A Pilot Foresight Study in Turkey on the Use of Advanced Materials in Automotive Industry

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Abstract - The need for advanced materials in automotive industry as replacement for conventional materials is identified. Advanced materials foresight activities in other countries, their outcomes and implications in industry together with policy suggestions stated by governments and research centers are assessed. A foresight of critical sub-sectors in advanced materials is defined for Turkey to allocate her resources for future development in the technological advancement route. The Delphi questionnaire constitutes the mean to conduct foresight and reach experts in industry, universities and other research organizations to define the sectors and corresponding sub-topics in advanced materials technologies that are critical for Turkey. Group-wide and individual electronic mail options are used. Results of the Turkish foresight on advanced materials were then compared to those of the UK foresight study for eleven topic statements common in both studies.

Key words: advanced materials, materials technologies, automotive, science and technology foresight, Delphi

I. INTRODUCTION

A thorough perception of today's technological and economic enhancements must be established well before evaluating the advanced materials concept. Unlike the conventional production structures, new generic technologies such as information technologies, biotechnology and advanced materials constitute the foundations for a new era in industrial sectors. Hence, it would be an incorrect approach to consider enhancements in advanced materials unrelated to new industrial orientations.

Various definitions have been presented for "advanced materials". The selected criteria in the definition relate to the characteristics of materials (organic, inorganic; metallic, non-metallic), their main application areas (electronics, space and aviation, automotive), functionality (semiconductors, superconductors, and structural materials), and manufacturing processes (powder metallurgy, injection molding, rapid solidification, vacuum technology). Moreover, the difference between advanced materials and conventional materials is not always distinct. Innovations in conventional materials may make these materials be considered as advanced materials also [13].

In a broad sense, advanced materials are defined as *exceptionally high value added materials with high purity, high technological performance, and high information intensity that contribute the world economy at an ever-increasing scale*. These include advanced ceramics, polymers, metals and composites. Considering this definition as a starting point, classification of advanced materials can be made with respect to functionality and application areas as follows [13].

1. Advanced metallic materials
2. Advanced ceramics
3. Advanced polymeric materials
4. Composites
   i. Polymer matrix composites
   ii. Metal matrix composites
   iii. Ceramic matrix composites

The purpose of weight reduction in today' s automotive industry is not merely reduced fuel consumption and emissions and improved vehicle performance, but also lowering the cost of individual components.

In this context, automotive industry constitutes the major leading sector for the implementation of advanced engineering materials. Automotive industry plays a strategic role in economies of industrially developed countries for a thorough technology transformation with the application of advanced materials.

II. LITERATURE REVIEW

A. International Science and Technology Foresight

The term foresight is used in the sense of outlook. This is not the same connotation as a prediction, which would be closer to forecast. Foresight is equivalent to a bundle of systematic efforts to look ahead and to choose more effectively. Thereby, foresight takes into account that there is not a single future. Depending on action or non-action at present, many futures are possible, but only one of them will happen. To select a desirable future and to facilitate its realization is one of the aims of technology policy. Foresight is the process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits.

Grupp and Linstone [5] defined foresight as a process by which one comes to a fuller understanding of the forces shaping the long-term future which should be taken into account in policy formulation, planning, and decision making. In addition to the fact that a foresight process should

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strive to be systematic and comprehensive, it must be able to accommodate a wide range of information, must be public and avoid prediction. It is a political question whether government bodies would like to give more emphasis to direct intervention in research matters (e.g., by financing specific R&D projects in industry) or to more indirect support (e.g., tax reductions for R&D projects or subsidies to those companies hiring new scientific and technical staff).

Unlike forecasting, foresight does not concern itself with probabilistic predictions of future technologies based on today' s knowledge base. Technology foresight combines analysis and communication processes in which informed parties and stakeholders participate in a forward-looking exercise [5].

In addition, Grupp and Linstone [5] stated that the architecture for understanding the impacts of a modern science and technology (S&T) policy portfolio is more complicated than it ever was. The interwoven nature of various types of policies and trade-offs any policy portfolio requires touches on different aspects of the entire quality of life issue. The challenges for a particular policy in the arena of S&T originate from increasing environmental, economic, and social problems. The aim of those policies is to make the (national, company) innovation system adaptive enough to meet those challenges. Further, in the area of S&T an increase in the interdisciplinary and transdisciplinary subfields is observed. Basic or even fundamental research moves into closer contact with industrial research and development (R&D), and science-based technology is pervasive in many industries.

Governments use foresight results in various ways. In Britain, a strong commitment was expressed with the Science Minister going as far as to reserve a considerable part of R&D funds for high priority foresight areas to be defined. In Germany, not only the federal government, but also state governments worked on profiling their S&T policy along foresight results. Internal budget distributions were reconsidered by the German Federal Ministry for Science, Education, Research and Technology in the light of synoptic tables comparing their own and foreign foresight findings.

From an economic perspective, modern foresight now has much more to do with benchmarking and feedback processes of economic agents than with systems analysis, cybernetics, or operations research as in the early years. Government activities aimed at assessing technical development and providing opportunities for informal technical exchange try to stimulate communication in the so-called "communities", that is, in the informal gatherings of scientists, engineers, and business people, where information tends to exchanged on a non-remunerative basis. The deliberate promotion of knowledge flows within these informal circles can contribute an important input for innovation [5].

Grupp and Linstone [5] stated one serious problem as the acquisition of information from such technology foresight. This sort of inquiry essentially gathers subjective opinions even if the respondents are scientifically trained experts. Even the Delphi process ultimately does not lead to true information about the future (which no enterprise can achieve because the future is itself shaped by innovative processes) but to a more reliable database.

Australian Science and Technology Council Report of 1994 [2] stated that a key to success in foresight is the involvement and commitment of companies. They could benefit from a better understanding of foresight techniques, enhanced communication with other groups, a better knowledge of specific technology foresight and an improved understanding of the capacity of research to meet their future needs. Yet there may be concerns to protect their commercially sensitive technology developments.

The present government foresight program in the United Kingdom has a strongly practical orientation and places a high value on economic benefits. Pre-foresight seminars showed strong support for a market orientation, with a particular interest in small and medium-sized enterprises. As a result sector panels have a strong representation from industry [2].

In the United States, the work of the Department of Commerce is designed to identify technologies that have the potential to create new products and industries with markets of substantial size, provide large advances in productivity or in the equality of products produced by existing industries which supply large, important markets, or drive the next generation of research and development and produce spin-off applications [2].

An objective of work in the Netherlands by the Ministry of Economic Affairs is to share information generated by its foresight activities with small and medium sized firms. This appears to reflect a concern that, while the major multinationals based in the Netherlands are high performers of research and development, the rest of Dutch industry does not have as strong a record in this regard [2].

Whenever comparisons are made between science and technology policy in Turkey and other countries, account must be taken of similarities and differences in national characteristics. The more important of these characteristics are the obvious ones of size of population and Gross Domestic Product, which inevitably affect the size of the science sector and hence the range and scope of the research activities that can be supported, the structure of science and technology, particularly in terms of the balance between public and private funding and performance, and the cultural context within which research is conducted.

B. New Materials in Automotive Industry

There was an increase of 15 – 20% in the mass of cars over the past 15 years. This resulted in an increase in fuel consumption ranging from 6 to 10% while maintaining comparable car performance.

