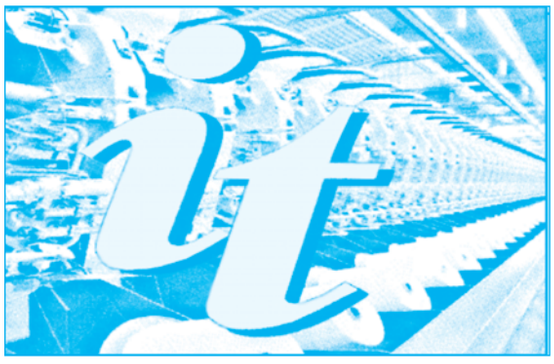

Industria Textilă

ISSN 1222–5347

3/2022

ISI rated *journal, included in the* ***ISI Master Journal List*** *of the Institute of Science Information, Philadelphia, USA, starting with vol. 58, no. 1/2007, with* ***impact factor 0.784 and AIS 0.070 in 2020****.*

The journal is indexed by CrossRef, starting with no. 1/2017 having the title DOI: https://doi.org/10.35530/IT.

Edited in 6 issues per year, indexed and abstracted in:
Science Citation Index Expanded (SCIE), Materials Science Citation Index®, Journal Citation Reports/Science Edition, World Textile Abstracts, Chemical Abstracts, VINITI, Scopus, Toga FIZ technik, EBSCO, ProQuest Central, Crossref
Edited with the Romanian Ministry of Research, Innovation and Digitalization support

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Aknowledged in Romania, in the Engineering sciences domain, by the National Council of the Scientific Research from the Higher Education (CNCSIS), in group A
Journal edited in colaboration with **Editura AGIR**, 118 Calea Victoriei, sector 1, Bucharest, tel./fax: 021-316.89.92; 021-316.89.93; e-mail: editura@agir.ro, www.edituraagir.ro

Performance evaluation of hot mix asphalt using textile waste

DOI: 10.35530/IT.073.03.202144

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ABSTRACT – REZUMAT

Performance evaluation of hot mix asphalt using textile waste

Polyester (PET) is used in asphalt binder to improve the sustainability and performance of the road. Modification of asphalt has become a serious demand these days due to performance requirements caused by significant traffic and heavy vehicles. Asphalt alone cannot bear the stresses. The Marshall Mix design method is used for testing treated and untreated asphalt samples. The properties of all asphalt samples were compared. The best combination of asphalt and PET for best performance is based on the study of PET content used in the mix of PET/Asphalt, i.e., 0%, 2.5%, 5%, 7.5%, and 10%. The following tests were performed on the asphalt samples for various aspects of performance: stability test, flow test, air voids, voids filled with asphalt (VFA), voids in mineral aggregate (VMA), and OAC. Polyester waste is utilized in road construction which has been proved helpful to improve the performance of conventional road construction and provide reliability in a sustainable approach. An asphalt grade of 60/70 was taken for evaluation.

Keywords: *asphalt, marshal mix design method, polyester fibre waste, road construction, sustainability*

Evaluarea performanței amestecului fierbinte de asfalt utilizând deșeuri textile

Poliesterul (PET) este utilizat în liantul de asfalt pentru a îmbunătăți durabilitatea și performanța carosabilului. Modificarea asfaltului a devenit o cerere serioasă în aceste zile, din cauza cerințelor de performanță impuse de trafic și de vehiculele grele. Asfaltul nu poate suporta solicitările. Metoda de proiectare Marshall Mix este utilizată pentru testarea probelor de asfalt tratate și netratate. Au fost comparate proprietățile tuturor probelor de asfalt. Combinația cea mai performantă de asfalt și PET se bazează pe studiul conținutului de PET utilizat în amestecul de PET/Asfalt, respectiv 0%, 2,5%, 5%, 7,5% și 10%. Următoarele teste au fost efectuate pe probele de asfalt pentru diferite aspecte ale performanței: test de stabilitate, test de debit, goluri de aer, goluri umplute cu asfalt (VFA), goluri în agregate minerale (VMA) și OAC. Deșeurile de poliester sunt utilizate în construcția drumurilor, ceea ce s-a dovedit util pentru a îmbunătăți performanța construcției de drumuri convenționale și pentru a oferi fiabilitate într-o abordare durabilă. S-a evaluat gradul de asfalt de 60/70.

Cuvinte-cheie*: asfalt, metoda de proiectare Marshall Mix, deșeuri de fibre de poliester, construcție de drumuri, durabilitate*

INTRODUCTION

There are several challenges being faced by all developed and developing countries among which high productivity and economic fight are major challenges. High productivity has not only increased the need to meet economic competitiveness, but safe and efficient transportation has also become a necessary requirement for the delivery of goods. To achieve the economic requirement, vehicle manufacturers are now moving towards the manufacturing of larger vehicles and containers which are applying high stresses, pressure, and axle load for the delivery of huge production to the market. The increase in the traffic, high axle load, high-temperature rutting, low temperature cracking and medium temperature fatigue are contributing to the deterioration and decomposition of conventional asphalt pavement sooner than the predicted time. For this purpose, it is important to make new pavement designs and construction that are durable and strong enough to bear stresses and require less maintenance and modifications. This modification can be done by using waste materials so that it could be cost-effective as well as sustainable for the environment by utilizing the waste as a substitute for binder in road construction [1].

A network of roads has been spread all over the world. In Pakistan Transportation by road is widely used; almost 91% of transportation takes place by road. So, it is necessary that the road should be safe, sustainable, and reliable. Heavy vehicles (trawlers and trucks which have high tons of weight) and huge amounts of traffic are applying different stresses on the road, which not only deteriorate the roads but also consume a large amount of asphalt. Therefore, an additive should be added to asphalt which can give the necessary requirements that are; should be strong enough, fatigue resistant and could bear high stresses [2]. Asphalt concrete (AC) is a composite material consisting of aggregate, asphalt binder and

air void. AC is used for road construction that meets different stresses, loads and different environmental conditions that affect its durability. So, different studies showed that adding some of the additives in asphalt can alter its properties like strength, fatigue behaviour and several engineering properties. The additives containing organic polymers and fibres that are used with hot mix asphalt for the construction of road pavements would be able to enhance their mechanical strength, reduce thermal susceptibility, change visco-elastic response and increase resistance to rutting [3–6]. However, not all the fibres can be used because of their limited availability and high costs [7]. The addition of polymer fibres in the pavements is the most innovative way which not only reduces the damaging problems but also improves the service life of the pavement. Also, this is the best way to utilize the waste of polymer fibres. This addition can lead to an increase in the service life of the pavement and reduce the maintenance requirement which is needed in conventional asphalt concrete pavements. Thus, the cost factor is also reduced by decreasing the quantity of asphalt and making the pavement more durable. Using polyester fibres is an innovative technique that is widely adopted all over the world as filler material to produce polyester-reinforced concrete (PFRC) and that can be used in pavement quality concrete (PQC) [2].

Asphalt shows different behaviours under different conditions, temperatures and other materials that are added to asphalt to improve its properties. Asphalt is known as viscoelastic material in nature that shows good viscosity behaviour at different temperatures and with different polymers [2]. Different modifications have been made to the asphalt mixture, but research work has shown that only polymer and fibres could obtain such tremendous effects on the asphalt pavements. Polymers have good strength and sustainability so their addition in asphalt is considered as an important modification in all the research work [8]. The synergetic behaviour of asphalt and the additives are strongly dependent on fibre type and structure. It would be crucial to compare fibre properties along with the mechanism that is being selected for the modification in asphalt design [7]. Both wet and dry processes can be used to add a polymer to asphalt mix: In the wet process, heated asphalt is mixed with heated polymer first, they then mix with aggregates. In the dry process, polymer particles are blended with heated aggregates or to be applied on aggregate by coating first, they then mixed with asphalt. Both methods have different effects on the properties of asphalt [9, 10].

Serfass and Samanos used the wet method and concluded after testing asphalt/polyester composite, that resistance to ageing, shear, flexure and tension have been improved. It also has a very low effect of water on it [11].

Asma reported that modified asphalt is highly resistant to stress, disruption, and water damage due to the multi-directional reinforcing function of polyester fibres. The bitumen film (mixed with polyester) becomes thick and adheres to the aggregate more firmly, giving it more strength than conventional asphalt mix [12]. According to the research carried out by Qunshan, different fibres (Polyester, Cellulose, and mineral fibres) were used out of which the only polyester is proved to be the best modifier for asphalt in terms of fatigue property [13]. Xu investigated the polyester fibre effect on fatigue life of asphalt by dry process. Different percentages were used. i.e., 0%, 0.2%, 0.35% and 0.5% were used in his research. A bending fatigue test was performed at 20°C. Fatigue life has increased significantly by using polyester fibres due to the binder stabilization on the surface of aggregate [7]. Anurag performed an indirect tensile strength test of asphalt mixtures, roofing polyester waste fibres were used as additives. Properties of tensile strength as well as Marshall stability, void content and unit weight of Asphalt mixture were improved [14]. Shaopeng found that polyester/asphalt composite could increase the viscosity of asphalt binder and the cycle number to fatigue failure by 3.6 times. The optimum fibre content of 0.30% on the weight of the total mixture was found [8]. Hasan, used different contents of Polypropylene fibres (0.10%, 0.20%, 0.30% and 0.40%) to be mixed with asphalt. Marshall Properties, indirect tensile strength, temperature susceptibility and resistance to moisture damage were studied on the developed fibre/asphalt composites. The results showed improved tensile strength, resistance to plastic flow and resistance to moisture damage of all composts compared to pure asphalt [15].

Peng, studied the effect of the addition of different polymers in asphalt using a dry process. He concluded that the addition of polyester in bitumen would prevent bleeding of asphalt caused by high temperatures in summer. Polyester is able to keep the bitumen film in a very stable state. This happens because polyester provides extra space for the expansion of bitumen, this can prevent bleeding and give sufficient high-temperature stability to the road. The study also shows a decrease in rutting depth and an improvement in the shear resistance of the asphalt mixture [16]. Essawy added polyester and polypropylene fibres from industrial waste, it was found that using polymer can reduce temperature susceptibility. Polypropylene was preferred over polyester because polyester fibre toughens the PMA sample [17]. Sabagh et al. studied stearyl acrylate and methyl methacrylate and styrene modified asphalt composites. They concluded that those HMA polymers were showing exceptional performance as compared to ordinary asphalt mixture after a series of tests performed on some chemical and physical properties [18]. Nura Usman used recycled PET fibre to make asphalt composite, using a dry method to add the PET fibres to the mixture. Resilience Modulus was tested on PET fibre modified composite samples in comparison to control samples. Research results revealed there was a significant increase in resilience modulus at low temperatures [19]. Afroz Sultana utilized plastic waste to make asphalt composite by the wet method. The waste consists of

polypropylene, low-density polyethylene and high-density polyethylene fibres. The test includes Marshall Stability to be performed on PMA sample and controlled sample. The research not only revealed better performance for asphalt concrete but also proved to be a cost-effective process [20]. Joohari et al. studied the effect of polypropylene (PP) fibre as a replacement of filler on asphaltic concrete performance. Marshall Mix design was used to obtain the optimum binder content and the compressive strength of the samples produced was determined. The study revealed that PP fibre as filer showed impressive improvement in terms of Marshall stability, flow and compressive strength as compared to the conventional bituminous mixture [21].

In light of the above findings deduced from experimental studies, it is clear that the addition of polyester to the asphalt to make asphalt composite can increase its many properties and extend its lifetime, requiring low maintenance. In this study, the addition method for polyester in asphalt used is the wet method by substituting approach to make the process cost-effective and sustainable by substituting asphalt binder by polyester in certain ratios. The main objective of this research is to minimize the deterioration in the conventional asphalt pavement by adding a certain percentage substitution of waste polyester as an asphalt binder and to evaluate the optimum amount of polyester on the weight of asphalt against best performance. After the modification of asphalt with polyester, the comparison is done between conventional and modified asphalt pavements through different tests such as stability test, flow test and specific gravity test. The other objective of this study is to reduce cost utilizing cost-effective PET waste and reduce the amount of asphalt used.

METHODOLOGY

This study comprises of making samples of flexible pavement using polyester waste by using the wet method. Polyester is added with asphalt in different ratios on the basis of the weight of asphalt, which are 0%, 2.5%, 5%, 7.5% and 10% respectively. For this purpose, 150 samples were made in which 90 of them were compacted and the rest were non-compacted. Asphalt also utilized was made in different weight fractions with respect to the weight of the aggregate samples which are 3.5%, 4%, 4.5%, 5%, 5.5%, 6%. All the samples were tested in a Marshall Test apparatus to evaluate the performance of asphalt/polyester composites in comparison to samples without polyester.

MATERIALS

Asphalt

For making Marshall Specimen three components are essential, which include asphalt, aggregate, and polyester. The asphalt used in this study is 60/70 grade with specifications given in table 1.

Table 1

ASPHALT AND BITUMINOUS PROPERTIES

Properties	Bituminous	Asphalt
Softening point (ºC)	49-56	43.75
Penetration value at 25ºC (Desi-mm)	-	64.92
Penetration grade	60–70	60/70
Fire flash point (ºC)	232	130
Specific gravity (Kg/cm^3)	1.01–1.06	0.99
Ductility at 25ºC (cm)	100	-
Loss of heating (%)	0.2 (max)	-
Drop in penetration after heating (%)	20 (max)	-
Solubility in trichloroethylene (%)	99	-
Spot test	Negative	-

Polyester fibre

As part of this research, polyester fibre waste with the following properties was used (table 2).

Table 2

PROPERTIES OF WASTE POLYESTER FIBRE

Polyester Properties	Values
Specific gravity	1.40
Tenacity (g/d)	3.5–7.0
% Elongation at break (%)	15–45
Moisture regain (%)	0.4–0.8
Shrinkage in Boiling Water (%)	0–3
Elastic recovery (%)	93 at 5%
Glass transition temp (ºC)	80
Softening temp (ºC)	230–240
Melting point (ºC)	260–270
Effect of sunlight (%)	70–80 tenacity at long exposure
Resistance to weathering	Good

Preparation of Marshall sample

Marshall Specimen were prepared following the standard procedure AASHTO T 245. The mixture was prepared using the sieved aggregate and asphalt grade 60/70 as mentioned earlier. The aggregate was preheated to 150°C then heated with asphalt at 175°C to get the desired viscosity. Asphalt was added to the aggregate samples up to the required weight and mixed thoroughly as pre-planned ratios. The preheated mould assembly was positioned on the mould holder of the marshal mix compaction machine. The mixture was poured into the mould in three layers. Each layer was spaded 25 times at the interior portion of the mix using a tamping rod. Once filled 75 blows were applied using a compaction hammer. The mould was then reversed and reassembled, and 75 blows were applied on the reversed side.

Table 3

TESTS PERFORMED ON AGGREGATES		
Test	**Standard**	**Apparatus**
Resistance to degradation of aggregate by abrasion and impact	ASTM: C131-89	Los Angeles Abrasion Machine
Specific gravity and absorption of coarse aggregate	ASTM: C127-88	Balance, sample container, a wire basket of 3.55 mm, Water tank
Impact value of aggregate	BS: 812 Part 112	Cylinder, impact testing machine, temping rod, sieve, balance

Table 4

TESTS PERFORMED ON BITUMINOUS MATERIAL		
Test	**Standard**	**Apparatus**
Penetration grade of bituminous material	ASTM: D5-86	Penetrometer, Penetration needle, sample container, water bath, Transfer dish, thermometers
Flash and fire point of bitumen	ASTM: D92-78	Cleveland open cup apparatus
Softening point of bitumen	ASTM: D36-8	Ring and ball apparatus
Specific gravity of semisolid bituminous material	ASTM: D70-76	Pycnometer bottle, beaker, Water bath, Thermometers
Ductility of bituminous material	ASTM: D113-86	Ductilimeters, Mould, Water bath, thermometer

Samples were taken out of the mould after 24 hours using a sample extractor. Tables 3–6 show different tests performed on aggregates and bituminous mix, including resistance to degradation, specific gravity and absorption and impact, penetration grade, flash and softening temperature, and ductile property.

Table 5

SPECIFIC GRAVITY AND ABSORPTION TEST ON AGGREGATES		
Parameters	**Natural Aggregates**	
	1/2”	3/4"
A	1998.9	2996.0
B	2013.1	3015.0
C	1257.9	1881.5
BSG	2.646	2.643
BSG_{SSD}	2.665	2.660
$BSG_{Apparent}$	2.720	2.688
Absorption %	0.710	0.643

Table 6

L.A. ABRASION AND IMPACT TEST ON AGGREGATES	
Parameters	**Natural Aggregates**
L.A. Abrasion %	28.3
Impact value	15.8

RESULTS AND DISCUSSION

The bituminous aggregate mixture without polyester is considered as control/reference sample. Modified samples were made by the addition of polyester to bituminous aggregate in 2.5%, 5%, 7.5% and 10% respectively on the weight of the mix.

Effect on air voids and density

The air voids percent indicates the basic physical characteristic of bituminous asphalt mix. Figure1, *a* shows that air voids are gradually decreased with the addition of polyester at a certain level. It can be noticed that there is a very little bit of variation in air voids within band 0–5%. But between 5% and 7.5%, there is a noticeable change that occurred in the air voids %. The air voids are decreased from 5% to 7.5% and increased from 7.5% to 10%. At a 10% polyester/mix ratio the asphalt content is getting low caused by more air voids observed. Figure 1, *b* shows the variation in density with the increase in polyester content in all Marshall Samples. The results show that the density is decreased with the increase in polyester content because polyester is lighter than asphalt. In the current research the asphalt content decreases with the increases in polyester content, this explained the reason for decreased density. At the stage when polyester content reaches 10% the density is abnormally increased.

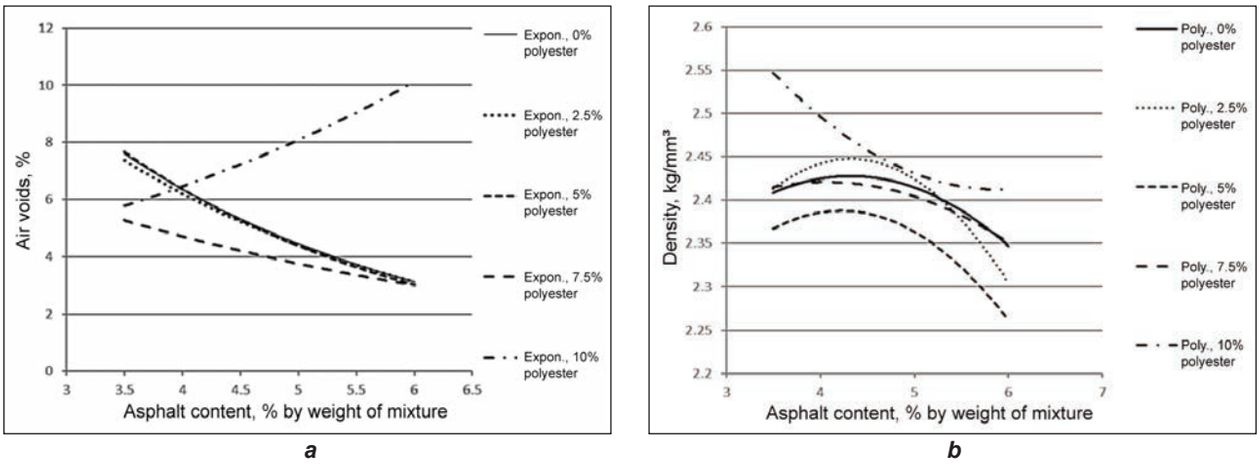
Effect on VMA and stability/flow

VMA indicates the portion of voids in a compacted asphalt aggregate specimen which not occupied by the aggregate. VMA is expressed as a percentage of the total volume of a mixture. The graph obtained for VMA as shown in figure 2, *a* is the opposite of density. There is a very less significant change in VMA percentage in samples with polyester/mix ratios of 0%,

2.5% and 5%. VMA percentage significantly decreases in samples with polyester content from 7.5% to 10%. This is because there was very low optimum asphalt content in those samples as compared to 0%, 2.5% and 5% PET containing samples which have a high value of optimum asphalt content. Asphalt fills the spaces between the aggregates, causing the low amount of asphalt and a higher percentage of polyester, VMA decreases. The linear curves in figure 2, *b* shows a direct relation between stability/flow and polyester at a certain level. It is observed from the stability/flow graphs, that stability/flow is increased with the increase of polyester content in the Marshall Mixture. The increasing trend is observed from samples with PET content of 0% to 7.5%, but there is a noticeable decrease in the linear curve of stability/flow at 10% PET modified sample. This is due to the reason that asphalt provides good adhesion and strength to the bituminous mixture. This explained the reason that in the sample containing 10% polyester the amount of asphalt is very low compared to 0%, 2.5%, 5% and 7.5% PET-containing samples, due to which stability/flow is increased to 7.5% and decreased after. It means that only a certain amount of PET can be substituted in place of asphalt in flexible pavements to have increased stability/flow than the conventional bituminous mixture. It is also observed from figure 2, *b*, that excessive increment in PET content in a mixture can result in a significant decrease in stability/flow of the bituminous mixture.

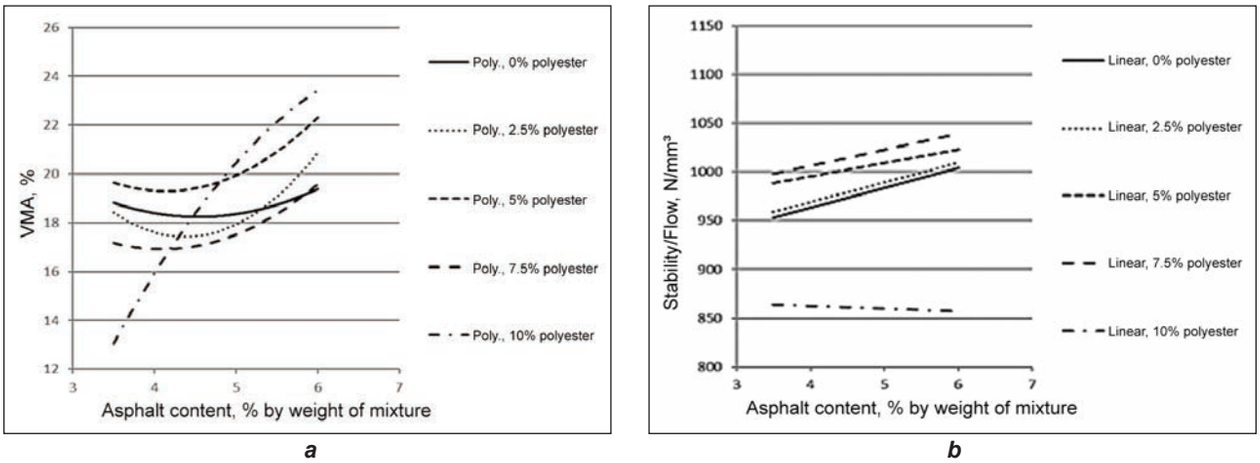
Optimum Asphalt Content (OAC)

By using the results of air voids (figure 1, *a*), the optimum asphalt content is determined. According to National Highway Authority (NHA) specifications, air voids in flexible pavement must be in the range of 4% to 6%. In this research, the optimum asphalt content for control/reference, as well as modified bituminous PET samples, is measured against 5% air voids, according to the NHA specifications. The theoretical values of Density, VMA, Stability and Flow were then obtained at Optimum Asphalt Content. According to figure 3, the OAC decreases with the increase in PET content in the mixture. After calculating the OAC against 5% air voids, the samples were prepared at OAC and tested, comparisons are made between results from the theoretical and experimental values in terms of physical properties which are Density, Stability, VMA and Flow.



a *b*

Fig. 1. Graphical representation of: *a* – percentage of air voids for different polyester level; *b* – density values for different polyester level



a *b*

Fig. 2. Graphical representation of: *a* – VMA values for different polyester level; *b* – Stability/Flow values for different polyester level

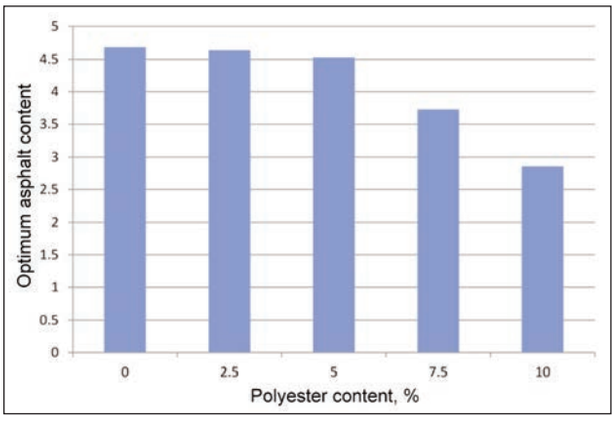


Fig. 3. Optimum asphalt content for different percentages of polyester

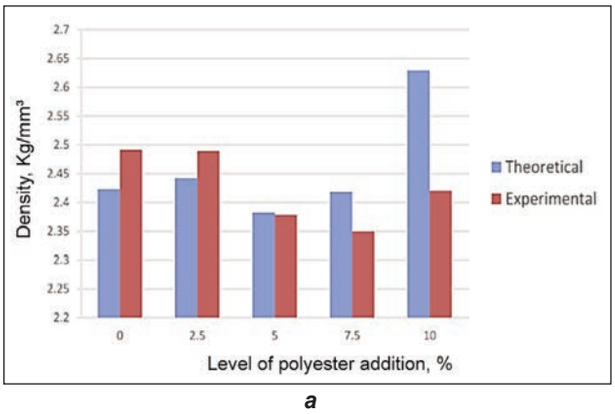
The values of VMA, Density, Stability and Flow corresponding to OAC were evaluated using experimentally recorded data at each level of PET/mix ratios, shown in figures 4 and 5. It can be seen that the difference between theoretical and experimental values is about 16%, and almost all theoretical and experimental values are similar with little variation.

Based on the research results of the tested samples of Marshall Mix, it can be found that:

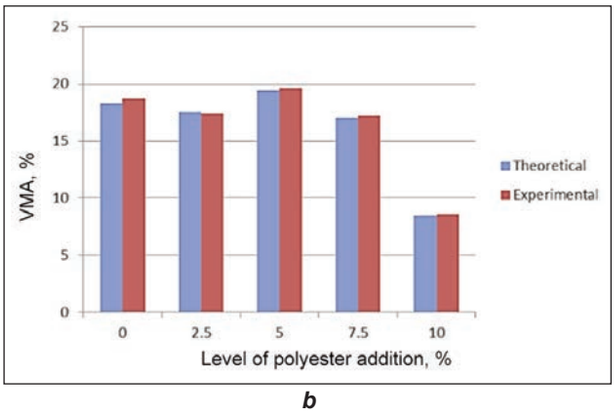
- There is very little change in VMA percentage from 0% to 5%, but a significant decrease in VMA percentage from 7.5% to 10% because of the low asphalt content.
- The modified bituminous mixture requires less asphalt content for absorption and binding as compared to the conventional bituminous mixture.
- The highest stability at optimum asphalt content with 5% air voids can be achieved at 7.5% PET content.
- The flow is also increased with the increase in the PET content at optimum asphalt content.
- The use of PET fibres provides a proper consideration of reduction in PET waste as well as a considerable reduction in the use of asphalt, which not only reduces the production cost but also provides stability to the flexible pavement and enhances its life cycle. The increased stability also ensures low maintenance costs, thus making flexible pavements more durable, sustainable, and economical.

CONCLUSIONS

The generation of waste plastics is increasing day by day. The addition of polyester shows adhesion property in its molten state. Polyester will increase the melting point of the bitumen. Hence, the use of polyester waste for pavement is one of the best methods for easy disposal of polyester. The use of innovative technology not only strengthened road

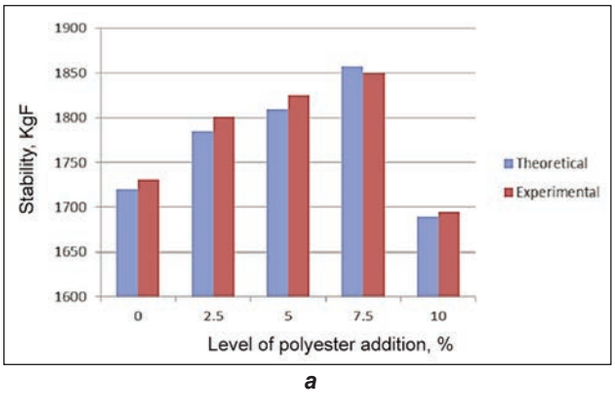


a

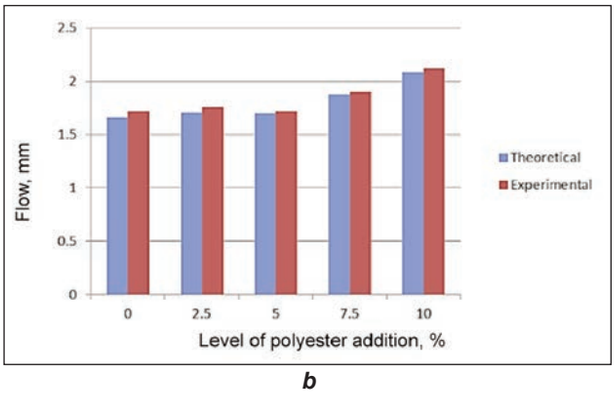


b

Fig. 4. Graphical representation of: *a* – theoretical and experimental data of density at OAC; *b* – theoretical and experimental data of VMA at OAC



a



b

Fig. 5. Graphical representation of: *a* – theoretical and experimental data of stability at OAC; *b* – theoretical and experimental data of flow at OAC

construction but also increased road life. Results of all the Marshall Mix design tests performed on control (conventional) and modified samples (PET asphalt mixture) show positive effects in terms of strength, flow, stability, and sustainability. The addition of PET also reduces the Optimum Asphalt Content (OAC) significantly. This reduction in OAC directly reduces the cost of Asphalt, and proves to be economical, sustainable and also suitable because of the use of polyester waste. The addition of polyester also increases the service life of flexible pavement due to the synergetic properties of polyester and asphalt. Polyester mixed with bitumen and aggregates can provide better performance on the roads. The polyester mixed with aggregates reduces the voids and moisture absorption. This results in the reduction of ruts without pothole formation. The modified flexible pavements can withstand heavy traffic and are more durable than conventional flexible pavement.

ACKNOWLEDGEMENT

The research is financially supported by NED University of Engineering and Technology, Karachi, Pakistan.

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Digital design of regional characteristic apparel pattern driven by GAN

DOI: 10.35530/IT.073.03.202117

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ABSTRACT – REZUMAT

Digital design of regional characteristic apparel pattern driven by GAN

In the links of apparel product development and production, apparel pattern design cannot reduce its marginal cost through economies of scale because of its creative characteristics. With the world entering the era of industry 4.0, machine learning can provide services for apparel design. This research takes the Chinese characteristic tachisme pattern as the research object and puts forward a new design method of regional characteristic apparel pattern driven by Generative Adversarial Networks (GAN). Firstly, the main framework based on GAN including discrimination and generation modules is established. Aiming at the training difficulties of regional characteristic apparel pattern sample situation with small quantity and disordered specification, the image self-amplification and normalization pre-processing module is added to the model. Secondly, by adding the Batch Normalization mechanism, Leaky ReLU and RMSProp algorithm, the problems of gradient disappearance and overfitting in the experiment are solved, and the convergence speed of the model is improved. Finally, the HSV colour model algorithm is introduced into the loss function to indicate the training process, so that the artistic expression characteristics of the generated results are closer to the human visual perception experience. Through index evaluation comparison, result authenticity investigation and product design practice, we prove the superiority and practicality of the proposed method in this paper. The new design method theoretically solves the scale economy dilemma of the previous apparel pattern design methods and provides reference ideas for more application scenarios currently trapped in the real-time presentation of design results.

Keywords: *apparel pattern, digitalization, design efficiency, generative adversarial network, machine learning, scale economy, regional characteristic*

Design digital al modelului de îmbrăcăminte caracteristic regional prin GAN

În relația dintre dezvoltarea și producția de produse de îmbrăcăminte, designul modelelor de îmbrăcăminte nu își poate reduce costul marginal prin economii de scară din cauza caracteristicilor sale creative. Odată cu intrarea lumii în era industriei 4.0, învățarea automată poate oferi servicii pentru designul de îmbrăcăminte. Această cercetare are ca obiect de cercetare modelul tașism caracteristic chinezesc și propune o nouă metodă de proiectare a modelului de îmbrăcăminte caracteristic regional prin Rețelele Adversare Generative (GAN). În primul rând, se stabilește cadrul principal bazat pe GAN, inclusiv modulele de discriminare și generare. Având în vedere dificultățile de prelucrare ale probei de model de îmbrăcăminte caracteristice regionale cu dimensiuni mici și specificații dezordonate, modulul de pre-procesare și autoamplificare a imaginii este adăugat la model. În al doilea rând, prin adăugarea mecanismului de normalizare a loturilor, a algoritmului Leaky ReLU și RMSProp, se rezolvă problemele de dispariție a gradientului și supraadaptarea în experiment, iar viteza de convergență a modelului este îmbunătățită. În cele din urmă, algoritmul modelului de culoare HSV este introdus pentru a indica procesul de prelucrare, astfel încât caracteristicile de expresie artistică a rezultatelor generate să fie mai apropiate de experiența de percepție vizuală umană. Prin compararea evaluării indicilor, investigarea autenticității rezultatelor și practica de proiectare a produsului, demonstrăm superioritatea și caracterul practic al metodei propuse în această lucrare. Noua metodă de proiectare rezolvă teoretic dilema economiei de scară a metodelor anterioare de proiectare a modelelor de îmbrăcăminte și oferă idei de referință pentru mai multe scenarii de aplicație blocate în prezent în prezentarea în timp real a rezultatelor designului.

Cuvinte-cheie*: model de îmbrăcăminte, digitalizare, eficiența designului, rețea adversară generativă, învățare automată, economie de scară, caracteristică regională*

INTRODUCTION

Along with the economic development of various countries to the middle and high-income levels, the great increase in production element costs and other factors have led to the gradual loss of the price advantage in the apparel industry. Some traditional apparel producing countries are trying to change their position in the value chain of the international apparel industry from low-end manufacture to high-end research and design [1]. At the same time, in the global cultural convergence, the world apparel industry derives a popular phenomenon of regional apparel characteristics [2]. Diversified regional characteristic apparel style has become an obvious global fashion trend, replacing the previous relatively single mainstream fashion style. This provides opportunities

for the upgrading and transformation of the apparel industry in more countries in the world and also puts forward higher requirements for the design method of regional characteristic apparel pattern.

Most of the traditional apparel pattern design methods are designers creating patterns with the help of computer-aided software [3]. Such a design method relies too much on manpower and cannot reduce the marginal cost. In addition to those shortcomings, traditional design methods also have some problems, such as low efficiency, poor controllability, low fault tolerance, unable to present in real-time and so on. Therefore, how to match the current high demands of the apparel industry by upgrading and transforming through the new design method has become an urgent research topic [4].

With the development of machine learning generation technology and the improvement of computing power, it is possible for computers to assist and replace human beings to complete the creative behaviour related to apparel design. Phillip Isola proposed an innovative conditional advertising network [5]. Human beings only need to provide the line draft of the apparel, and this network algorithm can quickly design the matching apparel rendering effect. The DiscoGAN network built by Taeksoo Kim based on GAN realizes the learning of cross-domain relationships without label or pairing, and successfully transmits the style patterns on the handbag to the shoes across domains, thus realizing the serial dress design by machine algorithm [6]. Donggeun Yoo presented an image-conditional image generation model by introducing a novel domain-discriminator [7]. The model successfully generated a piece of clothing from an input image of a dressed person. Although machine learning generation methods currently have some applications in the direction of apparel design, it is rare to apply the methods, especially the GAN theory to regional characteristic apparel pattern design.

MATERIAL AND METHODS

Material

In this study, the Chinese characteristic tachisme pattern is selected as the research object. As one of the important performance techniques of Chinese painting, tachisme has rich and changeable artistic expression, profound cultural connotation and oriental symbol image [8]. Different proportions of water and colour are mixed to get rich colour layers. Together with the blank layout, it shows the dynamic picture sense and lively life image, which is very suitable for textiles made of various fabrics.

Considering that solving the problem of regional characteristic apparel patterns with small samples and different specifications is also one of the important research directions of this paper, we collected 361 pieces of tachisme apparel patterns with different sizes and quality specifications as a small sample data set. The model is optimized with the addition of a pattern self-processing module, so the training samples material does not need to be prepared manually. The experiment environment for the study is Ubuntu 16.04 LTS, Intel Xeon(R) CPU E5-2637 V4.5, GeForce RTX 3090 * 4 / PCIe / 24 GB video Cards, 16g * 4 / DDR4 / 3200MHz RAM. The network is built with the Python 3.7 computer processing language.

Methods

Machine learning generation model

With the advent of the AI era, more and more scholars devote themselves to the research of machine learning generation model and apply it to the generation of images, audio, video and other objects [9]. Most of the machine learning generation models are based on the maximum likelihood estimation principle. Based on this principle, the generation models can be divided into explicit density model and implicit density model [10].

The explicit density model is based on an explicit density function, which is easy to calculate. It can be divided into the approximate density estimation model and the accurate density estimation model according to the calculation accuracy. Approximate density estimation models can be classified into the variational approximate model and MCMC (Markov Chain Monte Carlo) approximate model according to the approximate methods. Accurate density estimation models can be divided into fully visible belief network and variable models according to their definition methods. Compared with the explicit density generation model, the implicit density generation model does not need to define an explicit density function for training but realizes the training through an indirect interaction model from sampling. The generation models based on implicit density include GSN (Generative Stochastic Networks) and GAN. The classification relationships between different classes of generative models are shown in figure 1. Because of the differences in principles and training mechanisms, the performance of various classes of generative models and the kinds of data objects they are good at handling differ [11]. We summarize the advantages and disadvantages of different generation models, as shown in table 1.

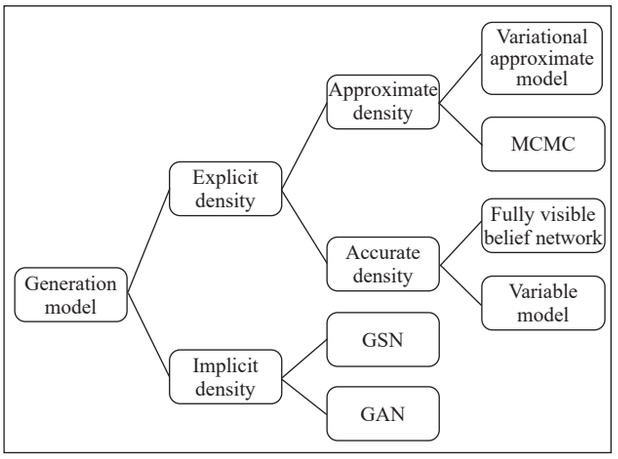

Fig. 1. Classification of generation models

Table 1

ADVANTAGES AND DISADVANTAGES OF GENERATION MODELS

Categories of models	Advantage	Disadvantage
Variational approximate	The quality of likelihood acquisition is high	The model is difficult to optimize and the probability of low-quality results is high
MCMC	The model is easy to converge	The convergence time of the model is long
Fully visible belief network	It is suitable for processing continuous and discrete data, and the training process is relatively stable	It takes a long time to generate the result and the quality of the generated image is low
Variable model	It is convenient to optimize the algorithm design directly on the training data	It is difficult to find the corresponding reversible mapping change
GSN	Suitable for approximate partition function and learning	It is difficult to deal with large sample data in high dimensional space
GAN	The quality of the generated results is high, and the model optimization design is flexible	The interpretability of the generation process is low. It is difficult to find a comprehensive evaluation index of the model performance

GAN

GAN is an unsupervised machine learning model which is trained by an adversary proposed by Ian Goodfellow in 2014 [12]. GAN generates high-quality samples with the unique idea of zero-sum game and adversary training, which has better feature learning and expression performance than other machine learning generation models [13]. The core units of GAN are generator and discriminator. The generator generates fake samples from the noise distribution for the purpose of deceiving the discriminator. The discriminator discriminates the authenticity of the generated samples. There is a zero-sum game for two relationships between the roles of generator and discriminator.

GAN can generate samples by sampling noise once, which is different from most generating models that generate samples by serial mode. GAN does not need a variational lower bound to generate the result directly. Therefore, the image quality generated by the GAN is generally better than other types of generation models. However, there are still some challenges to be solved, such as the low interpretability of the generation process, the difficulty to calibrate the comprehensive and objective evaluation index of the model performance, and the instability in the training process.

Model building

Based on the GAN, the main framework of the apparel pattern design model composed of a generator and discriminator is built, as shown in figure 2. The generator simulates human apparel pattern designers to create tachisme apparel patterns through training. The discriminator learns the artistic expression characteristics of tachisme apparel pattern through training and simulates human art critic to judge whether the input pattern is designed by human or by generation module.

The number and quality of training samples are required for the training of GAN. Regional characteristic apparel patterns are mostly artistic creation [14]. This is different from the real photos of the research objects in other popular application directions of GAN. In the sample collection of the training set, there are a few original training samples, and the image quality and size specifications are not unified. In order to improve the trainability of regional characteristic apparel patterns and the automation of the overall model, we built the module using an expansion standardization algorithm before the training set as input to the discriminator. This module can automatically enlarge the number and standardize the specification of the input training set image in the present appropriate range, which highly enhances the trainability of the sample set, and significantly decreases manual sample pre-processing effort. Specifically, we prepared 361 pieces of tachisme art design patterns in different specifications, which belongs to a typical small sample of regional characteristic pattern training data set. The image self-amplification normalization pre-processing module can effectively enlarge the number of samples to 821 by randomly flipping the image and randomly changing the brightness and contrast. After that, the module unifies the quality and size of the image automatically. This

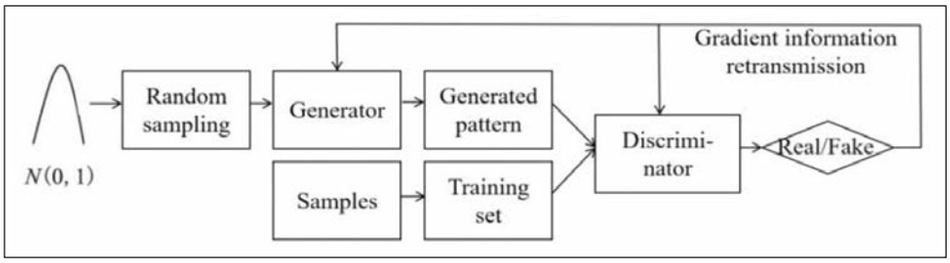

Fig. 2. Main model of pattern digital design

method also effectively reduces the negative impact of sample amplification random transformation.

For reducing the slow convergence and gradient dispersion phenomenon of the model in the experiments, which happen to vary degrees during learning, Batch Normalization and Leaky ReLU are added to optimize the parameters of the algorithm. The Batch Normalization mechanism avoids gradient disappearance by pulling hidden layer neurons from a non-normal allocation back to a relatively regular allocation [15]. By giving a gradient that is not zero to each negative number, Leaky ReLU can significantly speed up the learning speed of the model and shorten the convergence process [16].

There are two deficiencies in the original loss function of the GAN: it is easy to collapse the pattern, which can lead to the phenomenon of homogenization of the resulting image; its instability will lead to the failure to indicate the training process to a certain extent, making the training unable to converge [17]. Wasserstein loss function is proposed to solve the above problems by leaps and bounds, so it is used by many mainstream GAN models [18]. In order to ensure the performance and stability of the model, the Wasserstein loss function is used instead of the original function to optimize the model in this research.

In addition to the consideration of model stability, we make structural changes to the model loss function for the special artistic expression characteristics of tachisme patterns. The key artistic expression feature of the tachisme pattern is the rich colour layers after the mixing of water and colour. In order to make the output of the model closer to people's intuitive experience of tachisme art, we introduce the concept of HSV (Hue, Saturation, Value) colour model. Compared with RGB (Red, Green, Blue) colour standard which is widely used, the HSV colour model pays more attention to users' visual perception of colour and is closer to people's perception experience of colour. Therefore, it is more suitable for a quantitative description of tachisme apparel patterns with rich colour layers of visual performance.

Finally, we use Wasserstein and HSV colour space Euclidean distance to measure the quality of the generated image. In the HSV cone with hypotenuse length R, bottom circle radius R and height h, the coordinate axis is established with the ground circle centre as the origin and $H = 0$ as the positive direction of X axis [19]. Then the three-dimensional coordinates (x, y, z) of the point with colour value (H, S, V) are:

$$\begin{aligned} x &= r * V * S * \cos H \\ y &= r * V * S * \sin H \\ z &= h * (1 - V) \end{aligned} \tag{1}$$

In this case, the Euclidean distance D used to measure the similarity of two images in HSV space is calculated as follows:

$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \tag{2}$$

We combine these two measures and give them 0.5 weight to form the loss function of the model:

$$\text{Loss} = 0.5 * \text{Wasserstein loss} + 0.5 * \text{HSV loss} \tag{3}$$

Figure 3 shows the structure of the model after optimization design. The model will use the output and error calculated by the discriminant module to train and generate the module weight. The discriminators are learned independently, so we set the ranges of the discriminators to be non-trained so that we can ensure that only the ranges of the generators can be trained to be upgraded. The change of trainability in the weight of the discriminant module is only effective when training the whole model, but not when training the discriminant module alone. The overall network randomly samples the noise and inputs them to the generator for pattern creation. The created pattern is fed back to the discriminator as input and is dichotomized as real or fake as the output. The model uses a user-defined weighted loss function including Wasserstein loss and HSV colour space to optimize training with RMSProp in the 0.00005 training value.

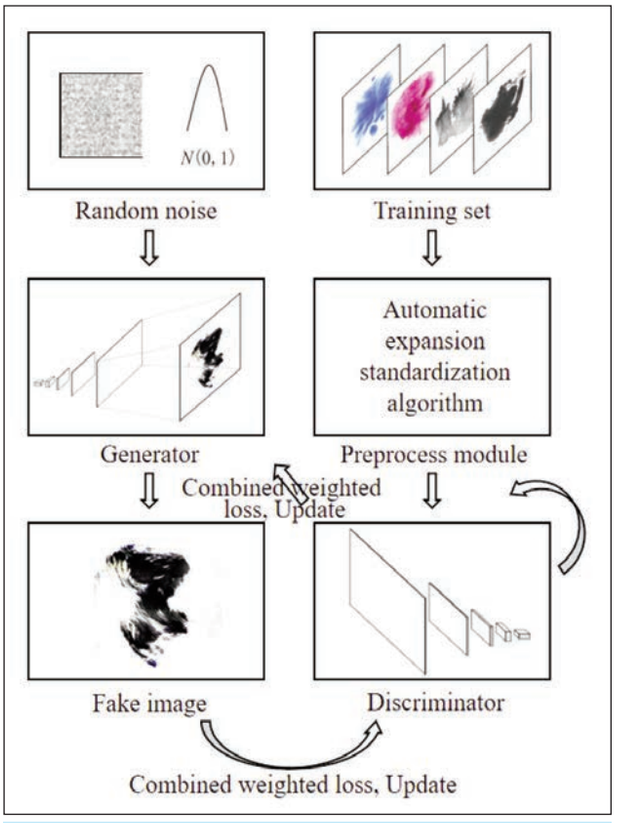

Fig. 3. Model frame diagram

The discrimination module and the generation module are the core parts of the whole model. Model optimization design such as Batch Normalization and Leaky ReLU is also reflected in these two parts. The specific structure of the discrimination module is shown in table 2. The input of this module is the 256*256 image processed by the pre-processing module, and the output is the score of the authenticity of the image. The module subsamples in Batch Normalization, Leaky ReLU of 0.2 value and convolution layer of 2*2 step size. The discriminant module

Table 2

HIERARCHICAL STRUCTURE OF DISCRIMINATE MODULE		
Layer	**Output Shape**	**Param**
Conv2D	(None, 128, 128, 64)	4864
LeakyReLU	(None, 128, 128, 64)	0
Conv2D	(None, 64, 64, 128)	204928
BatchNormalization	(None, 64, 64, 128)	512
LeakyReLU	(None, 64, 64, 128)	0
Conv2D	(None, 32, 32, 256)	819456
BatchNormalization	(None, 32, 32, 256)	1024
LeakyReLU	(None, 32, 32, 256)	0
Conv2D	(None, 16, 16, 512)	3277312
BatchNormalization	(None, 16, 16, 512)	2048
LeakyReLU	(None, 16, 16, 512)	0
Flatten	(None, 131072)	0
Dense	(None, 1)	131073

uses the combined weighted loss function of Wasserstein loss and HSV colour space to optimize under the random gradient descent of RMSProp with a learning rate of 0.00005. The total parameters of the model are 4441217.

The specific structure of the generation module is shown in table 3. The input of the module is random noise and the output is a single 256*256 image. The module uses Leaky ReLU, Batch Normalization and transposed convolution layer with a step size of 2*2 to upsample the data. The model uses tanh as the activation function in the output layer. The generation module also uses the combined weighted loss function of Wasserstein loss and HSV colour space to optimize under the random gradient descent of RMSprop with a learning rate of 0.00005. The total parameters of the model are 17548163.

Table 3

HIERARCHICAL STRUCTURE OF GENERATE MODULES		
Layer	**Output Shape**	**Param**
Dense	(None, 1, 1, 131072)	13238272
Reshape	(None, 16, 16, 512)	0
BatchNormalization	(None, 16, 16, 512)	2048
ReLU	(None, 16, 16, 512)	0
Conv2DTranspose	(None, 32, 32, 256)	3277056
BatchNormalization	(None, 32, 32, 256)	1024
ReLU	(None, 32, 32, 256)	0
Conv2DTranspose	(None, 64, 64, 128)	819328
BatchNormalization	(None, 64, 64, 128)	512
ReLU	(None, 64, 64, 128)	0
Conv2DTranspose	(None, 128, 128, 64)	204864
BatchNormalization	(None, 128, 128, 64)	256
ReLU	-	0
(None, 128, 128, 64)	-	4803
(None, 256, 256, 3)	(None, 256, 256, 3)	0

RESULTS AND DISCUSSION

Model training

The model continuously creates tachisme patterns that are closer to the real human designer's work through unsupervised self-learning under the direction of the loss function. Figure 4 shows the generated patterns we pulled out at different points in the model learning process.

The whole learning process lasted for about 16,000 cycles and took about 15 hours, and the final loss function was close to 0, as shown in figure 5.

Comparative experiment and design application

Compared with the previous apparel pattern design method based on designer creation, the method of this study exhibits significant productivity. In comparison

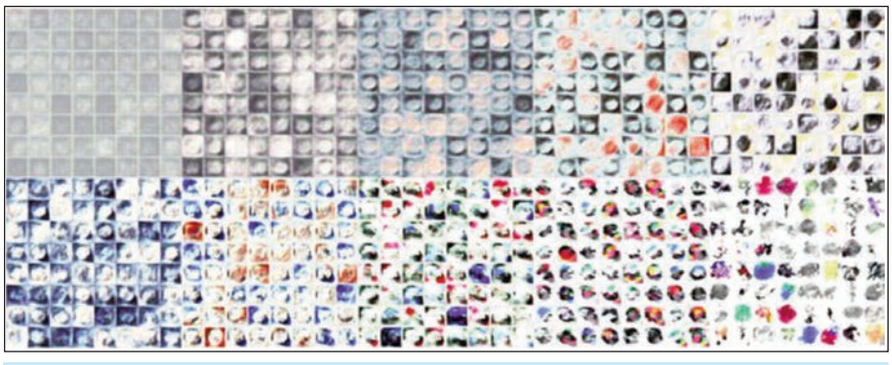

Fig. 4. The output pattern of generate module during training

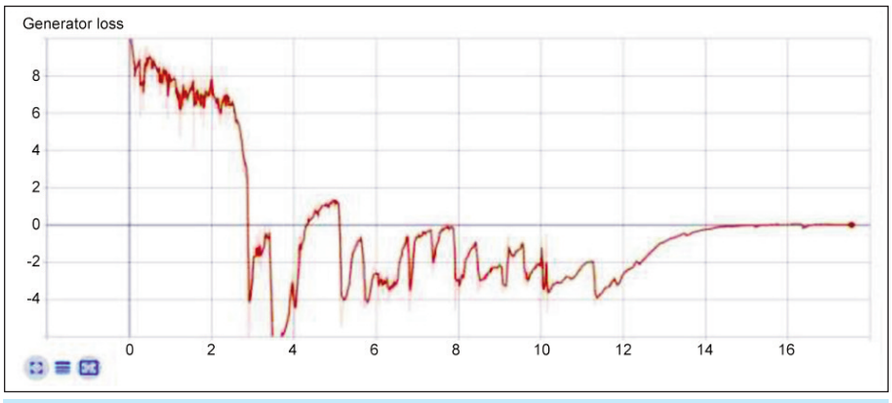

Fig. 5. Change of loss function

Table 4

THE COMPARISON EXPERIMENTAL RESULTS BETWEEN THE TYPICAL MODEL THE AND MODEL IN THIS PAPER					
Model	**Training time**	**Generation time of 10000 images**	**IS**	**FID**	**MS-SSIM**
Model in this study	15h	72.12s	3.13	24.7	0.23
Primitive GAN	24h	73.63s	2.34	39.6	0.39
DCGAN	18h	78.98s	2.493	27.1	0.27

with other non-adversarial generative algorithm models, the quality and time-consuming of the generated pattern of this research model are also significantly improved [20]. This is related to the principle and mechanism of GAN, the core theoretical framework of this research model. Therefore, we mainly select the comparison experimental group of the model proposed in this study among the models that also use GAN as the core construct. Through the analysis and experiment of other mainstream models based on GAN, we choose the primitive GAN and DCGAN as the comparison experimental group. We chose conventional measures including training time and 10,000 pattern creation time to evaluate the network model. We also selected IS (Inception Score), FID (Frechet Inception Distance) and MS-SSIM (Multi-Scale Structural Similarity Index) to evaluate the ability of the network model to process samples and the quality of the output results. IS is the value that is more often used to quantitatively evaluate the quality and richness of the results generated by GAN [21]. Is needs to use Google pre trained perception net to calculate the score value. The higher the IS score, the higher the diversity and quality of the image. FID is an index to measure the model performance by the distance between the generated data distribution and the real data distribution [22]. FID score is widely used to evaluate the performance of different models, it performs well in terms of discriminability, robustness and efficiency [23]. Martin Heusel have shown that FID is more consistent with the noise level than the Inception Score in his research [22]. The smaller the FID value is, the better the result is. MS-SSIM is described by many scholars as the most successful method for quantitatively evaluating image similarity by attempting to predict human perceptual similarity judgements [24, 25]. MS-SSIM is a multi-scale variant of a well-characterized perceptual similarity metric that attempts to discount aspects of an image that are not important for human perception [26]. The lower the MS-SSIM value (between 0 and 1), the higher the image diversity. The results of comparison experiment data are shown in table 4. It can be seen that compared with the primitive GAN and DCGAN, the model proposed in this paper shows better performance in dealing with the research object of regional characteristic tachisme apparel pattern.

