Value chain analysis in technical textiles and composite materials sector: a regional case study

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MEHMET KARAHAN
ALİ ARI
NEVİN KARAHAN

ABSTRACT – REZUMAT

Value chain analysis in technical textiles and composite materials sector: a regional case study

This study has been prepared as the value chain analysis for the Bursa Technical Textile and Composite Materials Cluster. The study aims to identify key actors in the value chain, competencies, and areas to be developed in the cluster ecosystem. The industrial scope of the study covers technical textiles and composite materials together, as, in many ways, Bursa enjoys the presence of sophisticated companies and strong infrastructure to specialize further and be one of the world's leading centres for the industry. Industry-level value chain analysis detailed each value chain process in terms of its main competencies and development areas. The value chain analysis reviewed the parameters of the Diamond Model to form the basis of a strategic vision for the future. Based on the findings, the report has an early-stage action plan for the cluster management team to undertake steps in the very short term, which can go hand in hand with the strategic development stage.

Keywords: *composite materials, technical textiles, value chain analysis, Bursa*

Analiza lanțului valoric în sectorul textilelor tehnice și al materialelor compozite: un studiu de caz regional

Acest studiu a fost elaborat ca analiză a lanțului valoric pentru Clusterul tehnic textil și materiale compozite din Bursa. Studiul urmărește să identifice actorii-cheie din lanțul valoric, competențele și domeniile care trebuie dezvoltate în ecosistemul clusterului. Domeniul de aplicare industrial al studiului acoperă atât textilele tehnice, cât și materialele compozite, deoarece, din multe puncte de vedere, Bursa se bucură de prezența unor companii sofisticate și a unei infrastructuri puternice pentru a se specializa în continuare și a deveni unul dintre cele mai importante centre mondiale pentru această industrie. Analiza lanțului valoric la nivel de industrie a detaliat fiecare proces al lanțului valoric în ceea ce privește principalele sale competențe și domenii de dezvoltare. Analiza lanțului valoric a revizuit parametrii modelului Diamond pentru a forma baza unei viziuni strategice pentru viitor. Pe baza constatărilor, raportul conține un plan de acțiune pentru etapa inițială, pentru ca echipa de management a clusterului să ia măsuri pe termen foarte scurt, care pot merge în paralel cu etapa de dezvoltare strategică.

Cuvinte-cheie*: materiale compozite, textile tehnice, analiza lanțului valoric, Bursa*

INTRODUCTION

The relentless progression of globalization presents an increasingly challenging environment for enterprises to maintain competitiveness [1]. The rapid pace of globalization, international trade, and advancements in communication and transportation technology have necessitated firms to engage in ongoing self-assessments due to the economic, social, and technological changes occurring worldwide [2]. The key aims for firms have been to remain relevant in a changing and evolving world, to get a larger portion of expanding markets, to transform risks into opportunities, and to ensure their survival [3].

The success of highly competitive products and services typically relies on the manufacturing company itself and the collective efforts of all the collaborating companies involved in delivering the final product or service to customers [4]. In the present era, numerous factors contribute to the intricate and ever-changing nature of companies' decision-making processes. These factors include the decreasing lifespan of products and services, necessitating the constant introduction of new offerings, evolving processes that demand swift adaptation, the arrival and departure of business partners, diverse customer preferences, alterations in distribution channels, the rapid pace of technological obsolescence, the impact of globalization, and the influence of government regulations. According to Stonebraker and Liao [5], the extent of environmental turbulence and the strategic orientation of a company directly and positively influence the extent, stages, and scope of value chain integration.

Organizations that pursue these objectives will gain a competitive edge. However, these firms must devote a significant amount of effort to ensure the long-term viability and enhance the competitive edge of enterprises. Enterprises and sectors can achieve a sustained competitive advantage by implementing strategies tailored to their individual needs and characteristics. The adoption of competitive strategies in response to changes in firms reflects the competitive standing of those firms within the industry. This situation is a crucial subject for all companies operating in the sector to consider. Porter's framework model, established to assess competitiveness, holds significant importance in this context. Within this paradigm, the critical factors that determine outcomes are "factor conditions", "demand conditions", "related and supporting industries", and "firm strategy, structure, and competition". The factors of "government" and "chance" also play a role in shaping outcomes. This type is characterized by its dynamic nature and versatility. Using this model, Porter developed a framework to evaluate the factors that determine why certain countries and enterprises, depending on the industry, are more competitive and successful than others. In 1990, Porter aimed [6] to establish a link between strategic management and international economics in his book "Competitive Advantage of Nations". He argued that trade-related theories have primarily focused on cost and needed a comprehensive understanding of competition, including segmented markets, differentiated products, technological differences, and economies of scale. Porter conducted an examination in ten countries for four years to identify factors determining competitiveness and contribute to the development of competitive structures. He developed the Diamond Model to identify factors of competitive advantage and the theoretical underpinnings of the interplay of country and industry competitiveness topics. The model consists of four corners: "factor conditions", "demand conditions", "firm strategy, structure and competition", and "the presence of related and supporting industries". Luck and government factors are also included in the system [7]. Factors affecting competitiveness include assets and skills vital for industry competitive advantage, information creating opportunities, interest group aims, and the company's power to invest and innovate [8].

Industries that rely on technology and innovation, such as composite materials, necessitate a comprehensive comprehension of the different levels or phases that make up the value chain. The basic configuration of the composites value chain consists of four tiers. The study conducted by Shakespeare and Smith [9] offers a comprehensive explanation of the various levels that make up the composite value chain. Currently, organizations prioritize the reduction of production costs for composite items. Over 70% of the manufacturing expenses are estimated to occur during the value chain design stage. Therefore, it is essential to minimize expenses during the initial stages of value chain design rather than during the production phase [10]. Value chain and logistics play a significant role in cost savings, as they account for nearly 80% of the product costs in the procurement value chain [11].

In our previous studies, technical textiles [12] and composite materials [13] market research and added value analysis were examined regionally and globally. According to our research, it has been observed that the demand for high-value-added products such as technological textiles is increasing in world markets. Over the last decade, many countries have restructured their production methods to focus on the production of these goods to increase their economic competitiveness on the global stage. World exports of technical textiles reached around 118 billion dollars, an increase of 3.38 percent compared to the previous year. Türkiye's 2021 exports amounted to 2 billion 413 billion dollars, a decrease of 12.91% compared to the previous year. The Grubel-Lloyd Index calculation for technical textile product groups in Türkiye reveals bilateral intra-industry trade, except for a few product groups. The average index value for all technical textile products was calculated at 0.7968. By 2028, it has been observed that the Mobiltech, Indutech, and Packtech subcategories of technical textiles will dominate the commercial market.

In today's global markets, the need for high-value composite products, such as technical textiles, is increasing. Over the last decade, many countries have shifted their production methods towards these goods to increase their competitiveness in the world economy. According to the data, Türkiye's composite material exports increased by 19.48 percent in 2021 compared to the previous year, reaching a total of 2.7billion lira. Based on the Grubel-Lloyd Index calculation, the study finds that intra-industry trade in Türkiye's composite material product categories is predominantly bilateral, with a few limited deviations. The average index value for composite materials was determined to be 0.6890.