The reasons for this increase in mass have been:

i. addition of new features,
ii. improved safety and security,

iii. improved acoustical/vibration comfort,
iv. compliance with latest standards and regulations (external noise, exhaust emissions, passive safety),
v. improved reliability.

Hence, this trend toward heavier cars will continue to meet consumers' demands and increasingly stricter standards.

For this reason, it is important to identify the most convenient ways to reduce mass, and maintain comparable performance. This can only be achieved by improving the conditions of use for each material and testing the applicability of new, light – weight materials from technical as well as economic viewpoints.

Langdon, Mann and Helps [7], and Mann [8] listed new materials that have found extensive application in automotive industry as follows.

High Strength Steels: Fig. 1 exhibits the increasing usage of high strength steels in automotive industry.

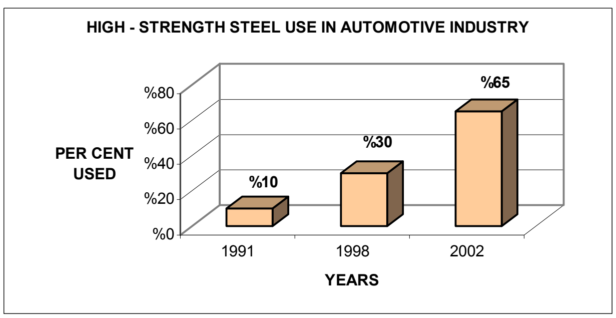


Fig. 1. Proportion of High – Strength Steel Use in Car Manufacture [6, 7]

Cast Iron: Compacted graphite iron (CGI) and full mould (FM) casting process using controlled gas or vacuum pressure have found an extensive usage for diesel and gasoline engine parts production.

Aluminum: It saves weight and thus fuel. Fig. 2 and Fig. 3 show effect of weight reduction on fuel consumption. With a high strength-to-weight ratio, it can give an equivalent performance to steel and save 60 per cent in weight over bake – hardenable steel.

On average in Europe, more than 65 kg of aluminum is used to reduce weight in every car of current design. That is approximately 5 per cent of the average 1300 kg weight.

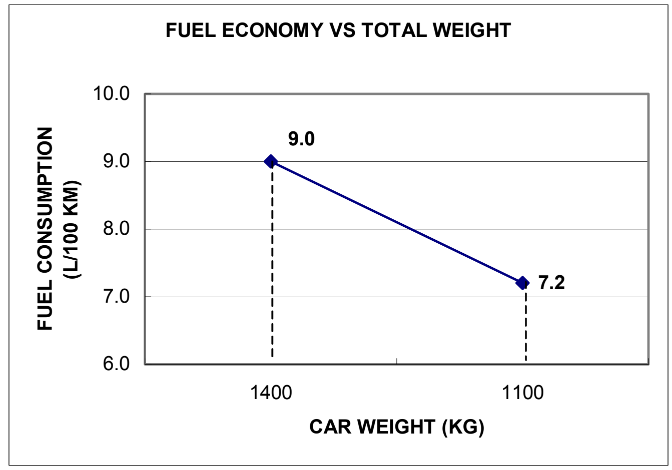


Fig. 2. Fuel Economy versus Total Weight [7]

Kimberley [6] emphasized the applications in engine and transmission that take the principal part with 37 per cent. The chassis and the wheels have 17 kg, applications of sheet metal in the bodywork have 9 kg, and configuration sections have 2 kg.

Langdon, Mann and Helps [7], and Mann [8] defined the main limitation on the use of aluminum as its price. Virgin aluminum requires a very high energy input, but recycled aluminum scrap uses only 5 per cent of that. Aluminum is recyclable, but requires greater care to avoid mixing different alloys than is the case with steel. In particular, silicon and non – silicon grades need to be segregated.

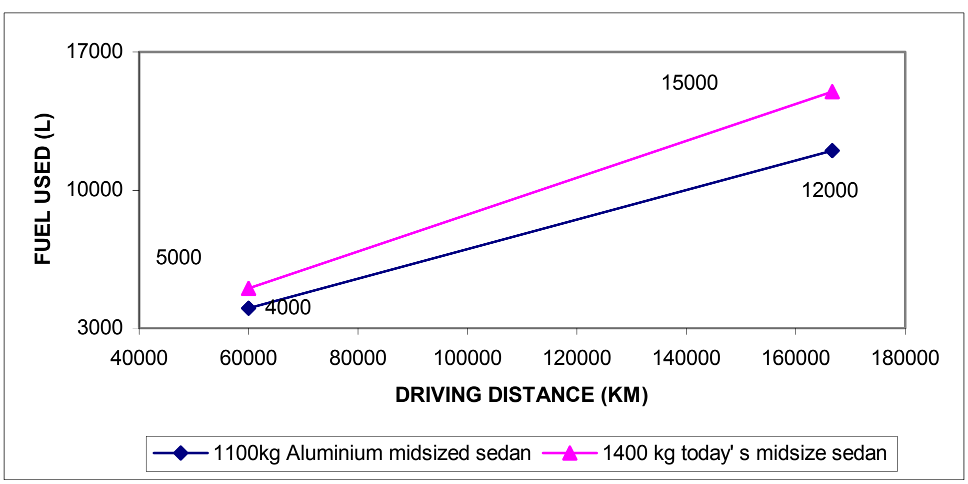


Fig. 3. Fuel Economy over the Lifespan [7]

Magnesium: Magnesium is attractive to carmakers because of its lightness – 1.81 g/cm^3 versus 2.7 g/cm^3 for aluminum. Additionally, magnesium damps vibration better than aluminum or steel [8].

Titanium: Titanium is attractive because it combines strength and lightness. It can provide the strength of steel at about half the weight. It also resists corrosion very well. However, titanium is expensive because it is hard to extract from its ores [8]. Pelagagge [12] offered use of titanium alloys for coil spring of an automotive suspension system for significant weight reduction whilst maintaining relevant elastic performances. Nevertheless, their high costs limit their use only for advanced applications.

Metal Matrix Composites: Metal matrix composites (MMC) based on aluminum or magnesium with powder or chopped fiber reinforcement, are relevant to automotive industry. Use of continuous fiber reinforced composites on a commercial scale is some years off. MMC are near commercial application in brake discs and drums, brake calipers, pistons, prop shafts and tire studs [8].

Plastics and Composites: In recent years, the share of plastics in automobiles has increased significantly to about 12 per cent of the average vehicle' s weight. The reasons for the extensive use of plastics as stated by Langdon, Mann and Helps [7] are

i. reduction in weight,
ii. integration of several functions in one component,
iii. freedom in component design.

The main plastic composite sheet materials used have been thermosets, sheet-molding compound (SMC) and reinforced reaction injection molded polyurethane (PU-RRIM). Both SMC and PU-RRIM, being thermosets, are more expensive to recycle than thermoplastics [7].

Environmental concerns increase interest in thermoplastics. Maxwell [10] defined main thermoplastic materials, that are in common use, are glass mat thermoplastic (GMT). They are being used for body panels. There has been an increasing use of plastics in the engine compartment. The main driving forces for these successful applications have been reduction in corrosion, noise and maintenance requirements, together with the ever – present potential for consolidation of parts and easier assembly.

Unfortunately, fiber reinforced composites have the disadvantage that their manufacturing process is labor-intensive, slow and expensive. Ahrens, Mallick and Parfrey [1] defined a highly automated thermoplastic fiber placement process, that is also of interest in the aircraft and automotive industries.