Considering the subjectivity of artistic creation in apparel pattern design, in order to test the authenticity of design results and the judgment ability of the model discriminator, we set up a personnel discrimination test. There are 60 respondents in this experiment. Among them, 40 respondents are engaged in clothing-related work and have different degrees of clothing-related professional and educational backgrounds. Another 20 respondents were engaged in work unrelated to clothing. All 60 respondents were from Binhu District, Wuxi City, China. The respondents' choice of gender and age is random. The gender and age distribution of 60 respondents is shown in table 5. A total of 50 tachisme apparel patterns were distributed to the interviewees, which were composed of 25 real patterns in the training set and 25 fake patterns generated by the model. The interviewees were asked to classify each pattern without knowing the proportion of two kinds of patterns. The comparison between a part of these two kinds of patterns is shown in table 6. The experimental results show that the accuracy of interviewees' judgment is concentrated between 40% and 60%, and the number

Table 5

GENDER AND AGE DISTRIBUTION OF RESPONDENTS				
Age range	**Number of men**	**Number of women**	**Number of people**	**Proportion of people number**
11–20	4	2	6	10.00%
21–30	9	14	23	38.33%
31–40	10	5	15	25.00%
41–50	6	5	11	18.33%
51–60	3	1	4	6.67%
61–70	0	1	1	1.67%
Total	32	28	60	100.00%

Table 6

COMPARISON OF REAL PATTERNS AND FAKE PATTERNS								
Real patterns								
Fake patterns								

Table 7

MANUAL EVALUATION OF EXPERIMENTAL RESULTS		
Accuracy	**People in this range**	**Proportion in this range**
100%–80%	1	1.67%
80%–60%	3	5.00%
60%–40%	52	86.67%
40%–20%	4	6.67%
20%–0%	0	0.00%

of interviewees in this area accounts for 86.67%, as shown in table 7. Moreover, most of the interviewees showed more uncertainty and conjecture during the test. This means that most of the respondents, including the design-related practitioners, cannot distinguish the authenticity of the resulting pattern. That is to say, the tachisme apparel pattern generated by the method in this study has a high degree of authenticity, and the model discriminator's ability to judge the research target is close to human through learning. To validate the effectiveness of tachisme apparel patterns designed by the method proposed in this study, we use some patterns generated by the model to design apparel products, as shown in table 8. The design results show that the regional characteristic pattern designed by the method in this study can be well applied to apparel products. And to a certain extent, it presents the aesthetic features and cultural semantics of Chinese tachisme techniques.

Table 8

PRODUCT DESIGN EFFECTS USING MACHINE-DESIGNED PATTERNS				
Machine-designed patterns				
Product design				

CONCLUSION

This study builds and optimizes the digital design model of regional characteristics apparel pattern driven by GAN. In comparison with conventional apparel pattern design ways, this method has the advantages of high automation, productivity, flexibility and resource conservation; compared with other types of generation model and the mainstream GAN model, it is more suitable to deal with regional characteristics of apparel patterns. The specific performance is to solve the training difficulties such as fewer samples, and miscellaneous specifications, and show better performance in the training process, generated results and pattern diversity. This study provides a new solution to the problem that the high development demand of regional characteristic apparel pattern does not match the old creation method. This study will contribute to the digital preservation of regional apparel civilization, the innovation and upgrading of apparel industry design and the promotion of marginal benefits of apparel design.

ACKNOWLEDGMENTS

This work was supported by the Key Special Projects of 2019 National Key R&D Plan (grant number 2019YFB1405704), 2020 Humanities and Social Sciences Planning Fund Project of the Ministry of Education (grant number 20YJAZH087), Postgraduate Research & Practice Innovation Program of Jiangsu Province (grant number KYCX20_1891). The authors acknowledge the above financial support.

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Study of operations in sewing process of girls' pants

DOI: 10.35530/IT.073.03.202124

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ABSTRACT – REZUMAT

Study of operations in sewing process of girls' pants

The sewing labour that has a portion of up to 70% of the labour cost in the clothing production, creates a very effective cost component. That is why it is necessary to analyse the workflow in the sewing room better and use the optimum performance and productivity of the workers.
In this research rationalizations of girls' pants production are studied and the developed method is implemented in a middle-sized company in Aegean Region of Turkey. As a result, the productivity of balancing was increased by 6.53 % (from 93.07% to 99.6%). Due to done method development studies, the Total Sewing Time/Piece was been reduced to 20.92 minutes from 21.22 minutes. Before method development studies the theoretical number of workers need was 37 and the actual employed number of workers was 38 at the end of method development studies (MDS) and line balancing this number was been decreased to 35 workers. This girls' pants order was planned for 12 days of production, thus, in total 576 $ saving was provided by the utilization of the rationalized method. The benefits attained through the method development in the company base will globally contribute to the garment industry in the world in terms of the competitive power and the rise in the employment of the labour.

Keywords: *work-study, balancing of sewing line, clothing production, rationalization, need of workers*

Studiul operațiunilor în procesul de asamblare al pantalonilor pentru fete

Manopera de asamblare, ce reprezintă până la 70% din costul forței de muncă în producția de îmbrăcăminte, creează o componentă de cost foarte eficientă. De aceea, este necesar să se analizeze mai bine fluxul de lucru în secția de asamblare și să se folosească performanța și productivitatea optimă a lucrătorilor.
În această cercetare sunt studiate raționalizările producției de pantaloni pentru fete și metoda dezvoltată este implementată într-o companie mijlocie din regiunea Mării Egee a Turciei. Prin urmare, productivitatea a crescut cu 6,53% (de la 93,07% la 99,6%). Datorită studiilor de dezvoltare ale metodei efectuate, timpul total de asamblare/bucată a fost redus la 20,92 minute, de la 21,22 minute. Înainte de studiile de dezvoltare a metodei, numărul teoretic de lucrători necesar a fost de 37, iar numărul efectiv de lucrători angajați a fost de 38 la sfârșitul studiilor de dezvoltare a metodei (MDS), iar echilibrarea a condus la necesitatea unui număr de 35 de lucrători. Această comandă de pantaloni pentru fete a fost planificată pentru 12 zile de producție, astfel, în total, s-a asigurat o economie de 576 $ prin utilizarea metodei raționalizate. Beneficiile obținute prin dezvoltarea metodei în cadrul companiei vor contribui la nivel global în industria confecțiilor din lume, în ceea ce privește puterea competitivă și creșterea gradului de ocupare a forței de muncă.

Cuvinte-cheie*: studiul muncii, echilibrarea liniei de asamblare, producția de îmbrăcăminte, raționalizare, nevoia de lucrători*

INTRODUCTION

In garment production, a big part of workmanship is spent in the sewing room. When the labour cost of a product is analysed, it can be seen that 70–80% originates from the departments of preliminary preparation, sewing, intermediate ironing, yarn cutting and intermediate quality control. Since the sewing labour that has a portion of up to 70% creates a very effective cost component, it is necessary to analyse the workflow in the sewing room better and use the optimum performance and productivity of the workers. Thus, the companies should carefully deal with the labour savings, by paying the same attention to the other labour costs and must try to minimize the time, which product spends in the sewing room.
There are many studies on cutting production time by analysing assembly line systems. The first known formulation of an assembly line balancing problem has been made by Salveson [1] in 1955 years. It assigned a set of tasks I = {1,2,y,i,y,9I9} to linearly ordered workstations M = {1,2,y,k,y,m}. The objective is to assign all given tasks concerning precedence and cycle time constraints while minimizing the number of workstations required [1]. One study presented a management design approach to assembly line systems by considering both the cost and lead time under demand fluctuations; a positioning strategy (cycle time and number of stations) was discussed for a case in which the lead time is restricted [2]. In another study,0–1 integer-programming models were developed by using GAMS-CPLEX mathematical programming software for a numerical example to establish a balance of the assembly line with a minimum number of stations and resources [3]. The objective of another survey is to analyse research on

balancing flow lines within many different industrial contexts to classify and compare the means for input data modelling, constraints and objective functions used and the survey covers about 300 studies on line balancing problems [4]. In research, optimization is used to yield the maximum production rate by using reprocessing machine selection and design strategies. The results indicate that the proposed optimization methodology effectively yields the maximum production rate and presents the optimal selection range and the optimal adjustment size of the reprocessing machine, and the reprocessing accuracy affects the maximum production rate but has little effect on the optimal selection range and the optimal adjustment size [5].

The situation in many clothing production factories is different from automatic production skills where the final products are done by machines. The research done to optimize the production efficiency of assembly lines in the clothing industry mostly are focused on computer programming solutions. Chen et al. [6] had developed a grouping genetic algorithm (GGA), by using real data from garment factories, for the assembly line balancing problem of sewing lines with different labour skill levels in the garment industry. Some researchers developed a genetic optimisation approach to balance an apparel assembly line. The impact of a different level of skill inventory, non the assembly makespan was also investigated in order to find out the optimal number of task skills an operator should possess in the apparel assembly process [7]. The data collected by the researchers from a dress assembly line in a factory in China were used to build a simulation using Pro Model software and the production line could be changed, generating higher productivity and lower work in process. Another research presented the global competence Index "CI" by applying the Weighted Sum Model (WSM) [8]. Using a simple linear regression model, the global competence was modelled [9]. Thereafter, the model was validated and justified. The resulting performance indicator allowed to predict the global competence level, compare different balancing proposals and make the optimal choice.

According to the Ministry of Commerce of the Turkish Republic in the last 3 years among "The Top 20 Exported Chapters" the "Knitwear and Accessories" is 5th and "Non-Knitted Clothing and Accessories" is in 10th place [10]. In the 2018–2020 years the total export of Turkey is between 169.5 and 180.9 million dollars and the percentage of the total "Clothing and Accessories Export" is between 8.81–8.97% [10]. Because the garment production sector is of big importance to the Turkish economy the related study is on shortening the standard production time, so the profit of the companies may be raised.

In this study rationalizations of girls' pants production are studied and a developed method is implemented in the production of girls' pants in a middle-sized company in Aegean Region of Turkey. The current production method of the girls' pants in the sewing line was studied by the trial-and-error method in the form presented by the bandmaster and then was reorganized due to engineering studies.

MATERIAL AND METHODS

Material

The material of this research was the pants for the 14 years old girls, from 1×1 plain weave, 140 g/m^2, 100% cotton fabric. Technical details are given in figure 1. The model of the pants has two pockets and the pockets are very large looking like darning. There is a decoration aimed zipper in front of the model, and the belt is in a wiper form. There is an opportunity of adjusting the waist width that is specific to the user by shrinking the pants through the drawcord. The label of the firm and the washing instructors are on the same label and sewed inside the belt part of the girls' pants in the middle back.

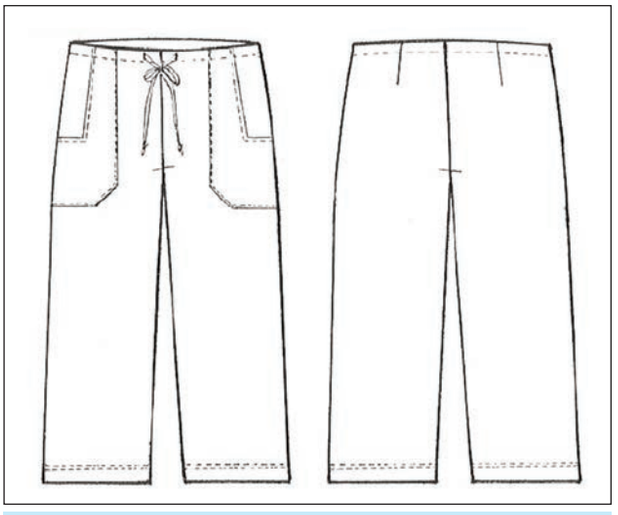

Fig. 1. Technical drawing of girls' pants [11]

Methods

The evaluation of the method in sewing operations is done, when the work-study and time measurements are applied through sewing operations of girls' pants. In this aspect, there is used six-step evaluation method that REFA has specified [12].

The present works were monitored and a work-study was done. Through the work-study, all working methods of the operators and the operations that belong to the sewing process were found. After the work-study time etude was applied and the time the operators consumed for each operation was determined. A Digital chronometer was used to measure each operation time. The measurements were done by applying both the continuous and one-shot measurement methods. The mean of the measurements was calculated and the distribution and the resting time were added as 20%. In the handwork operations, since the transport is done irregularly with flexible gaps, the time the workers spend for the transport of the goods was determined as 15% to 25% of "Measured time" through measurements, and the average of 20% was added. According to the work

and time etude data, saving time was fulfilled in the worker's moves, line balancing was enhanced, and by rationalization of the machine layout plans, it was aimed to shorten the time for the transportation and to make the material flow better. The girls' pants model studies for the related enterprise are calculated according to the following formulas:

$$Base\ time\ (Handwork) = Actual\ time + Distribution\ times = Measured\ time * 1.4 \quad (1)$$

$$Actual\ time = Measured\ Time + Transportation\ time = Measured\ time * 1.2 \quad (2)$$

$$Transportation\ time = 0.2 * Measured\ time \quad (3)$$

$$Distribution\ times = 0.2 * Measured\ time \quad (4)$$

$$Base\ time\ (sewing) = Actual\ time + Distribution\ times = Measured\ time * 1.2 \quad (5)$$

$$The\ Efficiency\ of\ the\ Balancing = \frac{Capacity * Total\ operation\ time * 100}{Number\ of\ the\ workers * Daily\ working\ time} \quad (6)$$

RESULTS AND DISCUSSION

Revealing the numerical expression of existing and reorganized line balancing after the work-study

According to the present working method in the company, it is seen that there is a waste of time in the job stream. The "Line Balancing" table shows the waste time of the operators as "Waste Time" in table 1 with bold numbers. The total of the lost times is 1325 min and this makes 22.08 hours per day.

If a good line balancing is applied and if there is no waste of time, it will be possible to produce 63 more pants (1328 : 21.22 = 62.6). When the performance of the present balancing is calculated:

- Daily production capacity: 800 pieces/day;
- Daily working time: 480 minutes/day;
- Total operation time: 21.22 minutes;
- Total number of workers: 38 people.

$$Efficiency\ of\ the\ Balancing = \frac{800 * 21.22 * 100}{38 * 480} = 93.07\%$$

The abbreviations used in this study are as follows:

- Method development studies – MDS
- Operation Number – Opn Nr
- Type of the Machine – TM
- Daily production quantity – DPQ
- Base Time – BT
- Necessary Time (minute) – NT (min)
- Necessary number of workstations and operators – NNWO
- Operator Number – Op Nr
- Total base time (minute) – TBT (min)
- Lost time (minute) – LT (min)
- Performance – Pr
- Measured operation time (seconds) – MOT (s)
- Hand iron – HI
- Handwork – HW
- Five threads overlock machine – 5TOM
- Three threads overlock machine – 3TOM
- Lock stitch machine – LSM
- Buttonhole stitch machine – BHSM
- Button stitch machine – BSM
- Two-needle lock stitch machine – 2NLSM
- Necessary number of machinery and workers – NNMW.

Table 1

WORK-STUDY OF COMPANY'S PRESENT SITUATION IN GIRLS' PANTS PRODUCTION AND LINE BALANCING [11]

Opn Nr	Operation name	TM	BT (min)	DPQ	NT (min)	NNWO	Op Nr	LT (min)	Pr (%)	MOT (s)
1	Marking the place of the pocket	HW	0.42	800	336	0.70	1	144	80	18
2	Pleating in two	HW	0.16	800	131	0.27	1	**13**	100	7
3	Marking for plaid overlap over pocked according to front pant	HW	0.89	540	231	1.48	2	**1**	95	38
			0.89	260		1.48	3	249	95	38
4	Marking with pattern over pocket seam place	HW	0.33	800	261	0.54	4	219	100	14
5	Pocket ironing with pattern	HI	0.92	400	368	1.53	5	**67**	70	46
			0.92	400	368	1.53	6	**112**	70	46
6	Pocket edging	HW	1.14	420	480	1.91	7	0	90	49
			1.70	280	477	2.84	8	**3**	70	73
			1.14	100	114	1.90	4	**105**	90	49
7	Pocket trimming seam	3TOM	0.17	800	136	0.28	9	344	90	9
8	Trim to pocked	LSM	0.84	570	479	1.40	10	**1**	80	42
			0.84	230	193	1.40	11	287	80	42
9	Turn trimming, pocket entry hemstitch and marking by cutting	LSM	1.20	400	480	2.00	12	0	80	60
			1.20	400	480	2.00	13	0	80	60

Table 1 (*continuation*)

Opn Nr	Operation name	TM	BT (min)	DPQ	NT (min)	NNWO	Op Nr	LT (min)	Pr (%)	MOT (s)
10	Stitching pocket from	LSM	1.30	365	475	2.17	14	**6**	100	65
	Profile and upper side		1.30	365	475	2.17	15	**6**	100	65
	To front pant		1.30	70	91	2.17	11	**196**	100	65
11	Seam pocket to pant by	LSM	1.40	340	476	2.33	16	**4**	95	70
	Hemming stitches from		1.40	340	476	2.33	17	**4**	95	70
	Sides		1.40	120	168	2.33	18	312	95	70
12	Closing front crotch	5TOM	0.72	665	479	1.20	19	**1**	80	36
			0.72	135	97	1.20	20	383	80	36
13	Marking placket preface	HW	0.23	800	187	0.39	21	293	90	10
14	Zipper fly uniting stitch	LSM	0.24	800	192	0.40	22	288	95	12
15	Marking placket fancy seam	HW	0.51	800	411	0.86	23	**69**	100	22
16	Placket fancy seam and front crotch hemstitch	LSM	0.70	685	480	1.17	24	0	90	35
			0.70	115	81	1.17	18	231	90	35
17	Marking dart place	HW	0.23	800	187	0.39	21	106	95	10
18	Dart stitch and hemming	LSM	0.80	600	480	1.33	25	0	85	40
			0.80	200	160	1.33	26	320	85	40
19	Front and back pant profile connecting seam	5TOM	1.04	460	478	1.73	27	**2**	90	52
			1.04	340	354	1.73	20	**29**	90	52
20	Back crotch seam	5TOM	0.40	800	320	0.67	9	**24**	100	20
21	Back crotch hemming	LSM	0.40	800	320	0.67	26	0	100	20
22	Inside trouser leg seam	5TOM	0.58	800	464	0.97	28	**16**	100	29
23	Trouser bottom seam	2NLSM	1.02	470	479	1.70	29	**1**	60	51
			1.02	330	337	1.70	30	143	60	51
24	Reverse pant	HW	0.21	800	168	0.35	31	312	90	9
25	Brand cutting	HW	0.09	800	75	0.16	3	**174**	90	4
26	Attach brand to waist	LSM	0.10	800	80	0.17	22	208	100	5
27	Cutting the pocket excess from the waist	HW	0.56	800	448	0.93	32	**32**	60	24
28	Marking of button and buttonhole place	HW	0.29	800	233	0.49	31	79	90	13
29	Opening of buttonhole	BHSM	0.36	800	288	0.60	33	192	95	18
30	Twisting of waist-band Seam	LSM	1.28	370	475	2.14	34	**5**	90	55
			1.62	295	478	2.70	35	**2**	60	81
			1.28	135	173	2.14	18	**58**	90	55
31	Button stitch	BSM	0.10	800	80	0.17	33	**112**	95	5
32	Cordon making seam	LSM	0.28	400	112	0.47	30	**31**	65	14
33	Cordon cutting	HW	0.19	540	101	0.31	22	**107**	85	8
			0.19	260	49	0.31	31	**30**	85	8
34	Cordon pass trough waistband	HW	1.16	400	464	1.93	36	**16**	65	58
			1.16	400	464	1.93	37	**16**	65	58
35	Knotting cordon ends and link	HW	0.63	760	479	1.05	38	**1**	50	27
			0.63	40	25	1.05	21	**81**	50	27
Total Sewing Time/Piece[1]: 21.22 min/piece Total Lost Time[2]: 1325 min										

Note: [1] it's calculated as the total of Base Times (BT) of all operations done for sewing of girls' pants and shown in the last line of table 1 and of table 3 as "min/piece"; [2] it's calculated as the total of Lost Times (LT) of all operators working for sewing of girls' pants and shown in the last line of table 1 and table 3 as "min".

Calculating the number of necessary machines and the workers for the production of girls' pants

The data relating to the operation time was given in table 1 according to the present job stream in the company, and the theoretically necessary number of machinery and workers in the current production of the girl pant line was calculated.

The number of machines (and workers) required was calculated according to the following equation:

$$Number\ of\ the\ required\ machinery\ (and\ workers) = \\ = \frac{Total\ operation\ time * Number\ of\ daily\ production}{Daily\ working\ time} \quad (7)$$

In the production of girls' pants, the theoretically need of machinery was calculated as 23.04 pieces and theoretically need for workers was find as 35.10 pieces.

The necessary machine and worker need according to the present line balancing

The necessary theoretical machine and worker need within the present working style, which was designed by line master in the company is shown in table 2.

Table 2

THE NECESSARY MACHINE AND WORKER NEED ACCORDING TO THE PRESENT LINE BALANCING

Necessary machines need		Necessary workers need	
Machine type	**Pieces**	**Workers**	**Pieces**
LSM	15	LSM	15
5TOM	5	5TOM	5
2NLSM	2	2NLSM	2
HI	2	HI	2
BSM	1	BSM+BHSM	1
BHSM	1	HW	12
Total	**26**	**Total**	**37**

Since the need for five thread overlock is 4.56 machines and the three thread overlock is 0.28 machines, a five thread overlock machine was converted to three thread. It is possible to sew all the overlock sewing with a total of five threads overlock. It is possible to do operations for both the buttonhole and button sewing by one qualified worker through the machines.

Rationalizing the job stream through method development studies

As a result of the time and motion studies, some inconvenient and unnecessary moves within the company's job stream were determined. Moreover, the insufficient use of the job loads by the masters causes financial losses that increase the cost. By removing these unnecessary motions and using the labour rationally a new line streaming study was suggested. As it is also seen in the line balancing table (table 3), as a result of method development, operation number 2 was removed because inadequacy of place is not present and it is more convenient to give them to sewing before the front sizes are folded. Operation number 3 is done by unfolding the piece that was folded and this means extra time. When the folding operation is removed, 6 seconds were saved in operation number 3. The operation time falls to 0.75 minutes from 0.89 minutes. As a result of the rationalizing studies in this working method, it can be seen in table 4. that the time needed for "Handwork" fell to 6.94 minutes from 7.24 minutes.

$$Efficiency\ of\ the\ Balancing = \\ = (800 * 20.92/35 * 480) * 100 = 99.6\%$$

As a result, the productivity of balancing was increased by 6.53%, from 93.07% to 99.6%.

Table 3

LINE BALANCING IN THE SEWING OF GIRLS' PANTS AFTER METHOD DEVELOPMENT STUDIES [11]

Opn Nr	Operation name	TM	BT (min)	DPQ	NT (min)	NNWO	Op Nr	LT (min)	Pr (%)	MOT (s)
1	Marking the place of the pocket	HW	0.42	800	336	0.70	1	144	80	18
2	Marking for plaid overlap over pocked according to front pant	HW	0.75	640	478	1.24	2	**2**	95	32
			0.75	160	119	1.24	1	**25**	95	32
3	Marking with pattern over pocket seam place	HW	0.33	685	224	0.54	3	256	100	14
			0.33	115	38	0.54	29	4	100	14
4	Pocket ironing with pattern	HI	0.92	278	256	1.53	3	0	70	46
			0.92	522	480	1.53	4	0	70	46
5	Pocket edging	HW	1.14	420	480	1.91	5	0	90	49
			1.70	282	480	2.84	6	0	70	73
			1.14	98	112	1.90	30	0	70	49
6	Pocket trimming seam	3TOM	0.17	800	136	0.28	7	344	90	9
7	Trim to pocked	LSM	0.84	570	479	1.40	8	**1**	80	42
			0.84	230	193	1.40	9	287	80	42
8	Turn trimming, pocket entry hemstitch and marking by cutting	LSM	1.20	400	480	2.00	10	0	80	60
			1.20	400	480	2.00	11	0	80	60
9	Stitching pocket from profile and upper side to front pant	LSM	1.30	365	475	2.17	12	**6**	100	65
			1.30	365	475	2.17	13	**6**	100	65
			1.30	70	91	2.17	9	196	100	65

Table 3 (*continuation*)

Opn Nr	Operation name	TM	BT (min)	DPQ	NT (min)	NNWO	Op Nr	LT (min)	Pr (%)	MOT (s)
10	Seam pocket to pant by hemming stitches from sides	LSM	1.40	340	476	2.33	14	**4**	95	70
			1.40	340	476	2.33	15	**4**	95	70
			1.40	120	168	2.33	16	312	95	70
11	Closing front crotch	5TOM	0.72	665	479	1.20	17	**1**	80	36
			0.72	135	97	1.20	18	383	80	36
12	Marking placket preface	HW	0.23	800	187	0.39	19	293	90	10
13	Zipper fly uniting stitch	LSM	0.24	800	192	0.40	9	**4**	95	12
14	Marking placket fancy seam	HW	0.51	800	411	0.86	20	69	100	22
15	Placket fancy seam and front crotch hemstitch	LSM	0.70	685	480	1.17	21	0	90	35
			0.70	115	81	1.17	16	231	90	35
16	Marking dart place	HW	0.23	800	187	0.39	19	106	95	10
17	Dart stitch and hemming	LSM	0.80	600	480	1.33	22	0	85	40
			0.80	200	160	1.33	23	320	85	40
18	Front and back pant profile connecting seam	5TOM	1.04	460	478	1.73	24	**2**	90	52
			1.04	340	354	1.73	18	**29**	90	52
19	Back crotch seam	5TOM	0.40	800	320	0.67	7	**24**	100	20
20	Back crotch hemming	LSM	0.40	800	320	0.67	23	0	100	20
21	Inside trouser leg seam	5TOM	0.58	800	464	0.97	25	**16**	100	29
22	Trouser bottom seam	2NLSM	1.02	470	479	1.70	26	**1**	60	51
			1.02	330	337	1.70	27	143	60	51
23	Reverse pant	HW	0.21	800	168	0.35	28	312	90	9
24	Brand cutting	HW	0.09	800	75	0.16	20	6	90	4
25	Attach brand to waist	LSM	0.10	800	80	0.17	16	151	100	5
26	Cutting the pocket excess from the waist	HW	0.56	800	448	0.93	29	**32**	60	24
27	Marking of button and buttonhole place	HW	0.29	800	233	0.49	28	79	90	13
28	Opening of buttonhole	BHSM	0.36	800	288	0.60	30	192	95	18
29	Twisting of waist-band seam	LSM	1.28	378	485	2.14	31	5	90	55
			1.62	300	486	2.70	32	6	60	81
			1.28	122	157	2.14	16	6	90	55
30	Button stitch	BSM	0.10	800	80	0.17	30	112	95	5
31	Cordon making seam	LSM	0.28	400	112	0.47	27	**31**	65	14
32	Cordon cutting	HW	0.19	540	101	0.31	19	**5**	85	8
			0.19	260	49	0.31	28	30	85	8
33	Cordon pass trough waistband	HW	1.16	400	464	1.93	33	**16**	65	58
			1.16	400	464	1.93	34	**16**	65	58
34	Knotting cordon ends and link	HW	0.63	760	479	1.05	35	**1**	50	27
			0.63	40	25	1.05	28	**5**	50	27
Total Sewing Time/Piece: 20.2 min/piece **Total Lost Time: 221 min**										

To complete the free time with a mission in line balancing, the operator that was sewing buttons and buttonholes was reinforced with a handcraft mission and one of the twin needle operator's free time was reinforced with an even sewing operation. As a result of line balancing, the number of even sewing staff fell from 15 to 14 persons.

Through the line balancing studies, it was possible to use the workers more productive, so the number of the workers was decreased. Before method development studies the theoretical need of workers was 37 and the actual used was 38 at the end of MDS and line balancing this number was decreased to 36.

The Total Lost Time from 1325 minutes fell to 221 minutes, so it was proved that it is possible to work losing almost no time on the sewing line. With done method development studies the Total Sewing Time/Piece was been reduced to 20.92 minutes from 21.22 minutes.

Economic benefit of the study

As a result, the productivity of balancing was increased by 6.53%, from 93.07% to 99.6%. Before method development studies the theoretical need for workers was 37 and the actual use was 38 at the end of MDS this number was decreased to 36 persons (table 4).

Table 4

THE NECESSARY WORKER NEED IN THE GIRLS' PANTS SEWING LINE AFTER MDS

Machine type	Worker need	Machine type	Worker need
LSM	14	BSM+BHSM	1
3SOM+5SOM	5	2NLSM+LSM	2
HI+HW	2	HW	12
Total worker need: 36			

In the Aegean region of Turkey payment given to workers in the textile and garment industry is mostly near minimum wage. The minimum wage for the 2021 year for Turkey, Romania and Bulgaria was given in table 5 [13–15]. In Turkey, the monthly cost of the determined minimum wage employee to the employer is 4 thousand 203.56 Turkish lira, approximately 517 US $. When the payment for an hour is 3 $/hour (payment average in Turkey), the savings in terms of money is 8 hours * 3 $ * 2 people= 48 $/day. This girl pants order was planned for twelve days of production, thus, in total, 12 days * 48 $ = 576 $ saving was provided by done rationalizations.

Table 5

THE MINIMUM WAGE FOR THE 2021 YEAR FOR TURKEY, ROMANIA AND BULGARIA

Country	Minimum Wage	US $/ month	US $/ hour
Bulgaria	650 Leva [15]	387	2.2
Romania	1.386 Lei [14]	340	1.93
Turkiye	2826 Turkish lira [13]	348	1.98

CONCLUSION

In this study, by using MDS the productivity of balancing was increased from 6.53% to 99.6%, and "Total Lost Time" from 1325 minutes fell to 221 minutes. Before method development studies the actually used workers was 38 and at the end of MDS, this number was decreased to 36 persons.

Today's competitive state requires the garment industry to take serious precautions. Since it is possible to increase the competition power by preventing the waste of materials and labour, the garment companies should prioritize the saving efforts.

It is useful to emphasize the necessity of minimizing the cost by increasing the labour performance and decreasing the production span since the garment industry is a labour centred sector.

The garment industry that is careful about the developments in the world and parallel with them can extend the operating periods by turning the profit it gets into the technological investments, that will enable the production of the goods that provide added value. The garment industry of Turkey can extend its leadership in making the country's economy more powerful to reach the economic level of the developed countries by creating international brands and reserving funds for the marketing by developing strategies, that are parallel to these investments.

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Analysing the nexus between artificial neural networks and ARIMA models in predicting customer lifetime value (CLV) for complex development of society and industrial activities

DOI: 10.35530/IT.073.03.202142

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ABSTRACT – REZUMAT

Analysing the nexus between artificial neural networks and ARIMA models in predicting customer lifetime value (CLV) for complex development of society and industrial activities

Today, the importance of customer relationship is not hidden from anyone, and predicting the value of customer life can help organizations to create an optimal relationship with their customers. The concept of industrial society represents a symbiosis between social and industrial activities using mass-production technologies. A sustainable CRM approach can generate significant benefits for the development of the textile industry. This paper compares ARIMA and neural network models in predicting customer lifetime value. The time-domain of the research is related to the year 2021 in the Lojoor company. To identify the variables needed to predict the value of customer longevity, experts in this field and university professors were used through descriptive survey method and using databases to collect other data. After collecting the data, the required variables were first identified by the Delphi method and then the databases were analysed using the artificial neural network method and the ARIMA model, for which MATLAB software was used. The results showed that both ARIMA and artificial neural network models can be used to predict customer lifetime value. In the case of the artificial neural network, it was observed that in addition to better prediction of the relationship between variables, which assumes them to be nonlinear, the artificial neural network model also performed better in terms of prediction results. In total, the values of MAPE error are 10.3% and MSE error is 11.6% for the neural network model. The neural network model is acceptable.

Keywords: *customer lifetime value (CLV), customer services, customer relationship management, artificial neural networks, ARIMA models, Markov chain, textile industry*

Analiza relației dintre rețelele neuronale artificiale și modelele ARIMA în estimarea valorii duratei de viață a clientului (CLV) pentru dezvoltarea complexă a societății și a activităților industriale

În prezent, importanța relației cu clienții nu mai reprezintă un secret pentru nimeni, iar previzionarea valorii duratei de viață a clientului (CLV) poate ajuta organizațiile să creeze o relație optimă cu clienții lor. Conceptul de societate industrială reprezintă o simbioză între activitățile sociale și cele industrial, folosind tehnologii de producție în masă. O abordare CRM sustenabilă poate genera beneficii semnificative pentru dezvoltarea industriei textile. Acest articol de cercetare compară modelele ARIMA și rețelele artificiale neuronale în estimarea valorii duratei de viață a clienților. Intervalul de timp selectat pentru efectuarea cercetării este anul 2021, în compania Lojoor. Pentru a identifica variabilele necesare pentru a previziona valoarea longevității clienților, experți în acest domeniu și profesori universitari au fost implicați prin metoda sondajului descriptiv și s-au folosit bazele de date pentru a colecta celelalte date. După colectarea datelor, variabilele necesare au fost identificate mai întâi prin metoda Delphi și apoi bazele de date au fost analizate folosind metoda rețelei neuronale artificiale și modelul ARIMA, pentru care a fost utilizat software-ul MATLAB. Rezultatele au arătat că atât modelele ARIMA, cât și modelele bazate pe rețele neuronale artificiale pot fi utilizate pentru a previziona durata valorii de viață a clientului. În cazul rețelei neuronale artificiale, s-a observat că, pe lângă o mai bună estimare a relației dintre variabile, care presupune că acestea sunt neliniare, modelul rețelei neuronale artificiale a funcționat și mai bine în ceea ce privește rezultatele predicției. În total, valorile erorii MAPE sunt de 10,3%, iar eroarea MSE este de 11,6% pentru modelul rețelei neuronale. Modelul rețelei neuronale este acceptabil.

Cuvinte cheie: *valoarea duratei de viață a clienților (CLV), servicii clienți, managementul relațiilor cu clienții, rețele neuronale artificiale, modele ARIMA, proces Markov, industria textilă*

INTRODUCTION

Today, customers have become the heart of business in any industry, and in order for companies to continue to operate in the current highly competitive environment, it is necessary to effectively manage their interactions with their customers, which is part of the strategy. Customer relationship management is discussed. One of the categories that are very important in attracting and retaining customers today and is one of the important factors in the success of companies

is the value of the customer life cycle [1]. Customer relationship management is the process of establishing and maintaining relationships with consumers in the business cycle [2]. It is a set of interactive processes that aim to achieve the desired interaction between industry investments and meet customer needs in order to achieve maximum profit [3]. In this regard, paying attention to the concept of customer longevity value as a strategic weapon in attracting and retaining customers is important. Customer lifetime value is the amount of profit that a customer brings to a company during the lifetime of being a customer. Basically, one of the benefits of CRM in marketing is identifying more profitable customers through the CLV tool, customer lifetime value (CLV or often CLTV), lifetime customer value (LCV), or lifetime value (LTV) is a prognostication of the net profit contributed to the whole future relationship with a customer. Net profit is the measurement of a company's profit once operating costs, taxes, interest and depreciation have all been subtracted from its total revenues. The term is often referred to as a company's “bottom line” and may also be described as “net earnings” or “net income”. The prediction model can have varying levels of sophistication and accuracy, ranging from a crude initiative to the use of complex predictive analysis techniques.

There are some research questions that lead to a fundamental perspective, such as the following: How a certain country can be considered an industrial society? What is Customer Relationship Management? Is there a linkage between customer relationship management and certain industries such as the textile sector (textile and clothing manufacturing industry)?

CRM stands for Customer Relationship Management and aims to best manage our customer relationship and how to respond to their needs and wants. This will make our business more and more successful. In general, a neural network is a series of algorithms that endeavours to recognize underlying relationships in a set of data through a process that mimics the way the human brain operates. In this sense, neural networks refer to systems of neurons, either organic or artificial in nature. Neural networks can adapt to changing input; so, the network generates the best possible result without needing to redesign the output criteria. The concept of neural networks, which is rooted in artificial intelligence, is rapidly gaining traction in the development of commercial systems.

Customer Relationship Management represents a very important instrument for retailers, wholesalers, and distributors in the case of the textile industry. Achieving performance in an industrial sector is inherently correlated with a high degree of customer satisfaction, and the textile industry is no exception. The implementation of CRM software can significantly contribute to the development of certain businesses in the textile industry by providing optimal and intelligent solutions. Moreover, in the case of the textile industry, a very important role is played by the supply chain network. The textile industry includes certain main categories such as upstream, intermediate stream and downstream industrial clusters.

Customer lifetime value is defined as the total revenue from the organization's customers during the life of their transaction with the organization, minus the total costs of attracting, selling and customer service. Used for different groups of customers. By estimating the value of customers, it is possible to identify customers who create high value for the company and to communicate with them in a motivational way. This relationship can increase loyalty and thus increase the life expectancy of beneficial customers and increase the profits obtained from these customers [4]. Customer value refers to the total present and future value of the customer and includes three dimensions of customer attraction, retention and development and can be divided into two categories: customer desired value and perceived customer value [5]. Predicting the value of customer longevity and consequently identifying profitable customers for organizations is a special priority. Statistical models and neural networks are a new generation of data mining techniques that have been greatly developed in the last two decades. Is. And it has always been questioned which one performs better in forecasting. On the other hand, the main purpose of modelling is to determine the relationships between variables, determine the effective variables and predict. The neural network model is a simulation of the human nervous system and is in fact an imitation of the human brain and neural network [6, 7]. Learning in the neural network is done by minimizing the mean squares of the output error and by applying the error post-learning learning algorithm using numerical repetition methods [8, 9]. The number of middle layer neurons is very important because if they are small, the network will lack learning resources to solve complex nonlinear problems, and if it is large, it will cause two problems, the first being training time. Enhanced network and secondly that the network may also learn the errors in the data and act poorly in forecasting [10]. Therefore, the purpose of this study is to predict the value of customer longevity by neural network and ARIMA model and compare the results obtained in industrial organizations and identify profitable customers.

LITERATURE REVIEW

Recently, Chalaki and Bazdar have used the beta geometric model to predict the lifetime value of customers of the Tehran Stock Exchange and have increased the accuracy of predicting the lifetime value of customers by creating a correlation between the number of transactions and profits earned by each customer. They have also shown through numerical comparisons that the dependent BG model is superior to the BG/NBD model and has better performance than the Pareto model and the NBD model [11, 12]. The most accurate method for estimating customer lifetime value for large companies is the

probabilistic modelling method. Although there are several techniques for modelling LTV, two methods are more common: Pareto/NBD and BG/NBD.) Many retailers today are losing customers due to the increase of e-commerce and its benefits. Yang and Chiang conducted research to predict customers' future buying patterns as well as to calculate their current lifetime value. They collected information about customers in a small store in Hong Kong and clustered customers based on RFM model parameters using the Means-K algorithm and then calculated the value of each customer's life using the weight RFM method(Recency, frequency, monetary value (RFM) a marketing analysis tool used to identify a firm's best clients, based on the nature of their spending habits). They have also used the Crisp algorithm(CRISP-DM stands for a cross-industry process for data mining. The CRISP-DM methodology provides a structured approach to planning a data mining project. It is a robust and well-proven methodology. We do not claim any ownership over it. We did not invent it. We are however evangelists of its powerful practicality, its flexibility and its usefulness when using analytics to solve thorny business issues. It is the golden thread that runs through almost every client engagement)to predict the value of customers' future lives, and finally proposed strategies that affect customer loyalty and increase profits and revenue [13].

Kaigeni et al. have proposed a new hybrid algorithm called the LLM model. The LIBOR market model, also known as the BGM Model (Brace Gatarek Musiela Model, in reference to the names of some of the inventors) is a financial model of interest rates. It is used for pricing interest rate derivatives, especially exotic derivatives like Bermudan swaptions, ratchet caps and floors, target redemption notes, auto caps, zero-coupon swaptions, constant maturity swaps and spread options, among many others. The quantities that are modelled, rather than the short rate or instantaneous forward rates are a set of forwarding rates (also called forward LIBORs), which have the advantage of being directly observable in the market, and whose volatilities are naturally linked to traded contracts in order to calculate the likelihood of a telecom company losing customers. This algorithm is a combination of decision tree and logistic regression and includes two stages of segmentation and prediction. They first identify the customers of each department using decision rules and then provide a model to calculate the probability of customers losing each department [14].

In 2018, Kavdar et al. conducted research on modelling the longevity of airline customers. They first modelled the customer lifespan based on a basic model that included only flight-related factors such as flight date, flight number, etc., and then predicted their lifespan using multiple linear regression methods. Customers have developed the model by integrating social media information with flight-related parameters. Finally, by analysing the data, they have shown that adding information related to social networks to the basic model has increased the accuracy and ability to predict [15]. In 2018, Yen et al. divided the third-party insurance clients of one of the insurance companies and determined their life value based on the RFM model and using fuzzy theory. In this research, based on the RFM model and adding a customer risk assessment index to this model, customers are divided into four groups, for each group, the value of customer life is calculated and the characteristics of each group of customers are described qualitatively [16].

Other research elaborated studies on maintaining and increasing customer satisfaction based on the quality of products and services have been done, among which we can refer to the inhibitory and active research in 2017. In this case, the chain changes test the key characteristics of product quality of connecting rods and The source of the error was identified, after which, by eliminating the causes of the error and reducing the quality characteristic changes, it is possible to improve the quality and increase customer satisfaction, and as a result, maintain and maintain its loyalty in purchasing and receiving after-sales service [12]. Moreover, some researchers [17] examined in a research study the value of customer longevity and the use of neural networks to predict membership in banks' telephone networks. They stated that one of the benefits of customer relationship management is identifying customers with more profitability. One of the important results of this research, which is for the telephone call centre to communicate with the customer, was that even without additional information, the performance of the organization can be predicted and improved.

Other researchers [18] have conducted a study to establish a computational framework for customer lifetime value for a car maintenance company in Taiwan. They stated that the value of the customer's lifetime is composed of the present and future value of the customers, which includes the estimation of longevity, future buying behaviour and the profit associated with each behaviour. They used three techniques to estimate customer lifetime value using a customer trading database. Logistic regression model and decision tree model to estimate customer turnover probability and predict customer lifespan. Then regression analysis to identify important variables affecting buying behaviour. Customers and the Markov chain, which expresses the probability model of changing customer behaviour. And finally, neural networks predict the profit offered by the customer under different buying behaviours.

Other researchers [19], while pointing to the importance of recognizing profitable customers for each organization, examined the types of CLV calculation models, then surveyed 5,000 customers for three consecutive years and after collecting and comparing customer information, customer retention and customer value creation after applying targeted advertising policies based on the results of CLV calculation were compared with 3 years ago. In this way, the effect of the programs that were used to increase

customer loyalty in the organization was determined. Moreover, [20] have studied the value of customer lifetime value by RFM analysis based on customer buying behaviour. In their study based on the RFM model, they calculated the value of customers' lifespan in the end, valuable and profitable customers. The organization was divided into 8 clusters based on the value of the life cycle and using the RFM model and their characteristics were analysed. [21] have considered the importance of recognizing the value of customer life in segmenting customers based on this value and then explaining the appropriate strategies for each segment.

In this paper, a new model of customer lifetime value and customer segmentation based on customer value and side sales opportunities is examined. Several researchers [22] analysed the value of customers of industrial equipment manufacturing companies using the RFM model and the clustering method. The characteristics of customers in the form of clusters were analysed using the value analysis of the customer life cycle. It was also presented to use appropriate promotion programs with different customer segments. By comparing and reviewing the research that has been done in the field of predicting customer behaviour, most of these methods have used different data mining methods in comparison with statistical forecasting methods, also among the various data mining methods, the most predictive method is Customers' behaviour has been using neural networks for this purpose. On the other hand, Qaiser Gillani et al. investigated the role of ecological consumption considering the importance of sustainability issues [23].

RESEARCH METHODOLOGY

Research questions

Some of the questions that can be considered in the present study are as follows:

1) What are the effective factors in measuring the value of customer longevity?

2) Is the neural network model suitable for predicting customer lifetime value?

3) Is ARIMA model suitable for predicting customer longevity value?

4) Which model has more efficiency and performance?

Realm of time

The period of this research is the first half of 2021 (April) and the data related to the analysis are also related to the initial period of 2021 (April).

Expert Group

The group of experts in this study includes 10 managers, experts and decision-makers in the field.

RESEARCH VARIABLES

The main variables of the research include: Exchange recently, Number of exchanges, repetitions, Exchange volume, The length of the customer relationship, Net present value and customer revenue. In the following, an overview of each of the variables is given:

Exchange recently: It is a method of trading in which goods or services are exchanged directly and without any intermediary with other goods or services and no means of exchange are used. For example, no money is received. This type of exchange has a bilateral mode, but there is also the possibility of being trilateral and multilateral. And in developed countries, it is similar to the monetary system of that country. Of course, this is usually the case and its use is limited.

Number of exchanges: The number of times goods or services are exchanged between people.

Repetitions: Repetition can mean one of the following:

– Iteration;

– Repetitive literary array;

– Repetitive and incremental development, a project management method and in particular, software development.

There are also used the following: exchange volume, the length of the customer relationship, net present value and customer revenue.

DATA COLLECTION AND RESEARCH METHODOLOGY

After collecting the data, the required variables were first identified by the Delphi method and then the data were analysed using the artificial neural network method and the Arima model, for which MATLAB software was used. The Delphi method is a structured communication method or technique that was originally developed and developed for the purpose of systematic and interactive prediction based on the thinking of experts. This method, which is used in future research, mainly pursues goals such as discovering innovative and reliable ideas or providing appropriate information for decision making. The Delphi method is a structured process for collecting and classifying the knowledge available to a group of experts which is done by distributing questionnaires among these people and controlled feedback on the answers and comments received. In this study, the mean absolute value of error percentage (MAPE) and MSE and R as well as the effect of the new trend predictor variable have been used as indicators to select the final estimator model more accurately.

$$MSE = \frac{\sum_{J-=0}^{P} \sum_{i=0}^{N} (d_{ij} - y_j)^2}{N \times P} \quad (1)$$

In the above relation, the output number of processed elements, and the number of samples in the data set. The network output for instance *i* in the processed element *j* is the output for instance *i* in the processed element *j*. The mean square of the errors shows the difference between the observed value and the calculated values. The lowest mean square of the errors indicates the highest accuracy of the prediction. Also, the correlation coefficient indicates

the amount of network efficiency, which is presented as follows:

$$r = \frac{\frac{\sum_j (x_i - x)(d_i - d)}{N}}{\sqrt{\frac{\sum_j (d_i - d)^2}{N}} \sqrt{\frac{\sum_j (x_i - x)^2}{N}}} \quad (2)$$

is the network output, d_i is the desired output, the average network output and the average desired output. The best answer for the model will be created when the correlation coefficient and the mean square of the errors tend to be one and zero, respectively.

Mean Absolute Percentage Error (MAPE) =

$$= \frac{100}{n} \sum_{t=1}^{n} \left| \frac{At - Ft}{At} \right| \quad (3)$$

EMPIRICAL ANALYSIS

There are some factors affecting the value of customer longevity. Delphi method was used to determine the effective factors in measuring the value of customer longevity. In order to achieve the effective factors in measuring the value of customer longevity in Iran, using experts and research literature related to this field, the existing criteria were extracted. In the next step, the decision group was asked to identify the most important criteria in the field of value. To determine the customer life expectancy, collecting their opinions according to the factors that scored above 0.8, is considered an effective factor in measuring the value of Iranian customer life expectancy. Finally, by confirming the figures obtained by experts, the data to perform the calculation operation, as described in table 1.

Table 1

PROBLEM VARIABLES		
Symbol	**Variable name**	**Score**
A1	Exchange recently	0.86
A2	Exchange length	0.75
A3	Number of exchanges	0.91
A4	The ratio of product sales to total purchases from the same product	0.63
A5	Money exchange value	0.83
A6	The amount of capital return per customer	0.62

As can be seen, the variables of the freshness of exchange and number of exchanges and monetary value of exchange have been identified as effective variables in measuring the value of customer lifetime. These variables are related to RFM model, which is one of the most common models for measuring length value. Are customer life. Therefore, in this research, RFM model has been used to measure customer lifespan.

CALCULATION OF CLV INDEX

Normalization of indicators

Due to the difference in the unit of each indicator, it is necessary to normalize the values of these indicators based on the same unit. These indices are normalized using the relations 4, 5 and 6 between the numbers 0 to 1.

$$R = \frac{R\max - R}{R\max - R\min} \quad (4)$$

$$F = \frac{F - F\min}{F\max - F\min} \quad (5)$$

$$M = \frac{M - M\min}{M\max - M\min} \quad (6)$$

Weighing the indices

To obtain the relative weights of the indices, the Hierarchical Analysis Course of the Hierarchical Analysis Process has been used. Finally, the weights of each of the variables *R*, *F*, and *M* are denoted by *WM*, *WF*, and *WR*, respectively, and the sum of these relative weights is equal to one.

Determining the value of indices for each customer

The value of each index of RFM model is determined by multiplying the normalized value of the index by its weight. The values of these indices are indicated by "M, "F and "R.
The calculated weights of the variables can be seen in table 2.

Table 2

WEIGHT OF VARIABLES				
Variable	**R**	**F**	**M**	**Final weight**
R	1	33/0	33/0	13/0
F	3	1	25/0	28/0
M	3	4	1	59/0

Determining the average value of indices

The average value of each of these indices is determined by dividing the total value of that index in all customers by the total number of customers.

$$R'' = W_R * R' \quad (7)$$

$$F'' = W_F * F' \quad (8)$$

$$M'' = W_M * M' \quad (9)$$

Calculating the value of customers' life cycle

The value of the customer life cycle is calculated from the total average value of RFM indices:

$$CLV = R_t + F_t + M_t \quad (10)$$

ARIMA MODEL

At this stage, after entering the data in the software, in order to initially analyse and review the data graph related to the customer's lifetime value was drawn.

This data can be identified by the symbol f in the variables. According to some authors [24] ARIMA model represents a category of time-series analysis based on prediction algorithms.

Static test and estimation of ARIMA model

As can be seen, the trend in parts has regular fluctuations and an increasing pattern. This issue should be analysed by examining the correlation diagram. Using the logarithm of data in the form of rates or ratios is not recommended. In this section, the root test of the Dickey-Fuller unit is used to determine whether the variable is meaningful. Dickey-Fuller test In statistics, the Dickey-Fuller test tests the null hypothesis that a unit root is present in an autoregressive model. The alternative hypothesis is different depending on which version of the test is used but is usually stationarity or trend-stationarity. It is named after the statisticians David Dickey and Wayne Fuller, who developed the test in 1979 [25]. The Dickey-Fuller test is one of the most widely used tests in order to determine stationary. The use of the OLS estimation method in experimental work is based on the assumption that the time series variables used are constant.

The first step in determining the meaning of a variable is to observe its time-series diagram. It is possible to detect the existence of a random trend in a time series simply through a single root test.

Consider the following first-order explanation process:

$$y_t = p\,y_{t-1} + u_t \; t = 1,2,\ldots \qquad (11)$$

To test whether the time series has a single root, or in other words is anonymous, we test the following hypothesis:

$$H_0 : p = 1 \qquad (12)$$

$$H_1 : p < 1 \qquad (13)$$

The test results are presented in figure 1.