The authors also studied the competitive factors in the technical textiles and composite industries [14]. According to this study, the technical textiles and composite industry has been found to significantly impact the global economy through factors such as production costs, technology, product quality, innovation, and sustainability. The growth and success of the technical textiles and composite industries depend on their ability to transform these competitive features into value-added products. Value-added goods distinguish themselves from commodity goods by offering special features, capabilities, and advantages. This allows businesses to charge higher prices and make more profits.

This paper aims to select, rank, and identify the fundamental correlations between the factors that influence the selection of manufacturing technology in a youthful and dynamic sector, such as the composite materials industry. The industrial scope of the research covers technical textiles and composite materials together, as, in many ways, Bursa enjoys the presence of sophisticated companies and strong infrastructure to further specialize and be one of the world's leading centres for the industry. This research is to perform a value chain analysis for the Bursa Technical Textile and Composite Materials Cluster. The objective of this study is to ascertain the principal participants, skills, and domains that require enhancement within the cluster ecosystem of the

Bursa Technical Textile and Composite Materials Cluster. This research aims to establish the foundation for the subsequent stages of cluster development in Bursa, particularly in terms of formulating the cluster strategy and implementation roadmap.

METHODOLOGY

The approach of cluster analysis has substantial importance to be able to understand and position competences of the cluster in consideration with future trends and directions for creating a competitive framework for the cluster and cluster companies. Unlike any traditional industry, technical textiles and composite materials are highly fragmented and have complex value chains where an in-depth understanding of industry structure, an integrated approach and a review of industry trends are needed. Before starting analysis with well-known tools such as value chain analysis and M. Porters' Diamond framework, there is a need to understand key determinants of the industry first. In the light of this main approach, this study has followed a tailor-made and well-structured analysis framework elaborating cluster environment and the industry by process, material, application and technology (figure 1).

The study is based on three main analysis tools: i) desk review, ii) value chain analysis and iii) cluster analysis (figure 2).

The findings of these analyses have been reviewed and organised through workflow and presented as follows:

1. Desk review: Desk review study aimed to review industry structure and provide a clear understanding of the industry by definition, market segments, market size and growth. Along with the industry overview, former analysis and reports conducted by the project were also reviewed and integrated into the relevant sections of the study about the current status of the industry in Bursa. As constituting secondary data collection of the study, before proceeding with further steps, desk review provided a solid insight for design and development of the tools to best fulfil aims of the work.

2. Primary data collection: The Value Chain Analysis conducted under this study has been the main analysis tool for collecting primary data. A tailor-made work has been designed in line with the industry structure. Primary data was collected through developing a survey sheet and applied through semi-structured interviews with companies and stakeholders. Throughout the study, 57 companies and key stakeholders were interviewed.

3. Data analysis: Primary and secondary data were reviewed and processed through different sector and cluster tools. Value Chain Analysis, Porters Diamond, SWOT used to analyse collected data. A draft value chain map was developed.

4. Data verification: Findings of analysis and draft value chain presented and findings were consulted through 2 workshops undertaken. Value chain map, key competences and areas for development were identified, and findings of the value chain analysis were verified.

5. Reporting: Based on the collected data, analysis and views gathered from stakeholders and cluster companies, the value chain map was finalised and reporting work undertaken.

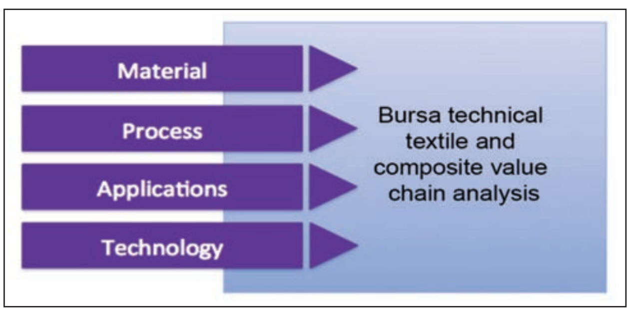

Fig. 1. Value chain analysis context

INDUSTRY DEFINITION

Technical textiles

Technical textiles are high-performance textiles with special functionalities used in various industries, including automotive, personal care [15], hygiene, agriculture, home care, construction, aerospace, protective gear, and healthcare. The global technical textiles market is divided into four segments by process, material, application, and technology [16–19].

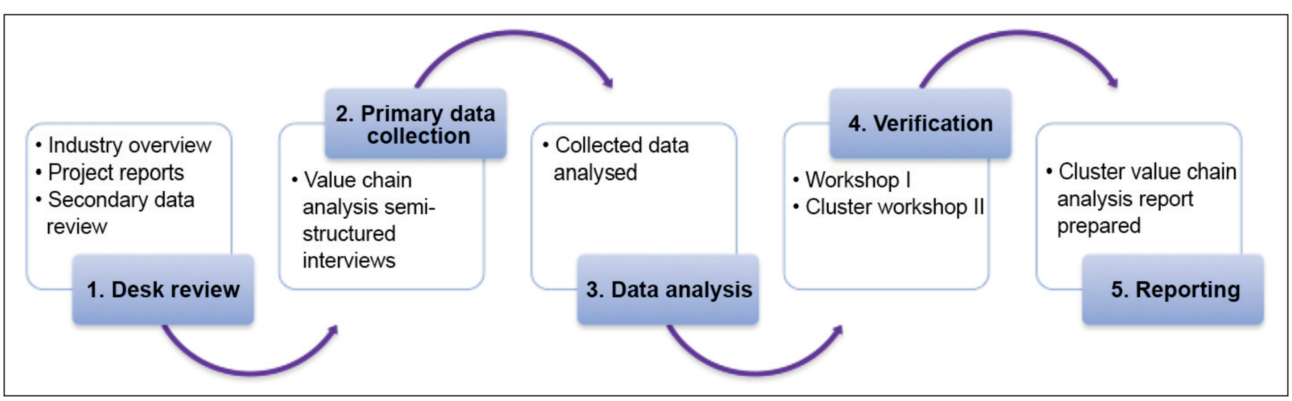

Fig. 2. Workflow

By process, the market is divided into knitted, nonwoven, woven, and other sub-segments. Nonwovens are used for various purposes, such as covers, carry bags, thermal insulation, ballistic protection, and fireproof layers. The growing demand for polypropylene in nonwovens is anticipated to propel the overall growth of the technical textiles market. The woven segment is expected to be the fastest growing in coming years due to ease of production and low cost. The market is also segmented by materials such as recycled fibre, mineral, synthetic polymer, natural fibre, metal, high-performance fibre, and others. High-performance fibres like aramid, carbon, and UHMW polyethylene are also included.

The application market is divided into twelve segments: Geotech, oekotech (echotech), Mobiltech, indutech, packtech, sportech, protech, buildtech, agrotech, hometech, clothtech, and medicaltech. Geotech focuses on agro-based geotextiles and geosynthetics, while oekotech uses technical textiles in environmental engineering and landfill waste management. Mobiltech uses technical textiles in automobiles, aircraft, railways, and shipbuilding.

Indutech focuses on industrial brushes, paper-making fabrics, filtration products, computer printer ribbons, printed circuit boards, composites, ropes & cordages, coated abrasives, AGM glass battery separators, bolting cloth, cigarette filter nods, drive belts, and conveyor belts. Packtech includes leno bags, wrapping fabric, jute hessian and sacks, soft luggage products, tea bag filter paper, woven sacks, sportsech, protech, buildtech, agrotech, hometech, clothtech, and medicaltech.