C. Advanced Materials in the Context of Industrial and Technological Improvements

Previous techno-economical principle that had been labor, energy, capital and raw materials intensive reverted to a knowledge intensive, integrated, flexible, systemic and multidisciplinary structure.

Information technologies, biotechnology and advanced materials technologies constitute the pioneering technologies of the future. Emergence of the new and advanced materials in microelectronics, information and computer industries, aviation, defense industry and automotive industry was a consequence of innovations in materials science and engineering that has become a multidisciplinary institution integrating production processes and advanced technology [13].

Transformation in Materials Technologies: The production and consumption of conventional metallic materials have declined between 1980 and 2000 whereas advanced materials presented a boom both in production and consumption with their differentiated functionality and vast implementation areas. For instance, engineering plastics and advanced ceramics exhibited an increase in production and consumption against basic metallic materials. The use of engineering plastics began in 1960' s and reached an amount of 2 million tons in 1990' s. Likewise, market value of advanced ceramics reached 12 billion US dollars in the beginning of 1990' s.

Transformation from conventional materials to advanced materials technologies exhibited a more indicative deviation in production processes. As observed in Table 1, analytical techniques and improvements in materials science and engineering are the driving forces for these transformations in materials design and production. It should be noted that industrial companies must well understand the differences stated in the table for attaining an effective initiative in a competitive market.

Fundamental Strategic Policies for Turkey in Advanced Materials Technology: The following issues constitute the primary points in scientific and technological strategies for Turkey [13].

1) Position of Strategic Sectors in the Social-Economic Development of Turkey: Strategically important sectors for the national economy should be determined and nominee sectors for improvement should be well defined.

2) Definition of Technologies for Future Industries: Sub-sectors of advanced materials should be defined and monitored for generic developments in industry. For achieving this target, science organizations that will perform technology monitoring are needed.

3) Social-Economic Needs in Tomorrow' s Society: National programs that will increase personal satisfaction of life standards, value human resource education and environment friendly should be stated.

Advisory statements for Turkey should be nation specific and based on realistic information. Hence, a flexible and future oriented structure can be established for a technological and economical transformation based on national potentials, industrial structure and competitive force.

TABLE 1. A NEW PERCEPTION IN MATERIALS PRODUCTION PROCESSES [13]

Conventional Perceptive	**Advanced Materials**
Macrostructure inspection	Microstructure inspection
Differentiation between research, design, production and application	Integration
Increase in big market/low consumption rate	Increase in small market/high consumption rate
Low cost standardized products/high production rate	Differentiated and integrated products, high purity, high added value, environment friendliness
Main consumer industries: Transportation and construction	Main consumer industries: Information and telecommunication
Raw material and energy intensive	Knowledge intensive
Specialization	Multidisciplinary team work
Product specific hardware	Flexibility
Automation	Computer controlled system
Low R&D	High R&D
Self technology accumulation	Research-production-application integration
Statistical and destructive testing after production	Simultaneous non-destructive testing
Single large firm, cartel	High cooperation among various firms
Raw material and energy shapes firm' s strategy	Special market and technology shapes firm' s strategy
Backward integration where material producers tend to control resources	Lateral and vertical interaction where material users tend to be producers and material producers tend to be users

Turkey underwent a structural renovation after 1980, but suffered heavily from short-term policies that restricted a complete transformation. The most vital problem of Turkey today is to determine how she will benefit the opportunities created by science, technology and new market requirements in a global and highly competitive environment. Turkey must follow consistent strategies for competing in a global market and improving her social-economic position in the world. Consequently, industrial sectors for achieving competitive advantage for Turkey shall be determined correctly [13].

The report *"Industrial Strategy: 1995-2005"* by the Ministry of Industry and Trade stated the relative importance of sub-sectors in the manufacturing industry with respect to a weighted index based on total employment, export, added value and sales income, and sorted these sub-sectors according to their relative strategic importance. Contribution of a sub-sector to employment and its relative weight in export were given more emphasis where the ratio of added value and sales income were given less importance in calculating the weighted index. Fig. 4 exhibits the relative strategic importance of sub-sectors on a social-economic basis.

The first five sectors had more impact on the national economy with a total contribution of 83% in export and 66% in employment. The fact that a crisis in these sectors would mean serious social-economic impacts makes them strategically important.

Despite their strategic impact on economy, these five sectors presented the following problems during 1988-1992 period [13].

1. A real and rapid increase in the added value was observed despite a general decrease and/or no change in employment level. It was worth noting that there was no increase in production rate to meet the increase in the added value.
2. R&D in these sectors were not sufficient enough for international competition in the global market.
3. These sectors did not seem to possess the dynamics for the future.

Transportation vehicles, electrical machinery and machinery manufacturing sectors that followed these five sectors constituted 8% of export and 18% of employment as a total. These three sectors, as engineering sectors, would be the most important industries in the technology intensive modern future. Developed economies based their competitive advantages and social-economic structures on these engineering sectors.

For the same 1988-1992 period, these three sectors presented the following development scheme [13].

1. Contrary to the first five industry sectors, the real and considerable increase in the added value resulted from an increase in production.
2. An increase was observed in employment level except in machinery manufacturing sector.
3. Most of the exported items of these three engineering sectors included advanced technology items. The value of exported technology items increased from $504 million in 1989 to $1.051 billion in 1992, and reached $1.416 billion in 1994.
4. Electrical machinery constituted more than 50% of the total export among these three sectors where Consumer Electronics and Telecommunication items formed the majority.
5. The priority in transportation vehicles belonged to manufacturing, assembly, repair and maintenance of motor vehicles.
6. The priority in machinery manufacturing belonged to household machinery.
7. Despite all development tendencies, R&D intensity in these sectors was at a low level.