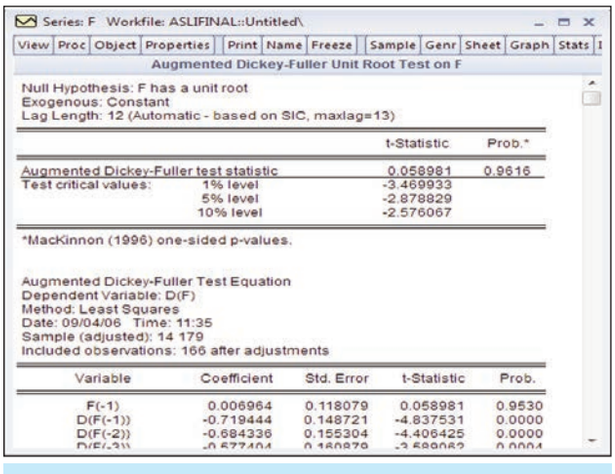

Fig. 1. Dickey-Fuller test

As can be seen, the model has a single and meaningless root. In figure 1, the absolute value of the Dickey-Fuller statistic is less than the critical values, so there is a single root. At this stage, the data are differentiated. The difference diagram is shown in figure 2.

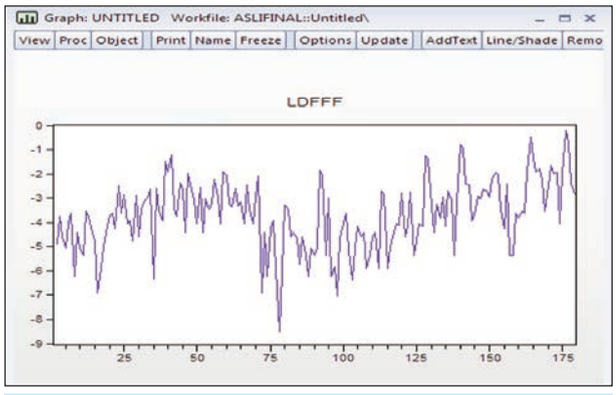

Fig. 2. Differentiation diagram

The Dickey-Fuller test is run again. As can be seen and shown in figure 3, once the absolute value of the Dickey-Fuller statistic was differentiated, it was greater than the critical values, which indicates that the unit root problem is solved.

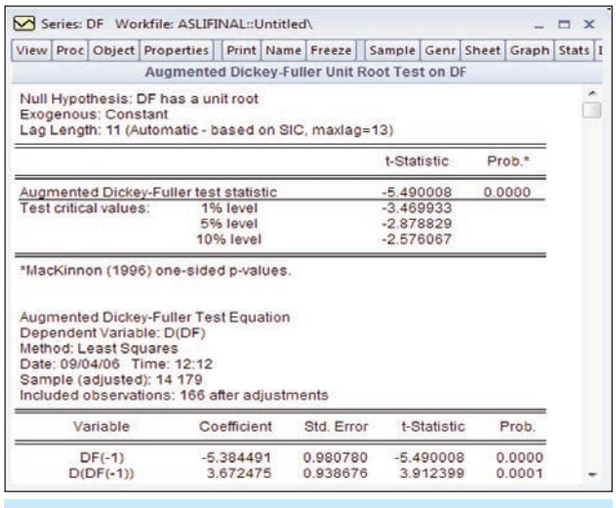

Fig. 3. Dickey-Fuller retest

As can be seen, by differentiating 1, the problem of variance anonymity is solved. Now the data self-correlation diagram is examined. The self-correlation diagram is presented in figure 4.

According to the data in figure 4, it can now be concluded based on the PACF and ACF columns that this model has AR (1), and according to the partial PC MA (2), MA (1) can be added to the model. After testing the model with equation 14, in figure 5, all MA and AR coefficients are significant and Watson camera statistic is close to 2, which indicates the absence of autocorrelation, and the value of F-STATISTIC indicates significant regression.

$$\text{LDFFF C AR (1) MA (1) MA (2)} \qquad (14)$$

Figures 6 and 7 show the forecast and actual graphs as well as the calculated errors.

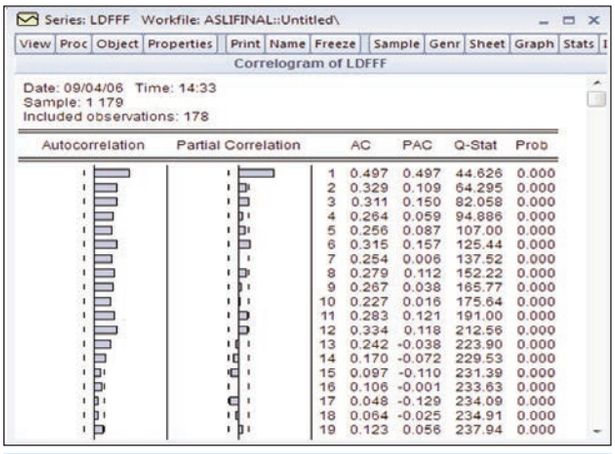

Fig. 4. Self-correlation graph after differentiation

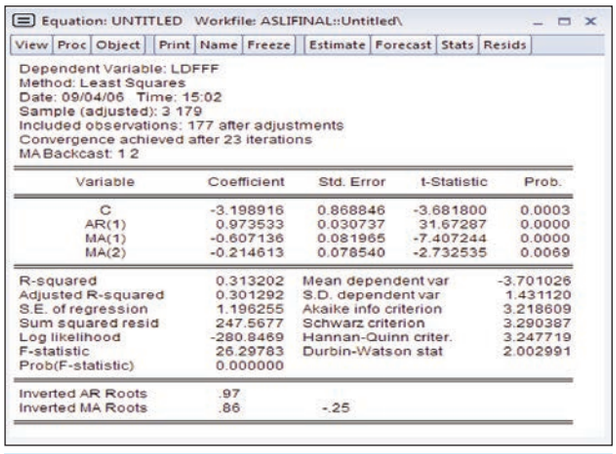

Fig. 5. Fit test of ARIMA model

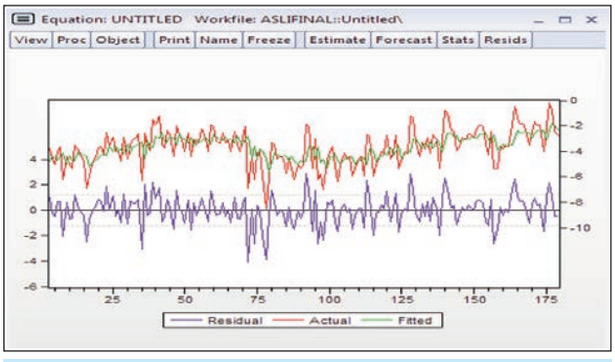

Fig. 6. ACTUAL and FITTED charts to compare actual and predicted values

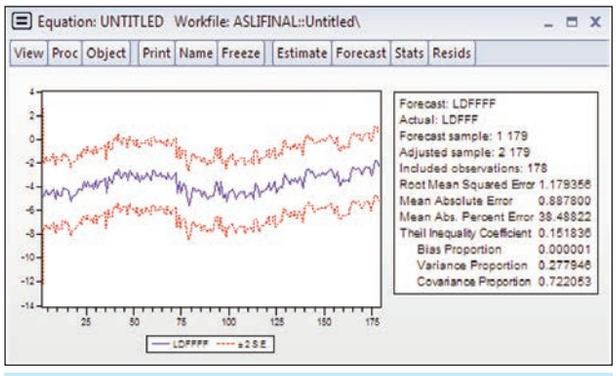

Fig. 7. Model output diagram and forecast error

NEURAL NETWORK MODEL

The neural network returns the error due to the difference between the network output and the actual value to the network and adjusts the parameters to provide a more accurate output with the next similar input pattern and reduce the error. The more training, the better the neural network performance and the less error. Mathematically, the neural network implements the extension of the desired unknown function in terms of the basic functions, which are the activity of neurons. Expansion weights are the same as network weights. Artificial neural networks are made up of simple processor parts that are interconnected by weight ratios and have the ability to learn the relationships between a set of variables. The contents of 4 important factors in the structure of neural network architecture are important in this research are as follows:

- Number of input and output variables: In the present study, the variables of exchange value, exchange volume and recent exchange were used as input variables of the forecast model and customer lifetime value data as the output variable of the forecast model and the number of 180. The customer is selected as the sample.
- Number of hidden layers: In this study, the hidden layers are two layers.
- Activation functions: The activation function of hyperbolic tangent and sigmoid tangent in hidden and linear layers have been used for transfer in the output layer.
- Learning algorithm: The number of these algorithms is very large, but the most widely used ones that have been used in this research are: the momentum algorithm, Lonberg-Marquardt algorithm, descending gradient algorithm, step algorithm, delta bar delta algorithm and Conjugate rotation algorithm.

Among the various networks, multilayer perceptron networks with error propagation algorithms are used more than others in engineering, which are usually made of three layers of neurons (input layer, hidden layer, output layer). Determining 90% of them for training and 10% of them for testing, we have changed the number of neurons from 1 to 50 and the two-layer neural network has been used. Also, the results of different neural network models are presented separately. The data of the mentioned variables are collected from the information provided by the company.

The neural network error rates in training mode using different arrangements and models are given in table 3.

Examination of previous table shows that the best state of artificial networks is when the first hyperbolic

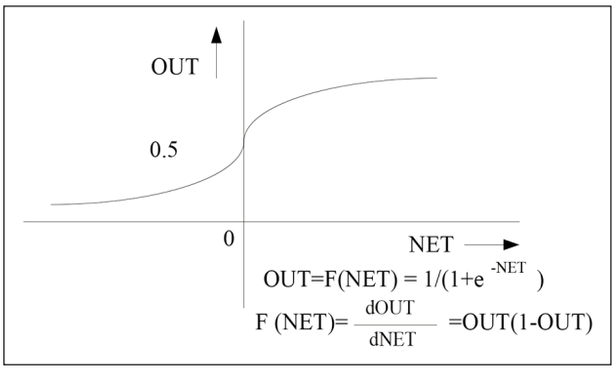

Fig. 8. Sigmoid tangent excitation function

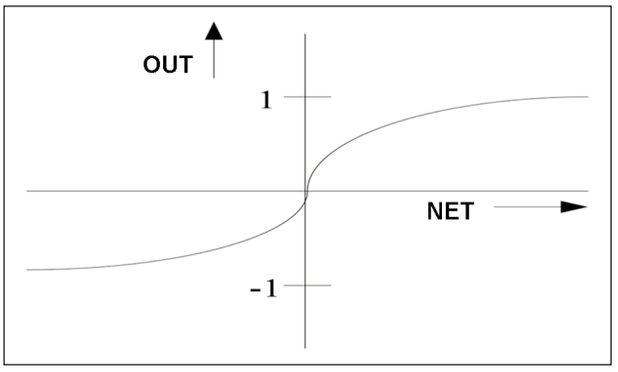

Fig. 9. Hyperbolic tangent stimulation function

Table 3

NEURAL NETWORK ERROR RATE IN TRAINING MODE								
Model type	**The number of repetitions**	**Training algorithm**	**Arrangement**	**Transfer function**			**MAPE**	**MSE**
				The first layer	**The second layer**	**Output layer**		
Perceptron 1	1000	Lonberg Marquat	3–4	Hyperbolic tangent	Sigmoid tangent	Linear	159/0	134/0
Perceptron 2	1000	Descending gradient	10–12	Hyperbolic tangent	Sigmoid tangent	Linear	153/0	156/0
Perceptron 3	1000	Descending gradient	9–11	Hyperbolic tangent	Sigmoid tangent	Linear	142/0	138/0
Perceptron 4	1000	Lonberg Marquat	12–8	Hyperbolic tangent	Sigmoid tangent	Linear	138/0	141/0
Perceptron 5	1000	Lonberg Marquat	16–5	Hyperbolic tangent	Sigmoid tangent	Linear	141/0	151/0

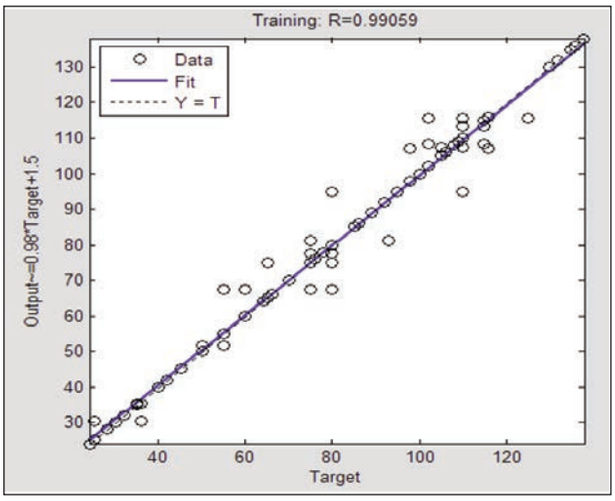

Fig. 10. Data distribution in training mode

tangent transfer function and the second sigmoid tangent transfer function and the output layer are linear and the Levenberg-Marquat learning function and the number of neurons in the first hidden layer 8 and the second hidden layer 12. In this case, the error rate of the best network is 13.8%.

The neural network error rates in training mode using different arrangements and models are given in table 4.

Examination of previous table shows that the best state of artificial networks is when the first hyperbolic tangent transfer function and the second sigmoid tangent transfer function and the output layer are linear and the Levenberg-Marquat learning function and the number of neurons in the first hidden layer 8 and the second hidden layer 12. In this case, the error rate of the best network is 10.3%.

Figure 11 shows the relationship between the predicted values and the actual values in the training mode. As can be seen, the variable *R* indicates a simple correlation between the two variables, in other words, the intensity of the correlation between the two variables. As can be seen from the value of *R* (Pearson correlation between the two variables), there is a very strong correlation between the two dependent variables and all the independent variables. As can be seen, the value of *R* is equal to 0.936, which indicates a strong relationship. It is between two variables, which indicates that independent variables are suitable for predicting the dependent variable.

Is ARIMA model suitable for predicting customer longevity value? As seen in the results, ARIMA model has been able to predict the value of customer longevity, in which the MAPE error values are 38.4%, which is acceptable and shows the efficiency of this

Table 4

NEURAL NETWORK ERROR RATE IN TEST MODE								
Model type	**The number of repetitions**	**Training algorithm**	**Arrangement**	**Transfer function**			**MAPE**	**MSE**
				The first layer	**The second layer**	**Output layer**		
Perceptron 1	1000	Lonberg Marquat	3–4	Hyperbolic tangent	Sigmoid tangent	Linear	128/0	123/0
Perceptron 2	1000	Descending gradient	10–12	Hyperbolic tangent	Sigmoid tangent	Linear	113/0	142/0
Perceptron 3	1000	Descending gradient	9–11	Hyperbolic tangent	Sigmoid tangent	Linear	108/0	123/0
Perceptron 4	1000	Lonberg Marquat	12–8	Hyperbolic tangent	Sigmoid tangent	Linear	103/0	116/0
Perceptron 5	1000	Lonberg Marquat	16–5	Hyperbolic tangent	Sigmoid tangent	Linear	116/0	123/0

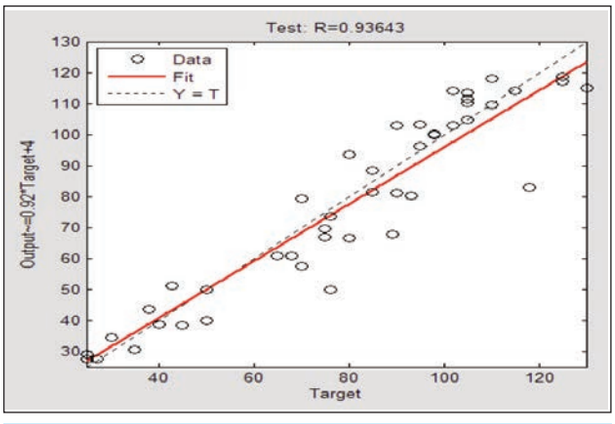

Fig. 11. Data distribution in test mode

model. Which model has more efficiency and performance? According to the issues raised, it can be seen that the artificial neural network model has a better ability to predict the lifetime value of the customer and by comparing the MAPE of each of the two models, which is shown in table 5, the model presented using the neural network. In this study, it has a better performance in predicting customer lifetime value than ARIMA model.

Table 5

COMPARISON OF NEURAL NETWORK AND ARIMA MODEL RESULTS	
Model	**APE**
Neural Network	3/10
ARIMA	4/38

CONCLUSIONS

Predicting the value of customer longevity and consequently identifying profitable customers for organizations is a special priority. Statistical models and neural networks are a new generation of data mining techniques that have been greatly developed in the last two decades. Is. And it has always been questioned which one performs better in forecasting.

What are the factors influencing the value of customer longevity? In this sense, certain optimal variants are provided, such as exchange recently, the number of exchanges and money exchange value. Is the neural network model suitable for predicting customer lifetime value? As can be seen, the neural network model has the conditions and assumptions to predict the value of customer life expectancy, so the neural network model can be used to predict the value of customer life expectancy. Also, the results show that for prediction the customer life expectancy value can be used by neural networks of the variables of recent exchange, the number of exchanges and monetary value of exchange. In total, the values of MAPE error are 10.3% and MSE error is 11.6% for the neural network model. The neural network model is acceptable.

On the other hand, the supply-chain activity is essential in the dynamics of the textile industry. CRM is primarily used for obtaining an important competitive advantage [26]. The purchase behaviour of the consumer of textile products and services can be influenced by the implementation of sustainable CRM-based strategies.

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The effects of consumer clothes design engagement on brand love and loyalty

DOI: 10.35530/IT.073.03.202140

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ABSTRACT – REZUMAT

The effects of consumer clothes design engagement on brand love and loyalty

This study aims to investigate the effect of consumer engagement in the clothing industry on brand love and brand loyalty. Besides social peer influence was added to the model as an independent variable affecting loyalty and consumer engagement. In line with the research purpose, a model was developed that demonstrates the effect of consumer engagement on brand loyalty and brand love. Data were obtained from 399 consumers through a questionnaire designed to test the developed model. The variables in the established model were tested with confirmatory factor analysis. Hypotheses were tested with path analysis in the AMOS structural equation model. Consumer engagement in the design of clothes has positive effects on attitudinal loyalty and behavioural loyalty. No conclusion that consumer engagement leads to brand love. According to the results, behavioural loyalty leads to brand love. However, this feeling of consumers who show attitudinal loyalty is not effective on their brand loves. The variable that triggers consumers to engage in product design is the social peer effect.

Keywords: *consumer engagement, brand loyalty, brand love, social peer influence, clothing industry, structural equation model*

Influența angajamentului consumatorului legat de designul îmbrăcămintei asupra atașamentului și loialității față de brand

Acest studiu își propune să investigheze influența angajamentului consumatorilor din industria de îmbrăcăminte asupra atașamentului și loialității față de brand. În plus, influența egalității sociale a fost adăugată modelului ca o variabilă independentă, care afectează loialitatea și implicarea consumatorilor. În conformitate cu scopul cercetării, a fost dezvoltat un model care demonstrează influența angajamentului consumatorului asupra loialității și atașamentului față de brand. Datele au fost obținute de la 399 de consumatori printr-un chestionar conceput pentru a testa modelul dezvoltat. Variabilele din modelul stabilit au fost testate cu analiză factorială de confirmare. Ipotezele au fost testate cu analiza traseului în modelul de ecuație structurală AMOS. Implicarea consumatorilor în designul îmbrăcămintei are efecte pozitive asupra loialității atitudinii și comportamentului. Nu s-a ajuns la concluzia că implicarea consumatorilor duce la atașamentul față de brand. Conform rezultatelor, loialitatea comportamentală duce la atașamentul față de brand. Cu toate acestea, acest sentiment al consumatorilor care arată loialitatea atitudinii nu este eficient asupra atașamentului lor față de brand. Variabila care îi determină pe consumatori să se implice în proiectarea produsului este efectul de egalitate socială.

Cuvinte-cheie*: angajamentul consumatorilor, loialitatea față de brand, atașamentul față de brand, influența egalității sociale, industria de îmbrăcăminte, modelul de ecuație structurală*

INTRODUCTION

Ever since experiential marketing emerged, it has been used by companies as a strategic weapon to create a competitive advantage. Today, businesses are faced with a quite different competitive environment. To create a competitive advantage in the market, companies should strengthen the products or services they offer to consumers, and it was underlined that it is an effective way to offer unique experiences to consumers [1]. Specific understanding of consumers' perceived requirements and meeting their demands and expectations is becoming a difficult situation [2].

Consumer engagement is vital, especially in the field of new product development. Consumers are ready to provide ideas for new goods or services that have not yet been fulfilled by the market or that can meet the needs that can be improved with existing offerings. For example, Ozbek's study, in which Turkish University students wanted to participate in the t-shirt design process, determined that 83.1% of female students and 87.9% of male students are willing to participate [3].

Nielsen Company stated in the 2015 Global Advertising Trust Report that, according to the research data conducted in 60 countries around the world, 83% of the consumers were most affected by the recommendations of their families, close friends and friends during the purchasing decision phase. They consider these sources the most reliable

source [4]. Edelman, who carries out marketing communication activities, stated in the BrandShare report published in 2014 that 80% of consumers want brands to listen to them, but a few brands can achieve this [5].

Allowing consumers to participate in marketing activities, comment on new products or be included in the new product development process creates the "Hawthorne Effect". The Hawthorne effect is the tendency to generate positive emotions and be closer to collaboration when a person feels valued about something. Consumers who participate in participatory marketing practices and have the opportunity to work with brands develop their emotional ties with the brand, their brand loyalty increases, and thus highly effective word-of-mouth marketing ambassadors are created. From the moment that consumers get involved in participatory marketing, they work as an ambassador of the brand and convey their honest comments about the brand and its products to their friends, close circles or other Internet users over the Internet.

In an environment where product differentiation has become increasingly difficult, global markets and competitors are increasing. And different consumers structure has emerged that have become increasingly difficult to predict, and businesses have started to apply different marketing strategies. In this context, the concept of brand love enables businesses to implement different solutions and practices to achieve a competitive advantage. Even though researchers have been working on consumers 'feelings of liking/disliking brands for years, there has been a rapid increase in interest in the topic of "consumers' love for brands" in recent years. Brand love; consists of the sum of elements that contain images about the product, make sense to the consumer and add symbolic value to the consumer with the consumption of the product. To stand out from other brands and become brand love, it is not enough to offer only a better quality or aesthetic product. In brand love, brand loyalty is beyond logical reasons. Businesses also seem to increasingly understand the importance of this issue. The advertisements that were frequently seen in the past, describing the product and highlighting the quality are gradually being replaced by advertisements that emphasize the consumer's passion for the product. Consumers' attachment to the brand with love enables them to continue their relations with the brand for a long time. When businesses create their marketing strategies, they should analyze well what creates loyalty in consumers and act accordingly. When businesses establish strong bonds, they also ensure consumer satisfaction and repurchase.

The success of any firm is influenced by its development capacity and the design of new products at the correct time. Innovation and designing a new product, provide a competitive advantage in the apparel sector [6]. The study aims to examine the effect of consumer engagement on brand love and brand loyalty in the clothes design sector. For this purpose, the conceptual framework of the variables used in the study was drawn and hypotheses were determined in the light of the relevant literature.

Brand's Consumer Engagement: Consumer Engagement (CE) is defined as "a psychological state that occurs by interactive, co-creative consumer experiences with a focal agent/object (e.g., a brand) in focal service relationships" [7]. Consumer engagement refers to "consumers' behavioural manifestation towards a brand or firm, beyond buying, resulting from their motivational drivers" [8]. Consumer engagement has been indicated to be linked with competitive advantages for companies, such as uncovering consumer demands, improving consumer loyalty, shortening production time to market, and diminishing cycle time from production to consumption [9]. Consumer engagement (CE) brings about positive outcomes for the firms for example; improved company performance, favourable reputation, and increased relationship quality. Likewise, it has been linked positively with consumer-specific outcomes as well, such as consumer satisfaction and welfare [10]. Companies concentrate on the procedure for producing particular task forces to operate upon co-creation of value using collating information and analyzing the shifting priorities of consumers and competition shifts in the market, assessing client responses, executing finest applications and decreasing consumer dissonance [11].

Consumer engagement was considered as both a dependent and independent variable in the literature. Consumer engagement is a driver of consumer trust, value, affective commitment, satisfaction and loyalty. Besides, other critical variables of brand performance, such as profit, sales growth and return on investment, have been linked to consumer engagement [12]. Consumer engagement programs have an influence on brand awareness, then sponsors and consumer engagement programs related to brand awareness [13]. Mobile apps' consumer engagement positively affects consumer equity, which further enhances the repurchase intention of existing consumers [8]. Consumer engagement in the early stages creates trends for products and contributes significantly to the launch phase [14]. Chiang et al. revealed that using social media is a new way of promoting user engagement and understanding potential user demands for a service company [9]. Besides, continuance purpose is positively linked with consumer engagement behaviour. According to Aziz and Ahmed, there is a significant impact of consumer engagement on buying intention in the fashion industry [15]. The results demonstrate that brand interactivity, brand intimacy, brand involvement and brand trust positively influence CBE (consumer brand engagement). Furthermore, this research also found that CBE positively affects buying intention. Consumer engagement with Facebook brand pages (FBPs) is positively affected by consumer intentions; knowledge, payment, social communications and personal identity in apparel/fashion. Consumer engagement is found to be positively associated with

FBP confidence and FBP usage [16]. According to some research; companies have the intent to involve consumers in the design process. They are using consumers' creative ideas, critical decisions and talent to produce new products [17]. Also, firms can get valuable feedback about Website quality, brand familiarity, and brand equity [18]. Perceived advantages positively affect emotional product attachment and attitudes toward the customization process [19]. Besides, commitment positively affects attitudes, which in turn to loyalty. Engaging consumers is important for retail brands because consumers may feel a stronger connection to the brand and the company. The findings provide an understanding of the main drivers of consumer-brand engagement that can lead to purchasing intentions [20].

Morgan et al. revealed that consumer participation is positively related to new product development performance and that the effect is mediated by innovativeness [21]. According to Kim, et. al. successful product development should be based on an in-depth understanding of the consumers and their unique needs [22]. Islam and Rahman found that each of the characteristics positively influences consumer engagement, with information quality and virtual interactivity bearing the strongest influence.

Consumer engagement also exhibits a strong positive impact on brand loyalty [23]. Based on the brand engagement literature of consumers, the main hypotheses of the research were determined as follows:

H1: Consumer engagement has a significant positive effect on attitudinal loyalty

H2: Consumer engagement has a significant positive effect on behavioural loyalty

H3: Consumer engagement has a significant positive effect on brand love

Brand's Consumer Engagement: Consumer loyalty is defined as a "deeply commitment that the consumer has to re-buy a preferred product/service consistently in the future [24]. Creating brand loyalty is seen as a long and difficult process. It is thought that a person who feels an emotional connection to that brand will have a positive effect on the processes of the purchasing behaviour of consumers. It is expected that this will increase its effect, especially on brand loyalty and that these people will have a higher level of loyalty to that brand than other consumers [25]. There are three types of brand loyalty namely, attitudinal, behavioural, and composite loyalty [26]. Attitude is a crucial aspect to predict the behaviours of consumers [27]. In the model of this research, consumer loyalty takes place in two forms, behavioural and attitudinal.

When the research is examined, it is seen that people can fall in love not only with other people but also with objects, products or brands [28–31]. The consumer love for a brand; includes the passion for the brand, the degree of attachment to the brand, positive evaluation and positive feelings toward the brand [28]. The concept of love for brands, inspired by the mutual relationship between people, is a concept that emerged by measuring the object-human relationship. The earliest study on this subject is the work of Shimp and Madden, which is based on Sternberg's Triangle Love Theory, which consists of sincerity, passion and commitment components and explains interpersonal love [32]. Brand love includes emotional, cognitive and behavioural elements. It consists of seven dimensions: "passionate behaviour, seeing oneself with the brand, positive emotional attachment, anxiety about the possibility of the brand being removed from the market, long-term relationship, positive attitude towards the brand, and trust in the brand" [29]. According to Albert and Merunka, brand love affects both attitudinal and behavioural loyalty. Brand love plays an important role in maintaining a long-term relationship with a brand due to psychological, functional and emotional reasons [33]. There is a lot of research which are searching relation between brand loyalty and brand love [33–39]. There is a significant link between consumer engagement, brand image and brand love [40]. It has been understood that consumer participation leads to consumer loyalty. Firms must interact with consumers while branding and marketing their fashion apparel brands to achieve a loyal consumer base. It is possible to mention that there is a strong relationship between brand love and brand loyalty [41]. In the light of this information, the following hypotheses were developed:

H4: Behavioural loyalty has a significant positive effect on brand love

H5: Attitudinal loyalty has a significant positive effect on brand love

Social peer influence: The young consumer group has gained tremendous attention from marketers as they have increased purchasing power [42]. Especially young people's interactions with various individuals and/or groups in the process of socialization as consumers play a key role in shaping their consumption behaviours. Although the persons/groups in question are referred to as reference groups/socialization agents in the relevant literature; it is examined under two main headings as normative and comparative reference groups [43, 44].

Normative reference groups are considered as individuals with whom there is direct interaction, such as mothers, colleagues/schoolmatesteachers, and where the skills, knowledge and attitudes needed are acquired [45–47]. Comparative reference groups, on the other hand, consist of individuals who are relatively more individual and/or socially distant, such as sports celebrities (heroes) and artists, who are inspired, admired and desire to achieve their standards of success [44, 47, 48]. Within the scope of this research, the role modelling situation is discussed in normative terms. Beaudoin, Lachance and Robitaille state that the peer group has great importance in the clothing shopping and brand preferences of adolescents [49].

Peer influence is generally used to understand the extent to which consumers are affected by others when purchasing goods [50]. According to Johnson,

Jorgensen and Ha, peer influence is present when making buying decisions, as individuals want to be viewed as popular within the group [51]. Peer influence occurs when people's opinions and behaviours are affected by peers [52]. Social peer influence has important effects on consumer behaviour [2]. Ahmed et al. revealed that the early adopters are actively influencing the buying decisions of the late adopters with viral marketing [53]. According to Wolny and Mueller, fashion has been characterised by peer influence [54]. Especially high brand commitment and fashion engagement motivate people to commit to talking about fashion brands [55], revealing that there is a significant effect between peer influence and shopping behaviour. They searched this effect between Chinese and American users. Consumers consider searching for information from their relatives and friends more than they search for it from the providers of the products [56].

These hypotheses developed in line with are as follows:

H6: Social peer influence has a significant positive effect on consumer engagement

H7: Social peer influence has a significant positive effect on behavioural loyalty

In the model established, it is seen that consumer participation has a mediating role between social peer influence and behavioural loyalty. Therefore, the mediation hypothesis H8 was established.

H8: Consumer engagement mediates the relationship between social peer influence and behavioural loyalty.

MATERIAL AND METHOD

While investigating the impact of consumer engagement on loyalty and brand love, the effect of social peer effect on engagement and loyalty was also examined. The questionnaire form consisting of 5 variables and 23 expressions with the Likert Scale was delivered to consumers online. First of all, a pre-test was carried out with 99 consumers and the model was tested. Later, the survey was completed with the participation of 399 people. It is sufficient to have a sample of more than 200 in terms of having sufficient statistical power for structural equation model analysis [57]. While it is sufficient to reach 5 times the number of expressions in the scale used in some studies [58–59], it is deemed appropriate to reach a sample of 10–15 times in some studies [58], [60]. In this study, it was aimed to reach at least 15 times the number of proposals. There are 23 expressions on the scale used. In this case, it is sufficient to reach 345 participants. The study was conducted with 399 people, in this sense, it can be said that the number of samples studied is sufficient. The data of the study were collected through an online questionnaire in January 2021. Figure 1 shows the basic model of the research.

The expressions of the 5 variables used in the study were prepared by making use of important studies in the literature [61–65]. After the pre-test, incomprehensible expressions were made more understandable. Table 1 includes the sources of the variables, their expression codes, and their reliability scores. The reliability scores of the variables vary between 0.82 and 0.89.

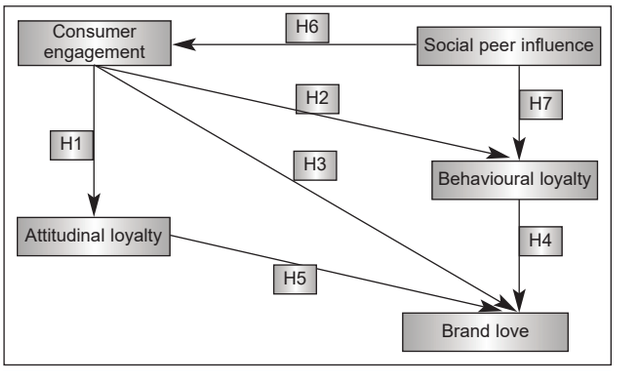

Fig. 1. The fitting curve of Exponential function

Table 1

VARIABLES AND REFERENCES OF SCALE

Variable	References of scale	Code	Cro. Alpha
Brand Love BL	Wallace, Buil, and de Chernatony, 2014 [61]	BL1	0.891
		BL2	
		BL3	
		BL4	
		BL5	
		BL6	
Behavioural Loyalty BEL	Halim, 2009 [62] Chaudhuri and Holbrook, 2001 [63]	BEL1	0.853
		BEL2	
		BEL3	
		BEL4	
Attitudinal Loyalty ATL	Halim, 2009 [62] Chaudhuri and Holbrook, 2001 [63]	ATL1	0.828
		ATL2	
		ATL3	
		ATL4	
Consumer Engagement CE	Hollebeek, Glynn and Brodie, 2014 [64]	CE1	0.863
		CE2	
		CE3	
Social Peer Influence SP	Hung et al., 2011 [65]	SP1	0.882
		SP2	
		SP3	
		SP4	
		SP5	
		SP6	

The data were analyzed first based on the demographic characteristics. We found that 60.2% of participants were female (n:240), whereas 38.6% of the participants (n:154) were male. 5 people among the participants stated that they do not want to answer this question. When the findings of the family income of the participants are examined; 16.3% (n: 65) stated

Table 2

STATISTICAL VALUES				
Variable	**Code**	**Factor loadings**	**AVE**	**CR**
Brand Love BL	BL1	0.82	0.596	0.897
	BL2	0.73		
	BL3	0.87		
	BL4	0.78		
	BL5	0.84		
	BL6	0.63		
Behavioural Loyalty BEL	BEL1	0.63	0.554	0.829
	BEL2	0.61		
	BEL3	0.85		
	BEL4	0.85		
Attitudinal Loyalty ATL	ATL1	0.79	0.578	0.846
	ATL2	0.73		
	ATL3	0.77		
	ATL4	0.75		
Consumer Engagement CE	CE1	0.84	0.694	0.871
	CE2	0.91		
	CE3	0.74		
Social Peer Influence SP	SP1	0.68	0.552	0.879
	SP2	0.61		
	SP3	0.84		
	SP4	0.88		
	SP5	0.75		
	SP6	0.66		

that they do not have a regular monthly income. 21.1% of the participants stated they earn 3500 TL or less; 16.5% between 3501 TL and 5000 TL, 22.3% between 5001 TL and 7500 TL, 10.3% between 7501 TL and 10000 TL, 13.4% between 10001 TL and above stated. Most of the participants falling between 18 and 25 years of age. In this study, the age groups were divided into three groups Generation X, Y and Z. Table 2 shows the factor loads, AVE and CR values of the variables.

When table 2 is examined, it is seen that most of the factor loads are above 0.70. Fornell and Larcker stated that the calculated AVE values should be greater than 0.50, and the CR values should be more than the AVE values [66, 67]. When the AVE and CR values of this study are examined, it can be easily said that the construct validity of the study is ensured. When the RMSEA, GFI, CFI and X2/df values given in table 3 are examined, it is possible to say that the model achieved the desired goodness of fit. Any expression has not been deleted because the values are within the desired range. A correlation link was established between BEL1 and BEL2 variables in line with the recommendation of the Amos program.

The numbers related to the standardized Beta coefficient, standard error, critical rate and p-value of the established structural equation model are given in table 4. According to the analysis, 6 of the 8 hypotheses established were accepted, while 2 were rejected. Significant results were obtained with the path analysis established in the Amos program for hypothesis

Table 3

GOODNESS OF FIT VALUES					
Scales	**X^2**	**df**	**X^2/df**	**GFI**	**CFI**
Brand Love	26.149	7	3.736	0.978	0.986
Behavioural Loyalty	0.000	1	0.000	1.000	1.000
Attitudinal Loyalty	6.410	2	3.205	0.992	0.993
Consumer Engagement	0.735	1	0.735	0.999	1.000
Social Peer Influence	10.076	8	1.259	0.992	0.998
Good Fit Scores *			**≤3**	**≥0.90**	**≥0.97**
Agreeable Fit Scores *			**≤4–5**	**0.89–0.85**	**≥0.95**

Table 4

RESULTS OF THE HYPOTHESES OF THE GENERAL MODEL						
Hypothesis	→		**St. Beta**	**St. Error**	**Critical Ratio**	**p**
H1	CE	ATL	0.778	0.059	13.257	***
H2	CE	BEL	0.658	0.055	11.902	***
H3	CE	BL	0.165	0.084	1.964	0.052
H4	BEL	BL	0.573	0.079	7.247	***
H5	ATL	BL	0.055	0.050	1.105	0.269
H6	SP	CE	0.337	0.054	6.269	***
H7	SP	BEL	0.188	0.043	4.401	***
H8	SP → CE → BEL		0.285	0.043	6.590	***

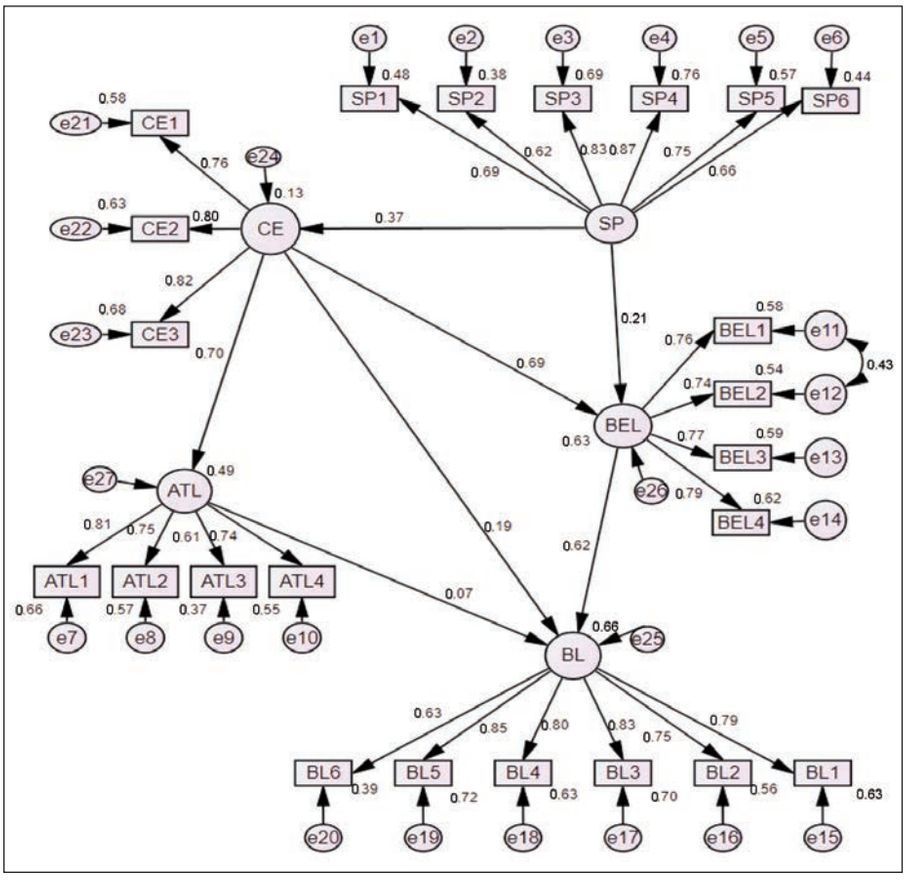

Fig. 2. Structural model of research (RMSA: 0.098, CFI:0.966; GFI: 0.890; CMIN/DF: 4.797)

testing. Consumer engagement in the design of clothes has positive effects on attitudinal loyalty (p:0.00<0.05) and behavioural loyalty (p:0.00<0.05). However, we cannot say that consumer participation leads to brand love (p:0.052<0.05). It is thought that loyalty will lead to brand love in the established model. According to the results, behavioural loyalty leads to brand love (p:0.00<0.05). However, this feeling of consumers who show attitudinal loyalty is not effective on their brand love (p:0.269< 0.05). The variable that triggers consumers to engage in product design is the social peer effect. social peer influence is also a factor affecting behavioural loyalty (p:0.00<0.05). In the model established, consumer engagement plays a role as both a dependent variable, independent variable and mediator variable. This study is important in terms of the originality of the model established.

The mediating role of consumer engagement in the relationship between social peer influence and behavioural loyalty was tested with the three-step method proposed by Baron and Kenny [68]. According to the authors, three stages should take place to speak of a mediating effect. In the first stage; the independent variable (social peer influence) should affect the dependent variable (behavioural loyalty). In the second step; the independent variable (social peer influence) should have effects on the mediator variable (consumer engagement). When the mediator variable (consumer engagement) is included in the model, the effect of the independent variable (social peer influence) on the dependent variable (behavioural loyalty) decreases, while the mediating variable (consumer engagement) has a significant effect on the behavioural loyalty. Figure 3 shows the mediator role of consumer engagement between SP and BEL.

The first direct effect was examined and all three variables were examined together. When the beta coefficient is examined, the consumer participation consumer engagement (CE) mediating role reduces the strength of the beta coefficient between (SP) social

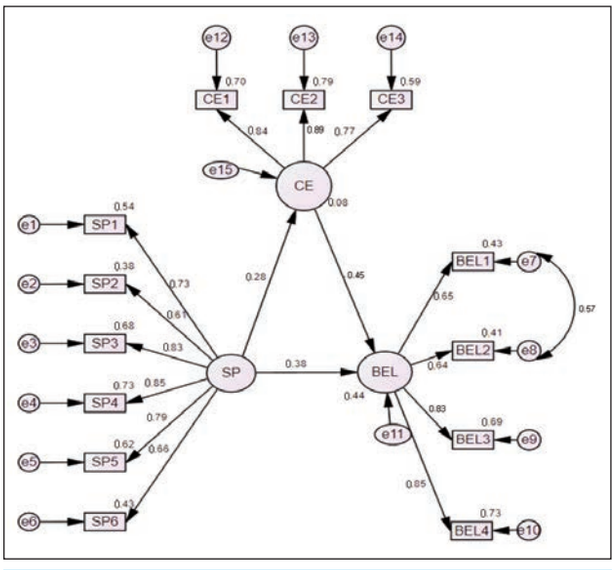

Fig. 3. Mediating effect model (X^2/df: 3.929 GFI: 0.911; CFI: 0.911 and RMSEA: 0.076)

Table 5

MEDIATING EFFECT FOR CONSUMER ENGAGEMENT

Direct and indirect effect		St. Beta	St. Error	Critical Ratio	p
SP	BEL	0.360	0.048	7.491	***
SP → CE → BEL					
SP	CE	0.270	0.054	5.002	***
CE	BEL	0.332	0.042	7.933	***
SP	BEL	0.270	0.040	6.697	***

peer influence and (BEL) behavioural loyalty. Thus, the result indicated that there is a partial mediation between independent and dependent variables. In this case, the H8 hypothesis is also partially accepted.

DISCUSSION

In this research, while investigating the impact of consumer engagement on loyalty and brand love, the effect of social peer effect on engagement and loyalty was also examined. The effect of consumer engagement on loyalty is in line with the results seen in the literature. Consumer engagement affects attitudinal loyalty more than behavioural loyalty. According to the analysis results, consumers participating in the design process continue to purchase the product. Even if there is another brand alternative, they still continue to buy the product of the brand they participated in the design process. It has been observed that consumers show not only behavioural loyalty but also attitudinal loyalty after participation. In other words, consumers even accept to pay more for the products they take part in the design/production process compared to other products. In the research model, three motivations that reveal brand love were determined. Among the variables of attitudinal loyalty, behavioural loyalty and consumer participation, it was seen that only behavioural loyalty led to brand love. This result is similar to some research from the literature [33–40].

Social peer influence was added to the model as an independent variable affecting loyalty and consumer engagement. Consumers with strong social peer influence are those who pay attention to their friends' purchases, do not use unfashionable products, and buy to leave a good impression around them. It is thought that consumers, who are under the influence of social peers, want to influence their environment and become popular by contributing to the production of special products for them. It has been revealed that consumers who are careful to use the same brands as the brands used by their friends, who are under the influence of social peers, have high behavioural loyalty. Finally, the partial mediating role of consumer participation, social peer influence and behavioural loyalty has been identified. An important share of social peer influence in increasing behavioural loyalty is the involvement of the consumer in the design process.

CONCLUSIONS

There are some limitations in every study like this research. Firstly, this research sample consists of only Turkish consumers. A comparative study would be desirable among other countries. Secondly, the model consists of 5 variables. Different and more variables can be used in further research. The sample of this research consists of 399 consumers. More different results can be obtained with a larger sample. Another constraint of the study is that consumer participation is not a very popular strategy in the country where the sample lives. Consumers participating in the research know the concept of consumer engagement through examples from around the world. However, there is no consumer participation strategy made by companies in our country. For this reason, while it was determined that consumers will participate in the design process of the product and show ethical and behavioural loyalty, no effect on brand love was observed. The rejection of H3 can be explained by the fact that it is not a product in which consumers actively participate in its design or manufacture. In the future, as consumer participation strategies are implemented, it is anticipated that hypotheses established with brand love will be accepted.

This research makes some sectoral recommendations. In the globalizing and digitalizing world, practices regarding “consumer engagement”, which can be regarded as the last step of consumer communication, should be made widespread. It is estimated that the brand of the product designed by consumers will be voluntary brand ambassadors. For companies that want to ensure continuity in loyalty; a fully inclusive attitude to the consumer is recommended. Consumer participation is especially important in terms of production, design, website infrastructure and social media content.

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Experimental and numerical study on rapid inflation process of air-launched balloon

DOI: 10.35530/IT.073.03.202132

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ABSTRACT – REZUMAT

Experimental and numerical study on rapid inflation process of air-launched balloon

The rapid inflation process is the most important stage in the whole working process of rapid deployment of aerostat. However, it is difficult to reveal its mechanical mechanism by existing experimental and numerical methods and reasonably explain the damage and helium leakage during the inflation process. An air-launched balloon for rapid deployment was designed and manufactured, and the related ground steady inflation experiment was carried out in this work. Then, the rapid inflation process of the folded balloon was studied by using the Simplified Arbitrary Lagrangian-Eulerian (SALE) method. Here, the folded balloon model was obtained by the reverse folding method. The structure and flow field were described by Lagrangian elements, and the coupling between them was obtained by a contact algorithm. The numerical results were in good agreement with the experimental results. The numerical method in this work could obtain abundant information on the structure and flow field which couldn't be obtained by the experimental method. The change law of structure and flow field was obtained and the failure mechanism in the destructive experiment was explained. The numerical method proposed in this work could provide a reference for the material selection, gas source selection and structure optimization of the rapid deployment aerostat system.

Keywords: *air-launched balloon, high strength fabric, inflation process, numerical method, rapid deployment*

Studiu experimental și numeric asupra procesului de umflare rapidă a balonului lansat cu aer

Procesul de umflare rapidă este cea mai importantă etapă a întregului proces de desfășurare rapidă a aerostatului. Cu toate acestea, este dificil să se analizeze componenta sa mecanică prin metodele experimentale și numerice existente și să se explice în mod rezonabil daunele și scurgerile de heliu în timpul procesului de umflare. A fost proiectat și fabricat un balon lansat cu aer pentru desfășurare rapidă, iar experimentul aferent de umflare constantă la sol a fost prezentat în această lucrare. Apoi, procesul de umflare rapidă a balonului pliat a fost studiat folosind metoda Euler-Lagrange Arbitrară Simplificată (SALE). Aici, modelul balonului pliat a fost obținut prin metoda de pliere inversă. Structura și câmpul de curgere au fost descrise de elemente lagrangiene, iar cuplarea dintre ele a fost obținută printr-un algoritm de contact. Rezultatele numerice au fost în corelație cu rezultatele experimentale. Metoda numerică din această lucrare ar putea oferi informații multiple asupra structurii și câmpului de curgere, care nu au putut fi obținute prin metoda experimentală. S-a obținut legea de schimbare a structurii și a câmpului de curgere și a fost explicat mecanismul de defecțiune în experimentul distructiv. Metoda numerică propusă în această lucrare ar putea oferi o referință pentru selecția materialului, selecția sursei de gaz și optimizarea structurii sistemului aerostat cu desfășurare rapidă.

Cuvinte-cheie*: balon lansat cu aer, țesătură de înaltă rezistență, proces de umflare, metodă numerică, desfășurare rapidă*

INTRODUCTION

The traditional aerostats have many limitations, high risk in the launching process and long deployment time [1]. In some applications, especially in outer space exploration and military applications, traditional aerostats are not suitable. Therefore, the concept of rapid deployment aerostat was proposed. The rapid deployment aerostat system is first transported to the launch area by vehicles (aircraft, rocket, etc.). After the rapid deployment aerostat is launched, the parachute is used to decelerate. Then the folded aerostat is pulled out and inflated rapidly. Finally, the inflated aerostat separated from the parachute system. The rapid deployment aerostat was originally used for Venus's suspension detection in the 1960s [2]. Subsequently, the Air Force Geophysics Laboratory (AFGL) started the development of the Air-Launched Balloon System (ALBS). The related research works mainly relied on a large number of ground tests and airdrop tests by different vehicles [3, 4] because the numerical simulation technology was not mature at that time. But the follow-up research progress has not been reported. With the increasing frequency of human activities to explore outer space, the rapid deployment of aerostats has once again attracted the attention of scholars, and the relevant research was restated gradually in the past decade [1].

Compared with the traditional aerostat, the most complicated stage of rapid deployment aerostat is the

rapid inflation in dropping. Due to the rarefied atmosphere at high altitude or in outer space, the parachute's deceleration effect is limited. The aerostat must be inflated rapidly to produce buoyancy. However, the nozzle velocity at the critical outgassing stage of the high-pressure helium gas source is about three times the air sound velocity. The huge impact velocity will make the aerostat deform and displace rapidly, and the displacement of the skin will change the direction of the gas source. While, this change will further aggravate the uncertainty of the internal flow field, and easily causes skin damage. Given the above-complicated engineering and science problems, the experiments are undoubtedly the most direct solution. However, the existing experiments only study the tearing performance of skin material [5], and it is difficult to obtain the internal flow field and the stress change of skin.

With the development of computer hardware and the maturity of numerical technology, numerical methods have gradually become an important research method. The representative works are as follows. Bessert proposed a fluid-structure coupling method based on potential flow theory to solve the static aeroelastic problem of airship [6]. Liu used the loose coupling method to realize the static aeroelastic analysis of airship respectively [7]. Zhang constructed an unsteady explicit dynamic fluid-structure coupling analysis framework and used this framework to study the relationship between vibration frequency and pressure difference of airship [8]. The above works focused on the static aeroelasticity, but few on the inflation process. Although the research objects were different, scholars also have proposed a variety of numerical models to study the inflation process of other inflatable fabrics. Stein proposed Computational Fluid Dynamics/ Mass Spring Damper (CFD/MSD) model [9]. The fabric was described by a series of mass points connected by spring and damper, so the stress change couldn't be calculated in this model. Tezduyar proposed the model of Deforming Spatial Domain/Stabilized Space-Time (DSD/SST) [10]. This method has high calculation accuracy based on body-fitted grid technology, but it is not suitable for inflation study of complicated folded fabrics. The Immersed Boundary Method (IBM) proposed by Peskin could be used in 2D and 3D fabric inflation process [11], but it is limited to a certain Reynolds number range. In addition, there are Ghost Fluid Method (GFM), Smoothed Particle Hydrodynamics/ Finite Element (SPH/FE), Arbitrary Lagrangian-Eulerian (ALE), Embedded Boundary Method (EBM) and other methods have also been used in fabrics inflation calculation [12–15]. However, most of these methods are used for a single infinite gas source (such as a fixed external wind field), and the effect of buoyance is not considered. So far, the works about rapid inflation of complicated folded rapid deployment aerostat are few.

To solve the above problems, an air-launched balloon used for rapid deployment was taken as the research object in this work. The SALE (Simplified Arbitrary Lagrangian-Eulerian) method based on multi-material fluid was used to calculate the rapid inflation process, and the corresponding ground inflation experiment was used to verify this numerical model. The change law of structure and flow field was analyzed. The method used in this work could provide references for the subsequent design and optimization of the rapid deployment aerostat.

MATHEMATICAL MODEL

There are a lot of irregular folds on the folded aerostat, so it is difficult to establish the body grid of the flow field. Here, the finite elements are used to describe the balloon and flow field. The biggest advantage of Lagrangian description is that it could accurately track the material boundary, which naturally satisfies the mass conservation. In addition, due to the short inflation time and the impermeability of the skin, the heat transfer between different materials was not considered in this work. Therefore, only the momentum equation needed to be considered:

$$\int_\Omega B_{lj}\,\sigma_{ji}\,\mathrm{d}\Omega - \int_\Omega N_l\,\rho\,b_i\,\mathrm{d}\Omega - \int_{\Gamma_{t_i}} N_l\,\bar{t}_i\,\mathrm{d}\Gamma + \\ + \delta_{ij}\int_\Omega N_l\,N_J\,\rho\,\mathrm{d}\Omega\,\nu_{Ji} = 0 \qquad (1)$$

where B_{lj} is geometric matrix component, σ_{ji} – Cauchy stress component, N_l – shape function, ρ – density, b_i – body force component, $\bar{t}$ – surface force component, ν_{Ji} – velocity component, δ_{ij} – Kronecker symbol, Ω – current configuration, Γ – current configuration boundary.