Technology is segmented into six segments: spinning, weaving, knitting, finishing, nanotechnology, and others. The wide applicability of technical textiles in various industries is a major factor driving market growth.

Composite materials

Composites are a combination of reinforcement material and matrix, with the reinforcement being the main load-bearing component. Its properties are superior to individual components, with fibres, particles, and flakes acting as reinforcement forms [20]. The matrix keeps reinforcement in a specific orientation and protects it from damage. Composites are used when traditional materials don't meet specific application requirements. They can be designed to achieve a wide range of properties by altering constituent materials, orientations, and process parameters. They have high mechanical properties with low weight, making them ideal for automotive and aerospace applications. Composites also offer high fatigue resistance, toughness, thermal conductivity, and corrosion resistance. However, high processing costs limit their wide-scale usage. Textile-reinforced composites consist of a textile form as reinforcement and a polymer matrix. Different textile architectures offer significant potential for designing composite properties.

CONSOLIDATED COMPETENCE MAP OF TECHNICAL TEXTILE AND COMPOSITE MATERIALS MANUFACTURING COMPANIES

A Competency Maps Study has been undertaken within the scope of the Diagnostic Studies of the Project. During this study, competency mapping was used to identify strengths and weaknesses of companies grouped by sub-sectors through a set of indicators. The aim was to better understand the relationship between different indicators and needs to increase competitiveness and facilitate transformation or new investments to technical textile or composite materials manufacturing effectively.

Through this document, based on the data generated within the Competency Map Study, a consolidated competency map has been prepared with selected 10 indicators to analyse the sub-sectors of technical textile and composite materials companies in Bursa. As seen in figure 3, 10 different indicators, including qualified workforce, access to finance, R&D opportunities, foreign trade, quality-technical competence, innovation competence, standardisation and certification, competition in the market, access to raw materials and logistic opportunities were presented.

In the Competence Maps Study, logistic regression models for the prediction of different dependent variables, which were defined by sector experts, have been constructed to determine factors affecting a dependent factor. Data were transformed to binary outcomes, which allow straightforward decisions between two alternatives based on the company's self-scoring in given parameters. For these models, the degree of competency was divided into less competent (between 1 to 5) and more competent (6 to 10). In light of the explained method, in figure 3, competencies were shown between a scale from 3 to 7, in which less competent indicators can be observed between 3 to 5 and more competent ones from 6 to 7. In this document, the scale has been set between 3 to 7 to be able to provide a concise view. Figure 3 presents competency indicators in identifed subsectors – composite, medtech, hometech, clothtech, protech and Mobiltech – in a linear direction from right to left and gives an impression of the grouping of subsectors or the relationship between factors represented by the XY axis. The consolidated composite map provides an integrated look and enables a comparable view for elaborating the relation between selected factors (Axis Y) on areas of identified areas of competences (Axis X) (table 1).

Within the framework of given parameters, it is seen that quality workforce, standards and certification, competition in the market and foreign trade competences are concentrated between 5.00 and 7.00 by Axis X. When relations examined; for example, in Mobiltech segment it can be interpreted that access to coaching and training services has positive implications on qualified workforce. In the composite's subsector, qualified workforce competence is high;

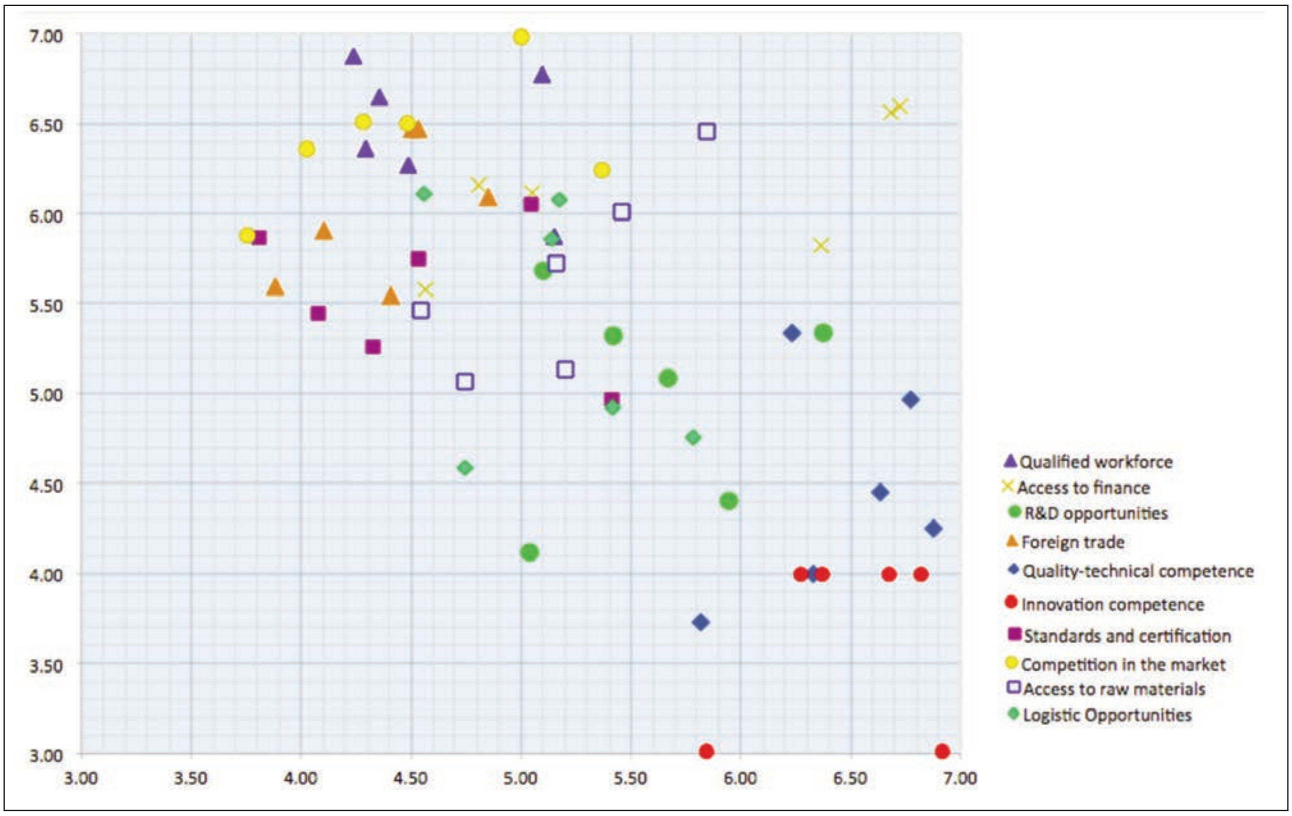

Fig. 3. Consolidated map of company competencies by sub-sectors

Table 1

VALUE GROUPS	
Axis X	**Axis Y**
Qualified workforce	Access to Coaching / Consulting / Training services
Access to finance	Access to government incentives
R&D opportunities	Access to raw materials
Foreign trade	Proximity to the market
Quality- Technical competence	Qualified workforce
Innovation compentence	Qualified workforce
Standards and certification	Quality-technical competence
Competition in the market	Quality-technical competence
Logistic opportunities	Network structure
Access to raw materials	Network structure

even access to training and coaching is at a moderate level. In foreign trade competence, Mobiltech has the strongest relation with proximity.