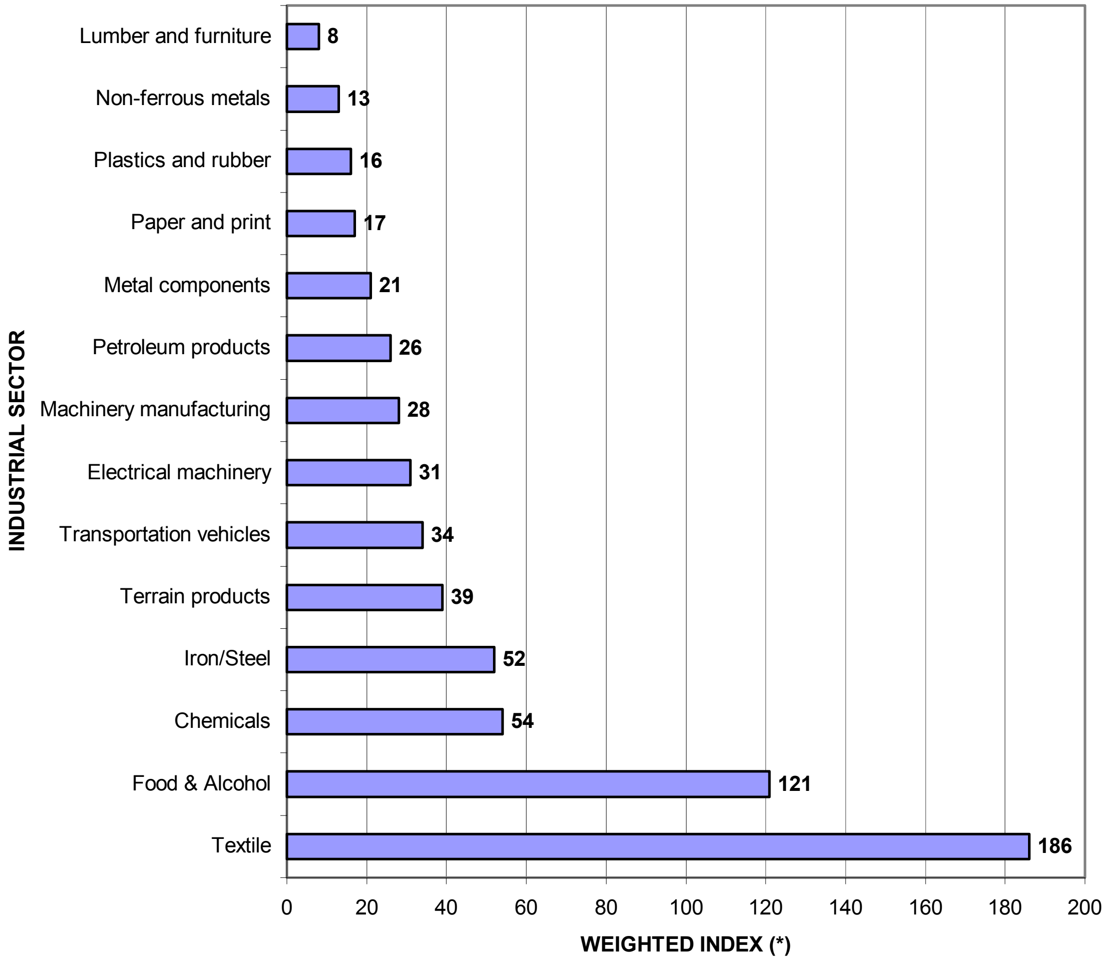


Fig. 4. Relative Importance of Manufacturing Sectors in Turkey [13]
(*) Weighted Index = (% Ratio of Sales Income x 0.5) + (% Ratio of Added Value x 1.0) + (% Ratio of Export x 2.0) + (% Ratio of Employment x 3.0)

According to import and export figures of Turkey, based on State Institute of Statistics data of 1994, machinery manufacturing and electrical machinery contributed to 33.1% of total import values, and outputs of transportation vehicles added up to 17.3%. However, the priority of exported commodity belonged to textile industry with a ratio of 51.5%. Hence, Turkey has to give considerable importance to increasing the ratio of engineering sectors in exported commodity beside the first five industry sectors [13].

D. Foresight Study Results Related to Advanced Materials Technologies in Other Countries

Foresight in Germany: The "21st century" study constituted the core of German foresight activities. This study was led by the Fraunhofer Institute for Systems and Innovations Research (ISI), in conjunction with a number of other specialized research and development management agencies.

The study identified nearly 100 critical technologies that were grouped under nine generic headings, where advanced materials were considered the first [2].

Foresight in the United States: In recent years a number of expert panels have prepared lists of critical or emerging technologies. The commonality of these reports has been a convergence on a set of technologies that are considered as candidates for special attention by government.

The technologies are often considered to fall into six broad areas, where developments in synthesis and production of new materials led the following list [2].

1. Advanced materials
2. Manufacturing systems
3. Information and Communication
4. Biotechnology and Life Sciences
5. Aeronautics and Surface Transportation
6. Energy and Environment

Foresight in the United Kingdom: The United Kingdom has been conducting foresight studies on materials for advanced technological use. The Materials Foresight Panel report of 2000 [9] seeks to give a glimpse at the way Materials Foresight has developed and to give an indication of the widespread ownership of the Foresight process by the materials supplier and user communities.

The main aim is to show how the nature of the global economy with respect to materials has changed and places the emphasis of sectors' main recommendations on more leading edge technology rather than just the increase in the performance of existing materials.

This report, in summary, attempts to provide a snapshot of what is happening in Materials Foresight in the UK by 2000.

Under these constraints the following two key recommendations were made [9]:

"Increased investment in the continuous improvement of materials and processes is the highest priority to emerge from the Materials Technology Foresight Initiative."

and

"Materials and processes which protect or re-mediate the environment and which can save lives and alleviate suffering should be targets for investment."

In addition to these key recommendations, the Materials Panel Report of 2000 [9] summarized that increased resources should be devoted to research, development, and exploitation in

1. Lighter weight materials and materials based weight saving technologies for specific applications in the aerospace, automotive, offshore, packaging and construction industries.
2. Higher temperature materials for specific applications in the aerospace, automotive, electronics and power generation industries.

Accordingly, Öner, Alsan and Dogru [11] defined the technological areas that create competitive superiority for developed countries. Advanced materials were considered a critical technology in the United Kingdom, Germany, Japan, South Korea and India.

E. The Delphi Approach

Grupp and Linstone [5] defined the Delphi method as experts' judgement by means of successive iterations of a given questionnaire, to show convergence of opinions and to identify dissent or non-convergence. Every iteration constitutes a round, and the questionnaire is the medium for the experts to interact. The Delphi method is considered especially useful for long-range aspects (20 to 30 years) as expert opinions are the only source of information available. The main advantage of this method is that panel members can shift position without losing face if they see convincing reasons for doing so.

Cuhls and Kuwahara [4] stated that research and technology policy decisions and entrepreneurial innovation management require a planned, systematic, organized approach

- which analyzes the state of a technology (*technology monitoring*),
- explores its development possibilities (*technology foresight*),
- estimates the direct and indirect impacts of its application on the economy, the environment, the health system, society and other areas (*technology impact assessment*),
- assesses these impacts based on defined aims and values, compares other desirable developments and formulates activity and organization possibilities from these *(innovation strategies or technology policy studies*).

The Delphi process is, in broader sense, a specialized methodology for technology assessment. Generally speaking, it is based on heuristic methods of scientific problem solving, which are described and applied particularly in systems analysis and systems technology. The classical repertoire of technological assessment can be split into qualitative and quantitative methods, although a mixture of the two is frequently used in practice. The Delphi survey has both characteristics and can be used to define and structure an area under investigation as well as to forecast and assess technology trends.

As Cuhls and Kuwahara mentioned [4], the Delphi method was developed by the RAND Corporation in the US in the 1950' s with the aim of making better use of the interaction in research groups. The questionnaire of the second and all consecutive rounds does not only repeat the questions of the first round but also transmits information about the extent of group consensus already achieved among the people questioned. It is generally the case that a convergence of opinions takes place from the second round onwards. Usually very diverse valuations on each individual question are presented to those questioned, but they are not always prepared to be influenced by their colleagues' views to the extent of changing their original opinions.

III. RESULTS

The Delphi questionnaire consists of eight sub sectors and thirty-seven events. The list of sub sectors and the distribution of events with respect to sub sectors are given in Table 2.

TABLE 2. SUB SECTORS AND CLASSIFICATION OF TOPICS

Sub Sector Title	Number of Topics	Topic Number Range
Advanced ceramics	3	1 - 3
Advanced metals	8	4 - 11
Polymers/polymer based composites	8	12 - 19
Recycling/re-use	7	20 - 26
Manufacturing	4	27 - 30
Economic market	1	31
Universities/research organizations	1	32
Vehicle weight and fuel efficiency	5	33 - 37
Total	**37**	

Eleven events of the Delphi survey, namely events numbered 1, 4, 5, 6, 12, 13, 14, 20, 21, 32, 33, are common to that of the United Kingdom Materials Foresight of 1995. The remaining events are based on current research and development activities for a new generation of vehicles with enhanced fuel efficiency and less weight, economically viable manufacturing methods of advanced materials, and new and achievable recycling technologies in the United States, the European Union, the United Kingdom and Australia. Table 3 shows the complete list of events in the Delphi survey with the corresponding sub sector titles.