The central difference scheme was used for time discretization:

$$\boldsymbol{\nu}^{n+\frac{1}{2}} = \boldsymbol{\nu}^{n-\frac{1}{2}} + \Delta t^n \boldsymbol{M}^{-1}\left(\boldsymbol{f}^{\mathrm{ext}}(\boldsymbol{d}^n,t^n) - \boldsymbol{f}^{\mathrm{int}}(\boldsymbol{d}^n,t^n)\right) = \\ = \boldsymbol{\nu}^{n+\frac{1}{2}} + \Delta t^n \boldsymbol{M}^{-1}\boldsymbol{f}^n \qquad (2)$$

where $\boldsymbol{M}$ is mass matrix, $\boldsymbol{d}$ – node displacement and t – time.

The folded balloon model was established by reverse folding method [16] in this work, the quadrilateral or triangular high order elements would cause the initial distortion before inflation calculation. Therefore, the simplest 3-node element was used to discretize the structure. In addition, the structure presents small strain and large displacement in the inflation process. The Kirchhoff constitutive model (equation 3) was adopted in this work. Then the second Piola Kirchhoff (PK2) stress $\boldsymbol{S}$ was converted into Cauchy stress $\boldsymbol{\sigma}$ by equation 4 and used for explicit calculation:

$$\begin{Bmatrix} S_{11} \\ S_{22} \\ S_{12} \end{Bmatrix} = \frac{E}{(1+\upsilon)(1-2\upsilon)} \begin{bmatrix} 1-\upsilon & \upsilon & 0 \\ \upsilon & 1-\upsilon & 0 \\ 0 & 0 & \frac{1-2\upsilon}{2} \end{bmatrix} \begin{Bmatrix} E_{11} \\ E_{22} \\ E_{12} \end{Bmatrix} \qquad (3)$$

$$\boldsymbol{\sigma} = J^{-1}\boldsymbol{F}\cdot\boldsymbol{S}\cdot\boldsymbol{F}^{\mathrm{T}} \qquad (4)$$

where S_{ij} is PK2 stress component, E_{ij} – Green strain component, E – elastic modulus, υ – Poisson's ratio, J – Jacobian determinant and $\boldsymbol{F}$ – deformation gradient matrix.

However, the flow field based on the finite element description doesn't need the transformation between PK2 stress and Cauchy stress, and its constitutive equation and state equation are as follows:

$$\sigma_{ij} = \mu(v_{i,j} + v_{j,i}) - p\delta_{ij} \quad (5)$$

$$p = (1 - \gamma)\rho\omega^{int} \quad (6)$$

where μ is dynamic viscosity coefficient, p – pressure, γ – specific heat of gas and ω^{int} – internal energy per unit mass.

Both the structure and flow field were discretized by the finite element method in this work, and the fluid structure coupling could be understood as the contact between the two materials. Therefore, the transmission of coupling information could be realized by contact algorithm [14].

The disadvantage of flow field based on Lagrangian description is also obvious. The fluid constitutive model is different from the structure and the shear force will cause element distortion, which makes it impossible to continue the calculation. Therefore, it is necessary to re-construct the distorted grids and update the flow field in-formation (figure 1).

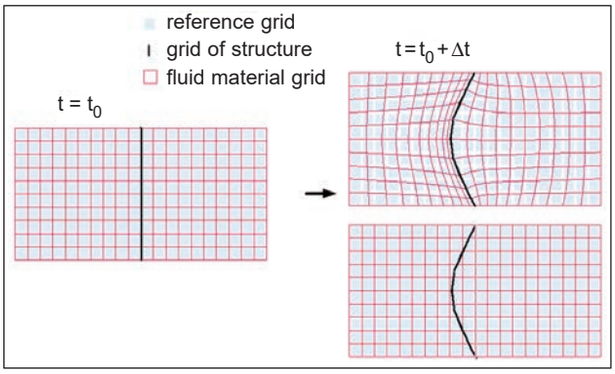

Fig. 1. Flow field reconstruction and information updating

The 4-node hexahedral grid is used to discretize the flow field (reference grid). At $t = t_0$, the fluid material grid based on Lagrangian description is consistent with the reference grid. Under the action of external force, the fluid material grid appears distortion. Then, the grid reconstruction is realized by solving Laplace differential equation.

The topological relationship between the fluid material grid and reference grid remains unchanged after grid reconstruction. The flux ϕ (mass, momentum and the other flow information) in the flow field is updated by solving equation 7:

$$\frac{\partial \phi}{\partial t} + \frac{\partial v_i \phi}{\partial x_i} \quad (7)$$

where v_i is convective velocity in flow field. The discretization scheme of convection term is as follow.

$$\phi^{n+1}V^{n+1} = \phi^n V^n + \sum_{j=1}^{6} f_j^{\phi} \quad (8)$$

Where V is volume of element and f_j^{ϕ} – flux form adjacent element. And the flux f_j^{ϕ} is obtained by MUSCL (Monotone Upwind Schemes for Conservation Laws) Scheme [17].

CASE STUDY

The air-launched balloon used for rapid deployment was taken as the research object in this work. The diameter of this balloon is 1.425 m (figure 2). In order to prevent the balloon's damage during pulling out, a central reinforcing rope (1.425 m) connected the top and bottom of the balloon is added. The outer skin has no reinforcement layer to achieve lightweight of system, so the rapid inflation might cause skin damage. Therefore, an internal airbag around the charging valve is added and 10 gas outlets with a diameter of 0.02 m are evenly distributed on the internal airbag. Here, the internal airbag is made of polyethylene composite with high strength fabric. The material parameters are shown in table 1.

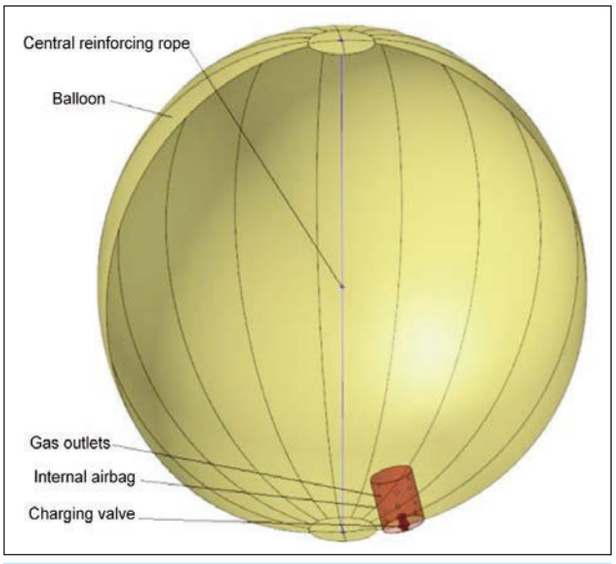

Fig. 2. Structure diagram of air-launched balloon

Table 1

MATERIAL PARAMETERS OF AIR-LAUNCHED BALLOON

Parameter	Outer skin (Type ZT1076)	Internal airbag (Type 3216LV)
Elastic modulus (Pa)	4.4E8	9.8E9
Density (kg/m^2)	0.05	0.205
Thickness (m)	2E-4	2.2E-4
Poisson's ratio	0.3	0.35

In order to simulate the rapid inflation process during airdropping, the flexible constraints are adopted at the top and bottom of the balloon. Helium is charged into the balloon through the inflating tube. After the internal airbag is inflated rapidly, helium inflates into the balloon through the 10 gas outlets on the internal airbag (figure 2). The whole experiment was carried out at standard atmospheric pressure environment (figure 3), and the folded balloon was inflated with 0.1

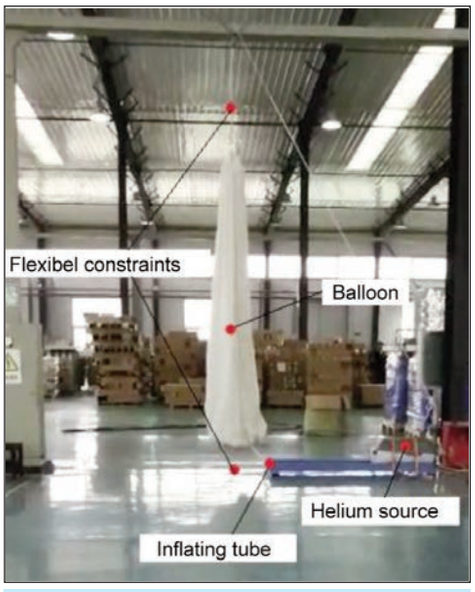

Fig. 3. Ground steady inflation experiment

kg/s steady flow for 20 seconds. The average temperature in the balloon was –30°.

It is very difficult to establish the folded balloon model as shown in figure 3 by using the traditional modeling method. Therefore, the reverse folding method [16] was used to obtain the final folded balloon model in this work. Here, the balloon is discretized by 3-node triangular elements (48,266), and the top and bottom of the balloon are fixed to replace the function of the central reinforcing rope. The area of charging valve's outlet and gas outlets on the internal airbag are very small. If these outlets are discretized by elements, the local element size and critical time step Δt_{crit} ($\Delta t_{crit} \leq \min\left(l_e / c_e\right)$, l_e is element's characteristic length, c_e – current wave velocity) will be too small and the amount of calculation will increase sharply in the explicit calculation. In order to solve this problem, the mass point is used to replace the whole charging valve and the point gas sources are used to replace the 10 gas outlets on the internal airbag. The hexahedral elements (308,705) are used to discretize the whole flow field, and the whole flow field is a cylinder with a height of 5.5 m and a diameter of 4.6 m. In order to simulate the buoyancy background, the flow field is divided into two parts. The outermost elements are flow field 1, and the rest are flow field 2. The upper surface hydrostatic pressure p_0 of the top elements of flow field 1 is defended as 1 atm, and that of the other elements of flow field 1 is defined as p_i ($p_i = p_0 + \rho_{air} \cdot g \cdot h_i$, h_i is the depth of the current element *i*, *g* is the acceleration of gravity). Finally, the elements of the balloon and flow field are assembled by interpenetration, and the complete fluid-structure coupling model is shown in figure 4.

The strength of the internal airbag is much greater than that of the outer skin (table 1). The previous strength experiments also proved that its strength was enough to meet the requirement. In addition, the

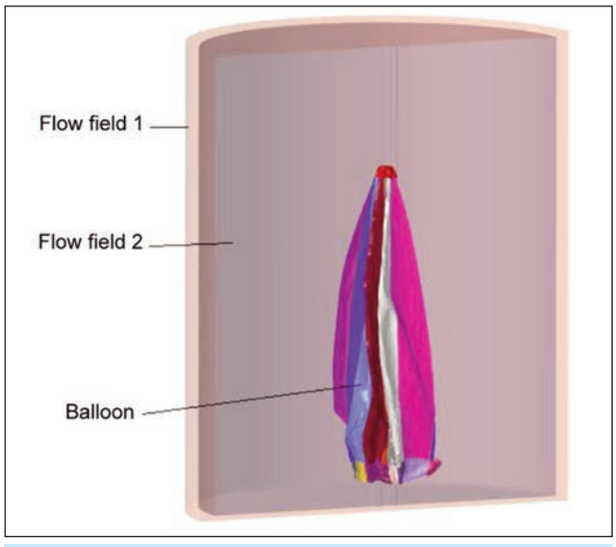

Fig. 4. Complete fluid structure coupling model

internal airbag was filled in a very short time and the main research focus of this work was rapid inflation process and the dynamic change of outer skin in this work. Therefore, the internal airbag didn't participate in the fluid structure coupling calculation, but only in the contact calculation with other structural parts. Here, an additional pressure with 1000 Pa was applied on the internal airbag to ensure the rapid expansion of the internal airbag and maintain the filled shape during inflation calculation. The point gas sources were defined on the nodes according to the design. While the charging valve (additional mass point) and the gas outlets (point gas sources) were used to define a vector to control the charging direction in this work (figure 5).

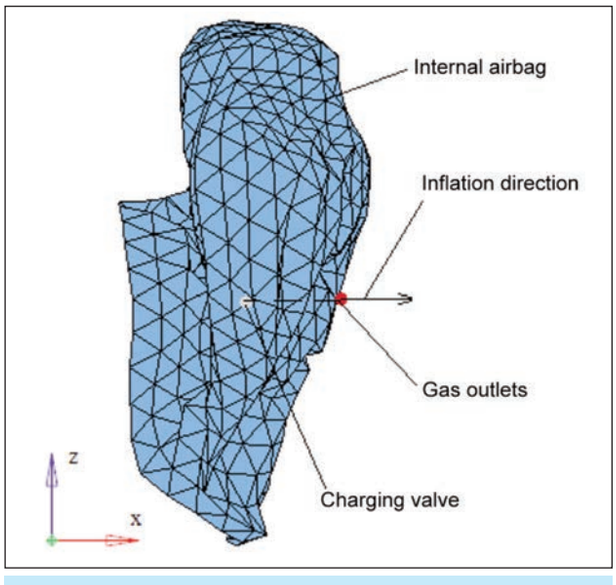

Fig. 5. Definition of inflation direction of gas outlets

RESULTS AND DISCUSSIONS

Figure 6 shows the shape change comparison of numerical results and experimental results. It could

be found that the two results are in good agreement. The whole rapid inflation process could be divided into three stages.

Initial inflation stage (0-2s): The shape change of balloon in this stage is the most violent during the whole inflation process. The bottom expands rapidly after helium is released from the point gas sources. Then helium flows to the balloon's top rapidly under the action of buoyancy. Because the internal airbag is on one side of the balloon, the shape change presents asymmetrical.

Middle inflation stage (2-6s): A large amount of helium gathers at the balloon's top, and the folds at the top part begin to expand gradually. The buoyancy overcomes the gravity of the balloon. The balloon begins to float and its shape gradually becomes symmetrical.

Final inflation stage (6-20s): After the top part is fully expanded, the balloon changes more stable. In this stage, the balloon is gradually filled from top to bottom. Finally, it forms the inflated shape shown in figure 6, *f*.

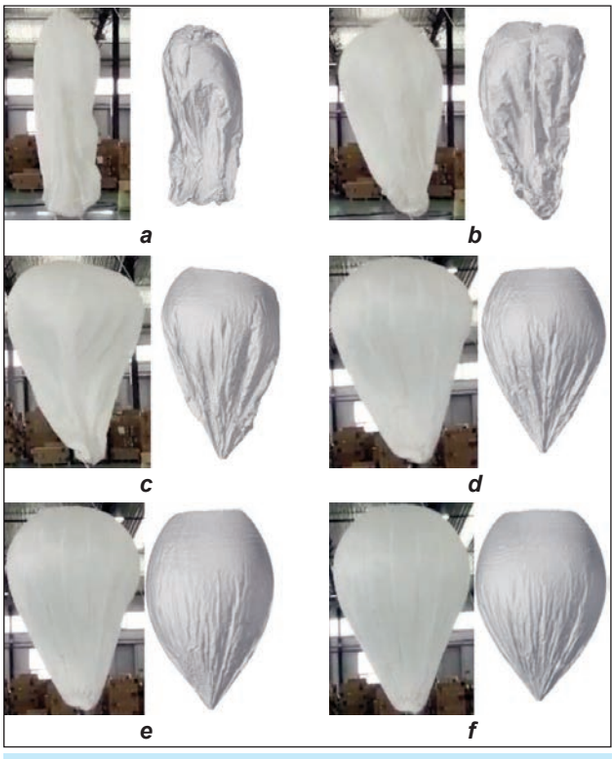

Fig. 6. Shape change comparison of numerical results and experimental results: *a* – *t* = 1 s; *b* – *t* = 2 s; *c* – *t* = 6 s; *d* – *t* = 10 s; *e* – *t* = 15 s; *f* – *t* = 20 s

Figure 7 shows the comparison of the maximum projected diameter. It also could be found that the change of shape is more violent in the initial and middle inflation stage and more stable in the final inflation stage. While the difference between the numerical and the experimental results are mainly caused by two aspects. On the one hand, there are some differences between the numerical model and the actual initial shape before inflation. On the other hand, the fixed constraints are used at the top and bottom, while the flexible constraints are used in experiment.

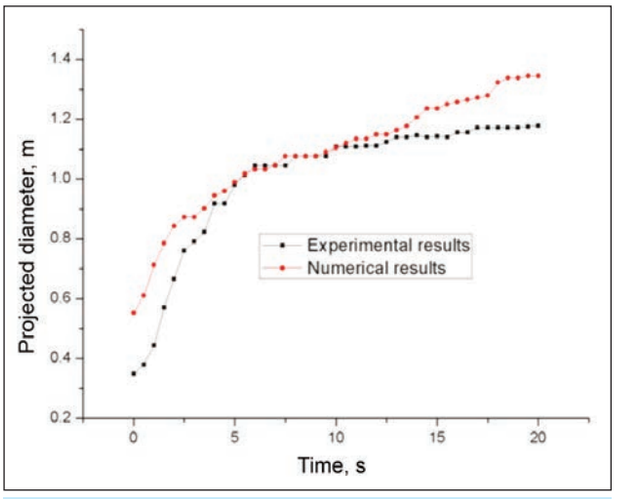

Fig. 7. Comparison of the maximum projected diameter

Figures 8 and 9 show the velocity vector and pressure contour of flow field during inflation.

Initial inflation stage (0-2s): Due to the asymmetric design of the internal airbag, the balloon partially expanded on one side (figure 8, *a*). The velocity of helium at the outlets is faster, while the density of helium is smaller than that of air. Therefore, there is no obvious high-pressure zone (figure 9, *a* and *c*), which has little effect on the outer skin far away from the internal airbag. Because the outer skin has not yet formed an effective constraint on the internal airbag, the point gas sources move with the displacement of the internal airbag. Furthermore, the displacement of the point gas sources aggravates the complexity of the flow field. The asymmetric flow field is obvious, and the balloon shows asymmetric expansion (figure 8, *b* and *c*).

Middle inflation stage (2-6s): The helium gathered at the top begins to flow to other unexpanded parts, and the balloon's top is further fully expanded. At the same time, the change of bottom is obviously affected by buoyancy. The bottom skin in the warp direction is almost completely expanded, while folds still exist in the weft direction (figure 8, *d* and *e*). Different

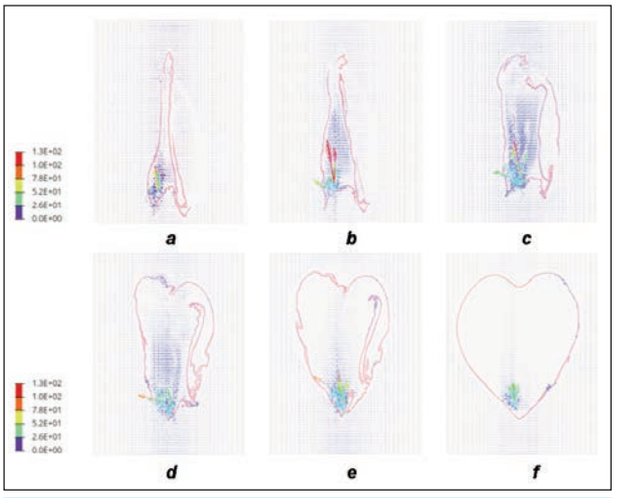

Fig. 8. Velocity vector of flow field: *a* – *t* = 0.1 s; *b* – *t* = 0.5 s; *c* – *t* = 1 s; *d* – *t* = 2 s; *e* – *t* = 6 s; *f* – *t* = 20 s

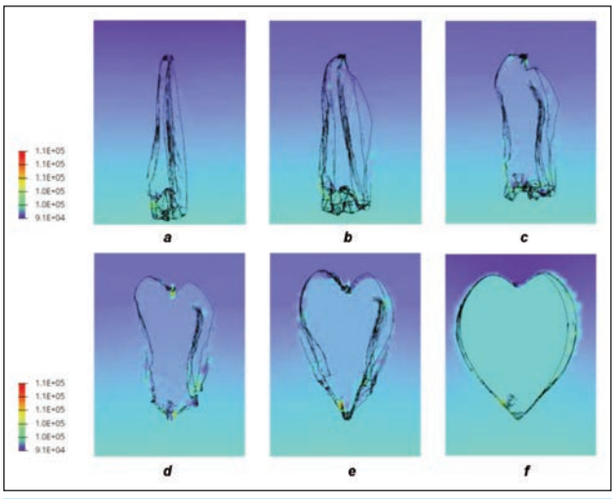

Fig. 9. Pressure contour of flow field: *a* – *t* = 0.1 s; *b* – *t* = 0.5 s; *c* – *t* = 1 s; *d* – *t* = 2 s; *e* – *t* = 6 s; *f* – *t* = 20 s

from the initial inflation stage, the internal flow field in this stage is greatly affected by the constraints and folds. The internal flow field forms a high-pressure zone at the top and bottom (figure 9, *d*). The high-pressure zone at the top disappears with the expansion of the balloon (figure 9, *e*), while the bottom high-pressure zone constrained by the skin doesn't disappear.

Final inflation stage (6-20s): As the shape of the balloon gradually becomes symmetrical, the internal flow field changes more gently (figure 8, *f*). The stable position of the internal airbag also results in the formation of a stable high-pressure zone near the point gas sources (figure 9, *f*).

Figure 10 shows the effective stress contour. It can be found that the folds zones usually are stress concentration zones. The stress concentration disappears with the expansion of these folds. At the same time, the stress at the top and bottom of the balloon increases gradually with the increasing of buoyancy. Especially, the balloon's bottom affected by all the buoyancy generated by helium, and the stress concentration zone is the most obvious.

Figure 11 shows effective stress variety at different positions of the outer skin where the internal airbag is located. The impact of helium on the skin near the point gas sources (Element 57067) causes a sharp increase in stress. With the expansion of the balloon, the stress concentration decreases rapidly. However, the stress increases gradually with the increase of buoyancy. The stress at the top (Element 19783 and Element 17903) increases with the expansion of folds, and decrease after these folds fully expanded. Although the skin at the middle and lower parts (Element 19007 and Element 57656) expands first than that at the top, the skin at these parts slowly expands with the inflation of the balloon. Therefore, the stress of these parts changes gently.

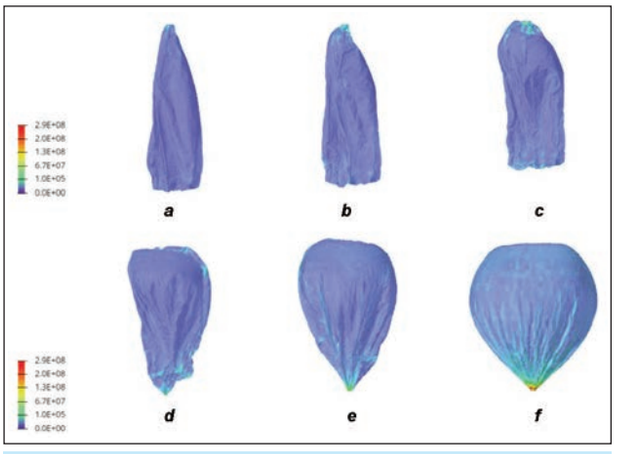

Fig. 10. Effective stress contour of flow field: *a* – *t* = 0.1 s; *b* – *t* = 0.5 s; *c* – *t* = 1 s; *d* – *t* = 2 s; *e* – *t* = 6 s; *f* – *t* = 20 s

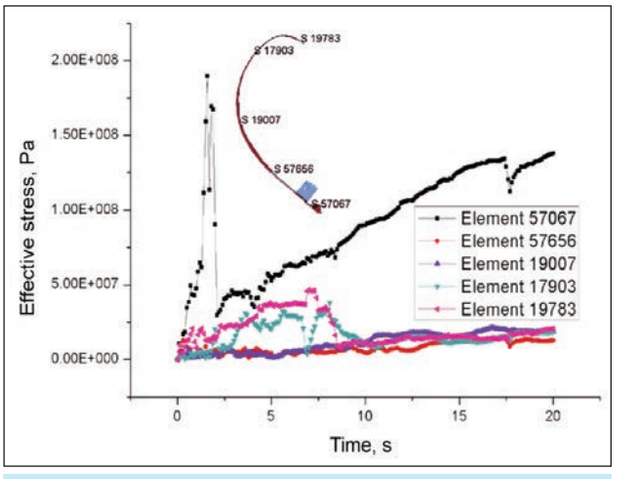

Fig. 11. Effective stress variety at different positions

CONCLUSIONS

In order to study the mechanical mechanism of the core working process of rapid deployment aerostat, an air-launched balloon for rapid deployment was taken as the research object and the ground rapid inflation experiment and corresponding calculation were carried out. The rapid inflation process was calculated based on SALE method. The numerical results were in good agreement with the experimental results, which proved the feasibility and accuracy of the numerical method used in this work. The structure and flow field information of each stage which was difficult to obtain by experiments was obtained. The variation characteristics of the structure and flow field in each stage of the inflation process were summarized according the analysis of numerical results. The helium leakage phenomenon in the destructive inflation experiment was explained by stress analysis. The method proposed in this work can provide a reference for the design and optimization of rapid deployment aerostat in future.

ACKNOLEDGEMENTS

This work was supported by Natural Science Foundation of Sichuan Province of China No. 2022NSFSC0478 and Characteristic Discipline Construction Project No. D202105.

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Customized clothes – a sustainable solution for textile waste generated by the clothing industry

DOI: 10.35530/IT.073.03.202112

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ABSTRACT – REZUMAT

Customized clothes – a sustainable solution for textile waste generated by the clothing industry

The textile industry plays an important role in Romania's economy and its products are a necessity in people's lives, not only in the form of apparel but also in the automotive industry, construction, computers, agriculture etc., due to the expansion of their fields of use. Numerous studies have shown that this industry is, after oil, the second most polluting industry in the world. In addition to the multitude of chemicals used in the production process and a large amount of water and energy consumed, the textile industry generates considerable waste. This paper aims to identify the main sources of textile waste in Romania and it proposes the alternative of customized clothes using textile waste in order to rethink, reuse or recycle waste in the production stage. This strategy can be successfully integrated into the vertical value chain by strengthening the creation department, and clothing design and by involving the marketing and sales divisions. In the clothing industry, the strategy of integrating design and retail can lead to a more flexible design process and therefore to high product performance.

Keywords: *linear economy, circular economy, environment, textile, waste*

Îmbrăcăminte personalizată – o soluție durabilă pentru deșeurile textile generate de industria de îmbrăcăminte

Industria textilă joacă un rol important în economia României, iar produsele sale sunt o necesitate în viața oamenilor, nu doar sub formă de îmbrăcăminte, ci și în industria auto, construcții, calculatoare, agricultură etc., datorită extinderii domeniilor lor de utilizare. Numeroase studii au arătat că această industrie este, după petrol, a doua cea mai poluantă industrie din lume. Pe lângă multitudinea de substanțe chimice utilizate în procesul de producție și o mare cantitate de apă și energie consumată, industria textilă generează deșeuri considerabile. Această lucrare își propune să identifice principalele surse de deșeuri textile din România și propune alternativa de îmbrăcăminte personalizată folosind deșeuri textile pentru a regândi, reutiliza sau recicla deșeurile în etapa de producție. Această strategie poate fi integrată cu succes în lanțul valoric vertical prin consolidarea departamentului de creație și design vestimentar și prin implicarea diviziilor de marketing și vânzări. În industria de îmbrăcăminte, strategia de integrare a designului și retailului poate duce la un proces de proiectare mai flexibil și, prin urmare, la o performanță ridicată a produsului.

Cuvinte-cheie: *economie liniară, economie circulară, mediu, textile, deșeuri*

INTRODUCTION

As it is known, textiles are a necessity in people's lives, both for the realization of clothing products and due to the expansion of their fields of use – automotive industry, construction, computers, agriculture, etc. With the increase in textile consumption, the problems related to the scarcity of raw materials and environmental damage increase too. During the entire cycle of making textile products, they generate multiple sources of pollution in the air, water and soil. At the same time, considerable volumes of waste are created that can mainly be classified into three groups: production waste, preconsumer waste, and post-consumer waste.

Production waste is composed of fibre, yarn, cloth scraps, flock, sweeping, fabric cut-offs, fabric roll ends and selvedge generated by fibre producers, weavers, knitting companies and apparel manufacturers. Preconsumer waste consists of products that are manufactured with design mistakes, fabric faults, or the wrong colours being produced for sale and consumption and postconsumer waste consists of any types of household articles or garments made from fabricated textiles that the owner does not require any more and has decided to discard. Consumers may discard these articles when they are worn out, damaged, outgrown, or out of fashion.

At present, a part of the textile waste resulting from the production processes is used for the production of vigour yarns, non-woven textiles, upholstery wool for furniture and cars, insulating materials, geotextiles, the creation of collections of clothing products made entirely or partially out of different kind of textile waste etc. This led to a significant decrease in waste from the Romanian manufacturing industry of textiles, wearing apparel, leather and related product: from 33,309 tons in 2004 to 10,394 tons in 2012.

Since 2012 this waste began to grow continuously, reaching 25,791 tons in 2018 (figure 1) [1].

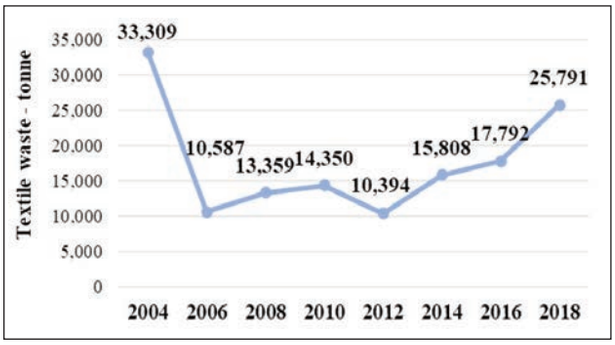

Fig. 1. The evolution of the quantity of textile waste generated by the Romanian industry of manufacture of textiles, wearing apparel, leather and related products

Analysing the sources of origin of textile waste in Romania, it is noticeable that they come mostly, 62.68%, from the industry of textile manufacturing, wearing apparel, leather and related products to which is added textile waste generated by other industries and households in different proportions (figure 2). The small amount of waste generated by households in Romania is due to the fact that there are very few people who throw textile waste in the trash, most of them give it to friends or relatives or donate it to charities [2].

BACKGROUND AND CONTEXT FOR THE STUDY

Linear economy versus circular economy

Much of the literature that analyses the issue of waste generated by industry highlights the advantages of moving from the linear production model to the circular one. The linear production model consists of extracting materials from resource-rich countries and then manufacturing products using those virgin resources [3]. The four stages of a usual product life cycle are extraction and processing of raw materials, manufacture, use and end of life. Stahel says that a linear economy flows like a river, turning natural resources into base materials and products for sale, through a series of value-adding steps. At the selling point, the customer is liable for risks and waste. They decide whether old things will be reused, recycled or dumped [4].

Because of this linear production model, resources are lost unnecessarily in different ways: waste in the production chain, end-of-life waste, use of excessive energy and erosion of ecosystems [5]. Materials that reach the end of their lives are considered waste and they are either sent to landfills or incinerated. This kind of economy has a major impact on the environment, namely – land-use change, climate change, resource scarcity, biodiversity loss, loss of biosphere integrity, an overload of nitrogen and phosphorus in biogeochemical cycles and increasing levels of pollution.

Even the elimination of these materials results in hazardous waste. When compared to pre-industrial levels (1850–1900), without modifying the usual business approach, it is predicted that the average temperature of the global surface will suffer an increase, from 3.7°C to 4.8°C in 2100 [6]. The upper limit of change in temperature is estimated to be roughly 2°C; exceeding this limit will most probably affect ecological systems, human health, and societies [7]. MacArthur shows that even at the microeconomic level it was found that the linear economic system increases its exposure to risks, most notably through volatility in resource prices and vulnerability to supply restrictions [8].

In these conditions, the transition to a circular economy is considered a viable solution that will have the main effect of reducing our global sustainability pressures. Geissdoerfer et al. define the Circular Economy is a “regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops”. They also consider that this can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling” [9].

The circular economy emerges as a potential strategy for the development of business practices based on environmental concerns [10]. A study of seven European nations shows that a shift to a circular economy would reduce each nation's greenhouse-gas

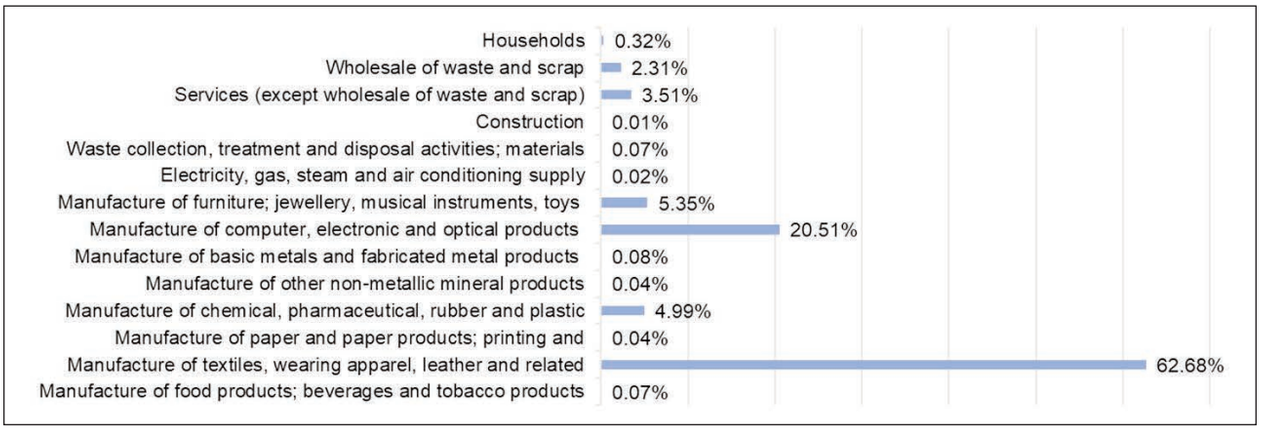

Fig. 2. The sources of textile waste in Romania, in 2018

emissions by up to 70% and grow its workforce by about 4% – the ultimate low-carbon economy [4].
Today, most authors agree that the circular economy refers to an industrial economy that is restorative and regenerative by intention and design [8]. Stahel compares a circular economy with a lake and highlights that the reprocessing of goods and materials generates jobs and saves energy while reducing resource consumption and waste [4]. In Sariatli's opinion, the strong points of the circular economy are considered to be: efficiency in the material flow cycle given by eliminating of waste from the value chain, development of higher quality and more durable products through incorporating the attributes of CE in the R&D phase, growth of the less exposed economy to price fluctuations of the materials, and better use of resources [11].
In a circular economy, not only the aspects of sustainability are essential for shaping the performance of companies, but also the relationships among these and other social and economic agents [12].
According to the European Commission (EC), the EU's competitiveness could be stimulated by the circular economy. This type of economy promotes businesses' protection against deficiency of resources and volatile prices, contributing to the creation of new business opportunities and innovative, more efficient ways of producing and consuming. Also, it will save energy, create local jobs for all skill levels and opportunities for cohesion and social integration and help avoid the irreversible damage caused by using up resources at a rate that exceeds the Earth's capacity to renew them [13].

The place and role of the textile industry in the Romanian economy

The textile industry plays an important role in the Romanian economy, both in terms of the significant number of people working in this field and in terms of the value of production and exports.
In the textile and clothing industry, there are currently employed about 3.8% of the total number of employees in Romania, namely 161,060 people, in 6,680 companies. Most people work in wearing apparel manufacturing – 128,366 people and 32,694 people in textile manufacturing. The low wage level, the structure of the production flow and especially the increasing pressure of other sectors in a deficit of labour are just some of the reasons why it is extremely difficult to stabilize the labour force in these sectors. Clothing production offers the lowest salaries in the manufacturing industry, with the average net salary in December 2018 being 1,698 lei, this representing 57.42% of the average net salary in the Romanian economy, in the same period. In the textile industry, the salary was 2,280 lei [1].
The value of production achieved in 2018 was 2197.7 million euros in the manufacture of wearing apparel and 1488.5 million euros in the manufacture of textiles – continuing the upward trend recorded in recent years (EUROSTAT – database). The main products made in Romania in 2018 are cotton yarns and cotton type – 16,756 tons, wool yarns and wool type – 28,057 tons, fabrics – 91,458 thousand sqm, non-woven textiles – 31,691 thousand sqm, knitwear – 14,222 thousand pieces, garments textile materials – 9,741,907 thousand lei [14].
Romania exports in 2019 clothing products totalling 2,703 million $ and textile products totalling 1,507 million $. As it can be seen from figure 3, garment exports decreased much compared to 2006, when they occupied the second position in the top of garment exports products of the manufacturing industry. They represented 17.39% of the products of the manufacturing industry. In 2019, these exports represented only 4.30% of the exports of the manufacturing industry. Regarding Romania's exports of textile products, they register an ascending trend, doubling compared to how they were in 2006 and reaching 1,508 million $ in 2019 (figure 4) [15].

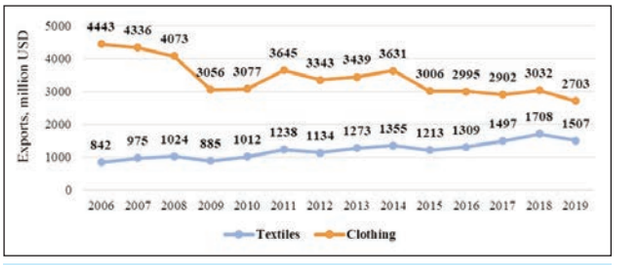

Fig. 3. The evolution of Romanian exports (textile, clothing), 2006–2019

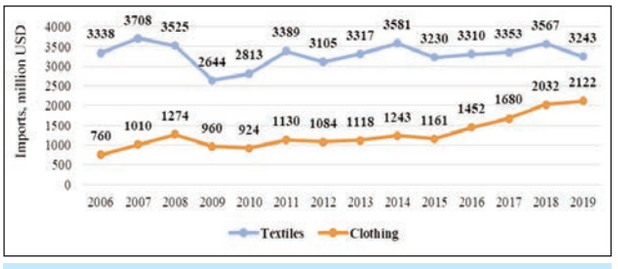

Fig. 4. The evolution of Romanian imports (textile, clothing), 2006–2019

Imports of textile products vary slightly around 3,300 million $, more precisely in 2019 they were 3,243 million $ – the trade balance remains negative this year as well. Imports of clothing products have increased significantly in recent years, reaching 2,122 million $ in 2019 [15].

EQUATIONS CUSTOMIZED CLOTHES USING TEXTILE WASTE – SUSTAINABLE SOLUTIONS FOR THE TEXTILE INDUSTRY

At present, the predominant production model in the Romanian garment industry is the linear one. Due to the multiple advantages of the circular economy, we consider that it is particularly important to make the transition to this type of production in all economic sectors and especially in the textile industry. Many authors consider that the transition from the linear to the circular economy is much more difficult in the fashion industry [16–18]. This is due to current business

models such as fast fashion and large-scale production [19]. Another reason is the increase in consumption due to falling prices and the diminishing quality of clothing [20]. This overconsumption is stimulated by design through fast fashion, resulting in short-term use of clothing products, psychological obsolescence and premature disposal [21].

Despite all these difficulties, there are many companies that have understood the importance of the transition of this industry to a circular system and have taken various measures in this regard. Cristina Osterman et al. presents 10 business models from the fashion industry that through different resource use strategies have managed to reduce materials use and consumption or closed-loop. The value creation processes of the all cases presented involve recycling of products, materials, and waste; upcycling; material design; supplier and customer connection; product-based access to services and results; access to product functionality; and meeting excessive capacities with insufficient capacities [16].

Another example is a group of 90 companies (including large companies) representing 12.5% of the global fashion market that in 2018 signed a commitment called “2020 Circular Fashion System commitment”. Through this commitment, they aim to achieve at least one of the lines of action in order to accelerate the transition of the fashion industry to a circular fashion system. The 4 lines of action included in the commitment are: implementing design strategies for cyclability, increasing the volume of used garments and footwear collected, increasing the volume of used garments and footwear resold and increasing the share of garments and footwear made from recycled post-consumer textile fibres [22].

Fischer and Pascucci analyse how requirements for transitioning to a circular economy create new organizational forms in inter-firm collaborations, and ultimately how they stimulate the emergence of new institutions enhancing sustainability. They identify two pathways to transition into the circular economy and to manage circular material flows, one focusing on optimizing materials and raising industry standards and another focusing on cascading and shifting in ownership [23].

Making customized clothes from textile waste in the clothing industry could be a solution to reduce waste in the textile industry [24]. In this article, the solution proposed by the authors is in line with what the literature proposes as opportunities for a more sustainable clothing industry, but also brings consumer involvement in this endeavour [25–27]. One of the solutions to reduce waste could be to include the patterns of other clothing items in the initial marker. The efficiency of the marker-making depends on the type of product, its model, the type of material, the number of framed products, etc. The new products can be made entirely of a single type of material or different combinations of materials can be used. In order to obtain the highest possible marker efficiency, we propose the creation of models of clothing items whose landmarks can be inserted in the existing marker.

In order to help the customer with the necessary support in choosing and designing the desired product and for him to be able to view the product on the computer before it is executed, the design of several clothing items was made in different combinations of materials.

To show how the combinations will glance in the final products of clothing, the program Inkscape ver. 0.92 were used (https://inkscape.org). Inkscape utilizes Scalable Vector Graphics (SVG), an open XML based W3C standard, as the main file format.

The models were created with the assistance of the online tools Art of Where Plain Lab (https://artofwhere.com).

The created models are full-bodied shroud type skirts with thick improving groups. Botanical themes were utilized, which can be considered by implication as geometric components. The model was made utilizing floral motifs with 45º rotation. Skirts will match with easy-going and dressy tops for adaptable styling alternatives. A creased plan with a good fit makes a lovely outline. The model can be overhauled with a belt, which will carry definition to the look.

The created designs are fitting for skirts, yet for different garments as well. Fitted sleeveless tops were designed as well. They make an extraordinary expansion to an easy-going assortment. They have a rib-sew structure, which gives a finished completion of the item. Squandered texture with a trace of stretch offers an adaptable fit for the day solace of the user. It tends to be matched with an assortment of bottoms and layering pieces for flexible styling (figure 5).

Fig. 5. The material combinations in the completed garment

The models can be presented to the customers and once they chose the desired product, the product realization can be taken into account, in the size requested by the customer.

Gemini CAD program was used for the pattern design, cutting plan and marker optimization of garments whose designs were made.

Initially, the marker contained only the parts of two dresses, sizes 40 and 42. As it can be seen in figure

6, between the parts of the two dresses there are large free spaces that will generate a significant amount of waste after the cutting plan. Due to these large free spaces, the maximum nesting efficiency was just 66.28%.

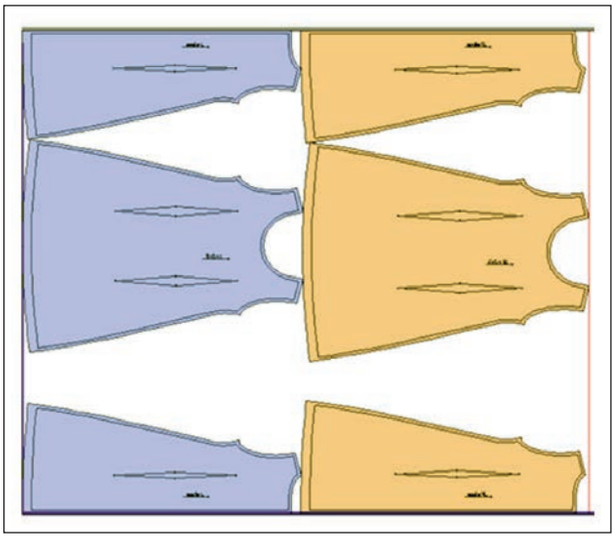

Fig. 6. The marker of the dresses for 40 and 42 size

The main objective was to find a minimum-waste arrangement of the parts to be cut without overlap. In order to reduce the empty spaces and to efficiently nest a variety of parts in these spaces, between the dress's parts were inserted the parts of two sleeveless tops and skirts. In the Gemini Cut Plan application, we set the number of pieces made for each model and size and some general settings regarding cutting: the preferred spreading length, the maximum number of sheets in the lay and the fabric's width (in case not all parts of a product can be inserted on a single sheet they can be placed on another sheet).
Through this operation, the amount of waste resulting from the cutting was significantly diminished, as can be seen in figure 7. By introducing the patterns of the sleeveless tops and skirts among the two dress patterns, the high nesting efficiency was 76.81% respectively 84.13% (compared to 66.28% as it was initially).

CONCLUSIONS

Textiles play an important role in the Romanian manufacturing industry, contributing considerably to economic growth and job creation. On the other hand, current production models generate a negative impact on the environment, an impact that has continued to grow in recent years.
Promoting a circular economy is one of the biggest challenges that our societies face. The transition to a circular textile system requires a fundamental systemic change throughout the textile value chain supported by appropriate policies. Along with technological innovation to improve efficiency and reduce environmental impact, new business models and policies must be adopted.
The model proposed by us comes to complete the numerous solutions for reducing textile waste by involving the consumer in this approach. As numerous studies show that, more and more consumers are interested in customizing their clothing products [28] and that they are willing to purchase products made through sustainable technologies [29] leads us to believe that this type of product will have a share in the future and that they will be among the consumer preferences.
In addition, the implementation of this model will bring numerous benefits to the company. The manufacturing of customized clothes using textile waste implies the decrease of the company's expenses with the acquisition of necessary materials in order to produce them. Moreover, the amount of production waste will entail cost reduction in waste management. All this will be reflected in the product's selling price and in the company's profit.
In the medium and long term, by promoting the products whose realization contributes to the decrease of the pressure exerted on the environment, the company will improve its image and will thus be able to increase its market share, thus increasing its economic benefits.

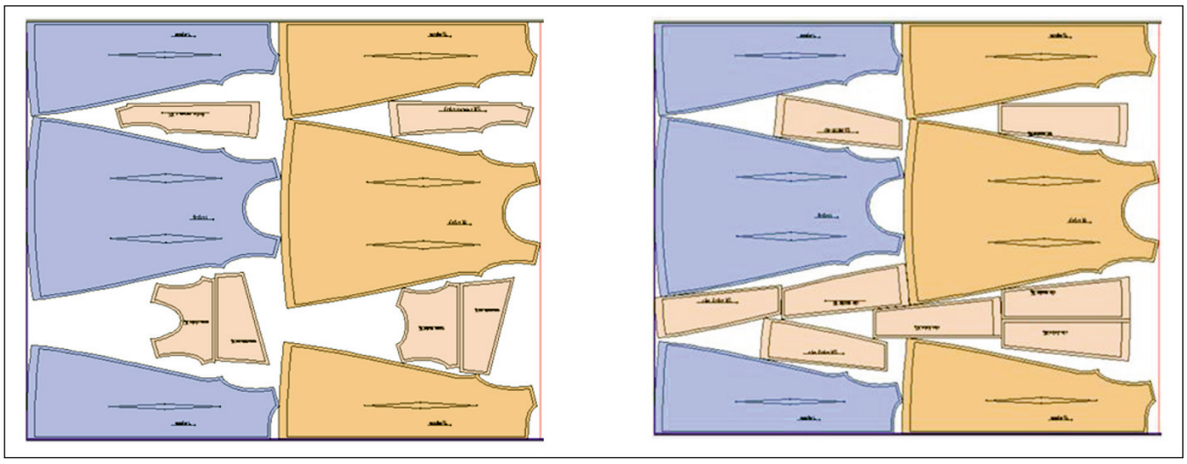

Fig. 7. The marker of the dresses, t-shirt pattern and skirts pattern

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Designing textile accessories from coffee ground

DOI: 10.35530/IT.073.03.202049

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ABSTRACT – REZUMAT

Designing textile accessories from coffee ground

Excessive consumption of natural resources restricts raw material production and threatens future generations' access to these resources. Therefore, most of the famous fashion and textile brands are used bio-based materials such as orange, banana, pineapple, coffee ground, etc. In this study, buttons are designed from the coffee waste collected from a local coffee house from an automatic espresso coffee machine located in Turkey for the completion of garments in the fashion industry. Coffee grounds are mixed with corn starch, glycerine, bio-epoxy resin and hardener with adequate concentrations. Bio-waste button is designed according to a mostly used circular shape. Colour fastness tests are performed to evaluate the quality of fabric such as appearance, stain release, water resistance, and colour fastness to domestic laundering and drying procedures. As a result, designed natural accessories can be adopted not only as environmentally friendly but also as cost-effective solutions for manufacturing other accessories used in the fashion industry. At the end of the domestic laundering, at the first three washing cycles, it is observed that there is no visible wear discolouration, flexibility or deformations.

Keywords: *bio-based materials, environmentally friendly, fastness properties, fashion industry, recycling*

Proiectarea accesoriilor pentru produsele textile din zaț de cafea

Consumul excesiv de resurse naturale restrânge producția de materii prime și amenință accesul generațiilor viitoare la aceste resurse. Prin urmare, majoritatea brandurilor renumite de modă și produse textile utilizează materiale bio precum portocala, banana, ananasul, zațul de cafea etc. În acest studiu, nasturii sunt proiectați din deșeurile de cafea colectate de la un automat de cafea espresso situat în Turcia, pentru realizarea produselor de îmbrăcăminte din industria modei. Zațul de cafea este amestecat cu amidon de porumb, glicerină, rășină bio-epoxidică și agent de întărire cu concentrații adecvate. Nasturii din deșeuri biologice sunt proiectați într-o formă circulară, aceasta fiind cel mai des utilizată. Testele de rezistență a culorii sunt efectuate pentru a evalua calitatea țesăturii, cum ar fi aspectul, rezistența la pătare, rezistența la apă și rezistența culorii la procedurile de spălare și uscare casnică. Prin urmare, accesoriile naturale concepute pot fi adoptate nu numai ca fiind prietenoase cu mediul, ci și ca soluții rentabile pentru fabricarea altor accesorii utilizate în industria modei. La sfârșitul spălării casnice, la primele trei cicluri de spălare, se observă că nu există decolorări vizibile la purtare, flexibilitate sau deformări.

Cuvinte-cheie*: materiale bio, ecologic, proprietăți de rezistență a culorii, industria modei, reciclare*

INTRODUCTION

Nowadays, with the rapid increase of the population, natural resources are consumed unconsciously. Excessive consumption of natural resources restricts raw material production and threatens future generations' access to these resources [1]. Therefore, within the framework of waste management, the European Union has been determined to prevent waste generation, reuse waste and recycle [2]. Economical control of waste management can only be managed by reducing waste generations. Reduction of waste generation can be accomplished by recycling. If it is not recycled, it remains like garbage. Any litter that does not participate in the recycling left in nature causes serious problems for the future. In the world and also in Turkey, plastic bags are started being offered to the consumer for a fee to be environmentally conscious.

Bio-based materials, some or all of which are obtained from biomass, contribute to sustainability by using the fashion and textile industry. The silk-like cellulose-based fabric was produced from the citrus wastes in the fruit juice sector, which is a bio-waste raw material by Orange Fiber. Another example produced from bio-wastes was produced by the company Singtex, which was named “S-Cafe” from coffee wastes. In addition to being sustainable, this fabric also performs many functions such as anti-bacterial and antiseptic by emitting coffee scents [3]. In addition, many garments were produced by the global giant companies such as sportswear, Timberland, New Balance, North Face, Puma and Nike by the French clothing company Eider Action Wear to reduce environmental pollution. A fibre called “Azlon” is produced from protein-based edible soy fibre, which is 100% eco-friendly and is a good alternative to silk and cashmere. It is used in making sweaters, jackets and blankets by being mixed with wool due to its natural antibacterial and harmonious structure. The yarn obtained from pineapple fibre with its

porous and irregular structure is used in home textile production where the strength properties such as carpet and curtains should be high. The banana fibre obtained from the bark and leaves of bananas is among the innovative natural fibres that have attracted attention recently. Banana wastes inevitably contribute to both nature and the economy by converting them into high-added value products [4]. Vasquez and Vega studied the sustainable life cycle used biodegradable materials to embed electronics. The electronic circuit is embedded into mycelium skin to produce an accessory. After the accessory has been worn, the electronic circuit is reused and the mycelium skin is composed. As a result, this material provides new possibilities for alternative wearable technology fields such as accessories [5]. Cao and et. al. developed from plant oils and natural fibres water-resistant and breathable eco-leather for shoes and coats. Wear tests and questionnaire surveys were conducted on female college students. At the end of the study, if the design and style met their requirements, the participants expressed they would like to buy footwear and apparel made from environmentally friendly leathers [6]. Cimatti et al. demonstrated some sustainable methods and techniques, such as eco-design and recycling for fashion manufacturing companies. A life cycle assessment of traditional products of the company is presented to enhance the significant aspects of sustainability in the fashion industry [7].

