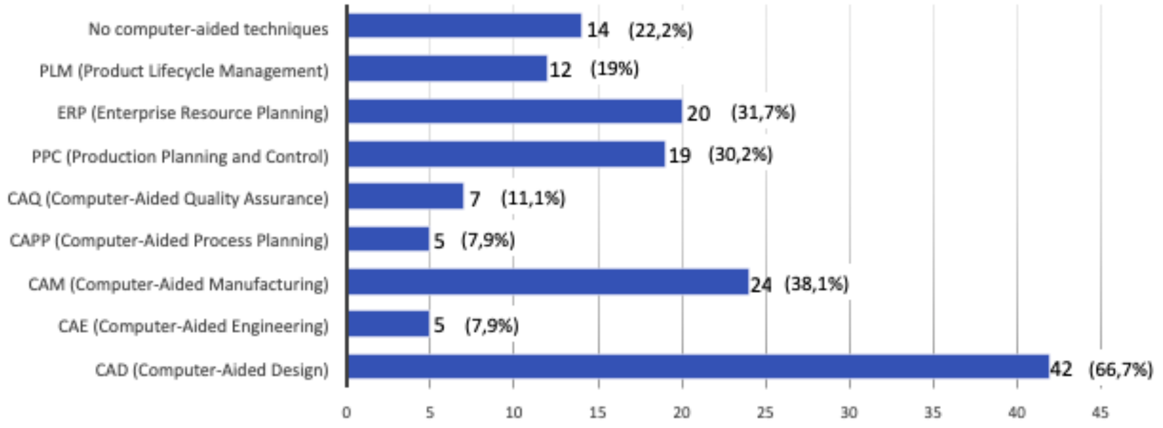
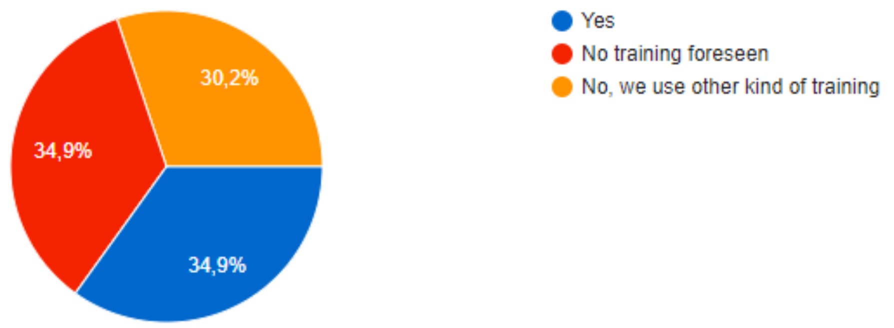
NEED FOR ICT SKILLS
COMPUTER-AIDED TECHNIQUES

Concerning the implementation of computer-aided techniques among the participating companies, we understand from the answers collected, that the most used are surely the Cad systems with 66,7% of usage. Also Cam Systems is used by a good percentage 38,1%, then we have ERP with a percentage of 31,7% and PPC with 30,2%.
However, a significant figure is represented by the high percentage of companies that do not use any computerized systems, about 22,2% of the total.
In addition we also understand how companies usually train their staff on the use of CAD / CAM software. 34.9% replied that they take advantage of the training directly provided by the software / machines owners, another 30,2% claim to use other kinds of trainings while a consistent percentage of 34,9% do not foreseen any kind of training for the staff.

9.6 What kind of computer-aided techniques are implemented in your company?



9.7 Is the dedicated staff regularly trained on using CAD/CAM software by the company owner of the software/machines used in your company?



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NEED FOR ICT SKILLS
COMPUTER-AIDED TECHNIQUES

Finally we would like to report here some useful comments released by the companies about the desired improvements in CAD/CAM products:

- Better Graphics needed
- New version of CAD/CAM and training.
- Integration of design, sketching, pattern making, 3D prototyping and grading into one software, with the possibility to simultaneously operate on the same work for several employees; no separate licenses for every module; better connection between patterns; graphic design and digital printing with less stages and less conversions needed.
- There is a lot of work that needs to be improved in our production centers, but that requests time and money. Digitalization is required in all areas.
- We are satisfied with our high-tech systems, but we expect their improvement in the future
- About CAD we mainly look for very realistic simulations (virtual reality)
- Too much software errors

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NEED FOR ENTREPRENEURIAL SKILLS