The Delphi survey was completed in two rounds. The structure of the respondents for the two rounds is stated in Table 4 below.

TABLE 4. STRUCTURE OF RESPONDENTS

	Industry	Ratio of respondents from Industry	University/Research Centers	Ratio of respondents from University/Research Centers	Others (university students)	Ratio of Others	Total
Round 1	16	66%	5	21%	3	13%	24
Round 2	16	62%	7	27%	3	11%	26

It is worth noting that only nine people, who responded the first round, attended the second round, and two new people gave their input for the second round. Nevertheless, those who attended the first round but did not respond the second round were considered to keep their opinions unchanged. This phenomenon of not giving feedback can be considered as "*unreadiness for learning*".

TABLE 3. COMPLETE LIST OF EVENTS IN THE DELPHI SURVEY

Advanced ceramics
1. Advances in reliability of engineering ceramics enable the production of economically viable small gas turbines for land-based transport.
2. The new front discs of carbon fiber-reinforced ceramics are about 60% lighter than comparable brake discs of conventional cast iron.
3. Carbon fiber-reinforced ceramic brake discs have an extremely long operating life of up to 300, 000 km.
Advanced metals
4. Widespread use of titanium alloys in automotive connecting rods, valves and springs.
5. Advances in corrosion resistance of high temperature performance new magnesium alloys create significant new applications in automotive industry.
6. Development of low cost aluminum based composites with high strength and stiffness and good damage tolerance: E>=110GPa; σ_y>=450MPa; ρ<=2.8 Mgm-3; K_{ic}>25MPam$^{-1/2}$.
7. Average vehicle mass reduces by 70% with the use of aluminum and composite materials in place of steel sheet material.
8. Use of high strength steels with sy>500MPa increases to 65% in automotive industry.
9. The steel industry developed an optimized automotive steel structure that is 24% lighter, 34% stronger, and $154 less expensive than traditional autobody structures.
10. Magnesium content reaches 115 kg per vehicle.
11. Aluminum content per vehicle reaches 20%.

TABLE 3. COMPLETE LIST OF EVENTS IN THE DELPHI SURVEY (cont.)

Polymers/polymer based composites
12. Economically viable non-toxic fire-retardant plastics with equivalent performance to currently employed materials are in widespread use.
13. New class of polymer discovered, capable of plastic processing, and with significantly improved high temperature and strength properties compared to existing organic polymers.
14. Development of a high speed formable/cold formable polymers that can be processed at speeds approaching those of metal forming (10x current speeds).
15. High strength requiring locations in glass fiber reinforced composite structures are reinforced with carbon fibers, thus reducing their cost of use in automotive industry.
16. Intensive use of manpower is abandoned for the sake of low cost automated production of carbon fiber reinforced composites.
17. Reduction in production costs of carbon fibers from $20/kg to $5/kg leads to widespread use of carbon fiber reinforced composite materials in place of aluminum.
18. A 50% percent reduction in production costs of carbon fibers leads to a 60% reduction in total vehicle mass.
19. SMC use in heavy-duty trucks reached up to 450 kg.
Recycling/re-use
20. Means of on-line identification of different plastics, incorporated at source, enables economical separation of waste plastics for recycling, re-use or disposal.
21. Development of recycling methods for composites used in automobiles.
22. Advances in vehicle design and recycling technologies enable 50% re-use of materials in a vehicle.
23. Recycling in motor vehicles boosts up to 85% based on governmental and private sector enterprise on recycling.
24. The amount of waste that is unsuitable for further use will decrease on average to 5% of a car' s weight.
25. A new recycling and disposal industry forms that collects the vehicles after ten year usage and conducts the business of resources extraction from them.
26. A technology to recycle mixed plastics based on different polymer chains has been developed.
Manufacturing
27. Improved low distortion, high speed joining methods leads to widespread application of composites and aluminum alloys in transport applications with consequent weight savings.
28. Manufacturing and assembly costs in automotive industry reduce by 30% with the use of advanced materials and new process techniques.
29. Anti-gravity aluminum casting produces non-porous, thin walled and lighter components.
30. Sintercast process enables compacted graphite iron (CGI) to be used extensively for diesel engine components.
Economic market
31. Public sector and defense industry constitute a major market for light and high energy absorbent advanced materials.
Universities/research organizations
32. Restructuring of university research and teaching on multidisciplinarity lines produces significant advances in materials science, design and engineering.
Vehicle weight and fuel efficiency
33. Lower density materials with equivalent properties and cost to current materials are employed in reciprocating internal combustion engine components.
34. Total vehicle weight reduces by 50% with the use of light power generating units (internal combustion engines, fuel cells, electric motors, etc.) without sacrificing vehicle safety.
35. Average fuel consumption of a motor vehicle reduces to 3 liter/100 km.
36. Weight of body panels and structure reduces by 50%, and weight of powertrain reduces by 10% with the use of advanced materials.
37. Weight of a 4-door sedan reduces to 650 kg.

The ratio of respondents who modified their opinions in the second round is 23%, those who did not give feedback constituted 69%, and the new respondents made 8% of the total respondents in the second round.

The Delphi survey includes degree of expertise, degree of impact on quality of life, period of occurrence, need for collaboration, current position in R&D-products and service delivery-marketing, and constraints on occurrence. The results related to these parameters are presented in the proceeding discussion.

Table 5. exhibits the distribution of degree of expertise for the respondents in rounds 1 and 2. The balance among ratio of low and non-expert respondents and that of high and medium expert respondents was kept nearly the same between the two rounds.

TABLE 5. DEGREE OF EXPERTISE IN THE TURKISH FORESIGHT STUDY ON ADVANCED MATERIALS

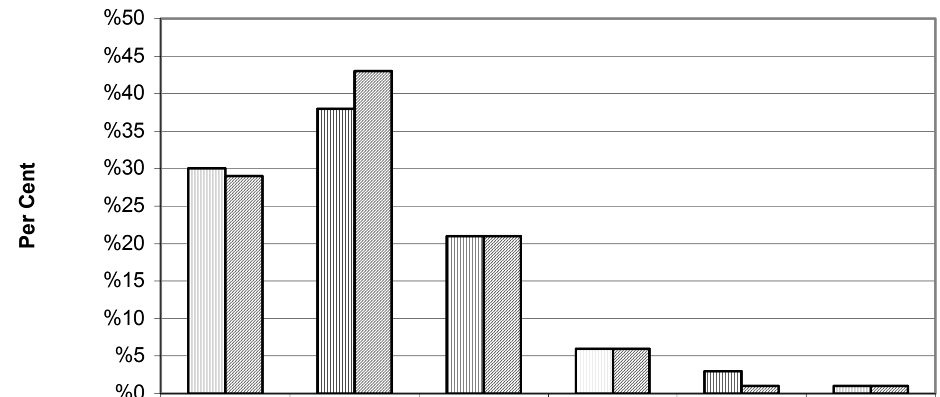
Degree of Expertise	1st Round	2nd Round
High	18%	20%
Medium	28%	28%
Low	22%	20%
None	32%	32%

TABLE 6. IMPACT ON QUALITY OF LIFE IN THE TURKISH FORESIGHT STUDY ON ADVANCED MATERIALS

Impact on Quality of Life	1st Round	2nd Round
None	2%	1%
Low	16%	14%
Medium	39%	42%
High	44%	43%

There was a consensus among participants that nearly all events present either high or medium impact on the quality of life. Table 6 shows that 85 per cent of all events were considered to have high and medium impact, where only 15 per cent of all event were accepted to have low and no importance in the second round.