The most widely consumed beverage of coffee grounds is also used for colouring fabrics. After colouring, the colour and surface properties of fabrics were investigated using spectrophotometry (CIELAB, Hue and Value/Chrome), colour fastness to laundering and crocking. As a result, natural dyes used in coffee grounds can be a good alternative to synthetic dyes in the textile and dyeing industries. Dyed fabrics were significantly different shades of brown in appearance [8–10]. Coffee grounds (0.074 mm) mixed with 100 gr corn-starch, 5 gr glycerine and 2 gr distilled water. After mixed up, the samples were brought to the microwave for heating under a power of 40 W for 6 minutes. Then, this mixture is deposited into polyacrylic moulds at 32°C in an oven. Differential scanning calorimetric, thermo-gravimetric and morphological analyses are performed. As a result, coffee ground reinforced materials did not change to thermal stability and have better mechanical tensile strength [11]. Many researchers have also used the coffee grounds for dyeing with different mordant. These mordants are zinc sulphate ($ZnSO_4 \cdot 7H_2O$), zinc acetate ($Zn(CH_3CO_2)_2 \cdot 12H_2O$) aluminium potassium sulphate ($AlK(SO_4)_2 \cdot 12H_2O$), copper (II) acetate ($Cu(CH_3CO_2)_2 \cdot H_2O$) [12], copper (II) sulphate pentahydrate ($CuSO_4 \cdot 5H_2O$), tin (II) chloride pentahydrate ($SnCl_2 \cdot 5H_2O$) and iron (II) sulphate heptahydrate ($FeSO_4 \cdot 7H_2O$)) [13], and natural (ash water, iron water, cow dung and lemon juice) [14]. Good colour shades and visibly more intense colours were recorded with different mordant used.

As a result of the literature search, it was seen that studies are focused on bio-based materials such as orange, tea, banana, etc., recycling, and eco-friendly textile materials. For textile accessories, coffee grounds were not produced and used before. In this study, two and four holed buttons are designed from the coffee waste collected from local coffee shops for the completion of garments in the fashion industry. These buttons are sewn on the mostly used woven fabrics. Domestic washing and drying tests were applied to the standards.

MATERIAL AND METHOD

Material

The coffee grounds used in this study were Brazilian coffee beams collected from a coffee house from an automatic espresso coffee machine located in Gaziantep/Turkey. Collected used coffee grounds were completely dried in a container for four days without open-air circulation not directly to the sun as soon as possible getting. Then these are turned into powder by grinding from the mill. Coffee grounds are mixed with corn starch, glycerine, bio-epoxy resin and hardener in the concentration given in table 1 for reinforcements. Then it was pressed into a silicone mould with the shape circular. The size of the button is 24 and the length is 15.2 mm. The prepared mixture was cured in a laboratory-type furnace. The buttons were removed from the silicone moulds for applications.

Table 1

CONCENTRATION OF MIXED COFFEE GROUNDS	
Ingredients	**Content (%)**
Coffee Ground	80
Corn Starch	8
Glycerine	3
Bio-epoxy	6
Hardener	3

Method

Bio-waste button is designed according to mostly used circular shape according to two and four holed [15, 16] from the coffee ground. Colour fastness tests are performed by TS EN ISO 105 C06: Colour Fastness to Domestic and Commercial Laundering. The aim of performing this test is to evaluate the quality of fabric such as appearance, stain release, and colour fastness to domestic and commercial laundering procedures. Test samples 100*40 mm dimensions are sewed between multi-fibre standard test samples (Acetate, Cotton, Polyamide, Polyester, Polyacrylic, and Wool). ECE detergent (4 g) (non-phosphate reference detergent) and sodium carbonate (1 g) were added to the one litre of distilled water. A gentle washing program at 40°C for 30 min. without stainless steel ball was performed. After the washing cycle was completed, the samples were dried by hanging on a line in a room without sunlight. The

average temperature inside the room was 24°C. At the end of the test, visible wear discolouration, unrecoverable deformation the occurrence of an error, and accessories flexibility corruption has been observed. Three washing cycles are performed.

Test materials are examined according to ISO 105-A04:1989; Textiles – Tests for Colour Fastness – Part A04: Method for the Instrumental Assessment of the Degree of Staining of Adjacent Fabrics with grayscale at the end of the test. The transference of colour from the test specimen to an adjacent specimen is commented with grayscale for staining and colour change. Five standard pairs are used. One half of each standard is white, and the second half ranges from white (no staining) to grey with the chroma value of the test specimen (a great deal of staining). A value of 5 corresponds to virtually no staining, whereas 1 indicates poor colour-fastness. The observer conditions are under the D65 daylight.

The changes in the colours of the designed button samples were investigated for each washing cycle using a photoelectric Minolta, İstanbul). The CIELab values provide L^* ("0" black, "100" white), the higher the L values, the lighter the colour. Also, the a^* value indicates red ($+a^*$) and green ($-a^*$), while the b^* value indicates yellow ($+b^*$) and blue ($-b^*$). The colour change (ΔE) value was calculated from the L^*, a^* and b^* values by using illuminant D65 and 10° standard observer conditions. L^*, a^* and b^* were calculated as follows, respectively;

$$L^* = 116\,(Y/Y_n)^{1/3} \quad (1)$$

$$a^* = 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}] \quad (2)$$

$$b^* = 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}] \quad (3)$$

where X, Y, and Z are CIE tristimulus values, and X_n, Y_n, and Z_n are CIE tristimulus values to the reference white under the source used. The ΔE value indicates the differences between the reference and the sample [9, 17].

In addition, colour strength, K/S, was calculated from the reflectance values using the Kubelka–Munk equation [18, 19] about the maximum absorption at 520 nm as follows:

$$K/S = (1 - R)^2 / 2R \quad (4)$$

where R is the reflectance of the dyed fabric and K/S (colour depth) is the ratio of the absorption coefficient (K) to scattering coefficient (S); the higher the value, the greater the colour strength.

EXPERIMENTAL STUDY

Coffee ground (80%), corn starch (8%), glycerine (3%), bio-epoxy resin (6%), and hardener (3%) are mixed. After being mixed up, the mixture was brought to the consistency of dense flowing. The preparing the mixture with adequate plastic consistency pours into two and four holed silicone moulds. In the silicone mould, each button is approximately 20 g each one. In the mould, the mixture is vibrated by a shaker in order not to let air bubble with homogenous distribution of natural components prepared with the coffee ground. The prepared mixture was cured in a laboratory-type furnace at 65°C temperature for 1 hour. After, they were left in the open air at 32°C with no air circulation for one day. The buttons were removed from the silicone moulds and made ready for testing (figure 1).

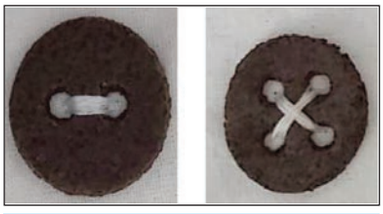

Fig. 1. Designed buttons

Buttons are sewed to three different woven fabrics. First fabrics technical properties are 98/2% cotton/lycra 150 gr/m^2, 40/1 Ne, 48 end/cm (weft), 30 end/cm (warp) plain (1/1) woven fabric. Second one is 100% Polyester 160 gr/m^2, 34/1 Ne, 46 end/cm (weft), 28 end/cm (warp) twill (2/1) woven fabric. Last fabric is 100% wool with 120 gr/m^2, 50/1 Ne, 32 end/cm (weft), 30 end/cm (warp) twill (2/1). Sewing thread is selected from 100% white colour polyester to have been chosen to avoid discolouration of white woven fabric.

Washing fastness

Fabrics with buttons are washed in the domestic laundry three times. This test aims to evaluate the quality of fabric such as appearance, stain release, and colour fastness to domestic and commercial laundering procedures. For all washing cycles, standard ECE detergent is used at 40°C for 30 minutes. After each cycle, the differences obtained between the control fabric and the multi-fibre, before and after washing was visually controlled with the grayscale to obtain the colour change and staining according to ISO 105-A03:1993. The rating scale is 1 (very poor) to 5 (excellent). Test results are shown in table 2.

As can be seen in the tables, there is no visible wear discolouration from button to fabric, deformation of button and flexibility of accessories. All fabrics sewed buttons produced from the coffee ground showed superior colour fastness (4 or higher and 5 grade). Table 2 also shows that very little colour transfer (colour staining) occurred from acetate, cotton, polyamide, polyester and wool fabrics, while no colour transfer to polyacrylic to the adjacent multifibre fabric for cotton/lycra. This result indicates that coffee ground would be a suitable natural dye for various fabrics and/or blends manufactured of acetate, polyamide, and polyacrylic. This is important since most commercial fabric blends contain 2 or more fibre types e.g., polyester/cotton. Colour transfer (colour staining) in cotton, polyester and wool is considered acceptable, with a rating of 4. According to the International Organization of Standardization

Table 2

TEST RESULTS AFTER WASHING										
Colour Change	Colour staining	**Cotton/Lycra**			**Polyester**			**Wool**		
		1.Cycle	2.Cycle	3.Cycle	1.Cycle	2.Cycle	3.Cycle	1.Cycle	2.Cycle	3.Cycle
		5	4/5	4	4/5	4	4	5	4/5	4
Acetate		4/5	4/5	4/5	4	4	4	4/5	4	4
Cotton		4	4	4	4	4	4	4/5	4	4
Polyamide		4/5	4/5	4	4–5	4	4	4	4	4
Polyester		4	4	4	5	5	5	4	4	4
Polyacrylic		5	5	4/5	4	4	4	4	4	4
Wool		4	4	4	4/5	4/5	4	5	5	5

(ISO) for textile materials, it is considered acceptable in the condition of a grade of 4 or higher for colour change and 3 or higher for staining. Dyeing with the coffee ground is acceptable according to standard. The ratings were >4.5 for acetate, polyamide and polyacrylic, showing excellent fastness to staining. While very little colour transfer (colour staining) occurred from acetate, cotton, polyamide, polyacrylic and wool fabrics, no colour transfer from polyester to the adjacent multi-fibre fabric for polyester fabric. There is no colour transfer (wool) is occurred for wool fabrics. This result indicates that button all fabric is excellent fastness to colour change and staining.

CIE Lab

CIELAB L^*, a^*, b^*, K/S, ΔE values for the buttons manufactured from the coffee ground at the end of each washing cycle were shown in table 3. When the button was washed with standard conditions, L^* values were found to be lower. While the highest L^* value belongs first washing cycle, the lowest L^* is obtained with 51.879 for the last washing cycle. It means deeper shades of brown colour for the last washing cycle. As a result of repeated washing, the colour on the button caused a deeper brown tone, contrary to what was expected. With this result, it has been concluded that the buttons can be washed easily.

Also, when the buttons were washed, a^* and b^* values were found to be lower. It was evident that it lost its brown bright colour and gained a matte appearance. When we look at the colour fastness values, we obtained results supporting this interpretation. Staining on the multi-fibre standard test fabric, a slight change was observed in all fibres (acetate, cotton, polyamide, polyester and wool) except polyacrylic fibre. During this staining, the brown colour on the button was stained while at the same time reducing the brightness and providing a matte appearance. The colour change of buttons is shown also in table 3. According to the washing test results, there is a little colour change is occurred. Furthermore, the total colour change (ΔE) values of natural brown colour on buttons were lower with each washing cycle (ΔE = 6.84, 4.75 and 3.10 respectively). It is good excellent colour absorption depending on three washing cycles. Therefore, analysing CIELAB values with washing cycles will inform researchers and textile sectors about natural colours. Based on table 3, buttons produced from the coffee ground showed that washing cycles increased Colour Strength (K/S) from 9.070 for the first washing to 30.381 for the last washing. Maximum colour strength is obtained at the end of the third washing cycle. The obtained values (table 3) show that buttons' colour after washing cycles is becoming darker and duller. It means darker and duller brown colour. The reason for this result can be explained by the aqueous solution that helps set the brown colour to buttons. Also, it can be explained that aqueous solution tends to form strong

Table 3

CIELAB VALUES							
Washing cycle	**L^***	**a^***	**b^***	**K/S**	**ΔE**	**Colour**	**Accessory**
1.Cycle	74.477	5.049	25.158	9.070	6.84	Dark Brown	
2.Cycle	60.254	5.002	16.037	14.289	4.75	Brown	
3.Cycle	51.879	4.576	14.308	30.891	3.10	Brown	

Note: L^*= lighter the colour, a^*= red values, b^*= yellow values, K/S = colour strength, ΔE = total colour change

bonds to coffee ground. Thus, consequently, a colour change is to be a darker shade. It can be concluded that buttons can be produced from natural sources such as coffee grounds as an alternative to plastics, wood and metals.

DISCUSSION AND CONCLUSION

Accessories used in the fashion industry like button is mostly produced from wood, plastics or metals. A huge amount of residue is generated annually while producing petroleum-based. Therefore, the idea of manufacturing buttons from the bio-waste coffee ground is an innovative and good alternative for future generations.

The experimental results of this study are summarized below:

- New natural textile accessories designed can contribute to developing another bio-waste alternative for buttons with cost-effective and high availability of materials.
- It is also demonstrated that recycled coffee grounds, which are still recognized as bio-waste can be possible materials.
- Designing buttons from bio-waste coffee grounds can help to contribute to long-term economic potential and promote suitable environmental management to minimize negative effects caused by the use of petroleum-based buttons like plastics instead of coffee ground buttons.
- Developed natural accessories can be adopted not only as environmentally friendly but also as cost-effective solutions for manufacturing other accessories used in the fashion industry as buckles, broach, tie pins, punch, claps, etc.
- At the end of the domestic laundering, at the first two washing cycles, it is observed that there is no visible wear discolouration, flexibility or deformations. However, after three washing cycles, there is only little invisible deformation. This is acceptable for buttons in the fashion industry.
- The washing colour fastness of button samples produced from the coffee ground showed 4 (good), 4/5 (very good) and 5 (excellent) resistances to colour staining for multi-fibre standard test samples This may be not only due to the strong combination to the coffee ground and also suitable for all fibres (acetate, cotton, polyamide, polyester, polyacrylic, wool). According to the International Organization of Standardization (ISO) for textile materials, it is considered acceptable in the condition of a grade of 4 or higher for colour change.
- High washing fastness values might be due to the migration of coffee-based materials firmly attached to the buttons. Because water molecules were not removed easily some water-soluble dyes (coffee ground) by the action of washing conditions.
- Buttons produced from coffee ground alter the washing fastness ratings into positive as well as makes them insoluble with water and ultimately improve washing fastness properties.
- The reason for choosing three different fabric types (%98 cotton/%2 lycra, %100 polyester and %100 wool woven) are alternatives for outwear for example coat, jacket and duster.
- K/S values increased in the order of 3.Cycle> 2.Cycle>1.Cycle for buttons produced from the coffee ground. It is remarkable that at the end of the 3. washing cycles have higher K/S values. This may be associated with the setting of brown colour value into the accessory by washing.
- Bio-waste materials with genuine characteristics offer innovative ideas for designers.
- Recycling coffee grounds is still recognized as industrial waste not only for the textile industry but also in other industries like agriculture, construction, food, chemistry, etc.
- One of the important characteristics gained during using the fabric is that naturally protect against bed smell like perspiration, cigarette, cooking, etc. The natural aroma of the coffee is spread during the production, using and washing of the fabric.

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Statistical analysis of yarn characteristics for multilayer fabric matrix meant for hemostasis and tissue regeneration

DOI: 10.35530/IT.073.03.202139

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ABSTRACT – REZUMAT

Statistical analysis of yarn characteristics for multilayer fabric matrix meant for hemostasis and tissue regeneration

Effective wound handling involves understanding the processes caused by several factors, such as the type of wound treated, the healing process, the general health of the patient (e.g., the existence of other diseases), the social environment, and the chemical and physical properties of available dressings. For the treatment of shot or burn wounds, the multilayer matrices that will be made must provide efficient oxygen permeability, but most importantly to simulate the structural and biological characteristics of the extracellular skin matrix (ECM). In order to achieve, by mechano-textile processing technologies, the textile structures that can be used as a base layer in the multilayer matrix, raw materials based on cotton, Lenpur, and bamboo mixed with zinc oxide were selected and analysed in accredited testing laboratories, from the point of view of the physical-mechanical characteristics. The results obtained in the case of the experimental program were analysed from a statistical point of view, the description of the statistical populations being made using a specialized program that allowed the calculation of the distribution parameters: mean, median, and standard deviation. To determine the outliers, for all the characteristics of the experimented variants the Q-Q Plot graphs were used. The information obtained as a result of the statistical analysis will be used to design the textile layers of the multilayer matrix using statistical techniques to create probabilistic prediction models that model the dependent variable Y is the hygroscopicity, depending on the independent variables x_1 – linear density, x_2 – twist/ply, x_3 – breaking force, x_4 – elongation at break.

Keywords: *database, descriptive statistics, Q-Q Plot graphs, skewness, kurtosis, probabilistic models*

Analiza statistică a caracteristicilor firelor pentru țesăturile matricii multistrat pentru hemostază și regenerarea țesuturilor

Gestionarea eficientă a rănilor presupune înțelegerea proceselor determinate de o serie de factori, cum ar fi tipul de rană tratată, procesul de vindecare, starea generală de sănătate a pacientului (ex. existența alor afecțiuni), mediul social și proprietățile chimice și fizice ale pansamentelor disponibile. Pentru tratamentul plăgilor împușcate sau generate de arsuri, matricile multistrat prevăzute a se realiza, trebuie să ofere o permeabilitate eficientă la oxigen, dar cel mai important să simuleze caracteristicile structurale și biologice ale matricei extracelulare a pielii (ECM). În vederea realizării prin tehnologii de prelucrare mecano-textilă a structurilor textile utilizabile ca strat de bază în componenta matricii multistrat, au fost selecționate materii prime pe bază de bumbac, Lenpur, bambus în amestec cu oxid de zinc care au fost analizate, în laboratoare de încercări acreditate, din punct de vedere al caracteristicilor fizico-mecanice. Rezultatele obținute în cadrul programului experimental au fost analizate din punct de vedere statistic, descrierea populațiilor statistice fiind realizată cu ajutorul unui program specializat, care a permis calcularea parametrilor distribuțiilor: media, mediana și abaterea standard. În vederea determinării valorilor extreme, pentru toate caracteristicile variantelor experimentate au fost utilizate graficele Q-Q Plot. Informațiile obținute ca urmare a analizei statistice efectuate vor fi utilizate pentru proiectarea straturilor textile din componența matricii multistrat, cu ajutorul tehnicilor statistice pentru crearea unor modele de predicție de tip probabilistic, ce modelează variabila dependentă Y ce este higroscopicitatea, în funcție de variabilele independente x_1 – densitatea de lungime, x_2 – torsiunea/răsucirea, x_3 – sarcina de rupere, x_4 – alungirea la rupere.

Cuvinte-cheie: *bază de date, statistica descriptivă, grafice Q-Q, asimetrie, curtoză, modele probabilistice*

INTRODUCTION

Wound dressings have to be designed to speed up the healing process and help protect the wound from contamination and moisture loss that could delay or affect its healing. The materials used as wound dressings involve films, sponges, fibres, or hydrogels of natural and synthetic polymers and combinations thereof. The ideal wound dressing has to provide efficient oxygen permeability, but most importantly has to simulate the structural and biological characteristics of the extracellular skin matrix (ECM) [1].

For the manufacture of multilayer dressings for the treatment of burns and wounds by shooting, by LBL technique, raw materials based on cotton/viscose/

acetate/bamboo/Lenpur, etc. for the base layer; carboxymethyl chitosan (CMC) for the middle layer and gelatine and alginate to obtain the porous layer are candidates.

The CMC can be grafted onto cotton fibres/yarns by an esterification reaction with the hydroxyl groups of the cellulose chains. The gelatine layer is deposited over the CMC layer. Alginate integration can be achieved by crosslinking reactions facilitated by Ca^{2+} ions in the gelatine layer [2].

Polyurethane/ polypropylene/polyethene films will be tested as an antibacterial barrier. The base layer, with the role of physical-mechanical support and rapid growth of an adhesive joint with healthy skin, adjacent to the lesion (not necessarily in the case of burns), will be made of fibres and yarns using weaving and nonwoven technologies. The layer will be sized and shaped in several variants and will include portions doped with reactive prepolymers or oligo polymers of the cyanoacrylates class, possibly seconded by fast-acting biocompatible crosslinking agents, such as functionalized poly (beta-amino-esters)/ polysaccharides.

A variant of stratified outer layer will be tested, by the physical-mechanical association of the textile material with a polyurethane film, able to protect the entire medical device against micro particulate physical impurities, excessive external moisture, including toxic compounds for military use, reached in solution in the conditions of theatres of military operations.

For the manufacture of these textile structures, raw materials based on cotton, Lenpur, and bamboo mixed with zinc oxide were selected, which were analysed from the physical-mechanical characteristics point of view. The results of the experimental program were interpreted using tools and programs dedicated to the description of statistical populations and the interdependencies between the analysed characteristics.

Table 1

EXPERIMENTED YARN VARIANTS		
Yarn variant	**Identify data**	
	Raw material	**Linear density**
V1	100% cotton	200 × 2 dtex
V2	80%/20% cotton/ZnO	150 × 2 dtex
V3	100% bamboo	300 × 1 dtex
V4	100% Lenpur	300 × 1 dtex
V5	100% acetate	130 × 1 dtex
V6	100% cotton	167 × 2 dtex

CHARACTERIZATION OF DISTRIBUTION PARAMETERS. DESCRIPTIVE STATISTICS

Description of statistical populations

The database presents the results obtained from the experiments of 6 yarn variants and represents the data regarding linear density, twist/ply, hygroscopicity, breaking force and elongation at break. The experiments were carried out in the testing laboratories within INCDTP and were coded as follows (table 1):

The description of the statistical populations was made by a specialized software application that allowed the calculation of the parameters of the distributions: mean, median, and standard deviation [3–5]. The variables and the options to be analysed were made according to the proposed statistical plan, respectively:

- statistical data processing: percentile values, dispersion, distribution, central tendency, skewness and kurtosis;
- plotting histograms and curves of normal distribution and Q-Q Plot graphs;
- output view.

The values obtained after processing the statistical populations for the linear density, twist/torsion, hygroscopicity, breaking force and elongation at break variables are presented in tables 2, 3, 4, 5 and 6.

Table 2

STATISTICS FOR LINEAR DENSITY V1 – V6							
Indicators		**Linear density V1**	**Linear density V2**	**Linear density V3**	**Linear density V4**	**Linear density V5**	**Linear density V6**
N	Valid	20	20	20	20	20	20
Mean		402.8500	296.5000	250.2000	298.8500	128.6500	347.4000
Median		402.5000	298.5000	252.0000	296.5000	129.0000	348.5000
Std. Deviation		4.20870	6.21120	6.22051	12.64609	1.46089	12.33480
Variance		17.713	38.579	38.695	159.924	2.134	152.147
Skewness		0.277	–0.170	–0.748	0.992	–1.567	–0.030
Kurtosis		–0.633	–0.536	–0.345	0.440	2.423	0.770
Minimum		396.00	285.00	238.00	283.00	125.00	323.00
Maximum		411.00	309.00	260.00	327.00	130.00	376.00
Percentiles	25	399.2500	290.0000	246.5000	290.2500	128.0000	341.2500
	50	402.5000	298.5000	252.0000	296.5000	129.0000	348.5000
	75	405.0000	301.5000	254.7500	303.7500	130.0000	353.5000

Table 3

STATISTICS FOR TWIST/ PLY V1 – V6							
Indicators		**Twist V1**	**Twist V2**	**Twist V3**	**Twist V4**	**Twist V5**	**Twist V6**
N	Valid	20	20	20	20	20	20
Mean		566.7000	719.6500	678.2500	601.2000	123.2000	705.8000
Median		568.0000	720.0000	668.5000	602.0000	124.0000	704.0000
Std. Deviation		22.66716	27.96102	39.52597	19.25343	6.78698	30.14282
Variance		513.800	781.818	1562.303	370.695	46.063	908.589
Skewness		–0.711	0.490	0.391	0.026	0.069	0.414
Kurtosis		1.560	–0.346	–1.061	–1.123	–0.035	0.949
Minimum		508.00	684.00	622.00	574.00	110.00	644.00
Maximum		612.00	784.00	756.00	636.00	138.00	776.00
Percentiles	25	557.0000	690.5000	644.5000	583.0000	118.0000	682.0000
	50	568.0000	720.0000	668.5000	602.0000	124.0000	704.0000
	75	583.0000	739.0000	719.5000	618.0000	128.0000	720.0000

Table 4

STATISTICS FOR HYGROSCOPICITY V1 – V6							
Indicators		**Hygroscopicity V1**	**Hygroscopicity V2**	**Hygroscopicity V3**	**Hygroscopicity V4**	**Hygroscopicity V5**	**Hygroscopicity V6**
N	Valid	20	20	20	20	20	20
Mean		5.162190	7.358095	11.987500	9.016500	6.300515	6.983635
Median		5.181600	7.333550	11.975000	8.980000	6.308150	7.052700
Std. Deviation		0.1406260	0.1512025	0.1560997	0.1642615	0.1224088	0.1416714
Variance		0.020	0.023	0.024	0.027	0.015	0.020
Skewness		–0.662	0.729	0.332	0.057	0.015	–2.229
Kurtosis		–0.984	–0.531	–1.586	–0.535	–1.039	5.359
Minimum		4.9230	7.1952	11.8000	8.7000	6.1263	6.5198
Maximum		5.3268	7.6685	12.2100	9.3000	6.4973	7.0891
Percentiles	25	5.019000	7.212975	11.852500	8.930000	6.224750	6.930000
	50	5.181600	7.333550	11.975000	8.980000	6.308150	7.052700
	75	5.291600	7.426150	12.177500	9.120000	6.405225	7.052700

Table 5

STATISTICS FOR ELONGATION AT BREAK V1 – V6							
Indicators		**Breaking force V1**	**Breaking force V2**	**Breaking force V3**	**Breaking force V4**	**Linear density V5**	**Breaking force V6**
N	Valid	20	20	20	20	20	20
Mean		8.1785	5.9430	3.6033	2.6075	1.3240	4.7510
Median		8.1250	5.8750	3.5700	2.7100	1.3200	4.8200
Std. Deviation		.37708	.22278	0.23297	0.35191	0.05113	0.37356
Variance		0.142	0.050	0.054	0.124	0.003	0.140
Skewness		0.023	0.266	0.135	–0.323	2.939	–0.920
Kurtosis		–1.408	–0.910	–1.310	–1.344	12.688	1.367
Minimum		7.57	5.57	3.25	2.00	1.25	7.57
Maximum		8.75	6.38	4.00	3.10	1.52	8.75
Percentiles	25	7.8475	5.7675	3.4200	2.2675	1.3200	4.5425
	50	8.1250	5.8750	3.5700	2.7100	1.3200	4.8200
	75	8.5525	6.1525	3.8150	2.9275	1.3200	5.0000

Table 6

STATISTICS FOR BREAKING FORCE V1 – V6							
Indicators		**Elongation at break V1**	**Elongation at break V2**	**Elongation at break V3**	**Elongation at break V4**	**Elongation at break V5**	**Elongation at break V6**
N	Valid	20	20	20	20	20	20
Mean		15.9310	7.4440	19.6815	8.7760	22.7085	7.1080
Median		16.6250	7.3900	19.8000	8.8950	22.3050	7.2400
Std. Deviation		2.39580	0.23002	0.95764	1.01828	2.30412	0.63678
Variance		5.740	0.053	0.917	1.037	5.309	0.405
Skewness		–0.409	0.918	–0.186	–0.522	0.344	–1.450
Kurtosis		–1.095	0.111	–0.633	–0.549	–0.813	2.845
Minimum		11.76	7.16	17.98	6.84	19.54	5.24
Maximum		19.23	7.98	21.30	10.40	27.18	7.98
Percentiles	25	13.7750	7.2800	18.9950	7.9500	20.6625	6.9050
	50	16.6250	7.3900	19.8000	8.8950	22.3050	7.2400
	75	18.0600	7.5650	20.3750	9.5875	24.7250	7.5300

By analysing the graphs from tables 2–6, can be concluded that the homogeneity of the populations is demonstrated by the fact that the value of the variability coefficient is below 11%, the average being representative and the asymmetry indicators highlight:

- for “linear density”:
  - at V2, V3, V5 and V6 there is a tendency to remove the median (skewness > 1.96), with a more accentuated character in the case of V5;
  - for V1, V4 and V7 the movement trend is to the left (the average is higher than the median);
  - the distribution is leptokurtic in the case of V4 and V6 because the kurtosis values are positive;
  - the distribution presents a strong variation of the variable and a weak one of the frequencies, so it is platykurtic in the case of V1, V2, V3 and V5;
- for “twist/ply”:
  - the average is higher than the median, so the displacement is to the left for variants V2, V3, V4, V5 and V6, and for V1 the displacement is to the right;
  - the negative values of kurtosis for V3, V4 and V5 determine the platykurtic curve of the distribution;
  - the positive values of kurtosis for V1, V2 and V6 determine the leptokurtic curve. For V1, the tendency to approach the maximum possible value of the normal distribution is noticeable (1.56 compared to 1.96);
- for “hygroscopicity”:
  - skewness values higher than 1.96 impose the tendency to move away from the median, so the curve moves away to the right from that of N (0,1) for V1 and V6;
  - skewness values less than 1.96 displacement is to the left (average is higher than the median) for V2, V3, V4, and V5;
  - the positive values of kurtosis for the variable V6 demonstrate the leptokurtic distribution, for the rest of the variables the distribution is platykurtic, so it presents a strong variation of it in parallel with a weak variation of the frequencies;
- for “breaking force”:
  - skewness for V1, V2, V3 and V5 demonstrates movement to the left and for V4 and V6 – movement to the right;
  - the vaulting index has positive values for V3, V4, V5 – the curve is leptokurtic and respectively platykurtic for V1, V2, V6;
- for “elongation at break”:
  - the skewness values for V2 and V5 show movement to the left and for V1, V3, V4 and V6 – a movement to the right, so it can be said that for V2 and V5 the average is higher than the median;
  - the kurtosis index has positive values for V6 – the curve is leptokurtic so it has a weak variation in parallel with the strong variation of frequencies and respectively platykurtic for V1, V2, V3, V4 and V5.

Detection of outliers

For all the characteristics of the experimented variants, the Q-Q Plot graphs were used in order to determine the outliers, because apart from the possibility of detecting the aberrant values, they allow the verification of the normality of the distributions using the Van der Waerden estimation method [3, 5, 6]. This type of chart was preferred to boxplot charts that highlight only the indicators of level (average, median), dispersion and outliers. It is well known that for the theoretical distribution (in this case – the normal distribution) the quantile values are represented by a line that passes through the origin and has slope 1; if the points Q-Q Plot outline a line that overlaps with the line representing the normal distribution, then it can be stated that the distribution of the tested variable is normal [3, 4, 6].

The disposal of the values obtained following the experiments for the 30 characteristics is presented selectively, for 6 variables, in the graphs from figure 1. Although it was found that the points do not deviate from the straight line, which means that all the variables studied have a normal distribution, it was considered that only those with extreme data values should be viewed.

The analysis of the graphs shows:

- "linear density" – the value 295 for the V4 variant and the values: 335 and 376 for the V6 variant can be considered outliers because the values corresponding to the interquartile deviations from the corresponding straight-line of the normal distribution are high;
- "hygroscopicity" – for variant V6 the value 6.5 can be considered an outlier because it is located at a greater distance from the corresponding straight-line N(0,1);
- "twist/ ply" – the values 580 (V1) and 732 (V6) are considered outliers;
- "breaking force" – no variable shows outliers;
- "elongation at break" – the values 7.1 (V2) and 7.04 (V6) can be considered outliers.

Histograms and distribution curves

The histograms and distribution curves resulting from the calculation are illustrated for several variables from the statistical populations represented by the 6 yarn variants, respectively: "linear density V1", "twist

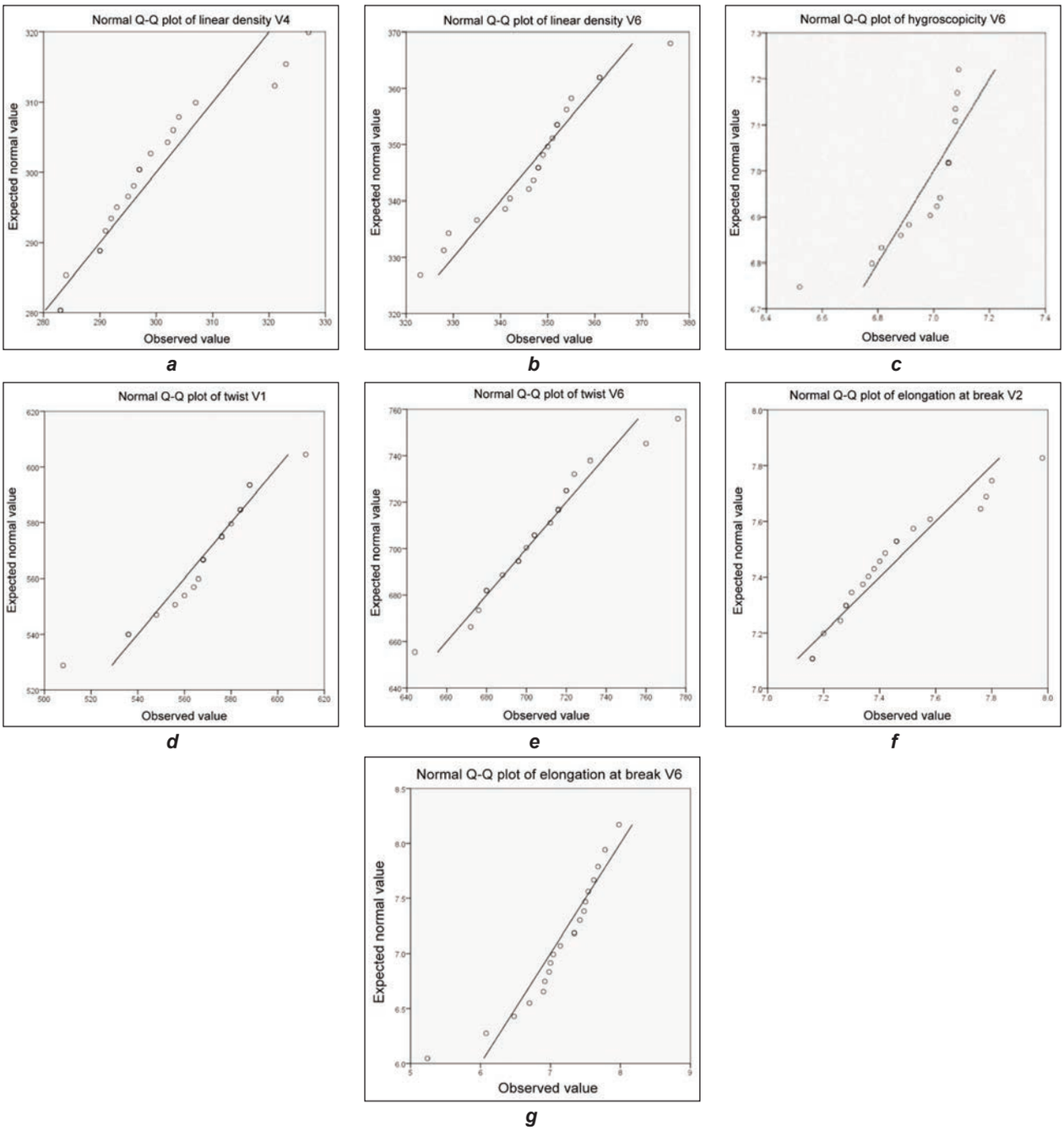
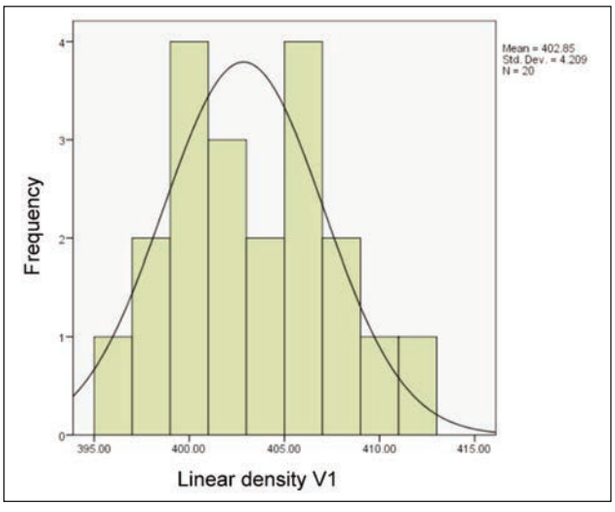


Fig. 1. The Q-Q Plot graphs for the variables: *a* – linear density V4; *b* – linear density V6; *c* – hygroscopicity V6; *d* – twist V1; *e* – twist V6; *f* – elongation at break V2; *g* – elongation at break V6

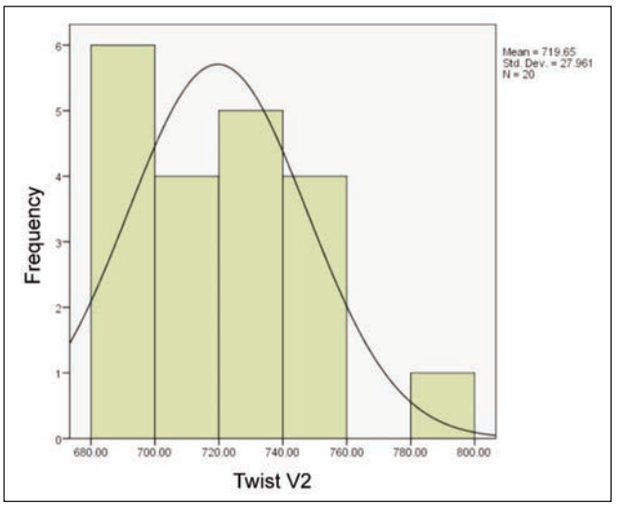
V2", "ply V5", "hygroscopicity V3", "breaking force V5", "elongation at break V4", shown in figure 2.

Interpretation of results:

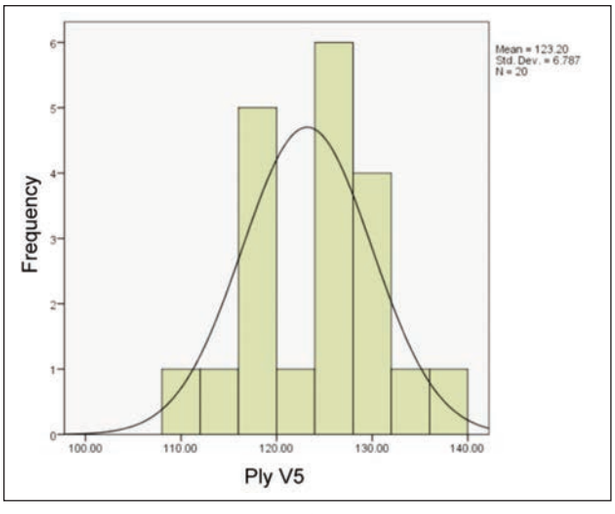
- for the variable "hygroscopicity", histograms indicate an asymmetric distribution for all 6 variants tested. It should be noted that the population of the V3 variable tends to deviate from the normality of the distribution;
- in the case of the variable "breaking force", in variant V5 there was a tendency to leave the normality because the value kurtosis (1.94) is close to the maximum possible value in the case of the distri-



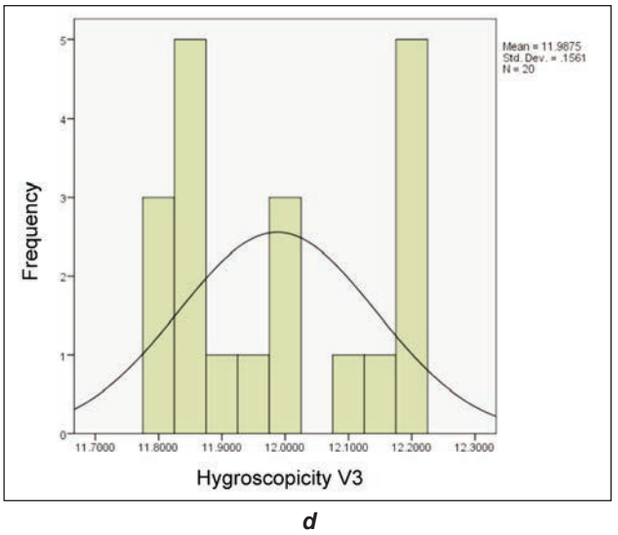
a



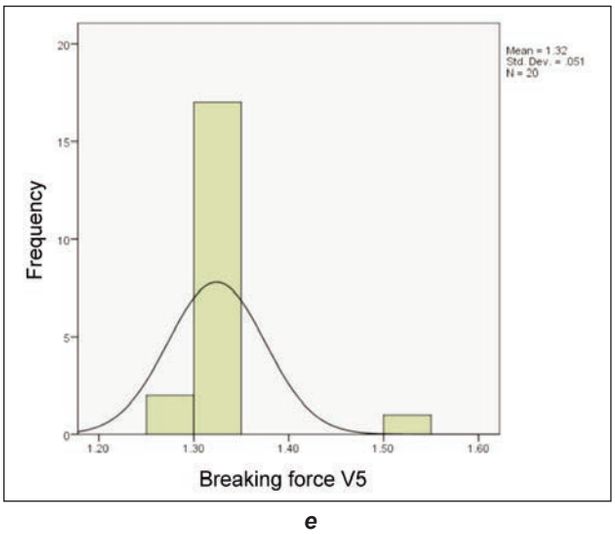
b



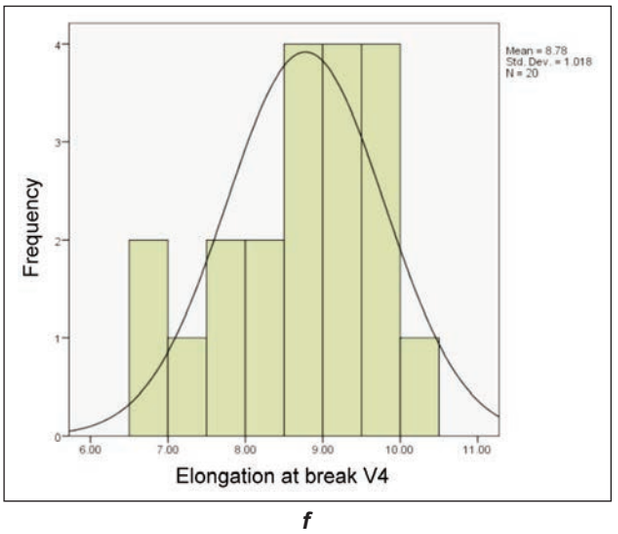
c



d



e



f

Fig. 1. Histograms and distribution curves for the variables: *a* – linear density V1; *b* – twist V2; *c* – ply V5; *d* – hygroscopicity V3; *e* – breaking force V5; *f* – elongation at break V4

bution N (0,1), which would mean the exit from the theoretical normality.

CONCLUSIONS

To describe the scores and group the obtained results after analysing the raw materials that will form the basis of the textile material layers in the multilayer matrix for hemostasis and regeneration of connective tissues in case of burns and shot wounds, the techniques provided by descriptive statistics were used.

The attributes of the 5 variables (600 values) obtained from the experiments were defined in Data Editor and Variable View of a specialized application that allowed: detecting outliers, calculating: percentile values, dispersion, mean, median, asymmetry and the skewness of the distribution; histograms and curves plotting of the normal distribution, as well as Q-Q Plot graphs.

The information obtained as a result of the statistical analysis will be used to design the textile layers of the multilayer matrix using statistical techniques to create probabilistic prediction models that model the dependent variable Y is the hygroscopicity depending on the independent variables x_1 is the linear density, x_2 is the twist/ply, x_3 is the breaking force, x_4 is the elongation at break.

ACKNOWLEDGEMENTS

This scientific paper is funded by the UEFISCDI within PNCDI III, Program 2 – Increasing the competitiveness of the Romanian economy through research, development and innovation, Subprogram 2.1. Competitiveness through research, development and innovation – Experimental – demonstration project, contract no. 496PED/2020.

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Simulation and influencing factors of carbon emission peak in Wenzhou's textile and clothing industry

DOI: 10.35530/IT.073.03.202122

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ABSTRACT – REZUMAT

Simulation and influencing factors of carbon emission peak in Wenzhou's textile and clothing industry

To reflect the huge pressure on the environment caused by carbon emissions (CEs) in the production process of the textile and clothing industry, this study uses the CE coefficient method to calculate the CEs of the textile and clothing industry in Wenzhou, China from 2004 to 2018. Moreover, this study analyses the decoupling relationship between Wenzhou's textile and clothing industry and economic growth by using the decoupling theory and using the Laspeyres decomposition method to analyse the impact of CE factors. Research results show as follows: the decoupling of the CE and economic growth in Wenzhou's textile and clothing industry from 2004 to 2018 was five years of non-decoupling (2005, 2006, 2007, 2012, 2016) and four years of relative decoupling (2008, 2010, 2013, 2015), five years of absolute decoupling (2009, 2011, 2014, 2017, 2018), the overall decoupling state is good; among the main factors affecting CE, the cumulative effect of industrial scale is the key factor that drives the growth of CE. The industry structure effect and technology level effect inhibit the increase in CE, and the technology level effect has a small impact on the CE of the textile and clothing industry. This paper fills in the gaps between the environmental regulation means and methods of pillar industrial clusters in specific regions and provides paths and measures for Wenzhou's textile industry and regional energy conservation and emission reduction.

Keywords: *textile industry, clothing, carbon emissions, decoupling, Laspeyres*

Factorii de simulare și influență ai vârfului de emisie de carbon în industria textilă și de îmbrăcăminte din Wenzhou

Pentru a reflecta presiunea uriașă asupra mediului cauzată de emisiile de carbon (CE) în procesul de producție al industriei textile și de îmbrăcăminte, acest studiu folosește metoda coeficientului CE pentru a calcula factorii CE ai industriei textile și îmbrăcămintei din Wenzhou, China, din 2004 până la 2018. Mai mult, acest studiu analizează relația de decuplare dintre industria textilă și de îmbrăcăminte din Wenzhou și creșterea economică prin utilizarea teoriei decuplării și folosind metoda de descompunere Laspeyres, cu scopul de a analiza impactul factorilor CE. Rezultatele cercetării arată după cum urmează: decuplarea CE și creșterea economică în industria textilă și de îmbrăcăminte din Wenzhou din 2004 până în 2018 a fost de cinci ani de nedecuplare (2005, 2006, 2007, 2012, 2016) și patru ani de decuplare relativă (2008, 2010, 2013, 2015), cinci ani de decuplare absolută (2009, 2011, 2014, 2017, 2018), starea generală de decuplare este corespunzătoare; printre principalii factori care afectează CE, efectul cumulativ la scară industrială este factorul cheie care conduce la creșterea CE. Structura industriei și nivelul tehnologic inhibă creșterea CE, iar nivelul tehnologic are un impact redus asupra CE din industria textilă și de îmbrăcăminte. Această lucrare completează golurile dintre mijloacele și metodele de reglementare a mediului clusterelor industriale pilon din regiuni specifice și oferă căi și măsuri pentru industria textilă din Wenzhou, precum și conservarea energiei regionale și reducerea emisiilor.

Cuvinte-cheie*: industria textilă, îmbrăcăminte, emisii de carbon, decuplare, Laspeyres*

INTRODUCTION

The massive emission of greenhouse gases and the resulting environmental problems are worsening, becoming a worldwide problem affecting human development [1]. Energy consumption, especially fossil energy consumption, is an important factor in the increase in the number of greenhouse gases in the atmosphere. And the more fossil fuel and non-green energy are used, the more negative impact on social and environmental sustainability [2], the usage of renewable energy not only enhances environmental sustainability but also spurs sustainable regional economic growth [3]. To accelerate the promotion of a resource-saving and environment-friendly society, the textile and clothing industry sector has to propose higher requirements for energy conservation, emission reduction and the elimination of backward production capacity in the textile industry, and the task of reducing non-renewable energy consumption further is imminent [4, 5].

China is the world's largest producer, consumer and exporter of textiles and garments. The textile and clothing industry of China is an important civilian production

and international competitive advantage industry [6]. This industry has made great contributions to China's national economy, social development and employment. However, China's textile and clothing industry typically consumes and emits huge amounts of energy and pollution, respectively [7, 8]. According to calculations, the energy consumption of the entire process of China's textile industry is approximately 4.84 t of standard coal/1 t of fibre which is equivalent to 10.99 t of carbon dioxide/1 t of fibre, and its total energy consumption accounts for 4.3% of China's industrial energy consumption [9]. The energy consumption of the printing and dyeing sub-industry accounts for approximately 58.7% of the entire industry. The water, electricity and steam energy consumptions of printing and dyeing plants account for 40–60% of the total cost of printing and dyeing fabrics which is the focus of energy conservation in the textile industry [9]. China's textile and clothing industry has been receiving great pressure to save energy and reduce emissions for a long time.

The textile and clothing industry is one of the four pillar industries in Wenzhou. Wenzhou, an economically developed coastal city in the southeast of Zhejiang Province in China, is an important textile production base and distribution centre in China, with obvious advantages in agglomeration, market and information. The main textiles include clothing and clothing accessories; textile yarns, fabrics and products; and upper shoe textiles. Wenzhou's textile and garment enterprises are booming. In 2018, there were more than 1,000 enterprises above the designated size in Wenzhou's textile and clothing industry, with an output value of more than USD 4 billion, accounting for approximately 4.7% of China's domestic textile and garment output [10]. Wenzhou's textile and garment industry occupies a pivotal position in the territory of China's textile industry. Wenzhou is known as 'China's Textile and Clothing Brand Central City' and 'China's Clothing Fashion Customisation Demonstration Industry Base'. In the international market, Wenzhou's textile and clothing exports are also highly reputable. Wenzhou textiles and garments are sold to more than 130 countries and regions, mainly in the European Union, Japan, Hong Kong, Macao and Taiwan regions and North America. From 2009 to 2017, Wenzhou's textile exports increased from USD 4.049 billion to USD 5.442 billion, an increase of 34.40%. Wenzhou's textile exports accounted for 5.8% of the annual average proportion of Zhejiang Province, China [11,12]. As the second batch of low-carbon city pilots in China, the 'Wenzhou City's 13th Five-Year Implementation Plan for Controlling Greenhouse Gas Emissions') targets the carbon emission (CE) intensity reduction of 18% and the carbon intensity per unit of industrial added value decrease of 20% in 2020 compared to those in 2005 and the effective control of CEs [13].

Decoupling analysis is widely used in the study of the relationship between the environment and economic development. In the field of resource-environmental economy, decoupling refers to the breakdown of the coupling relationship between economic growth, resource consumption and environmental emissions. Scholars at home and abroad have conducted extensive research on the relationship between economic growth, energy consumption and CE using the decoupling theory. Li et al. used decoupling theory to quantitatively analyse the decoupling relationship between China's environmental regulations, technological progress and water consumption from 2002 to 2015 [14] and studied and analysed the decoupling relationship between water resource consumption, water footprint and economic growth [15–16]. Lu et al. analysed the decoupling effect between economic growth, transportation energy demand and carbon dioxide emissions and concluded that rapid economic growth and motor vehicle ownership are the most important factors of CO_2 emissions increase [17]. Meanwhile, Kovanda and Hak analysed and compared the decoupling situations of resource consumption and the gross industrial output value of major EU countries from 1990 to 2002 [18]. Zhang et al. analysed the decoupling elasticity between carbon dioxide, the gross domestic product and energy consumption in China and the ASEAN countries over the period 1990–2014. Their research shows that the economic effect of per capita GDP is the dominant driving force for the increase in CO_2 emissions and suggests that energy policies in China and the ASEAN countries need to expand the proportion of renewable energy and increase the efficiency of energy use[19]. Scholars had carried out relevant research at the national and regional levels. At the national level, the research includes the decoupling analysis of energy consumption [20], carbon dioxide emissions [21–23], water resources consumption [24], wastewater discharge [25], farmland occupation [26] and economic growth, whilst that at the regional level includes the decoupling relationship between economic growth and farmland occupation [27], environmental pressure [28], CEs [29] and energy consumption [30, 31].

The factor decomposition methods commonly used in research mainly include two types, i.e. index decomposition analysis (IDA) [32–35] and structural decomposition analysis [36–40]. Among them, the IDA based on the Laspeyres index method was proposed by the German mathematician E. Laspeyres in 1864. This idea was gradually applied to the field of energy decomposition from the late 1970s to the early 1980s [41, 42]. Based on the CE and economic growth data of Wenzhou's textile and clothing industry from 2004 to 2018, this study uses the IPAT/IGT decoupling method to analyse the decoupling relationship between Wenzhou's textile and clothing industry's CE and economic growth and the Laspeyres decomposition method to determine the main factors affecting this decoupling relationship. This study provides paths and measures for Wenzhou's textile industry and regional energy conservation and emission reduction and offers relevant suggestions for sustainable development.

MATERIAL AND METHODS

CE Coefficient Method

According to the IPCC '2006 Greenhouse Gas Emissions Inventory Guidelines' guidance method [43], the CE coefficient method is used to calculate the CE of the textile and clothing industry as follows:

$$CE = \sum CE_{ij} = \sum E_{ij} \times f_j \times c_j \quad (1)$$

In equation 1, CE represents the CE of the textile and clothing industry; i = 1, 2, 3 respectively represent the three sub-sectors that constitute the textile and clothing industry, i.e. textile manufacturer, textile wearing clothing manufacturer and footwear and caps and manufacturer of chemical fibres; j = 1, ..., 11 respectively represent 11 energy types, such as raw coal, coke and clean coal; CE_{ij} represents the CE generated by sub-industry i that consumes type j energy; E_{ij} represents the amount of type j energy consumed by sub-industry i; f_j represents the conversion coefficient of type j energy into standard coal; and c_j represents the CE coefficient of type j energy. The CE and standard coal conversion coefficients of various energy sources are shown in table 1.