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NEED FOR ENTREPRENEURIAL SKILLS PERSONAL FEATURES

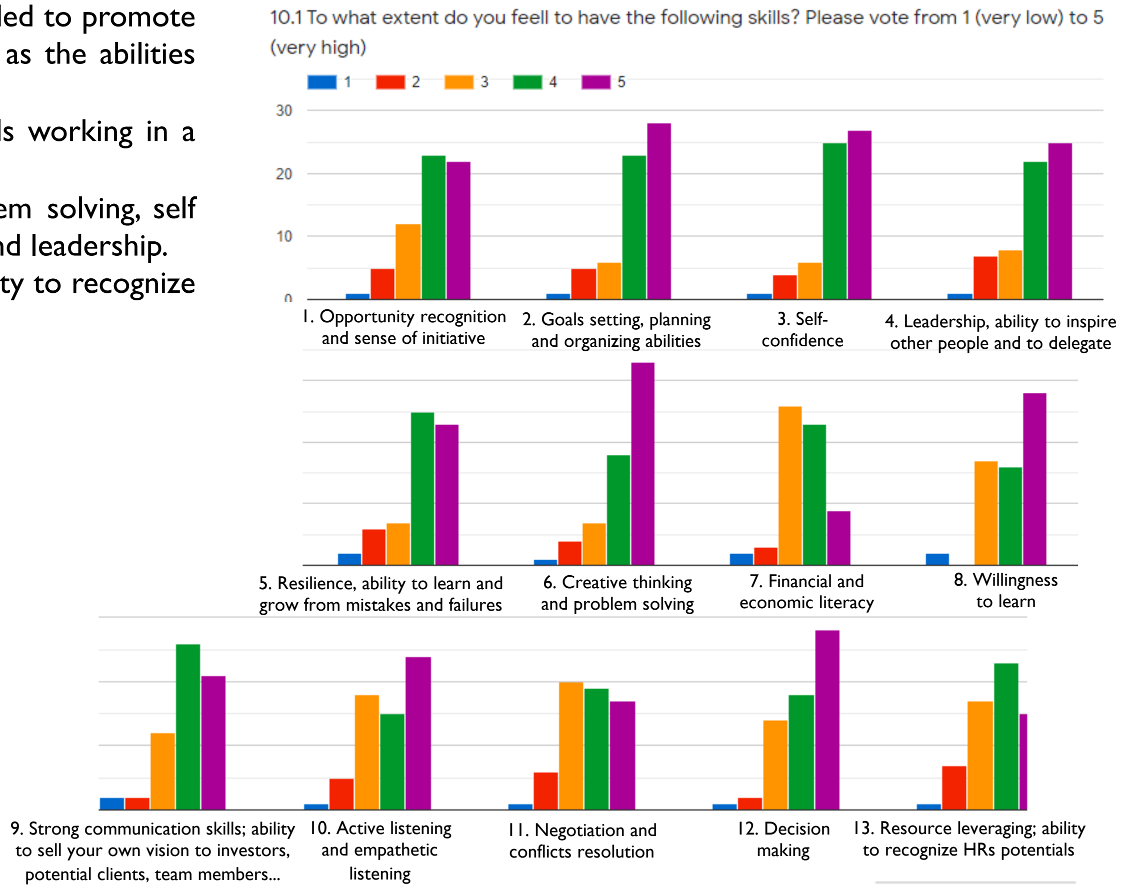
The last topic analyzed in our questionnaire is the entrepreneurial structure and the skills needed to promote an entrepreneurial mindset in the companies interviewed, meant in a more widen spectrum as the abilities that let an individual to reach their professionals objectives.

The responses collected are particular valuable because they largely come from professionals working in a managerial position.

Among the personal skills they feel to have the most, we find: creative thinking and problem solving, self confidence, goals setting planning and organizing abilities, decision making, willingness to learn and leadership.

On the other hand, among the skills that need to be improved, we have conflict resolution, ability to recognize the other employees potentials, financial and economic literacy.