When the relation between qualified workforce and innovation competence of companies is reviewed, it is seen that innovation competence in composite and Mobiltech are relatively low even qualified workforce indicator given higher scores. Likewise, in other segments, innovation competence has been scored low while qualified workforce has high-level scores. It can be interpreted that innovation competence can be increased not only by a high level of qualified workforce but other determinants may imply. In Mobiltech, for instance, it is seen that the qualified workforce scored almost at the highest level; however, innovation competence scored low.

The relation between access to raw materials and network structure is concentrated at a moderate level from both axes. It can be interpreted that there is a linear relation between two parameters in given sub-sectors. For instance, in Mobiltech, it is seen that a stronger network structure meets with stronger access to raw materials.

It is observed from the consolidated figure 3 that there is a linear relationship between quality technical competence and qualified workforce indicators. An increase in the qualified workforce can have positive implications on quality technical competence. Except for the composite sub-sector, it is seen that companies' level of quality technical competence has been scored at a moderate to high level.

Competence in access to finance and access to government incentives is high in all sub-segments of the industry. A linear relationship is observed between access to finance and access to government incentives. RD opportunities are at a relatively moderate level from both axes between 4.50 and 6.50. An increase in access to raw materials has positive implications for the R&D opportunities of the companies in sub-segments of the technical textile and composite materials industry.
Logistic opportunities about network structure constitute a position from moderate to high level in almost all sub-sectors. Improvements in network structures may have further positive implications on the logistic opportunities of companies.
A consolidated competence map of companies in selected competence parameters reveals that factors conditions such as qualified workforce, network structure, access to training and coaching services, and access to government incentives have linear relation and positive implications on key parameters of competitiveness, including innovation competence, quality technical competence, and competition in the market. Consolidated Map reviews may provide insights for possible decisions on investments and actions to be taken towards competitiveness of the industry.
It has to be remembered that consolidated figure 3 examines the relation between two parameters and cannot be accepted as the conclusion on the level of competences. Figure 3 can be a starting point for further analysis on competences of companies with different tools and analysis methods.

VALUE CHAIN ANALYSIS

The value chain is a concept which can be simply described as the entire range of activities required to bring a product from the initial input-value stage, through various phases of production, to its final market destination [21]. Within the scope of cluster analysis stage, industry value chain analysis has been conducted to understand present actors and value-added processes from input materials to manufacturing of products, supporting industries and actors and finally related end markets. Another aim of undertaking value chain analysis is to increase a sound insight on the current status of Bursa Technical Textile and Composite Materials Value Chain. This ability and knowledge will be used as precious means while analysing trends and identifying which parts, functions and approaches, along with the value chain, should be upgraded.
Value chain analysis study undertaken through semi-structured interviews and application of a specially designed set of survey questions. The analysis study was completed with the participation of 57 companies representing a wide range of actors present in the Bursa technical textile and composite materials value chain. Figure 4 shows the distribution of companies in terms of their perception of their position in the chain.

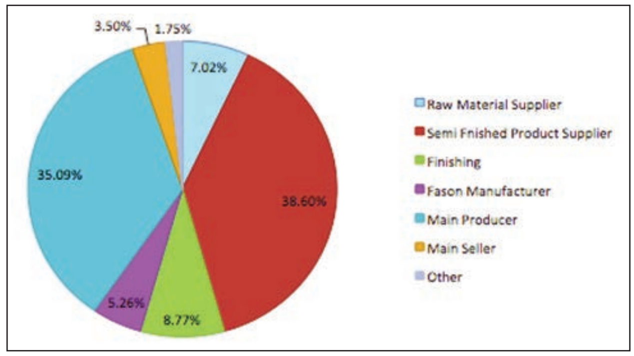

Fig. 4. Companies' perception of value chain position

In technical textiles and composite materials, it is not always possible to distinguish the roles and/or positions of companies as suppliers or manufacturers. As an example, companies defining themselves as manufacturers can be suppliers of companies providing goods for OEMs. In the light of industry structure and linkages – taking company products and operations into consideration – prepared final value chain map. It is seen from figure 4 that 35% of companies are main producers while 38% position themselves as semi-finished product supplier. 7% of the companies provide raw materials, including chemicals. 5.2% as suppliers (named as fason) and 8.7% has finishing operations.
The value chain map has been developed, and an in-depth understanding has been generated regarding key competencies and areas to be further developed. Due to their linkages within the chain, the analysis covers technical textiles and composite materials actors and processes together instead of elaborating on them individually. Additionally, the main processes of the value chain also cover information at national level related actors, which has direct implications on the value chain at Bursa at regional level. It is not possible to elaborate any industry as an isolated system. The below version of the Value Chain Map has been finalised based on the verifications and views received from the participants of two workshops held throughout the study (figure 5).

Fibres and yarns

Fibres are the main input materials used in the manufacture of technical textiles and composite materials. Within the scope of the value chain analysis study and map of Bursa Technical Textile and Composite Materials, fibres were elaborated under four main categories: i) Natural fibres, ii) Regenerated fibres, iii) Synthetic fibres and iv) High Performance Fibres. In technical textiles and the composite sector, material is one of the key determinants of high performance. For the manufacture of composite products, the most commonly used input materials are glass fibre-reinforced polymer (GFRP) and carbon fibre-reinforced polymer (CFRP) composites, followed by composites reinforced by aramid or natural fibres. Reinforced fibres and bio-based materials are gaining importance in parallel with developments and