Table 1

CE AND STANDARD COAL CONVERSION COEFFICIENTS OF DIFFERENT ENERGY TYPES

Energy	Carbon emission factor (kg/kg SCE)	Standard coal coefficient (kg SCE/kg)
Raw coal	0.7559	0.7143
Coke	0.8550	0.9714
Wash clean coal	0.7559	0.9000
Heat	0	0.03412
Electricity	0	0.1229
Petrol	0.5538	1.4714
Coal oil	0.5714	1.4714
Diesel oil	0.5921	1.4571
Fuel oil	0.6185	1.4286
Natural gas	0.4483	1.3300
Liquefied petroleum gas	0.5042	1.7143

The conversion coefficients of various energy sources are from the 'China Energy Statistical Yearbook 2014', and the CE coefficients are derived from the data provided in the 2006 'IPCC Guidelines for National Greenhouse Gas Emission Inventories'. The coefficient of conversion to standard coal for heat is kg/MJ, the coefficient of conversion to standard coal for electricity is kg/kW·h, and the other energy units are in kg standard coal/kg.

IPAT/IGT Decoupling Indicator

Based on the IPAT equation, Professor Lu proposed the decoupling indicator for resource use (D_r) [44] based on the IGT equation between resource consumption and economic growth [45–47] as follows:

$$D_r = \frac{t}{g} \times (1 + g) \quad (2)$$

In equation 2, D_r represents the resource decoupling indicator, g is the increase rate of total industrial output value (TIOV) within a certain period ($g > 0$ during the economic growth; $g < 0$ during the economic recession), and t is the average annual decrease rate in resource consumption per unit TIOV during the same period (when falling, $t > 0$; when rising, $t < 0$). Among them, according to the size D_r, the decoupling state of resource consumption and TIOV is classified into three types: absolute decoupling, relative decoupling and non-decoupling. The classification method is shown in table 2.

Table 2

CORRESPONDENCE BETWEEN THE D_r VALUE AND DIFFERENT TYPES OF DECOUPLING

Decoupling State	Economy Increase	Economy Decrease
Absolute decoupling	$D_r \geq 1$	$D_r \leq 0$
Relative decoupling	$0 < D_r < 1$	$0 < D_r < 1$
Non-decoupling	$D_r \leq 0$	$D_r \geq 1$

Laspeyres factor decomposition method

The Laspeyres factor decomposition method was first proposed by Howarth et al. [48] and Park [49] for the comparative analysis of similar research objects. Sun [50, 51] modified the method to effectively solve the residual problem in the traditional algorithm by using the principles of co-creation and equal distribution. This study uses the Laspeyres factor decomposition method to intensively analyse the factors influencing CEs in the textile and clothing industry in terms of industrial scale, industry structure, and technology level, and the CEs accounting formula can be transformed into:

$$CE = \sum_i CE_i = \sum_i TIOV \times \frac{TIOV_i}{TIOV} \times \frac{CE_i}{TIOV_i} = \sum_i TIOV \times I_i \times T_i \quad (3)$$

CE denotes the CE of the textile and clothing industry (tons); i = 1, 2, 3 respectively represent the manufacturers of textiles (MT), textile wearing clothing, footwear and caps (MTC) and chemical fibres (MCF); CE_i represents the CE of the sub-industry i; $TIOV$ represents the TIOV of the textile and clothing industry (million $); $TIOV_i$ represents the TIOV of sub-industry i; I_i represents the proportion of the TIOV of sub-industry i to the TIOV of the textile and clothing industry (%); and T_i represents the CE intensity of sub-industry i (tons/million).

Let I_i^{t-1} be the share of textile and clothing sub-industry i in the TIOV of the textile and clothing industry in year t–1, and T_i^{t-1} be the CE intensity of sub-industry i

in year t–1. According to Sun's complete decomposition model [50], the following equations can be obtained.

$$\Delta CE_{TIOV} = \sum_i \Delta TIOV \times I_i^{t-1} \times T_i^{t-1} + \\ + \frac{1}{2}\sum_i \Delta TIOV\,(I_i^{t-1} \times \Delta T_i + T_i^{t-1} \times \Delta I_i) + \\ + \frac{1}{3}\sum_i \Delta TIOV \times \Delta I_i \times \Delta T_i \quad (4)$$

$$\Delta CE_I = \sum_i TIOV^{t-1} \times \Delta I_i \times T_i^{t-1} + \\ + \frac{1}{2}\sum_i \Delta I_i (TIOV^{t-1} \times \Delta T_i + T_i^{t-1} \times \Delta TIOV) + \\ + \frac{1}{3}\sum_i \Delta TIOV \times \Delta I_i \times \Delta T_i \quad (5)$$

$$\Delta CE_T = \sum_i TIOV^{t-1} \times I_i^{t-1} \times \Delta T_i + \\ + \frac{1}{2}\sum_i \Delta T_i (TIOV^{t-1} \times \Delta I_i + I_i^{t-1} \times \Delta TIOV) + \\ + \frac{1}{3}\sum_i \Delta TIOV \times \Delta I_i \times \Delta T_i \quad (6)$$

In equations 4–6, ΔCE_{TIOV} is the contribution of industrial scale, ΔCE_I is the contribution of the industry structure factor, and ΔCE_T is the contribution of the technology level factor. If CE^{t-1} is the total CE of the textile and clothing industry in year t–1, and CE^t is the total CE of the textile and clothing industry in year t, then we can obtain the following equation by adding the three terms.

$$\Delta CE_{TIOV} + \Delta CE_I + \Delta CE_T = CE^t - CE^{t-1} = \Delta CE \quad (7)$$

ΔCE represents a change in the CE from the textile and clothing industry from year t–1 to year t. By combining ΔCE and equation 4, the following equation is obtained.

$$\Delta CE_{TIOV} = \Delta CE_{TIOV_1} + \Delta CE_{TIOV_2} + \ldots + \Delta CE_{TIOV_n} \quad (8)$$

Thus, the formula for calculating the contribution of each factor to the CE of subsector i in year t can be derived as follows.

$$\Delta CE_{TIOV_i} = \Delta TIOV \times I_i^{t-1} \times T_i^{t-1} + \\ + \frac{1}{2}\,\Delta TIOV\,(I_i^{t-1} \times \Delta T_i + T_i^{t-1} \times \Delta I_i) + \\ + \frac{1}{3}\,\Delta TIOV \times \Delta I_i \times \Delta T_i \quad (9)$$

$$\Delta CE_{I_i} = TIOV^{t-1} \times \Delta I_i \times T_i^{t-1} + \\ + \frac{1}{2}\,\Delta I_i\,(TIOV^{t-1} \times \Delta T_i + T_i^{t-1} \times \Delta TIOV) + \\ + \frac{1}{3}\,\Delta TIOV \times \Delta I_i \times \Delta T_i \quad (10)$$

$$\Delta CE_{T_i} = TIOV^{t-1} \times I_i^{t-1} \times \Delta T_i + \\ + \frac{1}{2}\,\Delta T_i\,(TIOV^{t-1} \times \Delta I_i + I_i^{t-1} \times \Delta TIOV) + \\ + \frac{1}{3}\,\Delta TIOV \times \Delta I_i \times \Delta T_i \quad (11)$$

ΔCE_{TIOV_i} represents the change in TIOV of the textile and clothing industry from year t–1 to year t, ΔCE_{I_i} represents the change in the share of the TIOV of sub-industry i in the TIOV of the textile and clothing industry from year t–1 to year t, and ΔCE_{T_i} is expressed as the intensity of CE in sub-industry i from year t–1 to year t.

Data Sources

According to China's national economic industry classification method, China's textile and clothing industry classification includes three sub-sectors: MT, MTC and MCF. The TIOV and energy consumption data of enterprises above the designated size in Wenzhou's textile and clothing industry and sub-industries were obtained from the 2005–2019 Wenzhou Statistical Yearbook. Given the inflation and other factors that influence the constantly changing prices, the gross production value of Wenzhou's textile industry was compared with its energy consumption which was calculated by the TIOV comparable price using 2004 as the base period. The nomenclature comparison is presented in table 3.

Table 3

NOMENCLATURE COMPARISON

Abbreviation	Detailed Name
CE	Carbon emission
TIOV	Total industrial output value
MT	Manufacturer of textiles
MTC	Manufacturer of textile wearing clothing, footwear and caps
MCF	Manufacturer of chemical fibers

RESULTS AND DISCUSSION

Descriptive analysis

The change trends of Wenzhou's textile and clothing industry's TIOV from 2004 to 2018 are shown in figure 1. The TIOV of Wenzhou's textile and clothing industry demonstrates an overall trend of rapid increase, smooth fluctuations and slow decline. The TIOV from 2004 to 2010 shows a rapidly increasing trend from 183.4 thousand dollars in 2004 to 667.5 thousand dollars in 2010, with an average annual increase of 24.02%, and the TIOV reached its peak in 2010. The TIOV fluctuated gently from 669.0 thousand dollars in 2011 to 470.2 thousand dollars in 2014 and exhibits a slow downward trend from 715.4 thousand dollars in 2015 to 583.9 thousand dollars in 2018, indicating an average annual decrease of 6.55%. In 2017, the TIOV was the smallest at 502.9 thousand dollars.

The CEs increased first and then decreased. The CE from 2004 to 2006 shows an upward trend, i.e., from 100.56 Kt in 2004 to 136.58 Kt in 2006, indicating an average annual growth of 16.5%, and CE reached the peak in 2006. The CE from 2007 to 2018 shows a downward trend, i.e., from 136.80 Kt in 2007 to 68.06

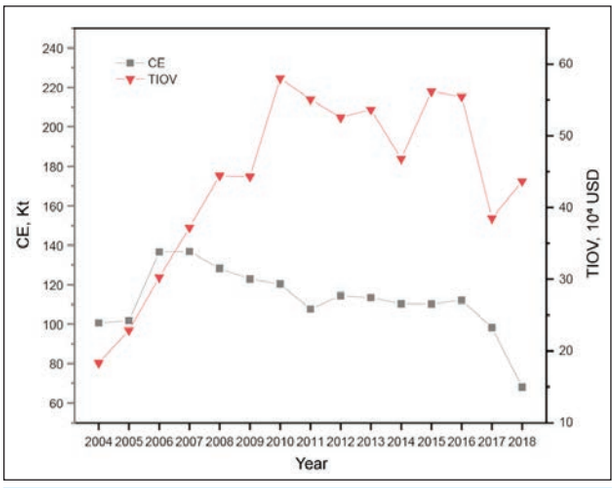

Fig. 1. TIOV and CE of Wenzhou's textile and clothing industry from 2004 to 2018

Kt in 2018, indicating an average annual decline of 6.15%. In 2018, the lowest CE was 68.06 Kt.

Decoupling analysis

The decoupling relationship between the CE and economic growth of Wenzhou's textile and clothing industry is shown in table 4. Table 4 shows that the decoupling state is generally good. From 2005 to 2018, 9 years displayed decoupling (5 years of absolute decoupling, and 4 years of relative decoupling), and 5 years exhibited no decoupling. The most recent five years, i.e., four of the five years from 2014 to 2018, displayed decoupling.

The year 2005 to the year 2007 showed no decoupling, 2008–2011 alternately presented a shock wave decoupling state of 'relative decoupling–absolute decoupling', and 2012 and 2016 were non-decoupling.

The relative decoupling states were observed for 2008, 2010, 2013 and 2015, and the absolute decoupling states were noted for 2009, 2011, 2014, 2017 and 2018.

From 2005 to 2007, Wenzhou's textile and clothing industry developed rapidly. Driven by international and domestic demands, China's entry into the World Trade Organisation (2001) and other factors, Wenzhou's textile and clothing industry's production capacity rapidly increased at an annual rate of more than 20%. Wenzhou, as an important textile and clothing production and export trade city in China, experienced long-term extensive economic growth and had a carbon-based energy consumption structure that led to its high CE. Therefore, the decoupling state at this period was not decoupled. Thus, the coupling relationship between CEs and economic growth was not completely broken.

From 2008 to 2018, 9 years were decoupling, and 2 years were non-decoupling (2012 and 2016). During this period, Wenzhou's textile and clothing industry's economic growth and CE were in a state of decoupling. Firstly, it was in the '11th Five-Year Plan' of China's textile industry (2005–2010), that China's textile and clothing industry's requirements for energy conservation, emission reduction and environmental protection were strengthened. Wenzhou City also actively responded to the call of the state. For example, 'Guiding Opinions of the People's Government of Zhejiang Province on Deepening the Remediation and Promotion of the Heavy Pollution and energy-consuming Industries in the 12th Five-Year Period' [52] and 'Wenzhou the Notice on Comprehensive Implementation Plan for Comprehensive Work on Energy Conservation and Emission Reduction' [53] were proposed for energy-saving technological transformation, with approximately 10 key energy-saving projects, such as textiles, printing and dyeing, and to promote the energy-saving actions of key energy-using enterprises; 'Opinions on Strengthening the Elimination of Backward Production Capacity' [54]

Table 4

DECOUPLING STATE BETWEEN THE CE AND THE ECONOMIC GROWTH OF WENZHOU'S TEXTILE AND CLOTHING INDUSTRY FROM 2004 TO 2018

Year	*t*	*g*	D_r	Decoupling state
2005	–0.0123	0.2477	–0.0621	non-decoupling
2006	–0.3416	0.3227	–1.4002	non-decoupling
2007	–0.0016	0.2289	–0.0085	non-decoupling
2008	0.0625	0.1951	0.3827	relative decoupling
2009	0.0417	–0.0032	–12.8962	absolute decoupling
2010	0.0211	0.3092	0.0895	relative decoupling
2011	0.1056	–0.0505	–1.9843	absolute decoupling
2012	–0.0626	–0.0461	1.2947	non-decoupling
2013	0.0080	0.0209	0.3928	relative decoupling
2014	0.0276	–0.1277	–0.1887	absolute decoupling
2015	0.0012	0.2009	0.0070	relative decoupling
2016	–0.0186	–0.0131	1.4007	non-decoupling
2017	0.1247	–0.3058	–0.2832	absolute decoupling
2018	0.3071	0.1339	2.6001	absolute decoupling

required the textile and clothing industry to eliminate printing and dyeing production lines with an annual processing capacity of fewer than 30 million meters and backward chemical fibre production capacity. Secondly, owing to the strict environmental access standards, Wenzhou strictly implemented the system of linking construction project environmental assessment and approval to regional environmental quality and pollution emission reduction performance and the total balance policy and substitute reduction standards of 'bringing the old with the new', 'increasing production and reducing pollution' and 'regional reduction and substitution'. Thirdly, the environmental supervision of the pollution sources of the gas-related textile and clothing industry was strengthened. Enterprises that emit air pollutants should set up air pollutant discharge outlets by laws, and relevant regulations and adopt effective waste gas treatment measures to reduce CEs and increase industry energy utilisation. Enterprises that could not stably meet the energy utilisation rate of the industry should take measures, such as clean production transformation, intensive pollution control and remediation and transformation within a time limit. Many factors cause CE and economic growth to be decoupled at this stage. Environmental pressures and CEs decreased as the TIOV increased.

The years 2012 and 2016 were not decoupled state. In 2012, the world economy slowed, the economic situation was bad and complicated, and international trade faced great pressure. Wenzhou's textile and clothing industry faced pressure from the continuous growth of domestic textile demand and the tight textile capital, and the CE increased significantly due to the long-term extensive economic growth model. In 2016, the growth rate of China's textile and clothing industry tended to be flat, and the profit margins were compressed. Wenzhou's textile and clothing industry is also affected by many unfavourable factors, such as sluggish domestic and foreign market demands, intensified industry competition, increased resource and environmental constraints, rising production costs and the emergence of new Internet-based business competition models. These and long-term high-speed and unbalanced development have led to problems, such as high low-end production capacity, irrational supply and demand structure and insufficient technological innovation, especially the relative increase in CE caused by companies in the industry with poor product quality, high chemical consumption, high energy consumption and weak production capacity. The CE of Wenzhou's textile and clothing industry increased in 2016 by 1.86% compared to that 2015. Therefore, the states of decoupling during these two years did not seem ideal, that is, they were both in the non-decoupling state.

Laspeyres factor decomposition

The CE of Wenzhou's textile and clothing industry from 2004 to 2018 was decomposed by the Laspeyres factor decomposition method. The three main factors included the industrial scale effect (ΔCE_{TIOV}), the industrial structure effect (ΔCE_I) and the technology level effect (ΔCE_T). The calculation results are shown in table 5 below in which the total effect of the CE of Wenzhou's textile and clothing industry from 2004 to 2018 pulls first and then suppresses, and overall pulling and suppressing trends can be observed from 2004 to 2010 and from 2010 to 2018, respectively. Figure 2 shows that the cumulative effect of industry size is positive for 2004–2018, and the cumulative effect of industry structure and technology level is negative for 2010–2018.

Table 5

CE FACTORS DECOMPOSITION OF WENZHOU'S TEXTILE AND CLOTHING INDUSTRY DURING 2004–2018

Year	ΔCE_{TIOV}	ΔCE_I	ΔCE_T	ΔCE
2005	2.45	–0.21	–0.65	1.59
2006	3.41	–0.04	0.21	3.57
2007	3.35	0.08	–2.05	1.38
2008	3.07	–0.07	–1.52	1.48
2009	–0.16	0.03	–0.46	–0.60
2010	3.85	0.06	–1.81	2.10
2011	0.02	–0.04	–0.47	–0.49
2012	–0.52	–0.02	0.02	–0.52
2013	0.62	0.07	–0.21	0.47
2014	–1.39	–0.04	0.26	–1.16
2015	2.00	–0.22	–0.28	1.50
2016	–0.08	0.05	–0.23	–0.25
2017	–3.67	–0.05	0.08	–3.64
2018	1.26	0.02	–1.76	–0.47
sum	14.22	–0.38	–8.88	4.96

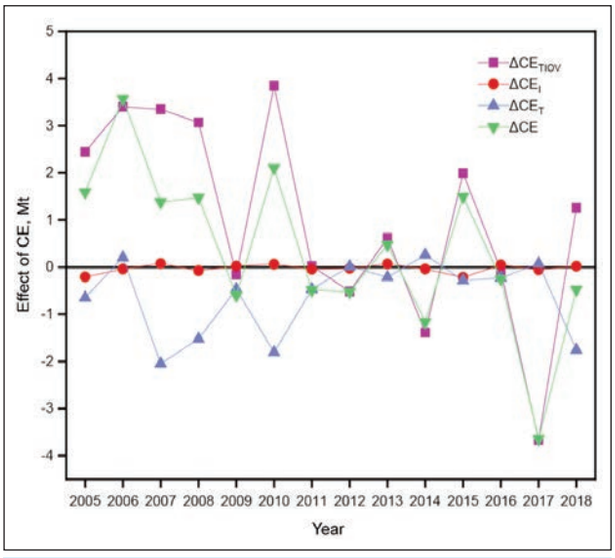

Fig. 2. CE effect decomposition of Wenzhou's textile and clothing industry during 2004–2018

Overall, the industrial-scale effect is positively correlated with the impact of CE in the textile and clothing industry. The CE contributed by the industrial-scale

effect in the textile and clothing industry from 2004 to 2018 was 14.22 Mt, and the increase in CE during the eight years was more than the total increase in CE in the same year (figure 2). From 2006 to 2009, the economic development of Wenzhou's textile and clothing industry declined because of two reasons. Firstly, in 2008, China's textile and clothing industry was affected by the financial crisis, the industry-wide economic growth was slow, the MT output growth was slow, and the MTC and MCF output regressed. Correspondingly, the cumulative industrial-scale effect of the three reduced the CE of the textile and clothing industry. Secondly, during the 11th Five-Year Plan period (2006–2010), China had strengthened energy conservation, emission reduction and pollution control, and the Wenzhou Municipal Government issued the '2007 Wenzhou City Rectification of Illegal Sewage Enterprises to Protect the Health of the Masses Environmental Protection Special Action Work Plan' [55], which conducted comprehensive inspections and clean-ups of printing and dyeing enterprises, specifically, enterprises with imperfect pollution control facilities, inability to achieve stable discharge standards and causing serious environmental pollution should all stop production for rectification. From 2010–2018, the cumulative industrial-scale effect was negative, because during the 12th Five-Year Plan period (2010–2015), 'Implementation Plan for Deepening the Regulation and Promotion of Heavy Pollution and High Energy Consumption Industries in Wenzhou During the 12th Five-Year Plan Period' [56] emphasised the resolute closure of small-scale, high-energy consuming, heavy-pollution emitting enterprises and production lines annually. Several companies with a relatively backward production capacity that does not have the advantage of environmental protection, have high pollutant emission intensity and low value-added products were being eliminated. The shutdown of enterprises partly led to the decline in the TIOV of the textile and clothing industry. Meanwhile, in 2011 the developed economies recovered slowly, the decline of textile exports in the international market, coupled with rising labour and energy costs, resulted in a slow economic development trend of the textile and clothing industry from 2011 to 2013. In 2016, the Wenzhou government issued the 'Wenzhou Heavy Pollution Industry Remediation and Enhancement of the Three-Year Action Plan (2016–2018)' [57] according to the 'shut down and eliminate a batch, gather a batch into a park and upgrade a batch' requirements to strengthen pollution prevention and control and ensure strict law enforcement supervision. Consequently, the 2016–2017 industrial-scale effect reduced the contribution value of CE to the textile and clothing industry.

The industrial structure effect on the CE of the textile and clothing industry is small. The cumulative effect of industry structure reduced the CE of the textile and clothing industry by 0.38 Mt from 2004–2018. The industry structure effect led to the largest reduction of CE in the textile and clothing industry in 2015, i.e., 0.22 Mt, and the largest increase of CE in 2007, i.e., 0.08 Mt. The industrial structure of the textile and clothing industry in Wenzhou from 2004–2018 is shown in figure 3. The trend of the economic share of the MT is decreasing, the trend of the economic share of the MTC is relatively flat, and the trend of the MCF is increasing. These trends can be attributed to the following reasons: it is difficult to treat the MT because of its long process chain, a large amount of input chemicals, a large amount of discharge of industrial wastewater and great variation of water quality; the MTC consumes less energy and accounts for a smaller proportion of the CEs; the TIOV of MCF accounts for less of the TIOV of the textile and clothing industry, and its CE is correspondingly smaller. The Wenzhou government has made the following efforts to reduce pollution in the textile and clothing industry. 'The Opinions of Wenzhou People's Government on Strengthening the Work of Eliminating Backward Production Capacity' [58] emphasised the elimination of backward production capacity in the textile and clothing industry, such as the elimination of printing and dyeing production lines whose annual processing capacity is less than 30 million meters; 'Notice of Wenzhou People's Government on the Three-Year Action Plan (2013–2015) for the Elimination of Backward Production Capacity of Wenzhou City' [59] (Notice of Wenzhou People's Government on the Three-Year Action Plan (2013–2015) for the Elimination of Backward Production Capacity of Wenzhou City) (Notice of Wenzhou People's Government on the Three-Year Action Plan (2013–2015) for the Elimination of Backward Production Capacity of Wenzhou City) strengthened the elimination of the printing and dyeing industry, and planned to eliminate 21.5 million meters of backward production capacity in the printing and dyeing industry by 2015; 'Three-Year Action Plan for Upgrading and Developing Wenzhou's Garment Industry (2014–2016)' [60] proposed the

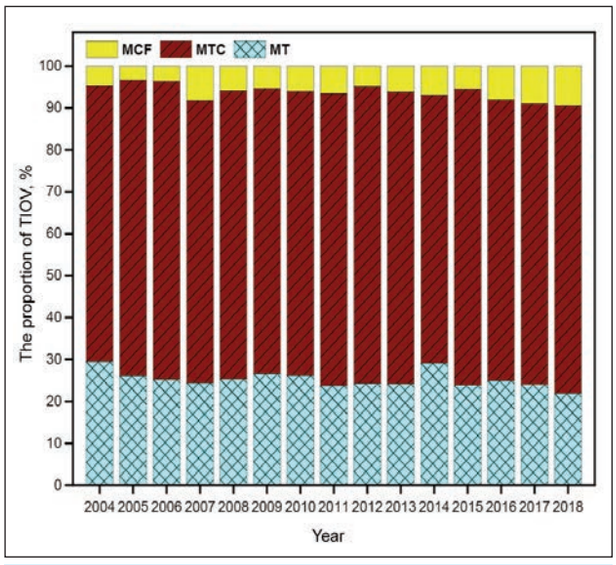

Fig. 3. The industrial structure of Wenzhou's textile and clothing industry from 2004 to 2018

vigorous promotion of the construction of industry-supported fashion blocks and the innovation in marketing models, moving towards fashion and branding to promote the transformation and improvement of the clothing industry. Overall, optimising and adjusting the structure of the industry, promoting brand marketing and strengthening brand building promote the industry structure effect on the suppression of CE in the textile and clothing industry.

The contribution of the cumulative technology level effect on CE is smaller with 8.88 Mt than that of the industrial structure effect. Specifically, the cumulative technology level effect is obvious from 2004 to 2010, and the suppression effect is moderate from 2010 to 2018. The cumulative technology level effect had the best suppression effect on CE in 2007, with 2.05 Mt, followed by those on CE in 2010 and 2018, with 1.81 and 1.76 Mt, respectively. Since the 11th Five-Year Plan (2006–2010), the technical transformation of Wenzhou printing and dyeing enterprises has been increasing, low-energy consumption and high-efficiency equipment have been utilised in the production process of the textile and clothing industry, and the strict control of production emissions has reduced the CE of the textile and clothing industry to a certain extent. Accordingly, the Wenzhou government issued the 'Notice of 11th Five-Year Plan Industrial Upgrading Plan' [61], proposing that the MTC should adopt international advanced technology and process equipment. During the 12th Five-Year Plan period (2011–2015), Zhejiang Province focused on strengthening key common technology research and improving the creative design to increase the added value of products. Technological progress has been used to upgrade the backward production capacity of the textile and clothing industry to reduce energy consumption, protect the environment and ensure quality. Wenzhou City advocates prioritising the development of low-toxicity, low-pollution and low-energy alternative and clean production processes and encourages the use of advanced, environmentally friendly production processes and equipment [56]. This advocacy has kept the cumulative effect of technology level contribution to the CE value of the textile and clothing industry flat. In the 13th Five-Year (2015–2020) period, given the few shortcomings of the Wenzhou textile and clothing industry technology assembly, the Wenzhou government directed the 'Wenzhou Garment Industry Promotion and Development Plan (2014–2020)' [62] and proposed the garment technology development priorities mission to improve product quality, promote the integration of garment production supply chain information, support enterprise technology transformation, improve the level of innovative design, and support the establishment of an enterprise design research and development centre [58]. Given the intensive and difficult protection of intellectual property rights in industries, such as shoes and garments, the garment chamber of commerce was established in Wenzhou City to support the new clothing brand enterprise and cultivate the development of designers. Therefore, the suppression effect of the technology level effect on CE from 2015 to 2017 was robust, and the suppression effect of development in 2018 reached the maximum.

Figure 4 shows the energy structure of Wenzhou's textile and clothing industry from 2004 to 2018. Among the six energy sources, raw coal, electricity and diesel oil are the main contributors to the energy consumption of the textile and clothing industry in Wenzhou, with raw coal and electricity as the main contributors. During the sample period, the proportion of electricity consumption increased, the proportion of raw coal and diesel consumption declined, and the proportion of other energy sources did not change significantly. Among the various energy sources, the CE coefficient of raw coal was second only to coke; the long-term thermal power structure in China placed the CE coefficient of electricity third only to coal [63]. In other words, the electricity and coal-dominated energy sources in Wenzhou's textile and clothing industry contribute a large amount of CE. The Wenzhou government has made many efforts to save energy and reduce emissions. The following is an example from three periods. During the 11th Five-Year Plan period (2005–2010), the office of the Wenzhou municipal people's government issued the 'Notice on Implementation Plan for the Comprehensive Work of Promoting Energy Conservation and Emission Reduction in Wenzhou' [64] that proposed to promote the adjustment and optimisation of the energy structure. Specific measures include promoting the clean and efficient use of coal, continuously optimising the electrical structure, and accelerating the research on strategies for the use of renewable energy, including wind power, solar power, waste incineration and straw power. During the 12th Five-Year Plan period (2010–2015), 'Wenzhou's Energy Development 12th Five-Year Plan' proposed the following development goals: enhance the energy supply capacity, build the province's important electric energy production base,

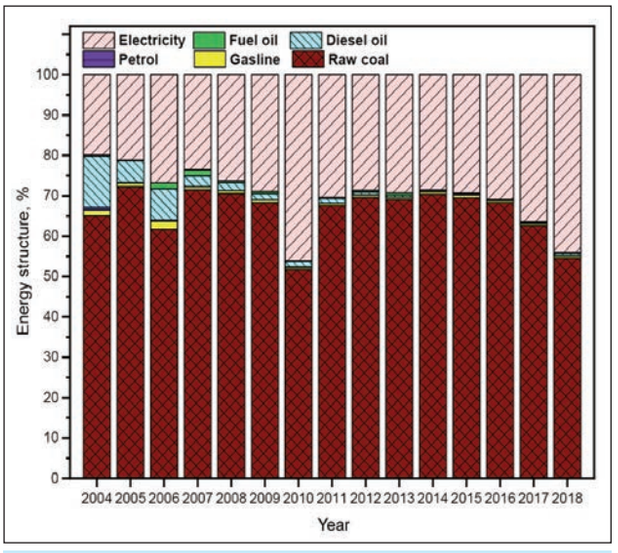

Fig. 4. Energy structure of Wenzhou's textile and clothing industry

build the province's new energy development and utilisation demonstration zone, and build the province's important energy equipment industry base. During the 13th Five-Year Plan period (2015–2020), the office of the Wenzhou municipal people's government issued the 'Notice of the 13th Five-Year Plan for Energy Development in Wenzhou' [65] that focused on promoting wind power, a new generation of biofuels and other technological innovation, vigorously developing non-fossil energy, effectively strengthening the clean utilisation of coal, and promoting the implementation of electric power substitution.

CONCLUSIONS

CE is an important factor in measuring the sustainable development of the region. This study accounts for and analyses the relationship between the CE and economic growth of the textile and clothing industry in Wenzhou and the three factors that affect the CE of the textile and clothing industry, providing a reference for the formulation of energy policies and sustainable development in Wenzhou. The conclusions of this study are as follows.

- Wenzhou's TIOV generally shows a fluctuating trend. The TIOV from 2004 to 2008 shows a continuous upward trend, with an average annual growth of 24.78%. The TIOV from 2008 to 2018 show downward and then upward trends, with the largest TIOV in 2015 at 715.4 thousand dollars and the highest and lowest gross values of output from the textile and garment industry in 2010 at 580.2 thousand dollars and in 2004 at 183.44 thousand dollars, respectively.
- The decoupling status of CE and economic growth in Wenzhou's textile and clothing industry from 2005–2018 is generally good, with 9 years out of 14 years of decoupling (5 years of absolute decoupling and 4 years of relative decoupling) and 5 years of non-decoupling. This condition is mainly attributed to the implementation of national energy conservation and emission reduction policies and the strengthening of environmental protection. Owing to the demand from both international and domestic markets, Wenzhou's a textile and clothing industry has flourished, with a growth trend in the gross industrial product, but it also leads to an increase in the CE. Wenzhou attaches great importance to energy-saving emission reduction and transformation and the upgrade of textile and clothing enterprises and helps enterprises transform and upgrade through technical subsidies, financial subsidies, intelligent manufacturing transformation and other measures. However, technical problems and insufficient capital have put pressure on several small and medium-sized enterprises, which have reduced the TIOV of the textile and clothing industry to a certain extent. Therefore, Wenzhou City should not only implement an energy-saving emission reduction policy but also should address the transformation of small and medium-sized enterprises according to the local conditions.
- The cumulative industrial-scale effect drives the increase of CEs, the industrial structure and technology level effects inhibit the increase of CE, and the technology level effect has a small influence on the CE of the textile and clothing industry. To reduce energy consumption, the textile and clothing industry must modify the industry structure and improve the technology level. Thus, new textile materials and green manufacturing technology should be the focus of research, eco-friendly chemicals must be developed to reduce the generation of pollutants from the source, and the use of natural gas, liquefied petroleum gas and other clean energy in the production process must be promoted. The influence of industrial-scale effect on CEs is the driving effect which means that the implementation of energy policy has not solved the problem of producing large amount of pollution caused by the production. Thus, Wenzhou's textile and clothing industry should expedite the adjustment of the industrial structure and focus on promoting independent innovation capacity.

With the transformation of the global economic situation, the development of Wenzhou's textile and clothing industry is facing many opportunities and challenges. With the current industrial structure of China's textile and clothing industry, economic development inevitably brings environmental degradation and CE increase. Therefore, optimising the industrial structure remains the most important reform for Wenzhou's textile and clothing industry. Meanwhile, enterprises should enhance the concept of environmental protection and accelerate the development of a circular economy in the textile and clothing industry to achieve the reuse of waste from the production of textile products. Technology level effect is the core of CE suppression. Therefore, promoting the innovation of products and production technology; vigorously developing new materials, processes and technology; and enhancing the network of product production, intelligence and automation are necessary endeavours. The government should enhance the formulation of policies and standards, strictly supervise textile enterprises, strictly prohibit the input and output of serious polluting substances and reduce CEs from the source. Furthermore, the process of Wenzhou's clothing industry's branding and fashion must be accelerated, and international brands must be actively created for a good fashion atmosphere.

ACKNOWLEDGEMENTS

The authors acknowledge financial support from Zhejiang Academy of Ecological Civilization of Zhejiang Provincial Key Research Base of Philosophy and Social Sciences (20JDZD076), Zhejiang Provincial Natural Sciennce Foundation of China (LY21G030004), Zhejiang Provincial Natural Science Foundation of China (LQ22G030014), Zhejiang Provincial Philosophy and Social Sciences Planning Project (22NDQN228YB).

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Does a greener supply chain lead to enhance organizational performance? Insights from the textile sector of Pakistan

DOI: 10.35530/IT.073.03.1817

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ABSTRACT – REZUMAT

Does a greener supply chain lead to enhance organizational performance? Insights from the textile sector of Pakistan

In the supply chain environment, the significance of the ecosystem in textile industries is getting popular in today's world. The adoption of greener supply chain practices can enhance the organizational performance of the industries. From this perspective, this study aims to examine the impact of four determinants of the greener supply chain practices on organizational performance in the scenario of Pakistani textile industries. The data was collected from the (n=200) experts of textile companies from different cities including Faisalabad, Lahore, Karachi and Multan. The greener practices were identified through literature review and evaluated by applying the four independent variables including customer involvement, supplier involvement, environmental involvement and financial involvement. By using descriptive statistics and multiple linear regression analysis, the results depict that except for supplier involvement, the rest of the three independent variables were found significant in predicting organizational performance. This study bridges the gap to understand the relationship between different dimensions of green supply chain management (GSCM) and organizational performance. The major contribution of this from the theoretical side is that supplier involvement has a negative impact on organizational performance. Finally, the findings of this research would be helpful for concerned managers and policymakers in making decisions to adopt greener practices in achieving business excellence.

Keywords: *customer involvement, supplier involvement, environmental involvement, financial involvement*

Un lanț de aprovizionare mai ecologic duce la îmbunătățirea performanței organizaționale? Perspective din sectorul textil din Pakistan

În lanțul de aprovizionare, importanța ecosistemului în industriile textile devine populară în lumea de astăzi. Adoptarea unor practici mai ecologice pentru lanțul de aprovizionare poate îmbunătăți performanța organizațională a industriilor. Din această perspectivă, acest studiu își propune să examineze impactul a patru determinanți ai practicilor mai ecologice ale lanțului de aprovizionare asupra performanței organizaționale în scenariul industriilor textile pakistaneze. Datele au fost colectate de la experții (n=200) companiilor textile din diferite orașe, inclusiv din Faisalabad, Lahore, Karachi și Multan. Practicile mai ecologice au fost identificate prin revizuirea literaturii și evaluate prin aplicarea celor patru variabile independente, inclusiv implicarea clienților, implicarea furnizorilor, implicarea mediului și implicarea financiară. Prin utilizarea statisticilor descriptive și a analizei de regresie liniară multiplă, rezultatele arată că, cu excepția implicării furnizorilor, cele trei variabile independente rămase au fost considerate semnificative în preconizarea performanței organizaționale. Acest studiu reduce decalajul pentru a înțelege relația dintre diferitele dimensiuni ale managementului lanțului de aprovizionare ecologic (GSCM) și performanța organizațională. Contribuția majoră a acestui aspect din partea teoretică este că implicarea furnizorilor are un impact negativ asupra performanței organizaționale. În cele din urmă, concluziile acestei cercetări ar fi utile pentru managerii și factorii de decizie în cauză în luarea deciziilor de adoptare a practicilor mai ecologice în atingerea excelenței în afaceri.

Cuvinte-cheie*: implicarea clienților, implicarea furnizorilor, implicarea mediului, implicarea financiară*

INTRODUCTION

In Pakistan, the textile sector is the largest manufacturing sector and has achieved a strong position all over the world due to its remarkable contributions to providing sustainable products [1]. In the Asia Pacific region, Pakistan is considering the 8th largest exporter of textile commodities. This sector contributes 8.5% to the GDP of Pakistan and also employs about 45% of the total labour force in the country. In addition, this sector engages 38% of the manufacturing labours directly or indirectly in employment. Pakistan ranked as the 4th biggest manufacturer and exporter of textile-related products with the third largest spinning production capacity in the Asia Pacific region after China, Bangladesh and India and generates 5% of the global spinning capacity. According to the Pakistan economic survey (2019), the involvement of the textile sector in contributing to the nation's economy was worth the US $10042 million in the 2018–19 fiscal years. In the last two decades, supply chain management (SCM) grabs significant attention and the combination of end-to-end supply chain businesses

to meet the aggregate demands of final consumers [2, 3]. Buyers and suppliers are getting conscious of ecological and worldwide warming issues and are very alert about products exchanged. In the textile sector, companies are initiating different methods to get better the accomplishment of GSCM, particularly at the phase of procurement, processing, selling & reuses [4].

Hervani [5] defined a GSCM as the idea that includes green outsourcing, cleaner production, eco-friendly orientation, reverse logistics and recycling of resources. Sarkis [6] stated it as a combination of the deeds that includes invention strategy, all phases of industrial, circulation and all features of contrary logistic and indicated the closing's prominence. The combination of environmental activities and organizational performance has received cumulative consideration over current spans. The motivation behind this study is that the GSCM is comparatively innovative in Pakistan so applications are partial. In previous research, the effect of GSCM on organizational performance was investigated in-depth, whereas in textile perspectives, was not mentioned much [7].

A big gap exists in emerging economies because studies on the relationship between GSCM and organizational performance are mostly carried out in developed nations. Based on the aforementioned shortcomings, in this study, researchers identified four GSCM dimensions (customer involvement (external factor), supplier involvement (external factor), environmental involvement (internal factor) and financial involvement (internal factor) and aimed to examine the impact of these dimensions on organizational performance [8]. The result of these proportions was calculated on the organization's performance in the context of GSCM internal and external factors within the textile industry of Pakistan. Pakistan is of the rising countries so for the economic expansion of the country industrialization is a considerable issue.

Greener practices are being applied by all businesses across the globe to draw attention to the problems of ecological indignity and corporate culture. In Pakistan, there is a gap in a study on GSCM in a textile supply chain. In the emerging supply chain environment, the awareness of environmental conduct is grabbing attention in the minds of consumers. Textile companies across the world specifically in Pakistan are facing heavy pressure from buyers to reduce hazardous chemicals and implement greener practices throughout the supply chain. Based on our knowledge, it is assumed to be the first empirical study in this discipline from the context of the Pakistani textile sector. This study is an effort towards providing a better overview of the relationship between greener practices and organizational performance. In a developing country context, the idea is novel and meets the present need of the manufacturer of the textile sector. This research contributes to the theory by introducing the four variables i.e., customer involvement, supplier involvement, environmental involvement, and financial involvement. This study is an effort toward providing a better picture of the relationship between greener supply chain practices and checking the impact of variables on organizational performance using descriptive statistics and multiple linear regression analysis. The results outcomes of this research would be helpful for concerned stakeholders in making decisions to adopt greener practices in achieving business excellence. This problematic scenario raises the following research questions:

(1) What are the factors of greener supply chain practices affecting organizational performance in the context of the textile sector of Pakistan?

(2) How can supply chain/managers evaluate greener practices and check their impact on organizational performance?

(3) Do the outcomes become helpful for policymakers, stakeholders and supply chain managers to design business strategies?

To deal with the above-mentioned research questions, the objectives of this study are: 1) to explore the greener practices in the textile sector of Pakistan; 2) to analyse the impact of greener practices on organizational performance; 3) to recommend managerial and global implications for the concerned stakeholders.

LITERATURE REVIEW

The concept of greener practices in the supply chain is based on triple bottom lines including socio-economic and ecological parameters [9]. The greener supply chain practices come under the umbrella of sustainability. The literature regarding sustainability perspectives is to some extent well-developed but it still needs attention from researchers and academicians to fill the gap in the field of green supply chain [10]. Seuring [11] defined GSCM as the coordination of information, raw material flows and money through the holistic supply chain in meeting the demand of customers considering the production of environment-friendly products and services. GSCM is the way to integrate ecological conducts into firm supply chain processes. Firms can build competitive priorities in operations and productions for implementing greener concepts/practices. Similarly, the initiation of greener practices in the supply chain environment enables firms not only to offer competitive priorities through capacities differentiation and cost leadership that would not be easy for their competitor to imitate but also to find out new market opportunities. Tsoulfas and Pappis [12] believed that the adoption of greener concepts in managing supply chain systems and designing green product approaches can reduce wastage. GSCM by the combination of supply chain management strategies in addition to dealings made in reaction to hesitations linked to the casual environment concerning the strategy, manufacture, dissemination use and re-use of the company's

merchandise. GSCM shields the entire stages of the goods existence sequences of designing towards circulation including distribution and all other required stages to the usage of the product by consumers and at last, its removal by the side of the conclusion of the goods existence sequence. GSCM is the addition of an 0ecological" element on the way to SCM involving all stages such as ecological design, ecological production, ecological planning and ecological operations [13]. A professional method that pursues to reduce a product to reduce a manufactured good's ecological in addition to societal influences is called GSCM. In this context, the activities are considered a threat to the environment. In developing countries just like Pakistan application of GSCM is still in its starting phase. Liu [14]concluded research based on high-order theory and green supply chain management theory, this research took 251 manufacturing enterprises from China, the United States and Vietnam as samples to gain data. Khan and Qianli [15] examined the effect of five determinants of the green supply chain practices on organizational performance from the perspective of Pakistani manufacturing companies. The textile industry played a very significant role in the financial system of the country particularly India, as India has been a developing country. The literature relevant to greener practices in the textile supply chain is in the initial phases of development, with related empirical studies and theoretical evidence (figure 1).

THEORETICAL MODEL

The theoretical model and hypothesis influencing organizational performance have been shown in figure 2. The four constructs have been identified using extensive reviews of literature and inputs from supply chain professionals of different firms. In addition, the description of the constructs selected in the proposed model is given in table 1.

HYPOTHESIS DEVELOPMENT

Customer involvement and organizational performance

In the competitive markets, customers are considering the main stakeholders in the green supply chain and can pressurize the organizations to minimize the toxicity of their processes [16]. Generally, customers are called kings because they can influence organizations to adopt greener practices. In simple words, customers' involvement plays a significant role in implementing greener practices in managing the supply chains [17, 18]. Stronger customer involvement moves the firms to enhance marketing and financial

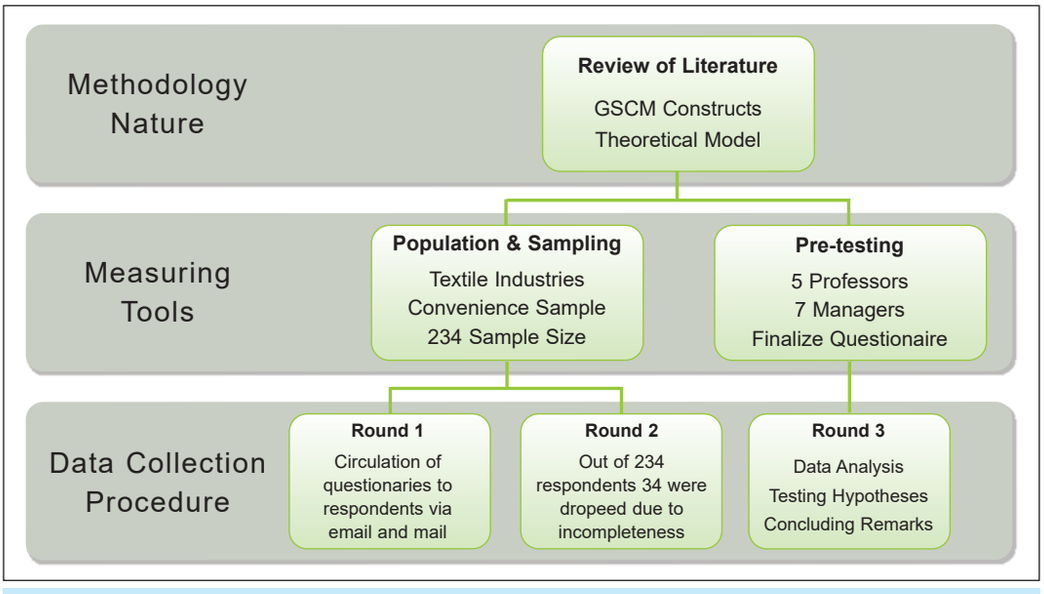

Fig. 1. Proposed research plan

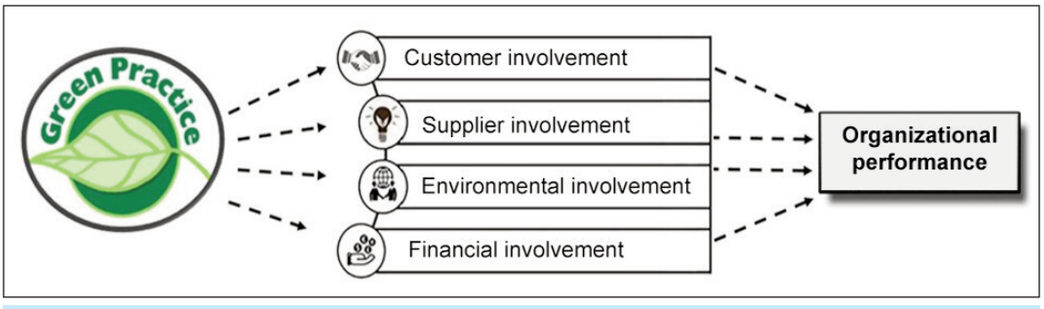

Fig. 2. Research model and hypothesis influencing organizational performance

Table 1

FACTORS OF GREENER PRACTICES AND DESCRIPTIONS		
Dimensions	**Variables**	**Descriptions**
Customer Involvement	CI_1	Cooperation with customers to achieve environmentally-friendly goals
	CI_2	Integration with customers to use green packing
	CI_3	Cooperation with customers to develop cleaner production.
	CI_4	Eco-friendly practices followed for the satisfaction of customers
	CI_5	For customers' satisfaction, avoiding the usage of hazardous products
	CI_6	Recycling the wastage is highly appreciated by our customers
Supplier Involvement	SI_1	Cooperation with suppliers to achieve environmental objectives
	SI_2	Providing decision specifications to suppliers to follow eco-practices
	SI_3	Environmental audit for vendors' internal supply chain system
	SI_4	Supplier adoption of greener initiatives to meet customers' demand
	SI_5	Suppliers focus to reduce the consumption of toxic/harmful materials
	SI_6	Compliance with ISO 14000 standards.
Environmental Involvement	EI_1	Greener practices took measures to lower the consumption of water, electricity and gas during the production or disposal processes
	EI_2	Greener practices help in recycling, reusing and remanufacturing materials or parts.
	EI_3	Greener practices redesigned production and operational processes to improve environmental efficiency.
	EI_4	Cooperation with customers for eco-design?
	EI_5	Greener practices decreased the consumption of hazardous/harmful/toxic materials.
	EI_6	Greener practices also in applying religious environmental regulations.
	EI_7	Reduce the frequency of environmental accidents
	EI_8	ISO 14000 certification
	EI_9	Applying green packing of products and design of products for reduced consumption of materials/energy
	EI_{10}	Use of chemicals to avoid hazardous products
Financial Involvement	FI_1	Greener practices decreased the cost of purchasing materials.
	FI_2	Greener practices decreased fees for wastes treatments
	FI_3	Greener practices decreased the cost of production and consumption
	FI_4	Greener practices improved/increased the overall efficiency of our firm
	FI_5	Greener practices decreased fines for environmental violation
	FI_6	Greener practices have increased the quality of products by reducing overall costing
	FI_7	Greener practices improved the supply chain responsiveness
	FI_8	Greener practices help in decreased the level of inventory

performance. Vaccaro and Echeverri [19] suggested that creating corporate transparency by the organization can encourage customers to actively participate in eco-friendly practices and further collaborate with the enterprises. In the supply chain system, manufacturers solely cannot recognize the environment-friendly requisites of their customers without understanding their needs, but also their positive inputs in terms of coordination and cooperation.

Hypothesis 1_a: Customer involvement has not significantly influenced organizational performance in the textile sector.

Hypothesis 1_b: Customer involvement has significantly influenced organizational performance in the textile sector.

Supplier involvement and organizational performance

Green purchasing is a proactive approach to focusing on collaborating with suppliers to produce environmentally friendly products [20]. Supplier involvement/cooperation can improve the product quality and reduces waste minimization. Suppliers are the key actors in the supply chain and organizational performance based on their responsiveness as well as commitments towards order fulfilment. Manufacturers of textile firms solely can't establish an ecosystem without collaboration with suppliers. Undeniably, a strong manufacturer-supplier relationship leads to enhance social, economic and environmental performance [21].

Hypothesis 2_a: Supplier involvement has not significantly influenced organizational performance in the textile sector.
Hypothesis 2_b: Supplier involvement has significantly influenced organizational performance in the textile sector.

Environmental involvement and organizational performance

Environmental involvement is a firm's development of its environmental protection policies and targets to ensure the protection of the environment [22]. Environment management serves two basic purposes within the organization. The first is to formulate the compliance policies by following ISO 14000 standards and, the second is to change the personnel behaviour in order to establish a sustainable relationship with the environment. Kleindorfer et al. [23] elaborated that a competitive edge is where enterprises introduce eco-design uniqueness in item development and improve value addition in developing inimitable production capacities, and acquire royalties for licensing greener technology which will lead the firms towards achieving sustainable competitive priorities.
Hypothesis 3_a: Environmental involvement has not significantly influenced organizational performance in the textile sector.
Hypothesis 3_b: Environmental involvement has significantly influenced organizational performance in the textile sector.

Financial involvement and organizational performance

The present studies depict that there is a contradictory viewpoint among some researchers regarding the improvement of financial gains using greener practices [24]. Rao and Holt [25] believe that the GSCM practices enhance organizational performance within an enterprise. Few researchers have suggested that GSCM practices have no significant impact on the financial performance of an enterprise, especially in short time periods [26]. It has been noticed by a few researchers that the lack of vigorous relationship between the adoption of GSCM practice and financial involvement is treated as a key hindrance [27]. These were contradictory views about how GSCM practices affect organizational performance postulates. The organizational performance of a company can be enhanced if its costs of production are minimized.
Hypothesis 4_a: Economic performance has not significantly influenced organizational performance in the textile sector.
Hypothesis 4_b: Economic performance has significantly influenced organizational performance in the textile sector.

MATERIALS AND METHODS

Scenario under study

This research study targeted the textile sector of Pakistan to investigate how greener practices affect organizational performance. Due to the increase in toxic waste, presently the country has encountered a big change in the climate. Therefore, greener practices are considered an integral part of strategic management within textile industries. This study considered four variables of green supply chain practices, i.e. (i) customer involvement, (ii) supplier involvement, (iii) environmental involvement and (iv) financial involvement. The research sample was taken from textile industries which are adopting greener practices. Several textile industries were considered to distribute questionnaires only among managers who had direct involvement with the supply chain process. This included supply chain managers, production managers, marketing managers, finance managers, logistics managers and industrial engineers.

Questionnaire development

The well-structured questionnaire was formulated to take the data from respondents in the textile industry. Due to a lack of awareness regarding implementing GSCM practices in the textile sector of Pakistan, a direct response data collection approach was given preference over sending the questionnaires through social media. While seeking inputs from the respondents, the data collection teams facilitate the respondents in a situation if they confronted any complexity regarding the questions' understanding. The questionnaire used in this study includes four GSCM practices and these practices are further divided into thirty-nine items. The data collection took three months and fifteen days [28].