Variable	Score					Global score
	1	2	3	4	5	
6. Creative thinking and problem solving	1	4	7	18	33	267
3. Self-confidence	1	4	6	25	27	262
2. Goals setting, planning and organizing abilities	1	5	6	23	28	261
12. Decision making	1	2	14	18	28	259
8. Willingness to learn	2	0	17	16	28	257
4. Leadership, ability to inspire other people and to delegate	1	7	8	22	25	252
9. Strong communication skills; ability to sell your own vision to investors, potential clients, team members...	2	2	12	26	21	251
5. Resilience, ability to learn and grow from mistakes and failures	2	6	7	25	23	250
1. Opportunity recognition and sense of initiative	1	5	12	23	22	249
10. Active listening and empathetic listening	1	5	18	15	24	245
11. Negotiation and conflicts resolution	1	6	20	19	17	234
13. Resource leveraging; ability to to recognize HRs potentials	1	7	17	23	15	233
7. Financial and economic literacy	2	3	26	23	9	223



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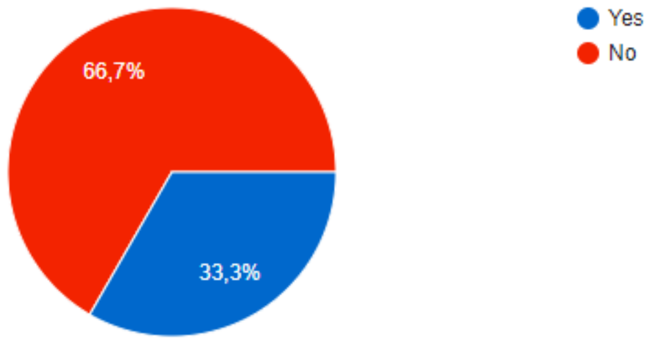
NEED FOR ENTREPRENEURIAL SKILLS IDEA SHARING AND RECOGNITIONS

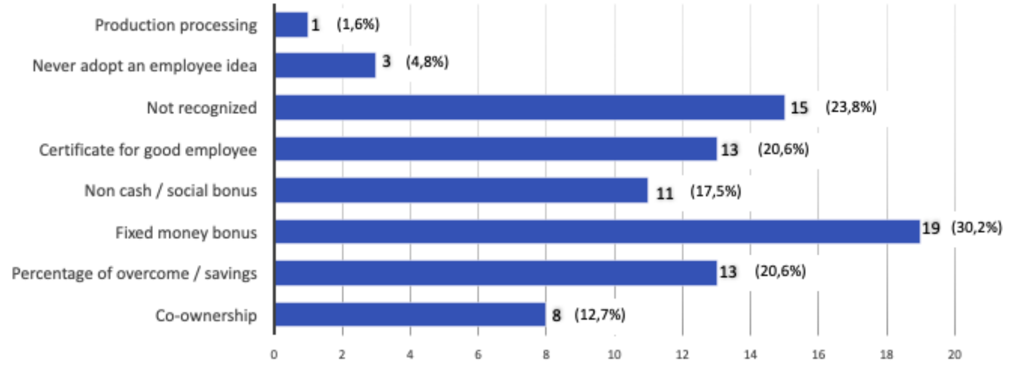
The answers obtained show that the majority of the companies, about 66.7%, do not keep a register of the innovative ideas proposed by the employees, however when employees share their innovative ideas, the ownership usually gives economic incentives, in 20.6% of the cases it can be a percentage on revenues or for another 30.2% a fixed money bonus. Instead we also find companies recognizing no-monetary incentives as for example certificate for good employee, used by 20.6% of the respondents and social bonus adopted by 17.5% of the companies interviewed. 12,7% recognize the co-ownership of the possible new venture.

However it has to be underlined that a considerable percentage of companies 23,8%, do not recognize any benefits.

10.2 Do you have an internal registry with the “hottest” business ideas?



10.3 Do the employees share ideas for new opportunities (products, technology, production processes)? If yes, please, indicate how your company recognizes their ideas



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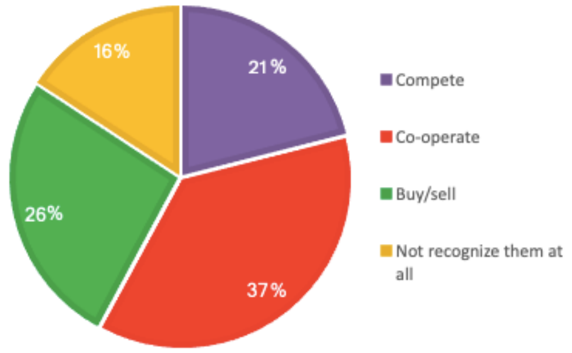
NEED FOR ENTREPRENEURIAL SKILLS NEW INITIATIVES PROPENSITY

From the responses received we also understand that in many cases even the most deserving employees fail, do not have the will or are not sufficiently incentivized to open a new enterprise. Indeed 80% of the companies reported that no one of their employees have ever started a new business in the T&C sector.