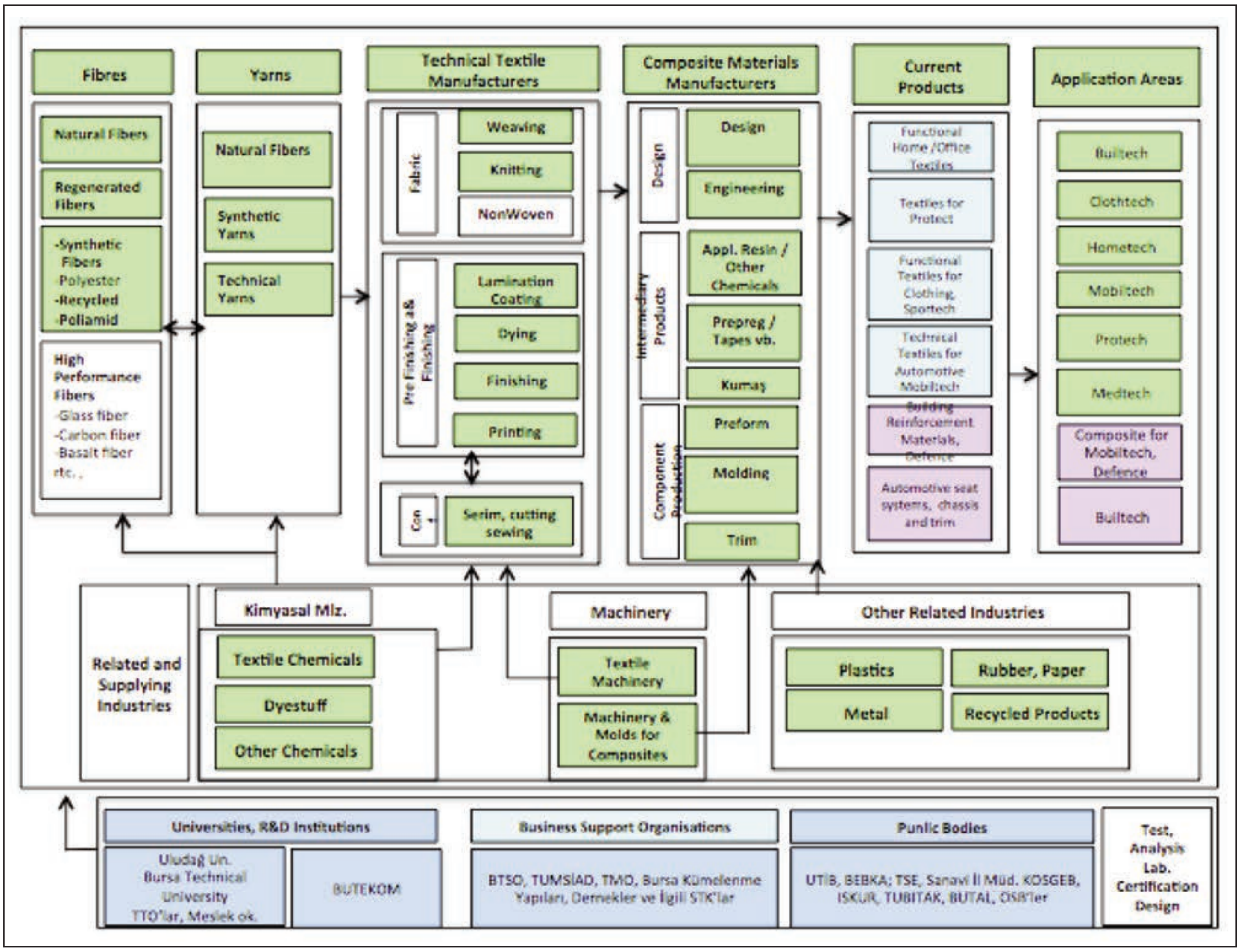

Fig. 5. Value chain map

needs in end industries. The presence of fibres – reinforced, bio-based, etc. – in Bursa in this regard can be considered as one of the "to be developed input material/process" of the value chain. In Bursa, natural and synthetic fibres are present; however, there is very limited manufacturing and/or ongoing studies on manufacturing high-performance fibres, glass fibre, carbon fibre, etc., at any level of scale yet. Currently, there is only one company within the cluster environment which has glass fibre. Carbon fibre is purchased from other regions. As stated earlier in this paragraph, bio-based fibres also gain importance in the textile industry and related industries. Upgrading the "manufacture of high-performance fibres" within the value chain can bring opportunities to Bursa. To conclude, i) developing bio-based fibres, ii) manufacturing and innovating on high tenacity synthetic fibres, and iii) studies on reinforced materials can bring competitive advantages to Bursa.

At this point, it is important to state that Türkiye is one of the global suppliers of glass fibres produced by ŞIŞECAM. In 2019, the total volume of glass fibre was 90.000 tons, and this volume met only half the need in Türkiye.

The manufacture of fibres such as glass, carbon, etc., needs a certain level of investment and may need specific infrastructure. At this stage, the lack of players manufacturing glass or carbon fibre cannot be accepted as a key weakness. However, suppliers of such critical input materials keep the power of bargain and price decision and may limit access to materials. Dependency, especially on glass and carbon or aramid fibres, may put pressure on the competitiveness of the companies. Based on the desk review study undertaken throughout the analysis study, it is seen that "sustainability" will continue to be the determining condition for competitiveness. Since innovation starts from material, studies on alternative and bio-based materials for bio-based fibres to be used in technical textile and composites seem to be one of the key strategic upgrades for the value chain.

Yarn manufacturing: The majority of companies that participated in the cluster analysis study are manufacturing textile products made of synthetic fabric and functions to fabric in most cases provided by chemical applications and at finishing process. Bursa is one of the strongest centres for yarn manufacturing, especially in synthetic yarns. The manufacture of synthetic yarns has direct linkages with the customers along with the value chain both for the needs of textile and technical textile manufacturing purposes and end products. Findings and cluster workshop reveals that in Bursa, along with synthetic yarns, there is production of regenerated and another type of yarns as indicated in the value chain map. The manufacturing of yarns from bio-degradable materials has just started; however, there is a need for further improvements.

Since the majority of technical textile companies also manufacture textile products for home and furniture use, fabrics made of synthetic yarns are widely seen. However, analysis reveals that there is a need for increasing both the number of companies manufacturing high tenacity yarns and increasing capacity to manufacture technical and high tenacity yarns.

Some of the areas high tenacity yarns are used automotive car seat upholstery, technical textile for outdoor products as well as fabrics for the use of protective wear.

Technical textile manufacturers

Technical textile manufacturing as one of the key processes along with the value chain has been analysed and elaborated through three sub-processes including manufacture of fabric, finishing applications and confection. In total, 57 companies participated in the cluster and value chain analysis. Out of 57 companies, 34 companies manufacture technical textile products. Fabric manufacturing in Bursa is mostly based on weaving technologies. Technical aspects or functions of fabrics are mainly given at finishing processes through the application of chemicals and/or substances.

This information has also been supported and is in line with the findings of the Stakeholder Analysis, which was conducted at the initial stage of the Project. As the findings state, "When the technologies utilised in company production are evaluated, that weaving technologies predominate in the Bursa textile industry. Following these technologies are those for weaving preparation, finishing, and dyeing. In companies that claim to only produce traditional textiles, weaving technologies and weaving preparation technologies rank first and second, respectively, while companies that produce technical textiles prioritise finishing and dying technologies. Although there aren't many companies that use knitting technology, it is clear that these companies generally focus on technical textiles**.** Most of these businesses produce for the automotive industry. It has been reported that weavers also manufacture technical textiles, as shown in figure 6. Dyeing and finishing relationships with technical textiles are assumed to be limited to functional textiles. Even though companies using coating technologies also make technical textiles, it is thought that the majority of them produce fabrics for roller blinds or upholstery".

Technical textile manufacturing technologies and finishing applications are directly linked to needs and areas of use. It is therefore highly important to understand and identify target sectors and application areas for Bursa, to invest, adapt and innovate in fabric manufacturing and finishing processes. For instance, it is known that for Mobiltech, warp-knitting capabilities constitute a substantial place, electrospinning in medical use products. As an early conclusion before developing cluster strategy and roadmap, having strong automotive industry in Bursa, companies should be supported for developing their manufacturing technologies including fabric manufacturing, applications, materials and know-how on how to apply innovative solutions.

Composite products manufacturing

Before proceeding on details of the value chain, it is beneficial to review the definition of composite materials. As stated in the industry definition section, a composite material is a material produced by combining two or more materials with significantly different physical properties, which allows obtaining desired unique properties. The combination of different materials allows obtaining new materials that are stronger, lighter, or less expensive compared to conventional materials.

The composite material is generally a combination of the matrix and the reinforcement. According to the matrix type, the matrix materials are classified into metals, plastics, and ceramics. Based on the polymer type, fibre-reinforced composites are divided into thermosets and thermoplastics. The fundamental difference between thermosets and thermoplastics is that the first type of material is cross-linked and cannot be re-melted, while thermoplastics can be melted and reshaped. Polymer-matrix composites cover the vast majority of the composites market, in which two-thirds correspond to thermoset composites, though the application of thermoplastic composites has increased significantly in recent years [22].