Sample design and measurement tools

The research data was analysed through appropriate statistical techniques and then interpret the final results. The study response has been considered as the frequency of responses in terms of interviews conducted in a study. The total sample size was (n=200) but data was collected from approximately 234 respondents of which the authentic was only 200 (table 2).
Analysis was made on the 200 authentic that also meet to sample size of the research. Descriptive statistics are describing the economic features of sampled data. The descriptive statistics method was providing summaries of sample measures and samples. Multiple linear regression analysis is performed to test the suggested hypothesis. In addition, it is used for finding the percentages and average frequencies through graphic analysis by the following formula.

$$\overline{X} = \sum X/N \quad (1)$$

where $\overline{X}$ is airthmetic mean, $\sum X$ = sum of all variables, N – total observations number.
The percentage was calculated through the following formula:

$$P = F/N * 100 \quad (2)$$

where P is percentage, F – frequency of the variables, N – total number of observations. Standard

Table 2

DEMOGRAPHICS ANALYSIS OF RESPONDENTS		
Demographics	**Frequency**	**Percent**
Type of textiles		
Spinning	8	4
Weaving	4	2
Dyeing	15	8
Stitching	169	84
Printing	4	2
Departments		
Supply Chain	30	15
Production	87	44
Marketing	43	21
Finance	9	5
Logistics	15	7
Engineering	16	8
Age group		
18–24	3	2
25–29	15	7
30–34	28	14
35–39	36	18
40–44	58	29
Above 44	60	30
Job Experience		
3–5 years	14	7
6–8 years	32	16
9–11	34	17
12–14	46	23
Above 14	74	37
No. of Employees		
100–500	8	4
301–500	18	9
501–700	9	5
701–1000	38	19
More than 1000	127	63

deviation expressed a quantity value of variations or distribution set of data how much the group value is different from its mean. The lowest standard deviation value explained that the value of the data set is closer to the mean value while the high value of standard deviation indicates that the data value spread away from the mean value.

$$S = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(X_i - \overline{X})^2} \quad (3)$$

where S is standard deviation, N – total number of observations, X_i represents each value of data, $\overline{X}$ represents mean of X_i.

RESULTS ANALYSIS

The results analysis is based on the reliability test, Pearson's correlation technique, exploratory factor analysis, and multiple linear regression method. The exploratory factor was conducted to check the impact of the underlying structure for the 39 questionnaire items on organizational performance. Regression analysis was employed for find the association among reliant and self-governing (dependent & independent) parameters for implementing line regression pattern using hypothesized equation. The relationship among reliant and self-governing parameters is given as:

$$OP = \beta_0 + \beta_1 CI_1 + \beta_2 SI_2 + \beta_3 EI_3 + \beta_4 FI_4 + e \quad (4)$$

where OP, CI_1, SI_2, EI_3 and FI_4 denote organizational performance, customer involvement, supplier involvement, environmental involvement and financial involvement respectively. In this equation, β_0 represents constants and e depicts error term in the model, whereas β_0 is slop and β_1, β_2, β_3 and β_4 are the coefficient. Organizational performance is a reliant i-e dependent parameter. Definite self-governing i-e independent parameters data were collected through a five-point Likert scale starting from (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree). Furthermore, the authors also computed Cronbach's alpha values of each variable used in the questionnaire. The overall reliability value of the scale was 0.886 of 39 loaded items to enhance clarity. Tables 3 and 4 show the items and variables used for reliability analysis.

In table 5, the researchers discussed the summary of hypothesis testing using multiple linear regression analysis for measuring organizational performance.

Table 3

RELIABILITY ANALYSES OF ALL VARIABLES		
Variables	**No of items**	**Cronbach's Alpha**
Organizational Performance	9	0.906
Customer Involvement	6	0.881
Supplier Involvement	6	0.703
Environmental Involvement	10	0.746
Financial Involvement	8	0.759
Total	39	0.886

Table 4

MEANS, STANDARD DEVIATION, STANDARD ERROR AND INTER-CORRELATIONS FOR ORGANIZATIONAL PERFORMANCE AND INDEPENDENT VARIABLES (N = 200)								
Variables	**Mean**	**SD**	**SE**	**OP**	**CI**	**CA**	**EI**	**EP**
OP	3.81	0.739	0.052	1				
CI	3.79	0.461	0.032	0.322**	1			
CA	3.80	0.484	0.034	0.283**	0.496**	1		
EI	4.04	0.483	0.034	0.426**	0.282**	0.258**	1	
EP	3.85	0.498	0.035	0.304**	0.351**	0.259**	0.266**	1

Note: *Significant p<0.05 (2-tailed); **highly significant p<0.01 (2-tailed).

Table 5

MODEL SUMMARIES USING MULTIPLE LINEAR REGRESSION ANALYSIS				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.423[a]	0.179	0.162	0.6768

Note: a – Predictors: (Constant), CI Customer Involvement SI Supplier Involvement, EI Environmental Involvement, FI Financial Involvement; b – Dependent Variable: OP Organizational Performance.

This table indicates that the R square value of this model is 17.9% which shows the fitness of the model. All the variables included in this study are influencing a 17.9% change in the dependent variable. Here the remaining change is due to other variables that were not included. The selected variable combinations were predicted by almost 17.9% of the total variance in predicting organizational performance F = 10.648, p<0.001, with given independent factors that statistically significantly predicted organizational performance except for supplier involvement in the given model. Hence, the coefficient of parameter estimates proposes that β "customer involvement" (0.375, p<0.05), β "environmental involvement" (0.175, p<0.05), and "financial involvement" β (0.239, p<0.05) affect the statistically significant impact on the dependent variable.

Furthermore, their three respective hypotheses (H1, H3, and H4) were supported, respectively. Whereas, supplier involvement (−0.104, p>0.05) has demonstrated a statistically insignificant effect on organizational performance. Hence, H2 was not supported. The second step in regression is "ANOVA" table 6 which includes "RSS (the regression sum of squares), residual sum of squares and TSS (total sum of squares along) with their D "(degree of freedoms)". Here in this ANOVA F=10.648 with a significance value of P = 0.000 shows that the model's overall fitness is very good. The (β) standardized coefficient of regression model explained the values of outcomes that create the in variable per unit change in values. This estimation allowed the other researchers to estimate the contribution of other outcomes (table 7).

In this research, multiple regression analysis was applied to conclude the research results. Where, OP, CI, SI, EI, and FI denote organizational performance, customer involvement, supplier involvement, environmental involvement and financial involvement respectively. The research finding indicated the adjusted R square that is a determinant of organizational performance (after GSCM implementation) with CI (customer involvement), CI (supplier involvement), EI (environmental involvement) and FI (financial involvement). The adjusted "R^2" is 17.9 percent of the total variation in OP (GSCM) can be described by CI, SI, EI, FI and 82.1 remaining due to other factors that are ignored in this research as this was done recently in the research of Liu [14] as he calculated the R^2 value nearly to the value found in this research. Furthermore, the model describes the overall significant and positive relationship between customer involvement, economic performance and environmental involvement at P = 0.000. The model indicates that customer involvement has a significant impact on organizational performance adoption as indicated by 0.003 significant value is less than 0.1 which is positively correlated with organizational performance. Per unit increase in customer involvement and increase in organizational performance by 0.375 units the effect of the independent variable remains constant.

Table 6

ANOVA					
Model	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig. *p* value**
Regression	19.490	4	4.872	10.648	0.000[b]
Residual	89.312	195	0.458		
Total	108.802	199			

Table 7

HYPOTHESIS UNDER CONSIDERATION FOR ORGANIZATIONAL PERFORMANCE						
Hyp.	**Predictors**	**B**	**Std. Error**	**T-Value**	**Sig. P Value**	**Remarks**
	(Constant)	0.366	0.545	0.672	0.000	-
H1	Customer Involvement	0.375	0.124	3.032	0.003	Supported
H2	Supplier Involvement	–0.104	0.116	0.895	0.372	Not Supported
H3	Environmental Involvement	0.175	0.112	1.564	0.019	Supported
H4	Financial Involvement	0.239	0.110	2.175	0.031	Supported

In total, hypotheses for customer involvement, environmental involvement and financial involvement are supported except for supplier involvement. The following equation highlights how to predict organizational performance using multiple linear regression analysis. M = 0.366 + 0.375 (CI) + 0.175 (EI) + + 0.239 (FI) – 0.104 (SI). This paper evaluates the impact of greener practices on organizational performance in the Pakistani textile context. Four dimensions of greener practices were examined including customer involvement, supplier involvement, environmental involvement, and financial involvement. Lastly, the outcome of the results indicates that except for supplier involvement, the rest of the three dimensions of greener practices have a significant and positive relationship with organizational performance, and these results have been validated by previous research including [28–30]. Furthermore, supplier involvement has a negative effect on organizational performance as greener materials are comparatively expensive than non-greener materials. In order to promote greener initiatives, textile organizations recently received no financial assistance from governmental authorities and regulatory bodies in the perspective of Pakistan.

DISCUSSIONS AND IMPLICATIONS

The results depict that customer involvement was found to be a key variable of organizational performance. Sezen and Cankaya [31] suggested that the involvement of customers reflected positively on the organizational performance of a textile supply chain. Undeniably, organizational objectives related to performance can be accomplished through successfully identifying the customer needs regarding greener concepts. Roy and Khastagir [32] mentioned that firms can gain monetary incentives through higher ecological performance due to truly involvement and perseverance of the strategic management in the adoption of greener practices in the supply chain. Customer involvement facilitates the concept of demand sustainability because organizations which forecast external customer demand can easily procure and manufacture the products. Furthermore, customers' involvement in the development of eco-friendly products not only facilitates environmental sustainability and organizations' environmental performance but also improves organizational performance in the long run. The Government bodies need to encourage eco-friendly products, support custom policies and try to reduce barriers regarding pollutant products. Textile firms in Pakistan are facing severe issues in the procurement of raw materials and resistance from suppliers as they are not implementing green practices. Due to awareness of eco-design products in the competitive markets, buyers are well-known for the hazardous effects and pollution generated by textiles industries in Pakistan. The policy-makers and authorized bodies in Government, as well as private sectors, have not been paying any reasonable compensation for green industries such as in terms of tax rebates or exemptions. Moreover, during the adoption of greener practices, industries dealing in green products are much more concerned about their customers because they are the key monetary source for their survival. Nowadays, most firms are conducting surveys to seek information about their customers' valuable input. The existing research studies also support the results of this study and ratify that the independent variable customer involvement or cooperation has a significantly positive impact on organizational performance. The results also show that environmental involvement has a significant impact on organizational performance. Industries cannot adopt environmental practices without adopting ISO 14000 standards and greening all manufacturing processes by eliminating the waste from their production processes. Textile firms should develop better buyer-supplier relations through collaborations and commitments in the area of the green supply chain. These kinds of collaborations might be strengthening the relations as well as satisfy the customer orders timely. Textile firms' managers need to enhance basic knowledge and skills relevant to green supply chain management. For this purpose, they must focus on the job and job capacity building programs in order to enhance firms' performance. In this study, the proposed developed model is expected to be applicable to any country to improve the organizational performance of organizations' end to end supply chain. The proposed model can be taken in a global context by following these steps: 1) a deeper investigation of GSCM literature and multiple linear regression analysis can help to check the impact of variables; 2) using the Cronbach alpha, the reliability of the variables can be checked for the analysis of factors of GSCM practices; 3) the results would be helpful to formulate the business strategy. It is suggested that the applicability of the model in the context of a different country, will generate a different result because every country has different economic, social, political, technical and environmental aspects. Furthermore, based on the findings, the results of this study would be helpful for the practitioners and industrialists in the establishment of an effective governance system that promotes the adoption of greener practices in improving the entire organizational performance. The green supply chain policies must support the business strategies and organizational capacities. The Government and regulatory bodies need to provide financial incentives to those textile firms which are applying the environmental standards. For this purpose, the government must encourage SMEs and provide capital subsidies on energy-efficient equipment. Finally, the social impact of this research is to improve the occupational health of workers [33–35].

CONCLUDING REMARKS

The results findings suggested necessary guidelines for practitioners to distinguish the impact of greener practices including external and internal factors on

organizational performance. In developing countries such as Pakistan, the basic aim of most textile industries is to enhance their production capacities, improve financial conditions, and reduce economic risk. Environmental sustainability has become a vital aspect to consider due to the current marketing needs of customers toward organic products. Therefore, organizations are much concerned to apply greener practices in their supply chain to ensure organizational progress. The greener practices considered in this research are customer involvement, supplier involvement, environmental involvement and financial involvement affecting organizational performance. This work deals with the impact of greener practices which can help textile exporters to enhance their organizational performance. This study supports experts by briefing the interrelationships between greener practices and organizational performance. Furthermore, the results of this research perceive that by adopting greener practices, the producers can reduce their operational costs and eventually will improve their organizational performance. The findings of this research would be a helping tool for the textile industries to implement greener practices. In this research, the authors included only four independent variables (customer involvement, supplier involvement, environmental involvement and financial involvement). The data was collected from the (n=200) experts of textile companies from different cities including Faisalabad, Lahore, Karachi and Multan in Pakistan. In future, more variables may be included like green physical distribution, investment recovery, and green logistics in the proposed model to evaluate the robustness among variables and further check the relationship with organizational performance.

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An overview on nanomaterials with magnetic properties used in the textile sector

DOI: 10.35530/IT.073.03.202176

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ABSTRACT – REZUMAT

An overview on nanomaterials with magnetic properties used in the textile sector

Nowadays, the world of materials around us has reached a new step in evolution. New materials with amazing properties and functions are innovated in our attempt to make our lives easier and turn the world into a better place for the future. The current generation of textile materials is based on innovative technologies and modern fibres, making them smarter and more technical than ever, giving to people the possibility to adapt to the conditions and evolution of this century.

Nanotechnology is a big contributor to the wide expansion of textile applications through the offered benefits and functionalities. It is used for the development of fabrics that are stronger, lighter, more durable or among others, capable of self-cleaning, self-repairing or resisting wrinkling.

The addition of magnetic nanomaterials, such as iron oxide or nanoparticles to textiles, either as coatings or as composite materials or as unique elements in industrial processes (e.g., in the dyeing process, in the wastewater treatment process), opens new possibilities for the improvement and future development of the textile sector.

This paper presents a summary of some of the latest developments regarding the types of magnetic nanomaterials, their functions, and applications in the textile industry and also the technologies used in different studies to manufacture textile materials with magnetic properties. Finally, the utility of the electrospinning technology to produce materials with full magnetic properties at the nano level and their usefulness in a series of applications proposed by researchers is demonstrated.

Keywords: *magnetic nanoparticles, functionalities, electrospinning, nanofibers, advanced materials*

O privire de ansamblu asupra nanomaterialelor cu proprietăți magnetice utilizate în sectorul textil

În prezent, lumea materialelor din jurul nostru a atins un nou pas în evoluție. Noi materiale cu proprietăți și funcții uimitoare sunt inovate în încercarea noastră de a ne face viața mai ușoară și de a transforma lumea într-un loc mai bun pentru viitor. Actuala generație de materiale textile se bazează pe tehnologii inovatoare și fibre moderne, făcându-le mai inteligente și mai tehnice ca niciodată, oferind oamenilor posibilitatea de a se adapta la condițiile și evoluția acestui secol.

Nanotehnologia este un important contribuitor pentru extinderea largă a aplicațiilor textile prin beneficiile și funcționalitățile oferite. Este folosită pentru dezvoltarea de țesături mai rezistente, mai ușoare, mai durabile sau, printre altele, capabile să se autocurețe, să se autorepare sau să reziste șifonării.

Adăugarea de nanomateriale magnetice, cum ar fi nanoparticulele de oxid de fier în textile, fie ca acoperiri, fie ca materiale compozite sau ca elemente unice în procesele industriei (de exemplu, în procesul de vopsire, în procesul de tratare a apei uzate), deschide noi posibilități pentru îmbunătățirea și dezvoltarea viitoare a sectorului textil.

În această lucrare, este prezentat un rezumat la unele dintre cele mai recente dezvoltări cu privire la tipurile de nanomateriale magnetice, funcțiile lor și aplicațiile din industria textilă, precum și tehnologiile utilizate în diferite studii pentru fabricarea materialelor textile cu proprietăți magnetice. În cele din urmă, este demonstrată utilitatea tehnologiei de electrofilare pentru a produce în întregime materiale cu proprietăți magnetice la nivel nano și utilitatea acestora într-o serie de aplicații propuse de cercetători.

Cuvinte-cheie: *nanoparticule magnetice, funcționalități, electrofilare, nanofibre, materiale avansate*

INTRODUCTION

Nanotechnology offers the textile field a huge potential for development, helping it to acquire great improvement and performance. The special properties of nanomaterials can provide high durable functions for fabrics and also efficiency and economic benefits. Nanotechnology can act in two ways on textiles, either the existing functionality of the textiles is improved or, entirely new properties or a combination of different functions can be attributed to them [1].

Special attention was directed to the nanoparticles (NP) of various complex topologies (e.g., nanorods, nanowires, nanotubes, nanocubes, etc.) that can be used as coatings on different textile structures or distributed in polymer matrices that are further processed into textiles. These NP can enhance the mechanical properties like toughness, abrasion resistance or tensile strength of the fabrics and [2] very importantly, do not affect the breathability or hand feel of the fabrics [3].

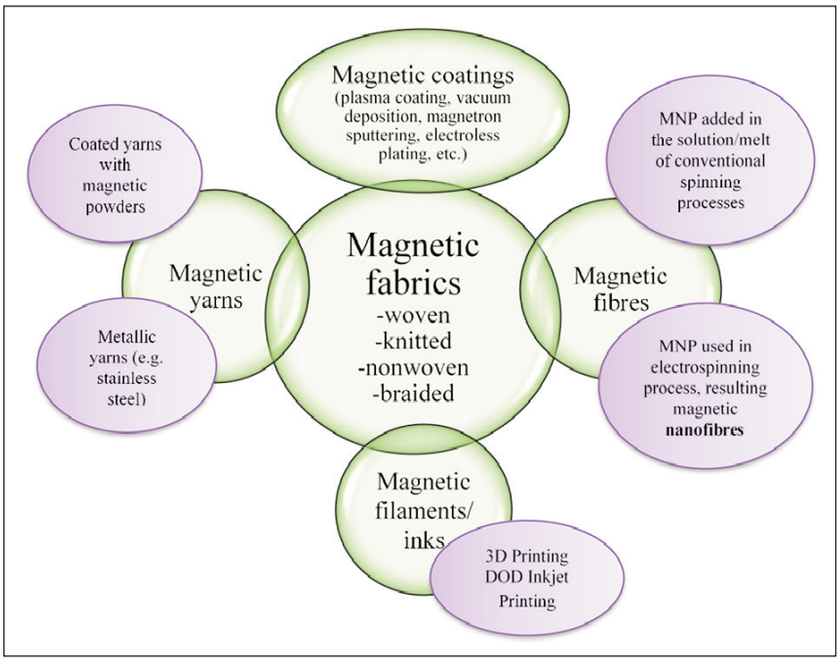

Fig. 1. Different methods for manufacturing textiles with magnetic properties

Magnetic nanoparticles (MNP) are a special class of nanoparticles that are based on pure metals, metal oxides, bi-component alloys or composites (metal core – protective metallic or non-metallic shell) and pose very impressive properties that offer the possibility to connect the textile field with many others like medical, energy, environment, agriculture, electrotechnical (actuators, EMI shields, memory devices), safety and defence sectors, and so on.

It is well known that the dying process of the textiles generates a strong negative impact on natural water pollution, people's health, the environment and ecosystems, thus a special contribution of these MNP to the textile industry is related to their ability to be used efficiently in the removal of harmful organic compounds such as dyes found in industrial wastewater.

There are several different approaches involved in obtaining textiles materials (woven, knitted, nonwoven) with magnetic properties, as shown in figure 1.

This research paper focuses on summarizing and making a short presentation on the fundamentals reported recently on different types of magnetic nanoparticles and their properties, the involvement of these nanomaterials with magnetic properties in the field of textiles, the generated properties, and methods of obtaining textile materials with magnetic properties.

NANOPARTICLES WITH MAGNETIC PROPERTIES

Nanoparticles (NPs) present interest because represent a bridge between bulk materials and molecules and structures at the atomic level [4]. Nanoparticles are quasi-dimensional (0D) elements with an order of magnitude between 1 and 100 nm. They can be synthesized from a number of materials, such as metals, metal oxides, carbon or polymers.

Nanoparticles with magnetic properties (MNPs) are a class of nanoparticles that can be manipulated using magnetic fields. They possess several unique properties and configurations such as large surface sizes, shape and size-dependent catalytic properties, superparamagnetic behaviour, small size, biocompatibility, the possibility of chemical modification of their surface and a high surface-to-volume ratio, which leads to different better properties compared to bulk materials [5]. Different factors are contributing to the magnetic properties of nanoparticles, including chemical composition, type of crystal lattice and its degree of deficiency, particle size and shape, morphology, particle interaction with the environment (the matrix) and adjacent particles (the magnetic interaction between particles) [6].

In fact, it should be noted that three major contributions, sometimes interconnected, offer the specific and remarkable properties of magnetic nanoparticle systems: intrinsic properties of components, size effects and interphase or intercomponents interactions [7].

Superparamagnetism is an important property of magnetic nanomaterials, which occurs in nanoparticles composed of a single magnetic domain. This is possible when their diameter is between 3 nm and 50 nm, according to the material [8]. This property prevents the agglomeration of nanoparticles [9], a phenomenon that causes poor corrosion resistance, high solubility and phase change of nanomaterials, and further damage. The smaller the particle size, the slower the agglomeration phenomenon will take place, but they do not always retain their original size after their synthesis, often requiring the encapsulation of nanoparticles [10].

This step of NPs encapsulation is designed not only to prevent agglomeration but also to prevent oxidation, corrosion, toxicity, and to improve the stability and solubility of nanoparticles, or to increase the biocompatibility and specificity of the target, characteristics generally required in the case of medical applications [11].

Therefore, they can be encapsulated in either magnetic or non-magnetic materials to: stabilize them chemically and colloidally, provide a modified surface that can be further functionalized, or modify the magnetic properties [12].

Types of magnetic nanoparticles (MNP)

Pure metals

Most magnetic materials used in current technology are either metals or metal oxides. Iron (Fe), nickel (Ni) and cobalt (Co) are the most important metallic MNPs because they present high magnetic properties and a good capacity to control and adjust their size, composition and shape [13]. However, the biggest drawback they face is the fact that they are not stable in air and are slightly oxidized, resulting in the change or loss (complete or partial) of their magnetization [14].

Metal oxides

The magnetic properties of metal nanoparticles are dependent on the degree of oxidation of the surface. Therefore, true knowledge of the degree of oxidation of nanoparticles is necessary to assess the magnetic characteristics of the materials obtained.

Among the most important and used oxides with magnetic properties are iron oxides, such as hematite (Fe_2O_3), magnetite (Fe_3O_4), ferrites (ex. $MnFe_2O_4$, $MgFe_2O_4$, $SrFe_{12}O_{19}$, $GdFeO_4$), wustite (FeO). Iron oxides have received increasing attention due to their significant advantages contributing to the expansion of their applications. Magnetic iron oxide nanoparticles have low production costs, have sufficient physical and chemical stability, as well as biocompatibility and are environmentally safe [15].

Magnetic bi-component alloys (Fe-Co, Fe-Ni, Fe-Pt, Co-Pt)

The magnetic properties of these metals improve considerably when mixed to form alloys, especially Fe-Co nanoparticles attracting considerable attention [16, 17, 18]. The use of bimetallic NPs is of great interest due to their increased stability, oxidation inhibition and increased reactivity [19].

Composites

Because stability is a crucial requirement when exposed to air, especially in the case of pure metal particles, the metal core of magnetic nanoparticles can be passivated by light oxidation, surfactants, polymers, precious metals, silica or carbon for various applications. These coatings not only help to protect the core but are also used as functionalizers; The magnetic properties of these structures can be controlled by varying the relative concentrations of the used magnetic nanoparticles and coatings [19, 20].

Morphologies of magnetic nanoparticles

In general, nanoparticles are considered spherical, isometric materials, but they can never exist in practice because they are crystalline and have preferential crystallographic planes on the surface. Research has revealed other types of nanoparticle structures, anisometric, created by different methods: NP in the form of cubes, nanoworms, nanostars, nanotetrapods, nanoprisms, nanotubes, nanowires, elongated NP (spindles, nanobelts, nanorods, nanowhiskers, nanorice), disks, nanoflowers, hollow structures [21–26].

The shape strongly influences both the magnetic properties and the surface chemistry of the MNPs. For example, MNP that possess different shapes can be used in sensors development for three essential purposes: improving the magnetic response time, adjusting the anisotropy-controlled signal, or creating additional functionality [27].

Dimensions

The properties of nanoscale materials are unusual compared to the properties of bulk materials. For example, transparency, colour, or melting point may differ significantly from the properties of the latter. Gold nanoparticles are red at the nanoscale, not yellow, as we are used to at the macro scale. From the perspective of magnetic NP dimensions, they can be classified as follows:

- Large particles (> 30 nm): particles around the monodomain-multidomain dimension, with high remanence and coercivity;
- Small particles: superparamagnetic nanoparticles, without magnetic remanence and no coercivity.
- Very small particles (< 2 nm) known as clusters [12].

APPLICATIONS OF MAGNETIC NANOPARTICLES IN THE TEXTILE INDUSTRY

Magnetic nanoparticles have a high potential to be used in the textile industry. Magnetic nanoparticles can be used either alone or as coatings on the surface of the textile or as basic elements in composite materials by embedding them in suitable matrices even during spinning processes. The most important uses of these nanoparticles in the textile industry are discussed below.

Textile actuators based on magnetic nanoparticles

The most recent and essential development of the textile field is the creation of intelligent textile systems capable to react to stimuli of different origins (actuators) with the help of stimuli-responsive materials like shape-memory polymers (SMP), electroactive polymers (EAP), electrochromic materials, or with the help of magnetic nanoparticles.

With great potential in conductive devices for wearable electronics, strain sensors, smart actuators or bioelectrodes, graphene oxide sheets grafted with Fe_3O_4 nanoparticles were used by a group of scientists to coat a cellulose woven fabric through a multi-dipping-drying treatment. The graphene oxide sheets were assembled layer-by-layer magnetic-field-induced onto the surface of cellulose fabrics many times. The well-aligned alternating ordered structures showed good thermal and electrical conductivity of coated cellulose fabrics and also excellent water laundering durability during tests [28].

Furthermore, cellulose nanocrystals decorated with magnetic nanoparticles reinforced in fibrous scaffolds have recently been used to make actuators with a role in the functional regeneration of tendons in

response to magnetic stimulation [29]. Also, nanoparticles like $CoFe_2O_4$ have been used in conjunction with PVDF, for the production of electrospun magnetic nanofibers useful in actuation systems, biosensors or tissue engineering systems due to their magnetoelectric properties [30].

Electronic devices have become essential components that can be integrated into the structure of textiles to create smart textiles that can improve the quality of daily life. However, a key factor for user acceptance of these wearable devices is the comfort appropriate to the type of physical demands we are exposed to. In addition, a still existing problem related to the use of nanotechnology and wearable smart fabrics is the stability in time, as clothes need to be periodically washed and electronics despise water. Moreover, nanomaterials can be transferred in this process to the wastewater and further in the environment, affecting, in the end, people's lives.

Electromagnetic interference (EMI) shielding

Another use of magnetic nanoparticles is in electromagnetic wave control systems, an important action because electromagnetic interference (EMI) can disrupt electronic devices, equipment and systems used in critical areas such as telecommunications, industry, defence, security, military and medicine and also affect our daily lives by utilising the wifi, mobile phone, computers, tablets, television, electric network, etc. [31]. By simply applying metals to the surface of textiles, structures with electrical and magnetic properties can be created to prevent electromagnetic noise through different methods. Recently, nickel nanoparticles have been deposited on the surface of a polyester material by a less expensive and simple method, called "click finishing". The results showed a considerable improvement in magnetic properties and shielding studies on a frequency range of 8.4–12.4 GHz indicated a 100% shielding for nickel-treated fabric [32].

Water treatment and catalysis

The textile industry uses huge amounts of dye and water to colour textiles, and so, complex residues are released with wastewater, having negative impact on natural water pollution, people's health, the environment and ecosystems. In this context, MNP or MNP-treated fabrics are a promising solution for decomposing organic pollutants from the wastewater and quick and facile recovery of the catalysts.

A composite magnetic coagulant (CMC) based on alum ($Al_2(SO_4)_3$)-coated ferromagnetic nanoparticles of Fe_3O_4 has been mixed with wastewater from the textile industry for successful residue removal [33]. A DBD (dielectric barrier discharge)/γ-Fe_3O_4 treated cotton fabric also showed good removal properties for pollutants from the wastewaters [34]. Also, MNP used as support for catalysis substances in the chemical recycling of synthetic fibres like PET allows the catalyst to be recovered [35].

A different method of approaching the problem of pollution due to the conventional dyeing processes of the textile industry was developed by impregnating dyes into magnetic nanoparticles (skin-core structure) to help dye textiles and so, being easily collected from wastewater with a magnet, significantly simplifying the wastewater treatment process and indicating a more ecological approach in the dyeing process of textiles [36].

Oil recovery

Also, in the context of industrial wastewater pollution or marine pollution with oil spills, scientists have developed some solutions recently to counteract the negative impact of pollution. Thus, one study proposes a method based on in situ coprecipitations to manufacture superhydrophobic cotton fabrics functionalized with Fe_3O_4 magnetic nanoparticles, which could be controlled to absorb the oil from water as oil absorbents, even in hot water. Increased separation efficiency and facile operation procedures were demonstrated as also remarkable mechanical durable properties of the created fabric [37].

Another study proposes using a mixture of magnetic Fe_3O_4 nanoparticles and dodecylamine (DDA)-modified TiO_2 to coat a textile material which by changing the pH value of the surface achieved switchable wettability the magnetism allowed easy recovery of the textile from the environment. The results indicated very good oil/water separation efficiency, high oil flux, good reusability and high-temperature resistance of the material. So, the proposed method is environmental-friendly and besides oil/water separation, it can also be used for sewage purification, as mentioned by the authors [38].

Biomedical and antimicrobial applications

Because abdominal hernia is a frequently encountered health problem, surgical mesh implants are proper solutions and act as reinforcement for the weakened or damaged tissue and support tissue restoration. But postoperative problems like pain, mechanical mismatch, infection and non-acceptance of the implant by the surrounding tissues are serious issues that endanger the patient's life. In this sense, scientists proposed the designing of meshes with appropriate textile structures made of warp-knitted polypropylene (PP) and covered with electrospun polycaprolactone (PCL) nanofibers or PCL-gelatine nanofibers that better mimic the performances of the human abdominal wall and improve tissue restoration [39, 40]. Furthermore, for a better and non-invasive revision of the implant after surgery, the incorporation of small superparamagnetic iron nanoparticles into the polymer allows visualization and tracking of the implant's behaviour over time using magnetic resonance imaging (MRI) [41].

Polycarbonate-urethane (PCU) nanofiber tubes, including magnetic nickel (Ni) nanoparticles also manufactured through electrospinning technology, were developed for their potential use in biomedical

applications as magneto-active components (stents, heart patches or artificial nerve guides), capable of being deformed under the application of a controlled external magnetic field [42]. Functionalized textiles with MNP can also be used as dressings and materials for the care of wounds that can cause infections or treat postoperative infections, and a number of studies demonstrate this. Thus, magnetite MNPs offer a high potential for use in the medical field and have been used against the actions of several bacteria or fungi, such as Pseudomonas aeruginosa, Staphylococcus aureus, Candida albicans, Escherichia coli [43–45]. Also, magnetite nanoparticles synthesized by an eco-friendly process from a lemongrass extract are effective as antimicrobial agents by coating textiles [46]. ZnO nanoparticles were also applied directly to 100% cotton textiles by a 'pad-dry-cure' method for antibacterial treatment [47].

Fig. 2. The influence of nanotechnology on textiles

Agriculture applications

An implemented project (MagPlanTex) by a team from Poland, in the context of the ClimateLaunchpad competition, consisted of a new method to grow lettuce with the help of a green knitted textile mat with magnetic properties. By using textile technologies combined with drop-on-demand (DOD) printing technology with functionalized inks, the resulted textile mat could produce plant growth intensification by the action of magnetic fields. This method is suitable to be further explored because it could greatly influence the stimulation of food production [48].

With the introduction of nanoscience and nanotechnology in the textile industry, several properties of textiles can be controlled and improved. The figure below exemplifies these properties.

ELECTROSPINNING – AN UNCONVENTIONAL TECHNOLOGY USED FOR PRODUCING MAGNETIC TEXTILE NANOFIBERS

If the aim is to obtain an entire textile structure with magnetic properties at the nanoscale, the very well-known method of electrospinning can be used to manufacture a fibrous nonwoven nanostructure with the help of MNP.

This process is based on using a high electrical voltage to create an extrusion force on a solution or melt. The basic electrospinning system consists of a high voltage source, a spinneret, and a grounded collector. By applying an electric field of adequate intensity to the solution or melt, a strand of fibres is obtained and deposited on a collector forming a nonwoven fibrous layer [49].

Electrospinning is the most common and widely used technique for manufacturing nanofibers due to its advantages: simplicity, applicability on a wide range of materials, and low costs. Electrospinning has also the advantage of allowing the preparation of large-scale nanofiber networks in a short time, without the need to use a clean room, very sophisticated equipment or very toxic material and is therefore often used to prepare nanofibers.

Micro- and nanofibers produced using electrospinning have many extraordinary properties, such as high surface-to-volume ratio, high porosity, extremely small diameters, along with interconnected micro-nanostructure and surface functionality [50]. But, rate and scale of production are serious limitations in some applications that require large-scale production of these nanomaterials and in this sense, several modifications have been made over time to the classical process to improve its effectiveness. Figure 3 shows different technology configurations depending on specific criteria (collector shape, number and arrangement of needles, etc.).

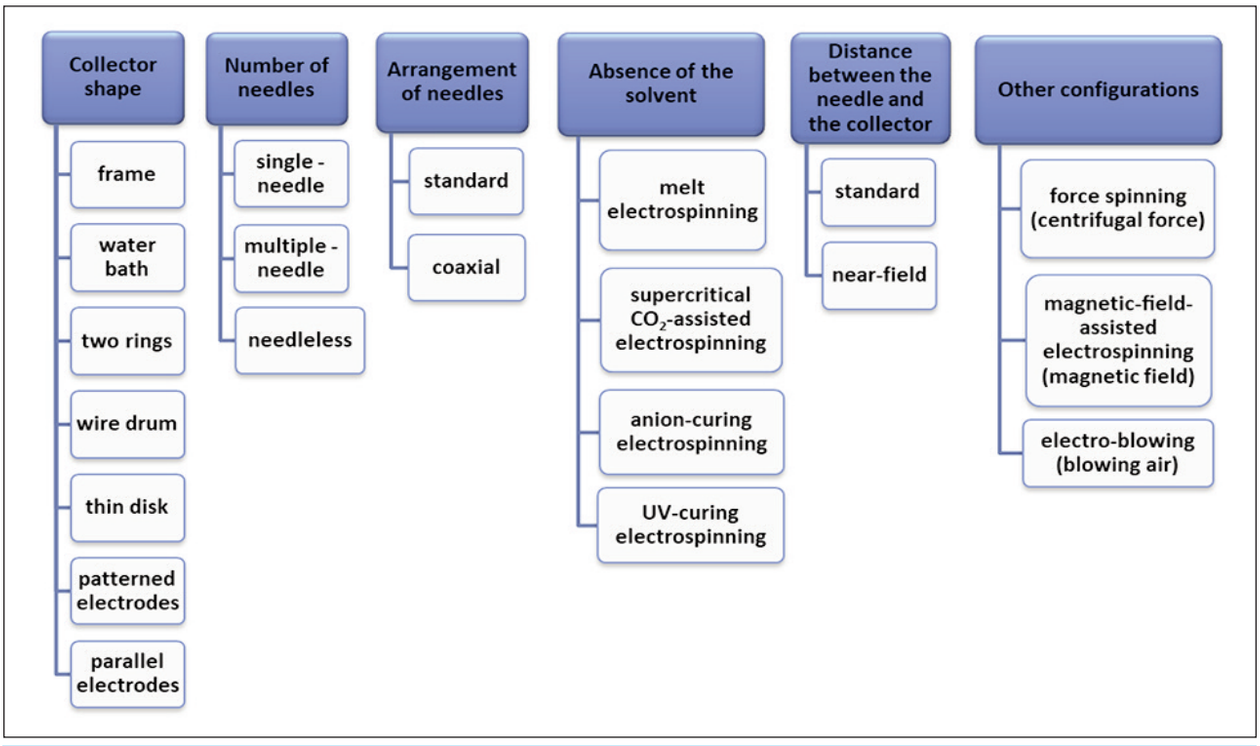

Fig. 3. Types of electrospinning technologies [51]

Table 1

RESEARCH ON COMPOSITE NANOMATERIALS MADE OF ELECTROSPUN NANOFIBERS WITH MNP FOR DIFFERENT APPLICATION AREAS

Polymer	Solvent	Nanoparticles	Use form	Application	Reference
PVP	DMF	$CoFe_2O_4$	Membrane(calcined nanofibers after electrospinning)	Microwave absorption	[53]
PCL	TFE:DMSO (90:10)	Fe_3O_4	Bandage	Skin cancer treatment	[54]
Methacrylic acid/methyl methacrylate copolymers	water	Iron oxide (SPION) and carmofur (an adjuvant in chemotherapy for colon cancer)	pH-responsive fibres for oral administration	Magnetic resonance imaging (MRI) for drug release	[55]
Recycled polyester	TFA/DCM (3:7)	Fe_3O_4 (magnetite)	Magnetic mat	Antibacterial applications	[56]
Silk fibroin	Formic acid	$CoFe_2O_4$	Magnetoactive scaffolds	Tissue engineering	[57]
PVDF-HFP	DMF:acetone (1:1)	$NiFe_2O_4$ and nanoclay	Magnetoelectric fibre mat	Energy harvesters, data storage, sensors, actuators	[58]
PVDF/PBI (5:1)	DMF:acetone (2:1)	Fe_3O_4	Composite nanofibers	Electronic devices (overheating phenomenon)	[59]
PVB	methanol	Fe_2O_3	Membrane	Removal of iron ions from groundwater	[60]
PVB	Ethanol:isopropyl alcohol (4:1)	Fe_3O_4	Magnetic yarn	Radiofrequency electromagnetic field shielding	[61]
PVP	DMF	$NiZnFe_2O_4$	Film (calcined nanofibers after electrospinning)	Electromagnetic interference shielding	[62]

There are four methods involved in the production of magnetic nanofibers through the electrospinning process, depending on the used raw material [52, 15]:

a) Magnetic nanofibers produced from polymeric solutions and metal salts. Through the chemical reaction in the gas phase, the metal salt in the polymeric nanofibers is subsequently converted into magnetic nanoparticles.

b) Magnetic nanofibers produced from polymer solutions and nanoparticles, mixed in an appropriate proportion to obtain composite MNF with uniformly dispersed MNP, thus, particle surfaces are protected from oxidation, dispersibility is improved, and chemical stability is also improved and toxicity is reduced.

c) Pure magnetic nanofibers obtained by calcination of electrospun composites to remove polymeric matrix;

d) Magnetic nanofibers are produced by using a polymeric intermediate that will be electrospun, then making a magnetic coating on the surface of electrospun NF.

CONCLUSIONS

By using nanotechnology, new materials are further developed by many research groups. Nanotechnology offers improved properties over bulk materials due to its specific structure. There is a very important phenomenon called the size effect, that when the material scale is reduced from micro to nanoscale, the fundamental properties of the materials can be changed, for example, strength or electrical and thermal conductivity.

Also, nanomaterials with magnetic properties in the form of nanofibers/membranes/films/yarns and obtained by electrospinning technology have been increasingly studied during the last two decades in applications such as microwave absorption, skin cancer treatment, magnetic resonance imaging (MRI) for drug release, electromagnetic interference shielding, energy harvesters or data storage sensors and actuators.

One easy way of producing these types of nanomaterials discussed in this paper is the introduction of nanoparticles with magnetic properties in the electrospinning solutions so that the obtained nanofibers have already incorporated these nanoparticles in their structure. The most used nanoparticles in different studies are magnetite and iron oxides in general due to their low price, physical and chemical stability, biocompatibility and environmental safety.

Electrospinning is a remarkable technology by its simplicity, flexibility, and versatility, meaning that a variety of materials can be used in this process to obtain nanofibers. But, in general, some limitations regarding this process occur and are needed to be solved in the future. The rate and scale of production are limited in some applications that require large scale or massive quantities of the electrospun nanofibers and are relatively time-consuming. However, significant steps have been taken in this regard by reconfiguring the classical electrospinning equipment by using, for example, multiple needles.

In order to be used to efficiently create advanced materials that are widely accepted by the consumer public, extremely challenging tasks related to nanotechnology will have to be further solved and ensured: manufacturability, affordability, usability, maintainability, durability and safety.

Therefore, nanotechnology is a bridge between several domains, it can bring many benefits and can be used to achieve increased functioning of almost everything in the world, but we must be careful with how it is used and controlled because it can be unpredictable and there are still some unknown effects of it.

ACKNOWLEDGMENTS

The research presented in this paper was prepared in the INCDTP laboratories. Funds support this work from MCID, National Project "Composite materials with electroconductive properties, based on 3D polymeric array for sensorial monitoring system and electromagnetic waves attenuation (3D ELECTROTEX)", Contract PN 19 17 01 01.

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Comparative analysis of working capital management in Turkish apparel industry in terms of firm sizes

DOI: 10.35530/IT.073.03.2021101

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ABSTRACT – REZUMAT

Comparative analysis of working capital management in Turkish apparel industry in terms of firm sizes

Working capital, which businesses need to carry out their daily activities and pay their short-term debts, also significantly affects the profitability of companies. The Covid-19 pandemic in 2020 forced countries to close during the periods when the disease increased, which led to almost cessation of domestic and foreign trade. Many enterprises with weak liquidity had to close their short-term debts. With the pandemic, working capital has become much more important for enterprises. In this study, apparel enterprises operating in Turkey and whose financial statement data can be accessed through the Central Bank were classified according to their size and the liquidity ratios of these companies between 2011–2020 were analysed. In the last 10 years, it has been determined that especially large and medium-sized enterprises have strengthened their liquidity and significantly increased their cash and cash equivalents. However, such an increase was not observed in the cash power of small enterprises. In addition, the factors affecting the profitability of the companies were analysed in the study, and it was determined that the decrease in the Financial Leverage and Debt to Equity ratios in large enterprises increased the profitability. In medium-sized enterprises, it has been determined that the increase in current ratio and receivables collection periods increased profitability. It has been determined that the only significant ratio that affects profitability in small-scale enterprises is the current ratio.

Keywords: *working capital, ratio analysis, financial analysis, apparel sector*

Analiză comparativă a managementului capitalului de lucru în industria de îmbrăcăminte din Turcia raportat la dimensiunea firmelor

Capitalul de lucru, de care afacerile au nevoie pentru a-și desfășura activitățile zilnice și pentru a-și plăti datoriile pe termen scurt, influențează, de asemenea, în mod semnificativ profitabilitatea companiilor. Pandemia de Covid-19 din 2020 a forțat țările să se închidă în perioadele în care boala s-a extins, ceea ce a dus aproape la încetarea comerțului intern și exterior. Multe întreprinderi cu lichiditate slabă au fost nevoite să-și închidă datoriile pe termen scurt. Odată cu pandemia, capitalul de lucru a devenit mult mai important pentru întreprinderi. În acest studiu, întreprinderile de îmbrăcăminte care operează în Turcia și ale căror date din situațiile financiare pot fi accesate prin intermediul Băncii Centrale au fost clasificate în funcție de dimensiunea lor și au fost analizate ratele de lichiditate ale acestor companii în perioada 2011–2020. În ultimii 10 ani, s-a stabilit că, în special întreprinderile mari și mijlocii și-au consolidat lichiditatea și și-au crescut semnificativ numerarul și echivalentele de numerar. Cu toate acestea, o astfel de creștere nu a fost observată în puterea de numerar a întreprinderilor mici. În plus, în cadrul studiului au fost analizați factorii care influențează profitabilitatea companiilor și s-a determinat că scăderea ratei Levier Financiar și Îndatorare la capitaluri proprii la întreprinderile mari a crescut profitabilitatea. În întreprinderile mijlocii, s-a stabilit că creșterea ratei curente și a perioadelor de încasare a creanțelor a crescut profitabilitatea. S-a stabilit că singura lichiditate semnificativă care afectează profitabilitatea întreprinderilor mici este lichiditatea curentă.

Cuvinte-cheie*: capital de lucru, analiză a raportului, analiză financiară, sectorul articolelor de îmbrăcăminte*

INTRODUCTION

Business finance covers three key areas: capital budgeting, capital structure and working capital management. While capital budgeting and capital structure are related to long-term investment and financing decisions, working capital management focuses on the management of a firm's short-term financing and investment decisions [1]. With the strong competition state in domestic and foreign markets, the financial crisis increased the significance of corporate finance. Due to the Covid-19 pandemic, the rupture of supply chains and the cessation of trade have deteriorated cash flows and once again revealed the importance of working capital.

Working capital is related to the managing of current assets and current liabilities of a firm. Managing the short-term assets and liabilities is significant for the being of the companies on a smooth course. Therefore, working capital neither should be excessive nor deficient but should be enough to cater for the daily requirement of a company. A surplus amount of working capital decreases profitability. Conversely, its insufficiency can induce of lack of liquidity and stock out. Ineffective working capital management causes non-operative assets and

decreases the liquidity and profitability of a firm [2]. Working capital is an important issue for financial decisions, as it is part of asset investment, which requires appropriate funding. On the other hand, working capital is being disregarded in financial decisions as it is related to short-term financing. Moreover, as it does not give a contribution to return on equity, it acts as a restrain in financial performance [3].

Working capital is deliberated as a measure of the capability of paying its liabilities back in case of liquidation. However, according to the new perspective, liquidity depends on the persistence of the company and it does not ride on the liquidation of the assets. In place of this, it relies on the cash flows that emerge from these assets [4]. The cash conversion cycle is the delay between the spending for the purchasing of raw materials and the collection of receivables from sales. Therefore, it is defined as an extensive measure of working capital [5]. Managers should be conscious of not only the final profit for their company but also the cash conversion cycle for their company [6]. Even if a business appears to produce very good products, sell effectively, and manage its long-term assets very well, it can be said that if its working capital is poorly managed, the business may face the risk of bankruptcy. The reason for this is not the loss of the business or low sales, but the inability to continue its daily activities [7]. The significant point in working capital management of a company is required to sustain its liquidity for daily operations to provide it's even running and fulfils its duties [8].

Surviving and growing, which are the main objectives of businesses, push companies to use their resources more effectively and this situation becomes more and more important in an increasingly competitive environment. Effective working capital management provides sustaining a firm's capability to gain a satisfactory balance between profitability and liquidity by preventing excessive investment in current assets. Thus, the efficient working capital management system has a crucial part in increasing profitability and getting a competitive advantage [9].

Working capital management can provide a competitive advantage for firms. Working capital is the assets that provide income flow to the business that are connected to the factors of production during the period from the production of the goods to the income generated from the products. Making a profit is the most significant factor for maintaining existence. While profitability is a long-term target for a company that it needs for surviving, liquidity is a comparatively short-term target that requires being collected to relieve the firm from bankruptcy [10]. Concentrating on long-term profitability at the cost of liquidity can cause a financial nuisance for companies. Therefore, the managers must concentrate on both and a balance between them must be set [11].

The firm size affects the working capital management and profitability [12–14]. The working capital needs of enterprises differ by firm size and their activity. Small businesses can limit their investment in fixed assets by renting them out. However, there is no way to avoid stocks and receivables. In this respect, current assets are very important for managers in small businesses. For these companies, the opportunity of finding long-term funds is very limited. For this reason, there is a tendency towards short-term funds in financing. Large enterprises have more opportunities in the capital market than small enterprises [15].

The apparel industry has the potential to create production volume, employment, and foreign trade gains for many countries, especially the developing countries, due to its labour-intensive structure and traditional production process. Turkey with a population of about 85 million people constitutes a large domestic market for apparel products. Having a high capacity of cotton growing and textile process facilities, the textile industry has always been a leader in the country's economic development. Turkey's close economic relations with Europe provided major trading areas with countries such as Germany, the Netherlands and other Europe countries. Moreover, the crumble of the former Soviet Union and the rise of new Turkic republics have resulted in new trades with Turkey and Russia and some Turkic republics such as Azerbaijan and Kazakhstan [16]. The Turkish apparel industry achieved 17.1 billion dollars of exports in 2020 and ranked third with its share in overall exports [17]. Therefore, it has an important place in the Turkish economy.

There are many performed works addressing the issues of working capital, liquidity etc. in the textile apparel sector. Samo and Murad investigated the effect of liquidity and financial leverage on the profitability of 40 textile companies using pooled panel regression and descriptive statistics models. The findings showed that there is a positive relationship between liquidity and profitability and a negative relationship between financial leverage and profitability [18]. Solanki analysed the working capital growth/efficiency of 22 textile companies in India over 10 years period. They concluded that the companies show different performances in terms of working capital ratios [19]. Muhammad and Ayub studied the relationship between working capital management and profitability of 138 textile firms in Pakistani. The results displayed the regression coefficient of firm size, inventory days, payables days, receivables days and days of cash cycle were statistically insignificant at a 5% significance level. Therefore, they concluded the relationship between working capital management and the profitability of firms of Pakistani was not supported statistically [20]. Karabay examined the profile of the Turkish clothing industry in terms of, capital structure, the working capital management strategies and the association between working capital and profitability by using the balance sheet of the industry published by the Central Bank of Turkey. Finally, she concluded that apparel firms should decrease the days of the debt collection, and the cash conversion cycle and found a balance between liquidity and profitability [21]. Shahid explored the relationship between working capital management and the profitability of textile firms in Pakistan. The results showed that average days in inventory, average days

receivable, and average days payable have a significant economic impact on return on assets [22]. Khan et al. conducted research to analyse the working capital management performance of 49 textile companies in Dhaka for the period 2000–2018 by using a regression model. They found that there is a negative relationship between a firm's profitability and a positive relationship between cash conversion and firm value [2]. Sheikh and Rafique's paper's objective was to examine the effect of firm-specific variables and board attributes on the working capital ratio of textile composite, spinning, weaving and overall firms listed on the Pakistan Stock Exchange during 2008–2014. They concluded while the firm-specific variables have a significant effect, the board attributes have a slight impact on the working capital ratio [23].

In these studies, it has been determined that there are significant differences between sectors in terms of the level of working capital investments and financing decisions. Various working capital indicators such as debt collection period, inventory turnover period, debt turnover period and cash conversion period differ significantly from sector to sector.

The overwhelming majority of early research has been generally conducted in analysing financial analysis of companies listed on the stock market in certain sectors. In general, the companies in the stock market constitute a small part of the sector. The size of the sample population is important in accurately reflecting the main population. Unlike other studies, in our study, financial statement data of all companies in the apparel industry in the country were collected through the Central Bank and financial analysis was performed, and the factors affecting their profitability were comparatively analysed by classifying the companies according to their sizes.

MATERIAL & METHOD

Aim of the study

In this study, the working capital of the companies operating in the apparel industry in Turkey was analysed according to their size and it was aimed to determine the internal factors that affect the profitability of these companies. In addition, companies were divided into three categories according to their size and the differences between the classes were revealed. In Turkey, the companies traded on the stock exchange are large textile and apparel enterprises and represent a few of the industries. However, when the whole sector is considered, a significant majority of the enterprises consist of small and medium-sized enterprises. In addition, the number of companies traded in the stock market is 19 and this is a very small part of large enterprises in Turkey. The sector's place in the Turkish economy is indispensable due to employment and the export income it provides. For this reason, using the consolidated balance sheets of the companies operating in the sector provided by the Central Bank of the Republic of Turkey will reveal more accurate results about the real situation of the sector. These balanced sheets were formed by the consolidation of financial statements of 6024 firms. In addition, since the presented data grouped the companies in the sector based on their size, a comparative analysis of the relationship between the working capital and profitability of the companies according to the size of the enterprises was also possible. Among the studies carried out so far, a comparative analysis study for the whole sector has not been encountered. Hence, it was aimed to contribute to the literature and the sector with this aspect.

Scope and method of research

The data used in this study was obtained from financial statements of the Turkish clothing industry published by the Central Bank of the Republic of Turkey on its website for the period 2011–2020.

The companies in the sector were divided into 3 groups according to their sizes within our study. According to a published report of KOSGEB; "Enterprises with less than 50 employees and less than 25 million TL of annual net sales are small businesses; Enterprises with less than 250 employees and whose annual sales revenue does not exceed 125 million TL are medium-sized enterprises; Businesses with more than 250 employees and a sales revenue of more than 125 million TL are classified as large enterprises" [24]. Additionally, 10-year liquidity, activity, financial structure, and profitability ratios were calculated for each group. The ratios and calculation methods used in the study are shown in table 1.

Table 1

MEASUREMENT OF VARIABLES

Variables	Measurement
Current Ratio (CR)	Current Assets / Current Liabilities
Receivables Collection Period (RCP)	360 / (Sales/ Accounts Receivables)
Inventory Turnover Period (ITP)	360 / (Cost of Goods Sold / Inventory)
Financial Leverage Ratio (FL)	Total liabilities / Total assets
Debt to Equity Ratio (DE)	Total liabilities / Shareholder's equity
Return on assets ratio (ROA)	Net income / Total assets

Within the scope of the study, data of 338 large companies, 1809 medium-sized companies and 3877 small-scale companies were evaluated as of 2020.

Ordinary least-squares regression analysis

Ordinary least squares (OLS) regression is frequently used in social sciences. It is beneficial to estimate the values of a continuous response variable using one or more explanatory variables. It helps also identify the strength of the relationships between these variables [25].