Fig. 5 shows the distribution of occurrence period for Delphi events, where the results presented a bell shaped distribution around period 2006-2010. The results were coincident with the realization periods of emphasized topics and sub-sectors presented in Table 16.



	2001-2005	2006-2010	2011-2020	2021-2030	Beyond 2030	Never
Round 1	%30	%38	%21	%6	%3	%1
Round 2	%29	%43	%21	%6	%1	%1

Fig. 5. Distribution of Occurrence Periods in the Turkish Foresight Study on Advanced Materials

Results revealed the European Union and the United States as two partners with whom close collaboration is needed, as shown in Table 7. Japan follows these two with a firm share of 25% for both rounds. Collaboration need with Turkish Republics came out to be 1% and dropped to zero at the end of round two.

TABLE 7. NEED FOR COLLABORATION (TURKISH FORESIGHT STUDY ON ADVANCED MATERIALS)

Country	1st Round	2nd Round
None	3%	2%
Turkish Republics	1%	0%
EU	38%	37%
USA	33%	35%
Japan	25%	25%

Turkey' s current position in three capabilities, namely R&D, product or service delivery and marketing, was also evaluated. All capabilities of Turkey exhibited "follower" characteristics, which are shown in Table 8. Capabilities evaluation resulted in a 2% increase for both product or service delivery and marketing at the end of round 2, where R&D capability remained at 4%. Even though "lagging", product or service delivery capability led by 6%.

TABLE 8. CAPABILITIES IN R&D, PRODUCT/SERVICE DELIVERY, MARKETING

Capability	1st Round	2nd Round
R&D	4%	4%
Product or Service Delivery	4%	6%
Marketing	3%	5%

Technological feasibility, economic viability and lack of funding constituted the three major constraints on the occurrence of all events in the foresight study. They consistently summed up to 79% for the two Delphi rounds. Regulations and policy constraints followed them with a ratio of 14%. Education level and skills, and social acceptability were not considered as important constraints, they just present 7% on the whole (see Table 9).

TABLE 9. CONSTRAINTS ON OCCURRENCE OF EVENTS

Constraints	1st Round	2nd Round
Social Acceptability	3%	3%
Technological Feasibility	28%	30%
Lack of funding	24%	23%
Economic viability	27%	26%
Regulations	7%	7%
Policy	6%	7%
Education/Skill Base	4%	4%

A. Evaluation of Turkish Foresight Study on Advanced Materials for Each Sub-Sector

The parameters evaluated for the entire Delphi survey in the preceding discussion are examined in close detail below for each sub-sector.

The sum of medium and high levels of respondents' degree of expertise exceeded or at least equaled the sum of low-level and no expertise levels for sub-sectors *"universities/research organizations", "vehicle weight and fuel efficiency", "manufacturing*", and *"advanced metals"* in round 1.

TABLE 10. DEGREE OF EXPERTISE FOR SUB-SECTORS

Sub-Sector	1st Round				2nd Round			
	None	Low	Medium	High	None	Low	Medium	High
Advanced ceramics	%36	%27	%23	%14	%32	%24	%26	%18
Advanced metals	%30	%20	%26	%24	%29	%20	%25	%26
Polymers/polymer based composites	%41	%25	%25	%10	%41	%23	%28	%8
Recycling/re-use	%36	%25	%22	%17	%36	%23	%25	%16
Manufacturing	%34	%9	%38	%18	%33	%11	%35	%22
Economic market	%32	%23	%27	%18	%29	%21	%29	%21
Universities/research organizations	%9	%17	%48	%26	%4	%17	%48	%30
Vehicle weight and fuel efficiency	%21	%23	%32	%25	%19	%21	%31	%30

The similar trend is also observed for the same sub-sectors in round 2, with the exception that respondents' expertise for *"economic market"* increased by 5% in favor of the medium and high levels on the total (Table 10).

Respondents agreed on the importance of all sub-sectors regarding their impact on quality of life as observed in Table 11. Sum of ratios for no and low level of impact on quality of life reduced in round 2 when compared to results of round 1.

Respondents foresaw the occurrence of events in all sub-sectors in the next two decades. Nevertheless, the majority agreed on 2006 – 2010 as the realization period for events in all sub-sectors. The ratio of respondents in favor of 2006 – 2010 increased in round 2 when compared to round 1 (See Table 12.a and Table 12.b for more detail).

TABLE 11. IMPACT ON QUALITY OF LIFE FOR EACH SUB-SECTOR

Sub-Sector	1st Round				2nd Round			
	None	Low	Medium	High	None	Low	Medium	High
Advanced ceramics	%0	%16	%61	%23	%0	%15	%63	%23
Advanced metals	%0	%19	%42	%39	%0	%18	%42	%40
Polymers/polymer based composites	%0	%19	%49	%32	%0	%17	%54	%29
Recycling/re-use	%3	%13	%22	%62	%3	%10	%31	%57
Manufacturing	%6	%13	%45	%36	%5	%9	%50	%36
Economic market	%14	%23	%36	%27	%13	%13	%46	%29
Universities/research organizations	%0	%5	%9	%86	%0	%4	%4	%91
Vehicle weight and fuel efficiency	%0	%16	%31	%52	%0	%14	%30	%56

TABLE 12.A. REALIZATION PERIODS – ROUND 1

Sub-Sector	Never	2001-2005	2006-2010	2011-2020	2021-2030	Beyond 2030
Advanced ceramics	%0	%31	%37	%31	%0	%0
Advanced metals	%0	%34	%39	%23	%3	%1
Polymers/polymer based composites	%1	%38	%32	%18	%8	%2
Recycling/re-use	%1	%20	%41	%23	%7	%8
Manufacturing	%0	%38	%42	%13	%5	%2
Economic market	%0	%18	%50	%23	%9	%0
Universities/research organizations	%0	%41	%32	%23	%5	%0
Vehicle weight and fuel efficiency	%1	%23	%39	%23	%8	%6

TABLE 12.B. REALIZATION PERIODS – ROUND 2

Sub-Sector	Never	2001-2005	2006-2010	2011-2020	2021-2030	Beyond 2030
Advanced ceramics	%0	%27	%49	%24	%0	%0
Advanced metals	%0	%33	%43	%22	%2	%0
Polymers/polymer based composites	%1	%32	%41	%16	%10	%0
Recycling/re-use	%1	%21	%42	%23	%9	%4
Manufacturing	%0	%40	%41	%16	%2	%0
Economic market	%0	%17	%58	%21	%4	%0
Universities/research organizations	%0	%35	%43	%17	%4	%0
Vehicle weight and fuel efficiency	%1	%23	%41	%23	%10	%2

Table 13.a and Table 13.b reveal the respondents' firm choice on foreign partners with whom close collaboration is needed. The ratios for the EU, the USA and Japan were nearly kept constant in both Delphi survey rounds.