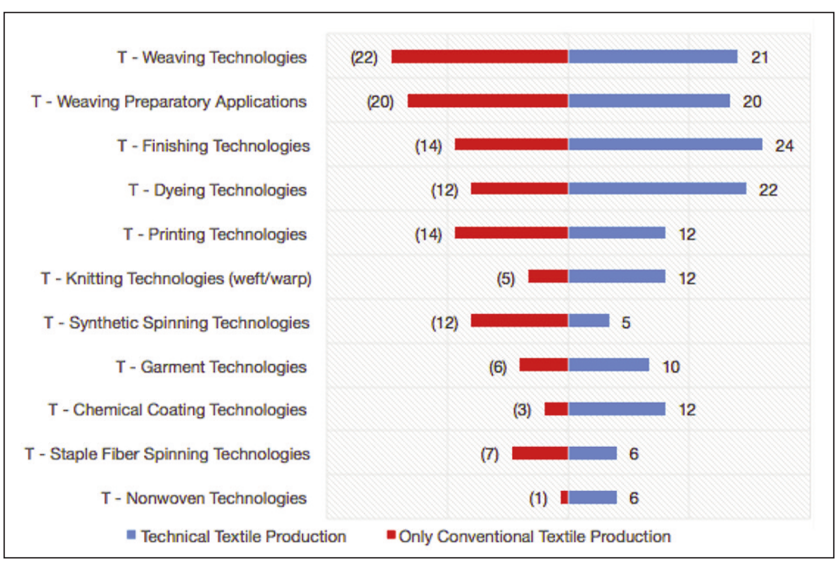

Fig. 6. Manufacturing technologies of companies

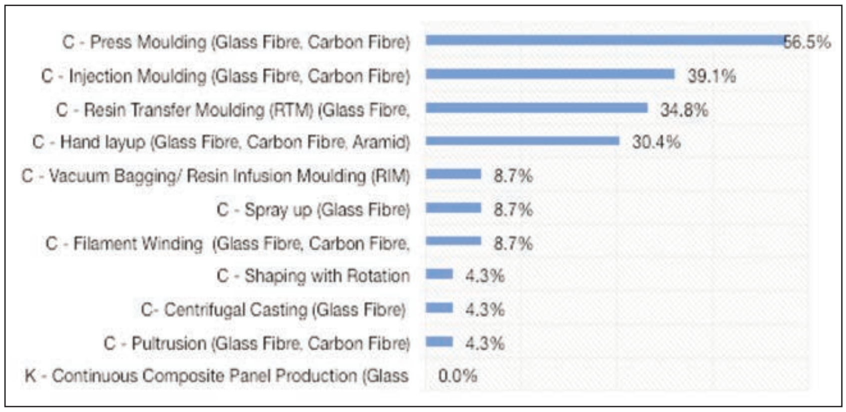

Fig. 7. Composite materials manufacturing process and technologies in Bursa (*Source:* Stakeholder analysis report)

The value chain of the composite materials involves many industrial sectors, from raw materials supply up to part production. Their manufacturing processes require equipment and machines but also a wide range of simulation, automation, testing and measurement techniques. The pace of innovation in the sector is extremely high among all parties involved, such as academics, R&D centres, large companies, and deep tech start-ups [23].

Within the value chain analysis and value chain map, composite materials have been elaborated in three main sub-processes: design, intermediary products and component production. In Bursa, out of 57 companies that participated in the cluster and value chain analysis study, 24 are operating in composite materials. In Bursa, operations related to technical textiles and composites are strongly interconnected with the Mobiltech segment of technical textiles. The presence of OEMs and Tier 1 and Tier 2 suppliers facilitates the production of plastic, metal and composite components for the automotive industry.

As it can be seen in the value chain map, the design of composite materials is the first step before manufacturing processes. In Bursa technical textile and composite materials, there are companies providing design, simulation, mould development and 3D printing services for design and development of composite materials.

The application of resin and other chemical substances constitutes the second process of the value chain in the manufacturing of composite materials. Resin is widely used in manufacturing composite products. Two major groups of resins make up what we call polymer materials: thermosets and thermoplastics. These resins are made of polymers (large molecules made up of long chains of smaller molecules or monomers). Thermoset resins are used to make most composites. They're converted from a liquid to a solid through a process called polymerization or cross-linking. When used to produce finished goods, thermosetting resins are "cured" by the use of a catalyst, heat or a combination of the two. Once cured, solid thermoset resins cannot be converted back to their original liquid form. Common thermosets are polyester, vinyl ester, epoxy, and polyurethane [24].

There is no capacity problem in resin production in Türkiye. The installed capacity of the resin-producing companies for the raw materials used by the composite industry is 310.000 tons. The total annual production in 2019 is 150.000 tons. Firms account for 80% of their total production. They sell a portion of their products to the domestic market and 20% to abroad. When their installed capacities are taken into consideration, it is seen that they have the potential to meet all the resin needs of the European Union.

About resin production, views from cluster and value chain analysis were as follows:

- Although in this section it is stated that Türkiye do not have capacity problems in resin production, companies that participated in cluster analysis studies stated that companies in Bursa are dependent on abroad – this statement may be subject to other regions and will be further reviewed during cluster roadmap development stage – in resin production.
- Regarding composite materials, the current competencies of companies in Bursa, as stated by the companies, are as follows:
- In Bursa, companies have thermoforming, hand layup, vac infusion, RTM, injection, moulding and trim.
- Areas need to be developed; prepreg, preform 2D and 3D, autoclave, type/band, composite textures.

Figure 7 verifies the companies' statements about the current capabilities of the companies in manufacturing composite materials. Figure 7 above shows the main processes of companies manufacturing composite materials. Press moulding is seen in 66% of companies and constitutes major weight, followed by 39.1% injection moulding, 34.8% resin transfer moulding and %30.4 hand layup.

Products, application areas and targeted export regions

Starting from input materials, the industry value chain enjoys the presence of diverse players with complementing competencies. Products and services can be classified as input materials, semi-finished products, finished products, supporting products and services. Seat systems for vehicles, functional home textiles made of technical materials and applications can be seen as the primary product groups. Based on the offered functions of the fabric or materials, application areas, in other words, end markets are automotive, Hometech, Buildtech, Protech, Geotech, Clothtech, Sportech and Medtech.

Within the scope of the value chain analysis study, participating companies were asked to state in which

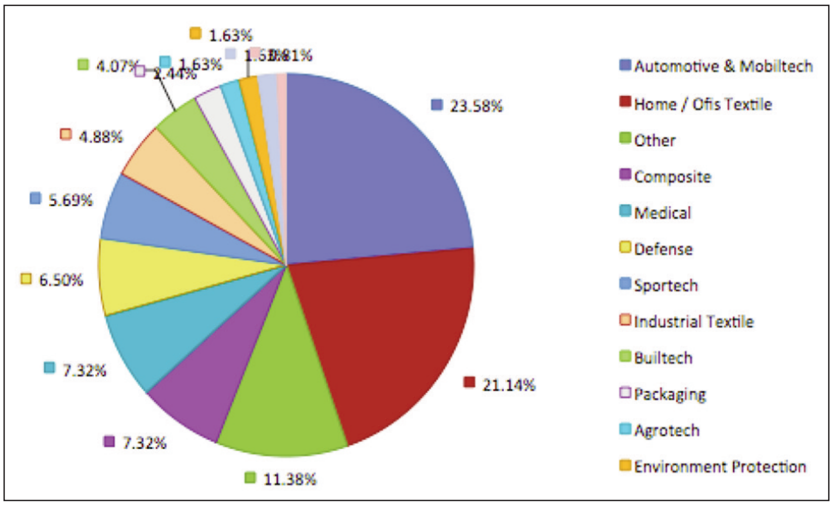

Fig. 8. Application areas of technical textiles and composite materials

end markets their products were being used. Figure 8 indicates the distribution of end markets, in other words, the application areas of the input products, semi-products and final products.