In the study, the dependent variable Return on Assets Ratio (ROA) was chosen to determine the factors affecting the profitability of large, medium and small

enterprises. Current Ratio (CR), Receivables Collection Period (RCP), Inventory Turnover Period (ITP), Financial Leverage Ratio (FL) and Debt to Equity Ratio (DE) ratios were chosen as independent variables. Three different regression models are presented for large, medium and small enterprises.

Model 1: $ROA_{Big} = \beta 0 + \beta 1\ CRt + \beta 2\ RCPt + \beta 3\ ITPt + \beta 4\ FLt + \beta 5\ DEt + et$

Model 2: $ROA_{Medium} = \beta 0 + \beta 1\ CRt + \beta 2\ RCPt + \beta 3\ ITPt + \beta 4\ FLt + \beta 5\ DEt + et$

Model 3: $ROA_{Small} = \beta 0 + \beta 1\ CRt + \beta 2\ RCPt + \beta 3\ ITPt + \beta 4\ FLt + \beta 5\ DEt + et$

FINDINGS

Analysis of working capital of enterprises

Liquidity ratios measure the short-term solvency of businesses and the adequacy of working capital. The companies subject to the study in table 2 are divided into 3 groups according to their sizes and their liquidity ratios have been indexed based on 2011.

When table 2 is examined, it can be said that there have been fluctuations over the years and that a certain trend has not occurred, but in general, enterprises have improved the adequacy of their working capital. The rise of quick and cash ratios in large and medium-sized enterprises draws attention, especially in recent years. On the other hand, in small-scale enterprises, it was determined that the level of 2011 was maintained in general, and there was some improvement in all ratios only in 2020. In all three categories, it was determined that the cash ratio increased significantly during that time. In Turkey, the business is performed on order bases in the apparel industry. In the Covid-19 pandemic period, the number of stocks of the enterprises to be purchased and the receivables from the customers decreased with the decrement in the orders. As a consequence of this situation, the enterprises aimed to reduce the risk by investing more in their cash and cash equivalents during that period.

Ordinary least-squares regression (OLS) analysis

In the study, three different regression models were established for large, medium and small-sized enterprises. OLS results for the three models are shown in table 3.

Table 2

10-YEAR CHANGE IN LIQUIDITY RATIOS										
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Big Size Companies										
Current Ratio	100	97	111	108	97	107	111	110	117	108
Quick Ratio	100	105	113	112	117	114	116	114	135	128
Cash Ratio	100	94	106	111	106	104	114	87	123	179
Medium Size Companies										
Current Ratio	100	97	94	93	93	97	97	105	110	110
Quick Ratio	100	96	93	93	94	95	99	107	111	120
Cash Ratio	100	82	98	93	104	94	121	112	129	171
Small Size Companies										
Current Ratio	100	101	99	95	93	94	94	99	98	103
Quick Ratio	100	99	100	89	91	91	96	99	101	110
Cash Ratio	100	88	98	77	86	91	77	94	99	117

Table 3

Regression Models						
Variables	**Model I (Big Comp.)**		**Model II (Medium Comp.)**		**Model III(Small Comp.)**	
	Coefficient	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
Current Ratio (CR)			0.0481	0.0042	0.0569	0.0078
Receivables Collection Period (RCP)			0.3849	0.0003		
Inventory Turnover Period (ITP)						
Financial Leverage Ratio (FL)	–0.063509	0.018				
Debt to Equity Ratio (DE)	–0.464573	0.0001	–0.0469	0.0503		
Durbin Watson	1.3035		1.4510		1.8483	
Adjusted R-squared	0.3890		0.4967		0.2971	
F-statistic	7.2082		10.624		5.1228	
Sig.	0.0002		0.0001		0.0023	

When table 3 is examined, it has been determined that the factors affecting profitability in large enterprises are FL and DE ratios. It was determined that the decrease in both ratios increased the profitability. The decrease in these ratios, which show the debt burden of the enterprise according to the assets and equity, increases the profitability of the enterprise, as it also reduces the interest burden of the enterprise.
Enterprises operating in Turkey bear high financial expenses due to high-interest rates. Particularly, large-scale enterprises, due to their financing policies, include more foreign resources, so interest expenses increase with them, and this situation negatively affects profitability. It has been determined that the ratios affecting profitability for medium-sized enterprises are CR, RCP and DE. Accordingly, while the increase in CR and RCP ratios increased the profitability of the enterprise, the decrease in DE affected the profitability of the enterprise positively. It is logical that an increase in the CR, which shows the ratio of current assets to current liabilities, will positively affect profitability as it also increases the liquidity of the enterprise. The increase in the RCP ratio also means that the collection power of the enterprise increases, and it collects its receivables in a shorter time.
This will also have a positive impact on profitability. As in large enterprises, the profitability of the enterprise increased as the DE ratio decreased in medium-sized enterprises. It can be said that the reason for this situation is the decrease in interest expenses. In small businesses, on the other hand, it has been determined that the only rate that affects profitability is CR. Increasing liquidity power also increases profitability in small businesses.

CONCLUSION

The apparel industry, with its labour-intensive structure, has the potential to create employment and foreign trade gains. The Turkish apparel industry, which has an increasing share in the economy with its development since the 80s, still maintains its place in the economy. For this reason, companies in the sector need to continue their existence. One of the important milestones of this is working capital management. Even if a business appears to produce very good products, sell effectively, and manage its long-term assets very well, it can be said that the business may face the risk of bankruptcy if its working capital is poorly managed. The reason for this may not be the loss of the business or low sales, but the inability to continue its daily activities. The ability to keep daily operations hangs on the level of investment in working capital. The firms should manage their working capital efficiently. Thus, they can meet their short-term obligations while they are avoiding excessive investment in current assets. By not investing too much in current assets, it can be ensured that the funds in hand are directed to important investments that need to be made in the future.
This study examined the working capital management of the Turkish apparel industry considering the firm size comparatively. The findings have shown that while the small-size firms' quick and cash ratios of maintaining the level of 2011, big and medium-size firms display an incrementing course. The fact that large and medium-sized companies are more successful in stock management than small businesses and that they are more competitive in the collection of receivables than small businesses may be effective in this result. In 2020, the cash ratio of all-size firms increased. The reason for this is the decrease in business stocks and receivables because of the decline of orders due to the Covid19 pandemic, and companies' investing more in cash and cash equivalents.
The results of the regression analysis showed that the relationship between the working capital of the apparel enterprises and the profitability differs according to the size of the firm. Financial leverage and debt to equity ratio in large enterprises, current ratio and receivables collection period in medium-sized enterprises, and current ratio in small enterprises are effective in the relationship between working capital and profitability of apparel enterprises. In this difference, the financial policies applied by the enterprises according to their size, their efficiency in stock management and the level of competitiveness in the collection of their receivables are effective.
It is important for businesses to consider the impact of their existing working capital structures on their profitability and to implement an effective working capital management policy in terms of increasing their profitability and sustainability of their assets.

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A digital-integrated solution for a customised 3D design process of garments

DOI: 10.35530/IT.073.03.202171

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ABSTRACT – REZUMAT

A digital-integrated solution for a customised 3D design process of garments

We live in a digital era in which we have become accustomed to using digital applications to access services or purchase products for daily professional activities, communication/socialisation, or entertainment. The digital transformation of the industry (including the apparel industry) is based on a new approach: the model is developed digitally, presented to the customer, physically manufactured for use and then recorded and made available for purchase on digital platforms. The latter can stimulate connections between customers and manufacturers; in this way, the customer can make specific requests regarding the desired product, and the manufacturer can provide the customer with specific details. Information and communication technologies (ICTs) play a big role in the fashion industry. They are used for the design, production, and distribution of fashion items, communication, and even product co-design. This paper illustrates a method to develop business attire patterns for different professions where a dress code is required (management structures, banking, commercial activities, flight attendants, etc.) by automatically integrating 3D customer data (obtained through a 3D scanning process) and product information. Both product information (dimensions, materials and accessories, manufacturing conditions, e.g.) and information about the customer's body (size, posture, conformation) can be integrated into the conceptual development phase in a tailored (customised) way. The virtual interactive simulation of the product on the avatar representing the customer (virtual 3D prototyping) makes it possible to assess the appearance of the garment on the human body and whether the design requirements have been met.

Keywords: *customised business attire, 3D prototype, virtual simulation, garment patterns, smartphone scanning apps*

Soluție integrată de proiectare 3D a îmbrăcămintei personalizate

Trăim într-o eră digitală, în care ne-am obișnuit să utilizăm aplicații digitale pentru achiziții de servicii sau produse, pentru activitatea profesională de zi cu zi, comunicare/socializare sau pentru divertisment. Transformarea digitală a industriei bunurilor de larg consum (inclusiv cea a îmbrăcămintei) are la bază o nouă abordare: modelul este dezvoltat digital, prezentat clientului, este realizat fizic pentru utilizare și apoi este introdus în rețele online pentru distribuție. Pe platformele digitale, se creează conexiuni între clienți și producători; clientul poate interveni cu anumite solicitări pentru personalizarea produsului dorit, iar producătorul îi poate sugera detalii ale modelului, în avantajul clientului.Tehnologiile informației și comunicațiilor (TIC) sunt puternic integrate și în industria modei. Ele sunt utilizate pentru a proiecta și produce articole de modă, pentru distribuție, comunicare și chiar de co-creare a acestora. Integrarea cerințelor produsului (dimensiuni, materiale și accesorii, restricții de fabricație etc.), ale corpului clientului (mărime, postură, ținută) se poate materializa prin utilizarea unor soluții integrate de dezvoltare conceptuală a îmbrăcămintei, într-un mod personalizat și individualizat. Lucrarea prezintă o soluție de dezvoltare virtuală personalizată și individualizată a produselor de îmbrăcăminte pentru femei, specifice domeniilor de activitate ce impun un anumit cod vestimentar (diferite poziții de conducere/management, domeniul bancar, comercial, aviație etc.) cu integrarea automată a datelor clientului (obținute prin scanare 3D) și ale produsului. Proiectarea și simularea interactivă în spațiul virtual a produsului pe avatarul clientului permite analiza modului de potrivire al acestuia pe corpul purtătoarei și de verificare a modului de îndeplinire a cerințelor de conformitate impuse de model.

Cuvinte-cheie*: ținută de afaceri personalizată, prototip 3D, simulare virtuală, tipare produs de îmbrăcăminte, aplicații de scanare pe smartphone*

INTRODUCTION

In the apparel industry, customers look for various products that meet their personal needs. Because of the changing nature of fashion trends and market demands, the collections are numerous, and stores demand new models at a high-speed rate. This inevitably leads to the expansion of the variety of models and to the shortening of the life cycle of the products. This new orientation determines manufacturers to invest in advanced technologies that enable them to achieve the desired goal at a high level of quality and in the optimal amount of time [1–3].

Internet connectivity, the expansion of wireless communications, the development of artificial intelligence, and real-time data analysis are causing essential changes in the production of consumer

goods. Industry 4.0. is significantly changing the entire production process by unifying digital technologies and the internet with conventional industry in order to manufacture products as quickly as possible and to quickly adapt to market changes (digitalisation). From an economic point of view, industry 4.0. is an excellent opportunity for restarting and modernising production and of developing business models for new services and products. In this digital/virtual environment, textile companies have to diversify their production so that it includes both mass production (small orders) and customised production (products adapted to the customer's needs) [4].

Creating personalised apparel products (fashion products) is a very complex process because fashion trends are highly dynamic. This process is easier to carry out in the case of business clothing, sports and protective items, since in this case, the purpose of the product, its conditions of use, the design constraint (dress code) and the information about the client's body shape are known from the beginning. There is also the possibility of contacting the customer during the design phase to check whether the designed product is correct and whether it meets his/her expectations.

The following essential elements are considered in the initial stages of customising a garment model:

- the model details and structure;
- the list of all materials which are required for producing it;
- information about the wearers' body shape;
- the production and quality control stages;
- storage and delivery conditions.

This paper proposes a method to develop business attire patterns for different professions where a dress code is required (management structures, banking, commercial activities, flight attendants, etc.) by automatically integrating the customer data and product information.

Information about the customer's body is captured using 3D scanning apps (the customer photographs their body from exclusive angles, and the app then "stitches" the snapshots together). These data are used as initial information to develop the needed customised 2D patterns.

The company's designers work out the model patterns and 3D virtual prototype and then send it to the client.

With the real-time virtual fitting mobile apps, the customer can visualise and analyse the item dressed on his body, save the result and send it to the company. In this way, the prototype is validated, and the manufacturing process can begin.

During the personalised design process, the designer [5]:

- develops the structure and shape of the main geometric blocks (main elements) for the personalised design process of the components of the chosen garment;
- receives the 3D data, output data from the mobile apps and integrates them into the design scenario;
- modifies the shape of the main geometric blocks to obtain the pieces of the chosen model (for all the layers);
- creates the 3D virtual prototype and dress it on a corresponding virtual mannequin of the client;
- analyses the appearance of the product. If he/she finds problems with the fit or balance of the product on the body, he/she will make the necessary changes to solve the problems (2D pattern);
- sends the 3D information to the customer for validation/confirmation.

After validation, the designer sends the digital patterns that will be used in the manufacturing process. In addition to the garment fitting well and looking good on the customer's body, this solution is key to reducing post-industrial waste in the garment industry – the number of garments that do not fit the customer's body (rejected or unsold items).

ELEMENTS OF THE PROPOSED SOLUTION

The personalisation of the clothing design process can be carried out in two ways:

(a) Via a customised 2D design of the shape of the product components, which employs special tools provided by a CAD system, as well as customer data and the dimensional characteristics of the products. Afterwards, they can be exported into or imported from a 3D virtual environment in order to obtain the virtual prototype of the chosen model.

(b) By directly designing the shape of the components of the model on the virtual mannequin (3D design) by taking into account: the type and the position of the layers (for each product), the stylistic lines of the product, volumes, interactions between layers from the product structure or between layers and the virtual mannequin. Afterwards, one can extract the components of the model.

In method (a), the new shape of the model patterns (for a new client) is automatically generated by changing the initial data used in the design scenario, while in method (b), the design process is performed again on the new mannequin.

In this paper, method (a) is used to obtain customised patterns for a women's jacket (business style), which are needed to develop the integrated digital solution for a 3D design process for a customised model.

The different phases of the design process focus on the jacket and are carried out using the specific tools of the Gemini CAD system's made-to-measure mode [6, 7]. This module is designed so that the user can geometrically design and control the size of the garment pieces. The user has the possibility to change the structure of the initial data or the mathematical relations immediately; the shape of all the garment pieces is automatically reshaped.

The development of the main geometric blocks

The Made-to-Measure module of the Gemini CAD system allows the use of the geometric 2D design method to obtain the shape of the main elements of the product (main blocks). This module uses values

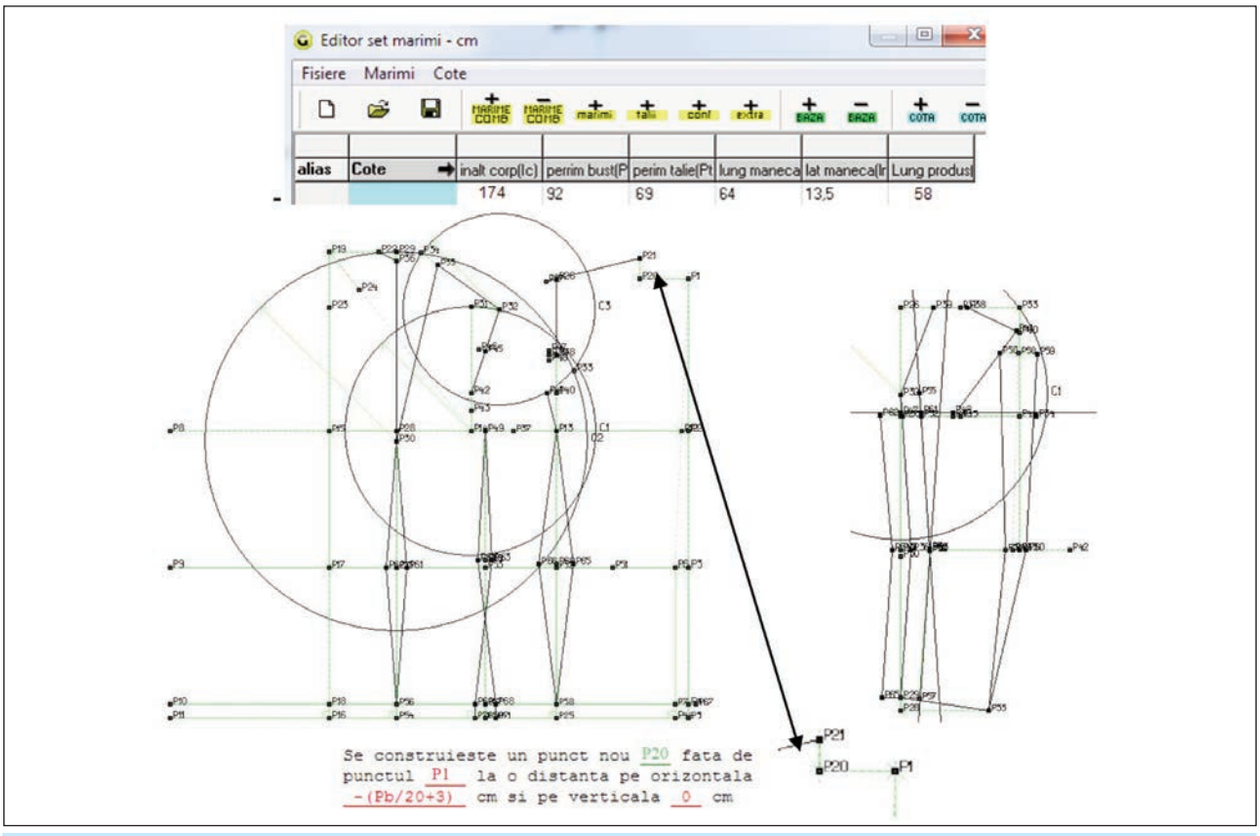

Fig. 1. The geometric layer of the MTM module

of specific body measurements of the customer, product measurements and style data (expressed by values of allowances and product characteristics). By using specific geometric functions, the mathematical relationships of the chosen design solution are transferred to the digital environment while maintaining the connection with the required output data [8–11].

For example, figure 1 shows the values of the client's body measurements necessary for the design process (personal data), the geometric layer on which the main patterns of the jacket are designed (front, back, side panel and sleeve), and it shows the relation that determines the position of the highest point of the back element (the base-neck point).

The basic block shown in figure 1 is used to design the pattern of the main elements for a woman's jacket with side panels (business style). The main steps of adapting the jacket block to the characteristics of the model are explained in the following sections of the article. The elaborated design scenario is flexible and can easily be altered/adapted to another scenario, e.g. a jacket without side panels but with a waist dart in the back.

Human body scanning

3D body scanning has two main applications in the apparel industry:

– monitoring population trends through anthropometric measurements in order to determine specific sizes by wearer group;
– developing computerised systems that integrate information from 3D scans into textile design applications.

With the advancement of artificial intelligence, special applications for mobile phones (smartphones) have also been developed in modern times. The scanning method with mobile apps is simple: the application takes photos of the person (front, back and side views). The images are then processed to create an avatar that reflects the customer's body measurements. When the avatar is created, the list of its measurements is also created (names and values, see figure 2). The client can store this information in the cloud (personal account) and reuse it anytime. Mobile scanning has one drawback: the process is

Fig. 2. Data about the human body obtained through scanning with mobile apps

not as accurate as stationary scanners. The accuracy of the information depends on the performance of the smartphone and the ability of the user to take good photos.

Personalise the blocks to get the patterns of the chosen business model

The main geometric blocks are suitable for designing the 2D shapes of the components of the jacket, a business style. This model can be considered a dress code for a flight attendant.

The necessary steps for obtaining the shape of the main elements are introduced in the geometric design layer. The designer receives the sketch of the model and then performs technical analysis to determine the steps that must be taken to produce the components of the model.

The customisation process requires the automatic transfer of the customer's measurements (obtained by scanning with mobile apps and stored in the personal cloud account) and specifications regarding the stylistic details of the product.

Figure 3 illustrates two customised models for women's jackets (business dress code) as well as the model sketches of the selected products.

The main steps for adapting the basic jacket block to the features of the model are:

– import the needed values of the client measurements;
– establish the new dimensions of the jacket model;
– change the shape of the upper contour lines (deep neckline) for both models;
– design the fastenings or closures systems (model a and b);
– design the upper yoke (model a);
– design the pockets patterns (model a);
– extract the model pieces.

Creation of the virtual 3D prototype

With the virtual prototypes, the user can check how the product looks on the virtual mannequin (avatar) and whether the chosen design solution is the right one. In the field of textile clothing, 3D solutions from well-known manufacturers such as Lectra, Optitex, Clo3D, 3dsMax, etc., are used.

The virtual 3D prototype of the jacket (model a, see figure 3) was created with the program 3dsMax. The 2D pieces of the garment model were imported in 3dsMax to create the virtual prototype. Figure 4 shows some work stages performed in 3dsMax [12, 13].

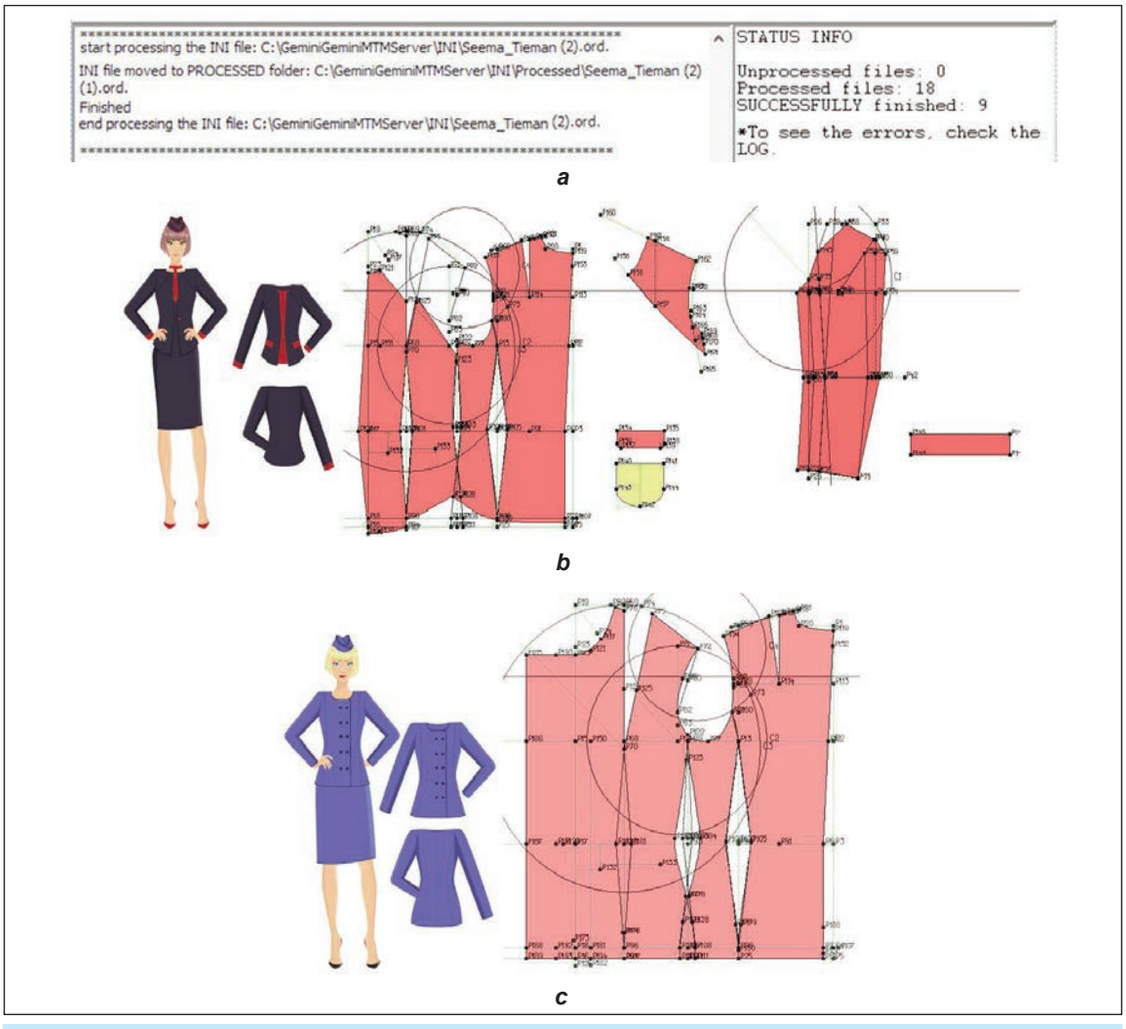

Fig. 3. Customised patterns of the selected models of jacket:
a – the automatic transfer of the customer measurements; *b* – women jacket-model a (design the yoke, fastening system, front pieces); *c* – women jacket-model b (fastening system, front pieces)

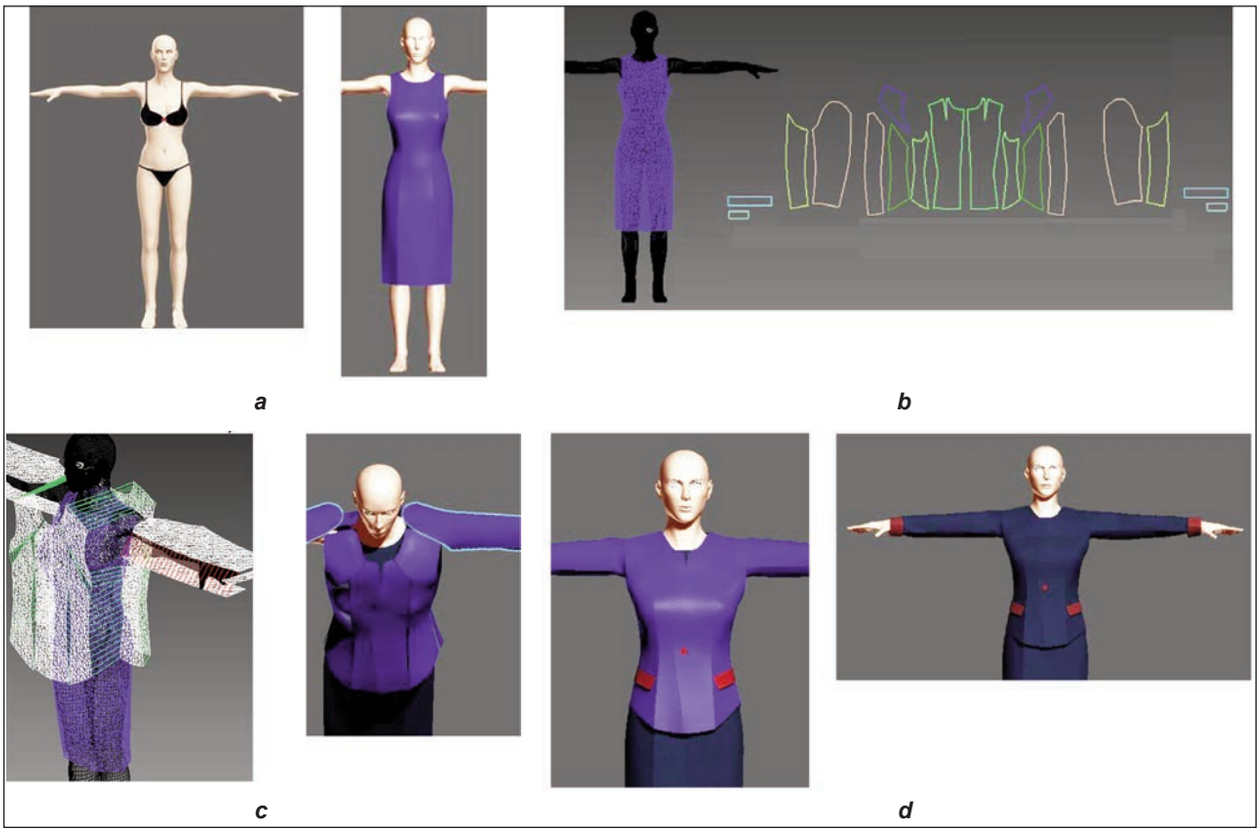

Fig. 4. The creation of the 3D virtual prototype (jacket):
a – dress the virtual avatar in a dress (as a formal business dress code); *b* – import the jacket pieces;
c – declare seam lines, simulation process; *d* – the final 3D virtual prototype, change the jacket colour

The validation of the prototype by the customer

The 3D scan application allows one to import images created by using the 3dsMax simulation program. In this way, the customer can visualise the product appearance on the body (fitting degree, balance, model details, general appearance, e.g.).

The software also enables the user to display the stress map, which depicts the stress areas that occur when the product is worn: red indicates stresses in the product (undersized pieces), blue means areas light product areas with and green is used in the case of a correct match [14].

Fig. 5. Tension map

Figure 5, for example, shows a sample with fitting issues (the garment is undersized in frontal areas). In extreme cases, it is necessary to alter the pattern to solve the issues. The customer sends the information (figure 5) she saw on the mobile to the manufacturing company, and the designer fixes the identified problems. After a re-check, the customer has the option to complete the order.

By validating the 3D virtual prototype, its patterns become production patterns and are then used to obtain the physical product.

CONCLUSIONS

In recent years, the concept of online commerce (or e-commerce) has evolved. Increasingly many companies have adapted their marketing strategies to this business environment, while others have developed theirs solely on this basis (such as E-bay).

Online retailing offers customers a whole range of significant advantages, such as the very convenient option of purchasing goods from the comfort of their own home. As time has become an increasingly valuable resource nowadays, offering this option becomes a necessity. Moreover, online shopping covers an unlimited geographical area as opposed to a store that can only serve a relatively limited one. Thus, a customer can buy products sold on other continents and receive the purchased products within an amount of time that is specified on the website. Besides this, prices in many online stores are lower than in traditional ones, both as a promotional strategy and due to the fact that the cost of maintaining a website is much lower than the rent for a store and the salaries of salespeople.

It is necessary to carry out a comprehensive study in order to employ the virtual design method that relies on the interactive simulation of the product, raw materials, and the virtual mannequin in order to find

the optimal way of putting together the structural parts of the garment. The 3D simulation of the product worn on the body is carried out by developing complex mechanical models for collision, rendering, and animations. One example from the latter category involves the system consisting of the garment and the human body and is elaborated sequentially depending on the animation levels of the skeleton. In this context, the movement of the garment with respect to the surface of the body surface is simulated by using mathematical modelling depending on certain contact points between the body and the garment during the given process. If a designer develops basic blocks for the main category of garments (which can also be worn as business clothes), these blocks can be easily adapted to the model's characteristics and the client's body shape.

The mobile scanning apps are accessible to any customer (with a smartphone) and very useful for a virtual try-on. In this way, the customer can assess the appearance of the garment on his body (corresponding virtual avatar) and the details of the model and, if the result meets his requirements, place the manufacturing order.

The proposed digital integrated solution for 3D customised design can promote the production of business clothing, reduce the number of returned non-conforming products, and increase customer satisfaction. When a company develops new models in a virtual environment and submits them to the customer for approval, the consumption of raw materials, the cost of the manufacturing process and the amount of waste are reduced. This has a positive effect on the environment and also on customer satisfaction.

ACKNOWLEDGEMENTS

The authors acknowledge Gemini CAD for technical support and collaboration with the Faculty of Industrial Design and Business Management from Iasi, Romania.

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Vegetable culture vs. climate change
Innovative solutions
Part 2. Research on the influence of shadow with different textile materials of Rubiniu onion plants (*Allium Cepa*)

DOI: 10.35530/IT.073.03.202121

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ABSTRACT – REZUMAT

Vegetable culture vs. climate change
Innovative solutions
Part 2. Research on the influence of shadow with different textile materials of Rubiniu onion plants (*Allium Cepa*)

Onion is an important vegetable in Romanian cuisine, implicitly in vegetable growing. The pedoclimatic conditions in our country are favourable for this culture. Onion shading technologies are rare, even in small areas. A Rubiniu red onion culture was established, in the agricultural year 2019. Three types of textile materials were used (2 of them were provided by INCDTP Bucharest), to overshadow the experimental variants and an unshaded witness. The present study aimed to observe the growth of the studied plants, shaded with different types of textile material, in the context of climate change. The analysed results indicate a positive influence of shading on plant growth and development compared to the control variant.

***Keywords**: Allium cepa var. rubra, agrotextiles, shading, development, warp knit*

Culturi legumicole vs. schimbări climatice
Soluții inovative
Partea 2. Cercetări privind influența umbririi cu diferite materiale textile a plantelor de ceapă rubiniu (*Allium Cepa*)

Ceapa este o legumă importantă în bucătăria românească, implicit în legumicultură. Condițiile pedoclimatice din țara noastră sunt favorabile pentru această cultură. Tehnologiile de umbrire a cepei sunt rare, chiar pentru suprafețe mici. O cultură de ceapă roșie Rubiniu a fost înființată, în anul agricol 2019. Au fost utilizate trei tipuri de materiale textile (2 dintre acestea au fost furnizate de INCDTP București), care au umbrit variantele experimentale și un martor neumbrit. Prezentul studiu a vizat creșterea plantelor luate sub observație, umbrite cu diferite tipuri de material textil, în contextul schimbărilor climatice. Rezultatele analizate indică o influență pozitivă a umbririi asupra creșterii și dezvoltării plantelor în comparație cu varianta martor.

***Cuvinte-cheie**: Allium cepa var. rubra, agrotextile, umbrire, dezvoltare de produs, tricot din urzeală*

INTRODUCTION

Onion is among the most important vegetable crops grown around the world mainly for its requirements for daily consumption and its health benefits for human beings [1].

Onion (*Allium cepa*) belonging to the Family *Alliaceae*, is a major bulbous vegetable which ranks second only to tomato in terms of total annual world production [2].

Due to this fact, its production is concentrated in the three world's top producers (China, India, and the USA) for both their daily consumption and/or for export market purposes [1]. Onion is cool-season vegetable crop [3]. Requirements for onion are estimated at 10 kg per person annually, including 7 kg of bulb onion, and 2 kg of onion with leaves [4].

There was increasing consumption of the inhabitant from 15.1 kg up to 15.7 kg which is higher than the average norm of consumption recommended in the country (10 kg) [5].

Besides the export of onion bulb with skin also quite a lot of quantities of the peeled onion for freezing or direct use for meat and fish industries, as well as for gastronomy is exported from Poland.

In some centres of onion production, specialized plants have been established for export only peeled onion [6]. Bulbs cultivar Babtu didieji are suitable for storage (7 months). Bulbs are big and oval. The weight of one marketable bulb reached 95–116 g [7].

To correct high and low temperatures, several shading systems are available in greenhouses: bleaching, mesh, screens and photovoltaic panels. Whitening is the simplest and most economical technique that is used as a shading system. It consists of applying a solution of water and calcium carbonate on the roof of the greenhouse.
The other systems that have been used (mesh and screens) can be used inside or outside the greenhouse and can be permanent (fixed) or mobile (movable) [8].
In addition, they revealed that shading mesh behaves like translucent materials and the colour and solidity of the mesh influence heat transfer.
Later, they confirmed that the temperature and porosity of the mesh are more relevant parameters than texture and colour when radiative transmission and reflection are measured.
That shading methods reduce energy and water consumption and increase fruit productivity and quality [8].
Shading reduces the level of solar radiation, the air temperature, and the rate of evapotranspiration, reducing water consumption – a fundamental aspect for countries where this resource is scarce.
Furthermore, it has been shown that shading combined with evaporative cooling is more effective in arid regions and hot seasons, while shading combined with thermal screens reduces the energy consumption used for heating in cold regions, maintaining the temperature of the internal air at 5°C higher than outside air [9].
On the other hand, fresh onions are usually short-day cultivars, transplanted from late summer to early spring and harvested at different bulb sizes, according to local climatic conditions and consumers' demands [10].
In contrast to pungency variability, the content of total sugars does not show wide differences among the cultivars (8% to 10%), with glucose in the highest amount, followed by fructose and sucrose.
It identified a locus accounting for the major differences in the content of reducing sugars and fructans in onion bulbs between storage varieties with high dry matter content and sweet varieties with low dry matter content [10].
Shallots are onions grown in various climatic zones – from Asia and Africa to northern regions of Europe and America [11].
An additional trend has been the increasing popularity of red onions with 10–15% from sets in 2005 just for the early market, planted in March and harvested mid-August [12].
According to research findings, the Adama red onion variety which has been evaluated under the fiche condition of Ethiopia has responded to different Intra row spacing on different bulb yield parameters [13]. A similar report that three onion varieties, Bombay red, Adama red and Nasika red, responded differently to the intra-row spacing on yield and yield components at Adami Tulu.
Therefore, the identification of this yield-limiting factor due to population density is very important for onions against lower yield trends in the country [1].
This work presents some technically-scientifically aspects regarding the influence of shading on *Allium cepa* crops var. *rubra.* Two warp-knitted fabrics are experimented with as unconventional textile solutions (the organic diatomite was another innovative solution in Part 1 of this research study) for strengthening vegetable culture, by shading, in the context of climate change.

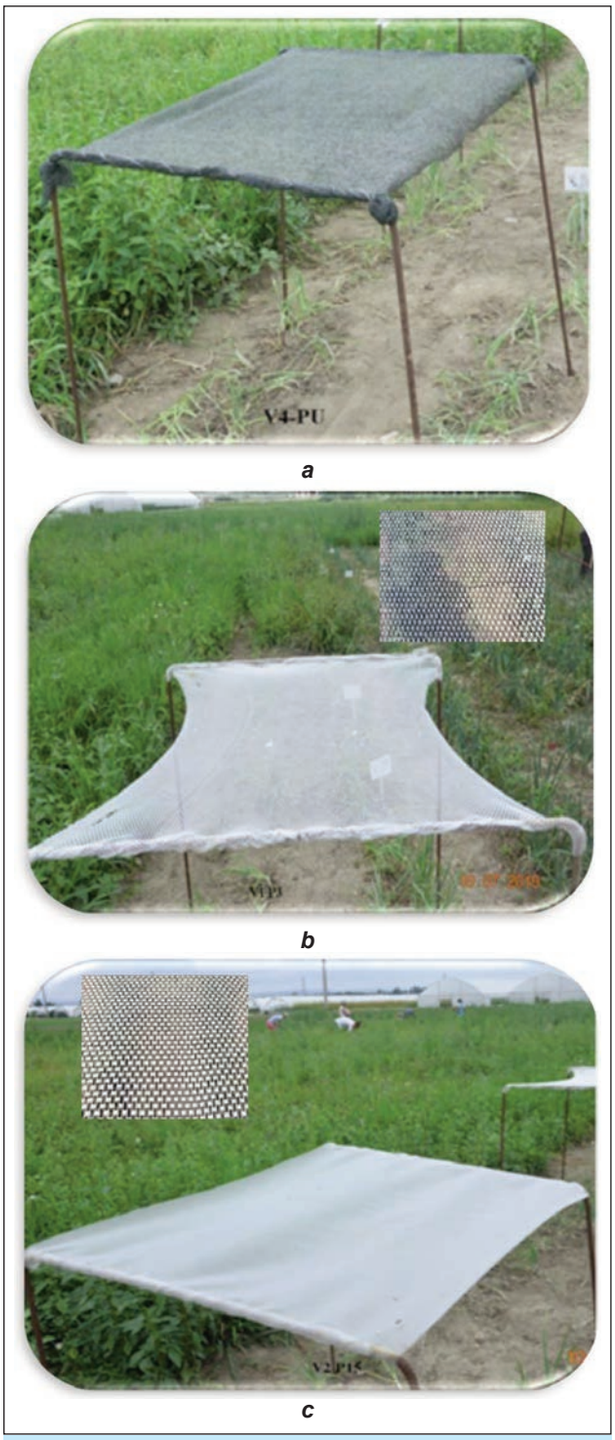
MATERIAL AND METHODS

The experiments were placed in the research field of the S.C.D.L. Buzau, field 32, plot A447 (45009`32,7``N and 26049`40,8``E), coordinates which gives together with soil composition, particularities of the vegetables from Buzau region, generally.
In 2019, 3 types of textile materials provided by the INCDTP Bucharest, were tested, and also with an unshaded control variant.
The variants of shading textile materials are warp knitted fabrics, and net type, which differ from each other by the surface of the net eye. The warp knitted fabrics are made of synthetic filament yarn of high tenacity, and low density, and with additional textured synthetic (micro) filament yarn.
Through the adopted structures (variants), the final aspect of the neat mesh is given and generates rectangular meso-surfaces, which have a uniform, well-defined distribution, "chessboard" type, with a variable coverage factor.
Thus, the entire fabric system formed has double functionality, of shading without overheating the microclimate, which must be shaded or dissipated in the air currents, by breaking off the aggressive air currents on the sides of the separation medium, represented by the developed knitted fabric variants [14].
These materials studied were mounted in the Rubiniu onion culture.
The onion variety (*Allium cepa*) Rubiniu, created by S.C.D.L. Buzau, is a semi-late variety of water red onion (150–160 days), with good tolerance to diseases and pests, and needs preventive treatments.
The production potential is 60–70 to/ha.
The edible part, the bulb, has the following characteristics:
– average weight 250.5 g;
– length 9.2 cm;
– shape cone trunk;
– package diameter 1.2 cm;
– median diameter 8 cm;
– disc diameter 1.6 cm;
– the number of fleshy tunics 10;
– the number of parchment tunics 3;
– the colour is red-purple.
It is recommended for fresh consumption [15].
The experiments located in onion culture had 4 variants with 4 repetitions (according to figure 1).
The pictures show the three experimental variants shaded with textile materials:

- V1 – warp knitted fabric, with 30% yarns cover factor, code P3 (figure 1, *b*);
- V2 – warp knitted fabric, with 50% yarns cover factor, code P15 (figure 1, *c*);
- V4 – woven fabric, with low technological threads density, from the specific market, used for shading property, Code PU (figure 1, *a*).

The shaded area was 0.8 m^2. The height at which the nets were installed was 1.10 m.

For the onion culture, the cultivation technologies specific to this species were used, adapted to the climatic conditions of 2019. The onion crop was established by direct sowing in the field, in the place established for the experiment, on 09.04.2019 and emerged on 29.04.2019. The nets were mounted on 04.07.2019.



a

b

c

Fig. 1. Shading nets in the culture of red onion Rubiniu variety: *a* – shading net PU; *b* – shading net P3; *c* – shading net P15

Climate

During the vegetation period of the red onion, minimum temperatures were registered in April, at 5°C, and the maximum temperature was 33°C (figure 2).

The amount of precipitation in a total of 297–322 mm was distributed according to the graph from figure 3 for the vegetation period. In general, in the plain area, the amount of precipitation is 400–500 l/m^2 [16] for a vegetation season.

For September, an amount of precipitation is estimated at 50 and 75 l/m^2 in the Subcarpathian area [17].

The soil

From a geomorphological point of view, the land on which the unit is located is in the form of an alluvial plain, anthropically shaped by levelling, within a dam, the former major riverbed of the Buzau River. The altitude of the land is 94.0 m, with a natural slope of NNV – SSE.

As a type of soil, we appreciate that it is alluvial, and depending on the humus content, groundwater intake, skeleton content and physical clay content, the soil is part of the group of soft soils, slightly salinized (table 1).

Table 1

AGROCHEMICAL CHARACTERIZATION OF THE SOIL [18]

Specification	Values recorded on mapping	Interpretation of values
pH (water)	8.20	weakly alkaline
Humus (%)	2.57	supplied environment
$CaCO_3$% carbonates	4.50	weakly carbonated
C: N	11	normal
N total%	0.151	good
P total%	0.183	very good
P mobile ppm	> 144	very good
K mobile ppm	> 268	very good

The bedrock consists of medium and heavy clays, carbonates and alluvial clays. The soil texture is loamy-sandy, and the groundwater depth is located at 2.0–3.0 m [18].

In culture, determinations were made regarding the following parameters: average plant height, the average number of leaves/plants, average leaf length, average leaf width [19–21], and area foliar calculation [22].

The production data were not recorded because during the intense growth of the bulb there were abundant precipitations that determined a strong rooting of the plants, and they maintained their green foliage to the detriment of bulb formation [23].

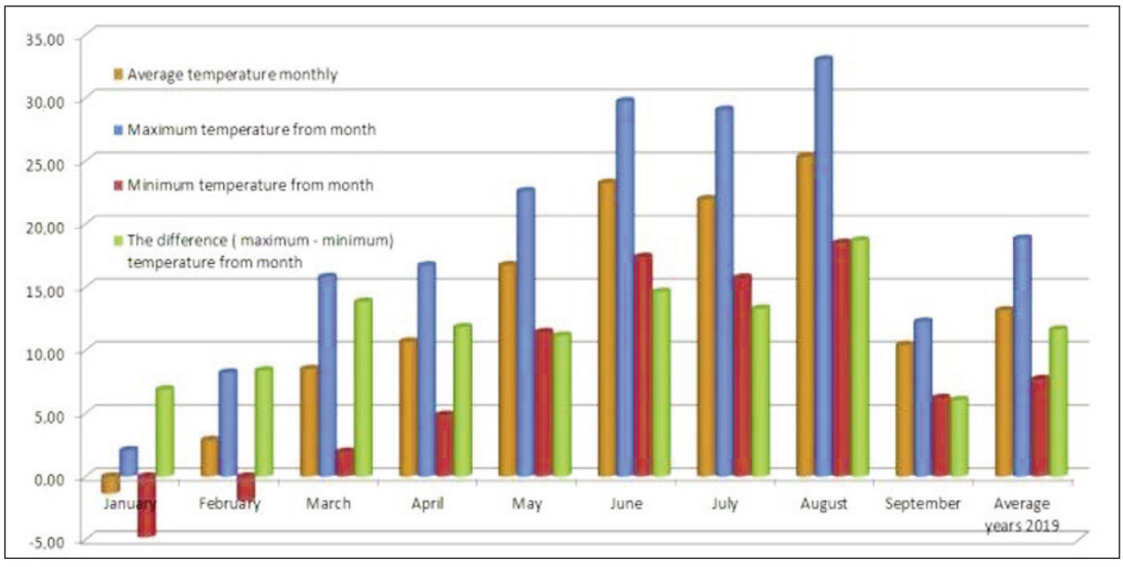


Fig. 2. Graph of monthly temperatures in 2019

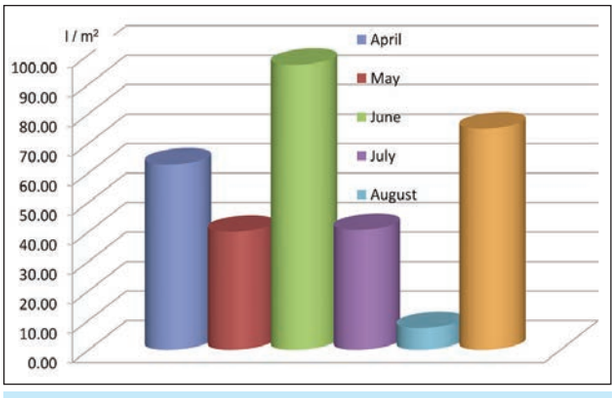


Fig. 3. The amount of precipitation, l/m^2, for each month, from April to August

In September was estimated an amount of precipitation of at least 50 l/m^2 [17].

RESULTS AND DISCUSSION

The analysis of the results regarding the evolution of the plant height is presented in figure 4.

The first determinations were made on 05.07.2019 (meaning 24 days of shading) and a maximum value of plant height was found in variant V2 with mesh P15 and a minimum value in variant V4 with shading mesh PU 30%.

At the last determination on 19.08.2019 (50 days of shading), the highest value of the height of a plant, in centimetres, was registered at variant V1 (the shading net-type P3), and the lowest at the control V3.

The evolution of the number of leaves per plant (figure no. 5) shows a higher number of leaves in all shaded variants (7.5–8 leaves on the average per plant).

The variant with the lowest average number of leaves per plant was V3 Control (4.5–5), the highest average value being variant V2 textile material type P15 (figure 5).

The surface of an onion leaf (mm^2), in the conditions of shading with textile materials as seen in figure 6, shows an increasing trend, with higher values for shaded variants (V1 – textile material type P3, V2 – textile material type P15, V4 – PU 30%) compared to the unshaded control starting from the 24th day of shading, until the last determination in the 50th day of shading.

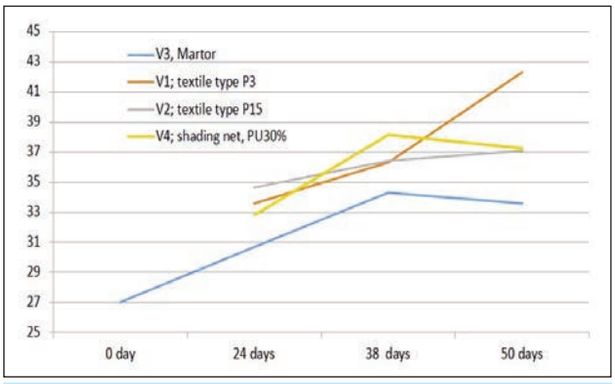


Fig. 4. Evolution, in days, of plant height in cm – Rubiniu red onion variety, different variants

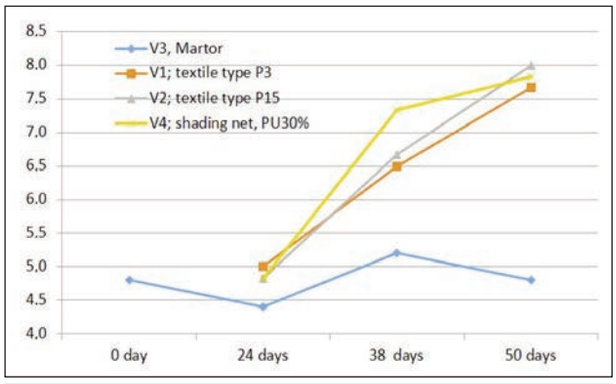


Fig. 5. The evolution, in days, of the number of leaves – the Rubiniu red onion variety, different variants

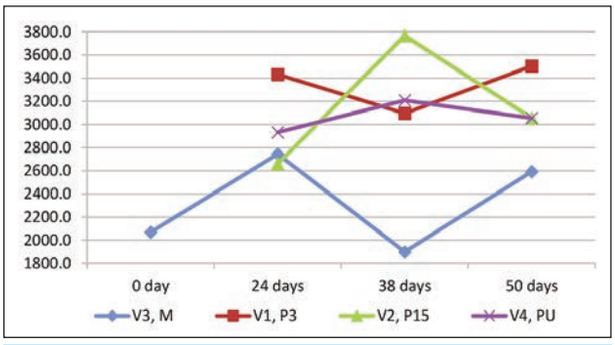


Fig. 6. Evolution, in days, of the surface of an onion leaf (mm^2), in the conditions of shading with textile materials (variants were: V1 – textile material type P3, V2 – textile material type P15, V3 – unshaded control, V4 – PU 30%)

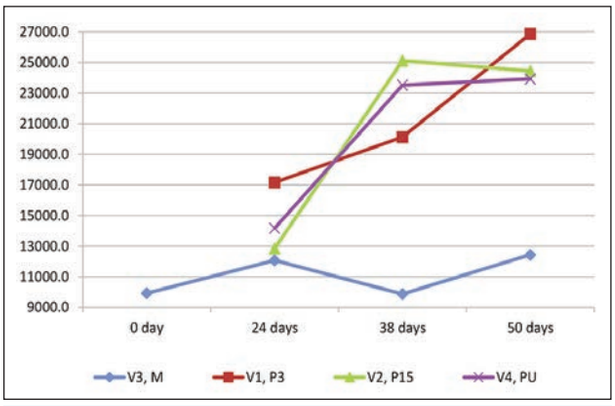


Fig. 7. The evolution, in days, of the total surface of onion leaves, in mm^2, in the conditions of shading with textile materials (V1 – textile material type P3, V2 – textile material type P15, V3 – unshaded control, V4 – PU 30%)

The smallest surface of a leaf is calculated in mm^2, it is found in the unshaded control variant, at 50 days of shading (2592.3 mm^2).

At the opposite pole there can be found the largest surface of a leaf at 38 days of shading variant V2 net P15 3767.2 mm^2 and 50 days of shading V1 net P3 3504.1 mm^2 (figure 6).

The shaded plants had a much larger leaf area per plant in the shaded variants than in the case of the non-shaded variants (figure 7).

The lowest value of the leaf area per plant at 50 days of shading is 12443.1 mm^2, representing approximately half of the value of shaded variants (figure 7).

The highest value is 26864.7 mm^2 at 50 days of shading in variant V1 with mesh P15 (figure 7).

CONCLUSIONS

After experimentation it was found that onion plants shaded with the material textile P15, have increased their leaf area; the number of leaves was higher under the mesh model P3 and the black shade.

Also, all the shaded variants had an almost double-leaf area compared to the unshaded control, which shows the positive influence of shading.

The use of textile fabrics in vegetable crops can contribute to a significant increase in plant height, having an important role in the faster growth and development of plants, as well as in protecting from the action of unfavourable climatic factors and sudden changes in the weather (frost, strong wind, high/low atmospheric heat, heavy rains, etc.).

The textile structures in agriculture were and still have an active, positive role. A circular economy, strengthens the complementarity of textiles in agriculture, in future.

ACKNOWLEDGEMENTS

This work was supported by a grant from the Romanian Ministry of Research and Innovation, PCCDI - UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0659/30.03.2018 - Contract 11 PCCDI/2018 - LEGCLIM, within PNCDI III.

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