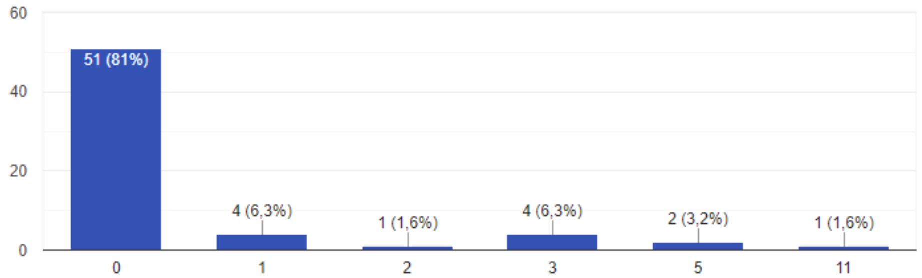
For the ones who responded affirmatively, the peculiarities of the new created enterprises are mainly connected to new products (70,6%). Following we have new services (29,4%), new technologies (23,5%) and innovative production processes (17,6%).

Concerning the relationship established with the newly created realities, the majority of the companies interviewed 37% replied that they actively cooperate with the employees who have decided to become entrepreneurs themselves, thus identifying a strong network interconnection between the businesses. 26% of them replied that they buy from or sell to the new companies, while 21% affirmed to be direct competitors.

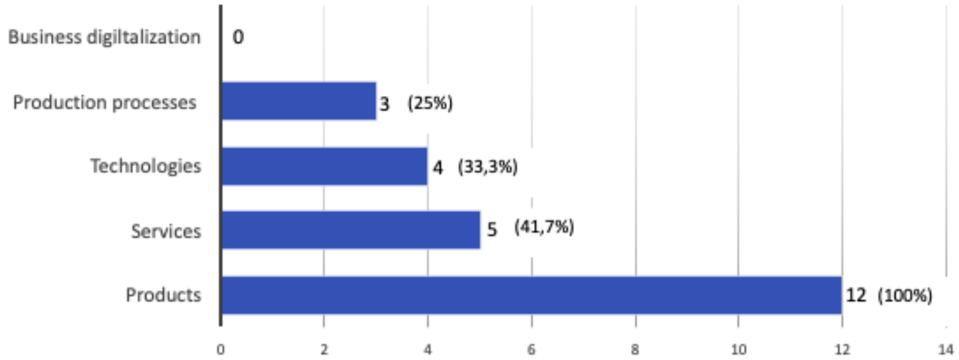
10.6 How does your company work with them?



10.4 How many employees from your company have started their own businesses in the T&C sector?



10.5 What is unique about their entrepreneurial business?



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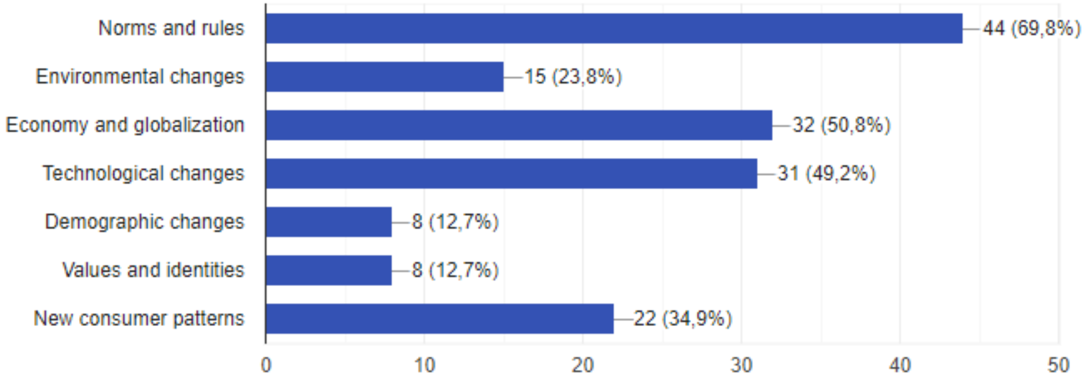
NEED FOR ENTREPRENEURIAL SKILLS
BUSINESS MODEL DRIVERS