Technical textile and composite materials products, along with the value chain starting from input materials to semi-finished and finished products, find a place in a variety of sub-segments of technical textiles. It is seen that automotive and home/office textiles are stated as the main areas of application. Buildtech, Protech, Sportech, and Buildtech are among other areas of application. From this figure 8, it is possible to say that products manufactured by the companies meet the needs of application areas/end markets by their functions and solutions offered. It is possible to conclude that innovation and new process development of companies will enable the Bursa technical textile and composite materials cluster to be a solution centre for specific areas of the industry.

Findings of the cluster and value chain analysis and findings of the stakeholder analysis outline the areas in which the products of the companies whose goods are utilized in one area are also used in other areas. For example, companies whose products are used in the agriculture sector also have goods used in healthcare, industrial, and automotive transportation. This demonstrates that, while concentrating on technical textile production, more than one sector can be targeted. The diagonal shows the specialized area, and others are supportive areas for that area. If a company's main area is the production of automotive and transportation textiles, the same company may also produce for home-office, clothing industry, and healthcare.

In terms of future end markets and areas for development, based on the cluster and value chain analysis and the views raised in the cluster workshop, the views of companies can be summarised as follows:

- Companies stated defence, aviation, Sportech, Agrotech, Buildtech, Protech, including military purposes, have to be considered among targeted end markets;
- The products and processes stated by the companies are metal lamination/coating, radar absorption, plasma, capsulation, lamination;
- Processes stated about composite materials are thermoplastic composites, automation, and industry 4.0.

Export development is one of the most important areas where clusters can support companies. In terms of targeted regions, value chain analysis reveals that the EU is the primary target market for companies, followed by overseas countries, and finally, Asia and the Middle East markets take place as stated targeted regions.

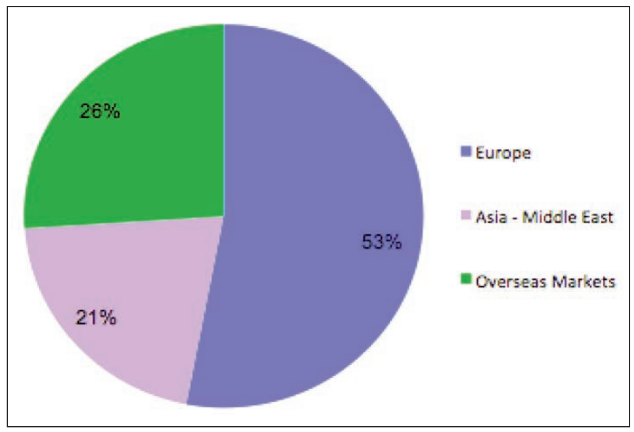

Fig. 9. Targeted export regionss

Insights on value chain upgrade

To be able to develop a solid cluster strategy and roadmap, it is vital to analyse and understand possible areas of the value chain to upgrade in line with the needs of the target markets. At this point, it is also important to draw out key competencies of the regional value chain. In light of this approach, during the cluster workshop held on XX, participants were asked to state and identify both current competencies and areas to be developed in the technical textiles and composite materials value chain in Bursa. Table 2 provides examples of Bursa value chain products and a summary of collected views in brief; a detailed competence matrix can be seen in Annex 1 of this report.

CONCLUSIONS

Analysis reveals that the technical textile and composite materials industry in Bursa is at a transition stage towards a more specialised level with value-added products and solutions offered through a cluster development approach. In terms of product diversification and manufacturing processes, it is seen

Table 2

CURRENT COMPETENCIES AND AREAS FOR DEVELOPMENT
Current capabilities and products
• Baby and kids' strollers with repellent fabric, Cordura outdoor fabrics • Disposable fabrics used for surgeries, surgical drapes, etc. • Polyethylene foam, thermoplastic pre-preg semi-finished product, continuous glass and carbon fibre reinforced composite, sandwich panel • Glass fibre fabrics (Core–Axial) • Vehicle seat group, trim and chassis systems • Water-repellent, flame-retardant textile chemicals • Design, simulation, mould development and 3D printing services • Acoustic curtains, blackout curtains • Glass fibre-reinforced polymer composite materials for Mobiltech • Thermoforming, vac infusion, hand layup, RTM, Injection, moulding and trim are present in Bursa as processes in composite materials
Areas/products to be developed/upgraded
• Bio-based flame-retardant composites • Natural fibre-reinforced technical fabrics, carbon and aramid fabrics • Problems in supplying yarns made of polyamide, aramid, modacrylic fibres • Problems in supplying insulating or conducting yarn mixtures and coatings, especially ones made of metal, copper, etc. • Fabrics for filtration purposes • Use of waste materials in composite production • Hi-tenacity and heat balance providing fabrics • Carbon tape production and products made of carbon tapes • Product tests, product optimisation and marketing support • Use of natural fabrics, increasing manufacture of carbon fibres and fibre filaments for additive manufacturing • Need for improving resin manufacturing capacity • In composites, matrix materials are purchased from abroad, and these input materials are expensive; there is a need for investing in engineering plastics, polymers, etc. • Need for improving capacity in thermoplastic composites • The manufacture of pre-preg is limited in Bursa; pre-preg manufacturing capacity has to be increased • In technical textiles, there is a need for increasing capabilities and capacity in electromagnetic, capsulation lamination, plasma, metal coating • Environmental studies in thermosets and thermoplastic studies should take place • Defence, aviation, Geotech, Sportech and Buildtech, and lightweight industries should be targeted among end markets • Need for increasing capacity in warp knitting and fabrics such as spacer fabrics • Need for studies and actors for improving coating and lamination chemicals • Need for improving capabilities for coating techniques for finished products • For composite materials needing pressure tank tests, there is dependency on foreign test centres in this area • In automotive cluster can increase specialisation in seat systems, under bonnet, trim etc. • Need for improving automation ad industry 4.0 (Digital Transformation) • Need for improving sustainability and green transition implementations • Prepreg, preform 3D, 2D, autoclave, tape fabric, thermosets, epoxy, and peek engineering plastics are areas stated to be developed in Bursa in composite materials • In technical textiles, 3D weaving, braiding, spacer fabric, lamination, nonwoven, fibre laying, and embroidery (conductive technical yarns) are stated as areas to be developed in technical textiles • Technical yarns, meta-aramid, natural, linen, hemp, carbon fibres, glass fibres, moda acrylic, solution acyclic, copper yarns, basalt, silver yarns are among areas stated to be developed in Bursa

that there are areas for upgrading value chain almost at all processes to be competitive with companies in EU and globe. Due to well-developed structure and concentration of automotive, textile and apparel and furniture industries, technical textile and composite materials production flourished at certain level. Seat systems for Mobiltech, upholstery, and curtains made of functional textile, chassis, and trim can be listed among the forefront products of the value chain, thereby the cluster at the current stage of the value chain.