TABLE 13.A. NEED FOR COLLABORATION – ROUND 1

Sub-Sector	**None**	**Turkish Republics**	**EU**	**USA**	**Japan**
Advanced ceramics	%0	%2	%40	%34	%24
Advanced metals	%3	%1	%37	%32	%27
Polymers/polymer based composites	%6	%0	%42	%35	%17
Recycling/re-use	%1	%0	%44	%31	%24
Manufacturing	%3	%1	%36	%33	%28
Economic market	%4	%0	%35	%41	%20
Universities/research organizations	%8	%4	%29	%31	%29
Vehicle weight and fuel efficiency	%1	%0	%33	%35	%30

TABLE 13.B. NEED FOR COLLABORATION – ROUND 2

Sub-Sector	**None**	**Turkish Republics**	**EU**	**USA**	**Japan**
Advanced ceramics	%0	%2	%37	%36	%26
Advanced metals	%3	%1	%35	%34	%26
Polymers/polymer based composites	%3	%0	%40	%39	%18
Recycling/re-use	%1	%0	%44	%32	%23
Manufacturing	%3	%0	%34	%34	%29
Economic market	%6	%0	%31	%41	%22
Universities/research organizations	%10	%4	%27	%33	%27
Vehicle weight and fuel efficiency	%1	%0	%33	%35	%31

Turkey's capabilities as a *"leading figure"* in R&D, product or service delivery, and marketing are shown in Table 14. R&D capability in *"advanced ceramics"*, *"economic market"*, and *"universities/research organizations"* was nearly kept unchanged with 4 to 5 % in both rounds. For *"advanced metals"*, *"manufacturing"* and *"vehicle weight and fuel efficiency"*, R&D capability increased in round 2. However, in *"polymers/polymer based composites"* sub-sector, respondents' evaluation for R&D capability reduced by 3%. Turkey has no R&D capability in *"recycling/re-use"*.

The situation for product or service delivery is nearly the same as in R&D capability. Turkey's capability remained unchanged in both rounds for *"advanced ceramics"* and *"universities/research organizations"*. *"Advanced metals"*, *"polymers/polymer based composites"*, *"manufacturing"*, *"economic market"*, and *"vehicle weight and fuel efficiency"* presented an increase while product or service delivery capability in *"recycling/re-use"* is still negligible.

Marketing capability presented a relatively important increase in sub-sectors *"advanced metals"*, *"economic market"*, and *"polymers/polymer based composites"* in round 2, followed by *"manufacturing"* and *"vehicle weight and fuel efficiency"*. The others remained unchanged.

TABLE 14. CAPABILITIES IN R&D, PRODUCT / SERVICE DELIVERY AND MARKETING

Sub-Sector	1st Round			2nd Round		
	R&D	**Product / Service Delivery**	**Marketing**	**R&D**	**Product / Service Delivery**	**Marketing**
Advanced ceramics	%4	%4	%4	%4	%3	%3
Advanced metals	%1	%4	%4	%4	%7	%8
Polymers/polymer based composites	%12	%7	%4	%9	%10	%7
Recycling/re-use	%0	%0	%0	%0	%1	%1
Manufacturing	%4	%5	%5	%6	%7	%7
Economic market	%5	%5	%5	%4	%9	%9
Universities/research organizations	%5	%10	%5	%5	%9	%5
Vehicle weight and fuel efficiency	%0	%0	%0	%2	%2	%2

Technological feasibility, lack of funding, and economic viability constituted the major constraints on occurrence of events for all sub-sectors as observed in Table 15.a and Table 15.b. Regulations came out to be another major constraint for *"recycling/ re-use"*. For *"universities/ research organizations"*, and *"vehicle weight and fuel efficiency"* regulations and policy accompanied the three previously mentioned constraints.

TABLE 15.A. CONSTRAINTS ON OCCURRENCE OF EVENTS – ROUND 1

Sub-Sector	**Social Acceptability**	**Technological Feasibility**	**Lack of Funding**	**Economic Viability**	**Regulations**	**Policy**	**Educational/Skill Base**
Advanced ceramics	%7	%30	%25	%22	%4	%5	%8
Advanced metals	%0	%34	%27	%24	%4	%6	%5
Polymers/polymer based composites	%1	%28	%26	%32	%5	%3	%5
Recycling/re-use	%6	%22	%17	%27	%15	%10	%2
Manufacturing	%3	%29	%26	%32	%4	%3	%2
Economic market	%2	%27	%23	%18	%13	%13	%3
Universities/research organizations	%10	%14	%23	%14	%18	%15	%7
Vehicle weight and fuel efficiency	%2	%33	%24	%29	%3	%4	%4

TABLE 15.B. CONSTRAINTS ON OCCURRENCE OF EVENTS – ROUND 2

Sub-Sector	**Social Acceptability**	**Technological Feasibility**	**Lack of Funding**	**Economic Viability**	**Regulations**	**Policy**	**Educational/Skill Base**
Advanced ceramics	%5	%31	%27	%20	%3	%6	%7
Advanced metals	%0	%37	%24	%25	%4	%5	%4
Polymers/polymer based composites	%1	%30	%25	%31	%4	%5	%4
Recycling/re-use	%6	%25	%16	%25	%16	%10	%2
Manufacturing	%3	%31	%26	%30	%4	%4	%2
Economic market	%1	%28	%22	%19	%14	%13	%3
Universities/research organizations	%9	%14	%23	%12	%17	%16	%9
Vehicle weight and fuel efficiency	%2	%33	%24	%28	%3	%5	%5

The statements that exhibit:

1. The highest *Degree of Impact on Quality of Life*
2. The nearest *Realization Period*
3. The least *Need for Global Collaboration*
4. The minimum number of *Constraints*

should be emphasized for resource allocation. All topics in the Delphi questionnaire were sorted in the manner that satisfies the four requirements stated above. The topic statements and related sub sectors that rated the highest are tabulated in descending order in Table 16. It is apparent that Turkey should better allocate her resources on these topics to realize usage of advanced materials technologies in automotive industry.

B. Comparison of UK and Turkey Materials Foresight Results for Common Topic Statements

Table 17 shows the eleven topics in the current Delphi questionnaire, which were taken from the UK Materials Foresight Delphi Survey of 1995 with the comparison of realization periods. Even though time intervals are different in the UK questionnaire, it is still possible to make a comparison with the Turkey results.

Topics 6, 12, 14, 20, and 33 present deviations between the UK and Turkey foresight results with respect to realization periods.

The experts' opinion in the UK for topic 6 foresaw an earlier development time of nearly six years for aluminum based composites. The same realization period difference is observed for topic 14 also, which states competitive manufacturing speeds of cold formable polymers compared to metals.

Widespread use of commercially viable fire-retardant plastics in automobiles, statement of topic 12, was considered to occur in the UK ten years earlier than Turkey.

Recycling issue, in topic 20, came out to be more important for the UK than for Turkey since it was considered to occur in 2002 at the end of round 2 where the realization period was first foreseen as 2005. For Turkey, there is still seven years to cover from now for the full realization of the recycling issue.

Weight reduction issue in internal combustion engines of topic 33 is near to realization for the UK. However, Turkey still needs eight years to realize the weight reduction in engine components.

In the context of the preceding discussion, it can be summarized that the UK is competent in the extensive use of aluminum based composites, advanced plastics, and recycling issue. These results are consistent with the outcomes of the Materials Foresight Report of 2000 [9], which placed enormous emphasis on sustainability and light metals, especially increased aluminum use in the transport sector.