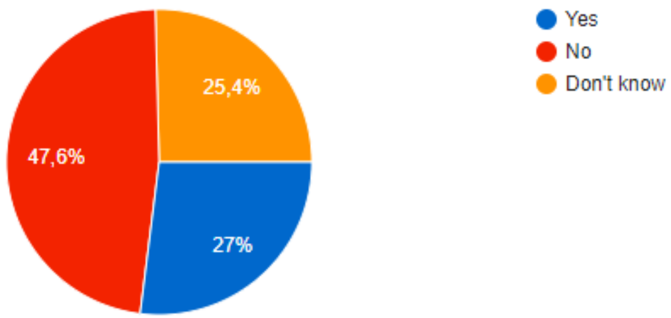
Regarding the main drivers of changes having a major impact on the companies business model, variations in norms and rules are indicated as the factor more affecting the business with a percentage of 69,8% of the responses collected. Technological changes, economic trends and globalization also register a high percentage 50%. A remarkable impact it is also assigned to new customer patterns (34.9%) and environmental changes (23.8%). Finally we find values and identities shifts and demographic changes with a percentage of only 12,7%.

An important figure is highlighted from the responses received to the question related to the companies propensity to make use of the services offered by incubators, hubs or management consultancy agencies. We understand that the great majority of the companies never get advantage from the collaboration with these kind of business actors in the last 5 years, indicating a low propensity towards innovation patterns.

10.7 In your opinion which ones of the following drivers of changes have major impacts on your company business model?



10.8 Has your company collaborated and/or received support from incubators, hubs, management consultancies in the last 5 years?



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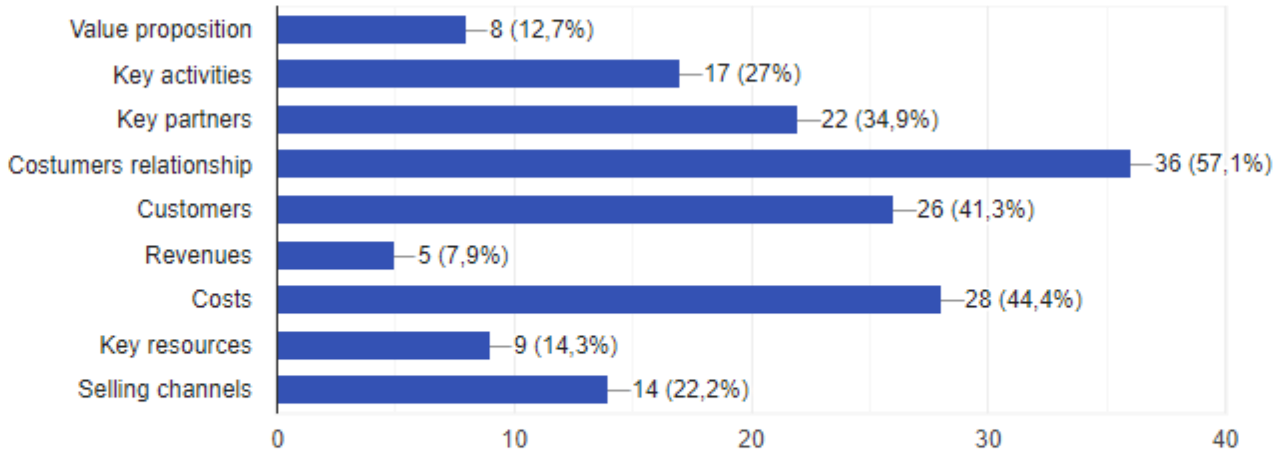
NEED FOR ENTREPRENEURIAL SKILLS
BUSINESS MODEL DRIVERS

To conclude our analysis we are going to explore the main aspects that the companies innovate the most taking inspiration from the Canvas Business Model elements.
With a high percentage of 57.1% we can see that the customer relationship is certainly the item that the companies interviewed take more into consideration in their innovative initiatives we also find with good percentages: customers segmentation (41,4%) cost structure (44,4%) key partners (34,9%) key activities (27%) and selling channels (22,2%)
On the other side the business model elements objective of a lower innovation level are: the composition of the key resources (14,3%), the value propositions (12,7%) and the revenue streams (7,9%).

10.9 According to your perception, which of the following items does your company innovate the most?



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