Different from traditional textile products, technical textile is defined by the solutions and functions offered by the product, where composite materials can be defined by strength and performance mostly gained by reinforced materials through unique processes applied. Mobiletech and Hometech are the first two segments in which Bursa can improve manufacturing capabilities, innovation, skills development and knowhow. Through improving its competitive value chain, with supporting industries cluster can provide benefits to companies with tailor made services and help especially SMEs to be part of global value and supply chains.

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REFERENCES

[1] Cetinkaya, B., Ewer, G., Piotrowicz, W., Cuthbertson, R., Klaas-Wissing, T., Tyssen, C., S*ustainable Supply Chain Management: Practical Ideas for Moving towards Best Practice*, In: Sustain. Supply Chain Manag. Pract. Ideas Mov. Towar. Best Pract., 2011, 1–283, https://doi.org/10.1007/978-3-642-12023-7/COVER

[2] Hasan, M.R., Wuest, T., *A Review of Sustainable Composites Supply Chains*, In: IFIP Adv. Inf. Commun. Technol., 2022, 663 IFIP, 448–455, https://doi.org/10.1007/978-3-031-16407-1_53

[3] Coronado Mondragon, A.E., Mastrocinque, E., Hogg, P.J., *Technology Selection in the Absence of Standardised Materials and Processes: A Survey in the UK Composite Materials Supply Chain*, In: Prod. Plan. Control, 2017, 28, 158–176, https://doi.org/10.1080/09537287.2016.1252070

[4] Lambert, D.M., Cooper, M.C., *Issues in Supply Chain Management*, In: Ind. Mark. Manag., 2000, 29, 65–83, https://doi.org/10.1016/S0019-8501(99)00113-3

[5] Stonebraker, P.W., Liao, J., *Environmental Turbulence, Strategic Orientation: Modeling Supply Chain Integration*, In: Int. J. Oper. Prod. Manag. 2004, 24, 1037–1054, https://doi.org/10.1108/01443570410558067/FULL/PDF

[6] Porter, M.E., *The Competitive Advantage of Nations*, Free Press 1990, 1, 1–929

[7] Smit, A., *The Competitive Advantage of Nations: Is Porter’s Diamond Framework a New Theory That Explains the International Competitiveness of Countries?,* In: South. African Bus. Rev., 2010, 14

[8] Bakan, İ., Doğan, İ., *Competitiveness of the Industries Based on the Porter’s Diamond Model: An Empirical Study*, In: Int. J. Res. Rev. Appl. Sci., 2012, 11, 441–455

[9] Smith, F., Shakspere, P., *UK Composites 2013. A Study into the Status, Opportunities and Direction for the UK Composites Industry*, London: Composites Leadership Forum, Department for Business, Innovation & Skills, UK, 2013, 12

[10] Ma, W., *Cost Modelling for Manufacturing of Aerospace Composites*, Cranfield University, 2011

[11] Texier, F., *Airbus Fastener’s Supply Chain Optimization*, 2008

[12] Karahan, M., Ahrari, M., Karahan, N., *Technical Textiles Market Research and Added Value Analysis: A Regio-Global Case Study*, In: Recent – Rezult. Cercet. Noastre Teh., 2023, 24, 162–180, https://doi.org/10.31926/recent.2023.71.162

[13] Karahan, M., Ahrari, M., Karahan, N., *Composite Materials Market Research and Export Potential Analysis: A Regio-Global Case Study,* In: Recent – Rezult. Cercet. Noastre Teh., 2023, 24, 113–121, https://doi.org/10.31926/recent.2023.70.113

[14] Ahrari, M., Karahan, M., Karahan, N., *Competitiveness Factors in Textiles and Composites Industry and Transformation into Value-Added Products*, In: Recent – Rezult. Cercet. Noastre Teh., 2023, 24, 132–141, https://doi.org/10.31926/recent.2023.70.132

[15] Ari, A., Karahan, M., Kopar, M., Ahrari, M., *The Effect of Manufacturing Parameters on Various Composite Plates under Ballistic Impact*, In: Polym. Polym. Compos., 2022, 30, 1–15, https://doi.org/10.1177/09673911221144874

[16] Ari, A., Bayram, A., Karahan, M., Karagöz, S., *Comparison of the Mechanical Properties of Chopped Glass, Carbon, and Aramid Fibre Reinforced Polypropylene*, In: Polym. Polym. Compos., 2022, 30, https://doi.org/10.1177/09673911221098570

[17] Ari, A., Bayram, A., Karahan, M., Arslan, O., *Comparative Evaluation of Mechanical Properties of Short Aramid Fibre on Thermoplastic Polymers*, In: Materials Science-Poland, 2023, 41, 161–176, https://doi.org/10.2478/msp-2023-0012

[18] Ali, A., Mehmet, K., Ali, B., Seçgın, K., *Evaluation of the Mechanical Properties of Chopped Carbon Fibre Reinforced Polypropylene, Polyethylene, Polyamide 6, and Polyamide 12 Composites*, In: Industria Textila, 2023, 74, 175–183, https://doi.org/10.35530/IT.074.02.202214

[19] Rad, H.K., Shariatmadar, H., Ghalehnovi, M., *Simplification through Regression Analysis on the Dynamic Response of Plates with Arbitrary Boundary Conditions Excited by Moving Inertia Load*, In: Appl. Math. Model., 2020, 79, 594–623, https://doi.org/10.1016/j.apm.2019.10.054

[20] Ari, A., Karahan, M., Ahmed, H.A.M., Babiker, O., Dehşet, R.M.A., *A Review of Cellulosic Natural Fibres’ Properties and Their Suitability as Reinforcing Materials for Composite Panels and Applications*, In: AATCC J. Res., 2023, 10, 163–183, https://doi.org/10.1177/24723444221147365

[21] United Nations Industrial Development Organization, *Agro-Value Chain Analysis and Development*, Vienna, 2009, 8, 3–38

[22] Shehab, E., Meiirbekov, A., Amantayeva, A., Tokbolat, S., *Cost Modelling for Recycling Fibre-Reinforced Composites: State-of-the-Art and Future Research*, In: Polym., 2023, 15, 150, https://doi.org/10.3390/POLYM15010150

[23] JEC, *JEC Observer Overview of the Global Composites Market, 2021–2026*, Available at: https://www.jeccomposites.com/press/jec-observerbroverview-of-the-globalbrcomposites-market-2021-2026-eco/ [Accessed on January 25, 2024]

[24] Ari, A., Karahan, M., Kopar, M., Ahrari, M., Khan, R.M.W.U., Hussain, M., *Comparative Analysis of Natural Fibres Characteristics as Composite Reinforcement*, In: Industria Textila, 2023, 74, 403–411, https://www.jeccomposites.com/press/jec-observerbroverview-of-the-globalbrcomposites-market-2021-2026-eco/ 10.35530/IT.074.04.2022110

Authors:

MEHMET KARAHAN[1,2], ALİ ARI[3], NEVİN KARAHAN[1]

[1]Vocational School of Technical Sciences, Bursa Uludag University,
16059, Bursa, Türkiye
e-mail: mkarahan@uludag.edu.tr

[2]Butekom Inc., Demirtas Dumlupinar OSB District,
2nd Cigdem Street No:1/4, 16245, Osmangazi, Bursa, Türkiye

[3]Department of Weapon Industry Technician, Vocational School of Higher Education, Ostim Technical University,
06374, Ankara, Türkiye

Corresponding author:

ALİ ARI
e-mail: ali.ari@ostimteknik.edu.tr