It is worth noting that topics 5, 13, 14, 21, and 32 are among the most emphasized events for Turkey (see Table 16). In other words, experts have a consensus that achievements in advanced metals, polymers/polymer based composites, recycling, and a more effective role of research organizations in the near future will contribute to technological advancement and enhanced social welfare. Experts in the UK Materials Foresight Survey foresaw 11 to 16 years from 1995 on for these events to realize whereas Turkish experts believe in the necessity of achieving those goals in a shorter period from 2001 on except topic 14. Even though it comes the first among the most emphasized sixteen topics, topic 14 still has twelve years to be realized.

TABLE 16. EMPHASIZED TOPICS AND SUB SECTORS FOR RESOURCE ALLOCATION

Order No.	Topic Statement	Sub Sector	Realization Period
1	**14.** Development of a high speed formable/cold formable polymers that can be processed at speeds approaching those of metal forming (10x current speeds).	Polymers/polymer based composites	2013
2	**17.** Reduction in production costs of carbon fibers from $20/kg to $5/kg leads to widespread use of carbon fiber reinforced composite materials in place of aluminum.	Polymers/polymer based composites	2009
3	**19.** SMC use in heavy-duty trucks reached up to 450 kg.	Polymers/polymer based composites	2009
4	**10.** Magnesium content reaches 115 kg per vehicle.	Advanced metals	2009
5	**13.** New class of polymer discovered, capable of plastic processing, and with significantly improved high temperature and strength properties compared to existing organic polymers.	Polymers/polymer based composites	2009
6	**16.** Intensive use of manpower is abandoned for the sake of low cost automated production of carbon fiber reinforced composites.	Polymers/polymer based composites	2008
7	**32.** Restructuring of university research and teaching on multidisciplinarity lines produces significant advances in materials science, design and engineering.	Universities/research organisations	2008
8	**8.** Use of high strength steels with $\sigma y>500MPa$ increases to 65% in automotive industry.	Advanced metals	2007
9	**9.** The steel industry developed an optimized automotive steel structure that is 24% lighter, 34% stronger, and $154 less expensive than traditional autobody structures.	Advanced metals	2008
10	**11.** Aluminum content per vehicle reaches 20%.	Advanced metals	2008
11	**15.** High strength requiring locations in glass fiber reinforced composite structures are reinforced with carbon fibers, thus reducing their cost of use in automotive industry.	Polymers/polymer based composites	2009
12	**24.** The amount of waste that is unsuitable for further use will decrease on average to 5% of a car' s weight.	Recycling/re-use	2014
13	**5.** Advances in corrosion resistance of high temperature-performance, new magnesium alloys creates significant new applications in automotive industry.	Advanced metals	2009
14	**21.** Development of recycling methods for composites used in automobiles.	Recycling/re-use	2008
15	**23.** Recycling in motor vehicles boosts up to 85% based on governmental and private sector enterprise on recycling.	Recycling/re-use	2016
16	**28.** Manufacturing and assembly costs in automotive industry reduce by 30% with the use of advanced materials and new process techniques.	Manufacturing	2007

TABLE 17. COMPARISON FOR COMMON TOPIC STATEMENTS

	Realization Period for UK Materials Foresight							Realization Period for Turkey
TOPIC STATEMENTS (common in UK and Turkey Materials Foresight Delphi Surveys)	**1995 - 1999**	**2000 - 2004**	**2005 - 2009**	**2010 - 2014**	**2015 or beyond**	**Never**	**UK Results Rounds 1 & 2 (1995)**	**TR Results Rounds 1 & 2 (2001)**
1. Advances in reliability of engineering ceramics enable the production of economically viable small gas turbines for land-based transport.	5	36	24	21	12	2	2009	2008
	7	35	24	22	11	2	2008	2008
4. Widespread use of titanium alloys in automotive connecting rods, valves and springs.	26	43	16	5	5	6	2008	2008
	32	40	14	4	8	2	2005	2008
5. Advances in corrosion resistance of high temperature performance, new magnesium alloys creates significant new applications in automotive industry.	15	37	29	8	7	4	2008	2009
	18	36	25	5	7	7	2011	2009
6. Development of low cost aluminum based composites with high strength and stiffness and good damage tolerance: E>=110GPa; σ_y>=450MPa; ρ<=2.8 Mgm-3; Kic>25MPam-1/2.	19	44	29	8	1	0	2003	2008
	28	50	17	3	2	0	2002	2009
12. Economically viable non-toxic fire-retardant plastics with equivalent performance to currently employed materials are in widespread use.	18	44	27	5	4	2	2005	2016
	25	48	21	2	2	2	2004	2014
13. New class of polymer discovered, capable of plastic processing, and with significantly improved high temperature and strength properties compared to existing organic polymers.	10	31	35	12	10	3	2009	2009
	11	30	38	8	10	3	2008	2009
14. Development of a high speed formable/cold formable polymers that can be processed at speeds approaching those of metal forming (10x current speeds).	7	36	43	11	1	1	2006	2013
	11	47	34	5	0	3	2007	2013
20. Means of on-line identification of different plastics, incorporated at source, enables economical separation of waste plastics for recycling, re-use or disposal.	30	39	19	6	4	2	2005	2009
	33	47	10	7	4	0	2002	2009
21. Development of recycling methods for composites used in automobiles.	22	35	26	7	7	3	2007	2009
	25	35	29	3	6	3	2006	2008
32. Restructuring of university research and teaching on multidisciplinarity lines produces significant advances in materials science, design and engineering.	37	37	12	6	3	7	2008	2008
	42	34	11	6	2	6	2007	2008
33. Lower density materials with equivalent properties and cost to current materials are employed in reciprocating internal combustion engine components.	14	43	23	14	4	2	2006	2014
	19	45	16	17	3	0	2004	2012

IV. CONCLUSION

Materials Foresight Activities in technologically and economically developed countries, where the U.S.A., the U.K., Germany, and Japan have been conducting extensive study nationwide, have revealed the high priority of advanced materials technologies in achieving both economic and social welfare. The important points leading to the success of foresight activities in those countries can be summarized as follows.

1. Applying a systematic method of setting priorities for science and technology.
2. Assessment of the future potential and application of a technology.
3. Identification of a market opportunity for which the technology will be required.
4. Identification of technological and economic strengths, potential failures, and social-technological-economic constraints in the technology roadmap.
5. Industry involvement and commitment.
6. Enhanced communication between public and private sector, and research organizations.
7. Sharing of foresight activity outcomes nationwide.
8. Considering foresight activities as a continuous process, and conducting foresight at a specified time horizon periodically.
9. Linking foresight outcomes to national policies.

In Turkey, however, the Supreme Planning Council formulated the improvement in Turkey' s scientific and technological capabilities in the following way [13].

1. Acquisition of the global technology.
2. Learning the acquired technology.
3. Implementing the new technology in industry.
4. Generating the new technology at a higher level.
5. Gaining the scientific fundamentals for regenerating the new technology.

The preceding procedure, in fact, lacks the following issues when compared to the points stated for a successful foresight activity.

1. Priority setting for resource allocation is important for Turkey that has limited financial resources.
2. Neither the public nor the private sector is conducting a nationwide analysis for assessing Turkey' s future potentials. A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis should be conducted to foresee national potentials and pitfalls.
3. Necessity of a nationwide commitment, both public and private sector, is not emphasized.
4. Two-way communication channels should be established and improved continuously between the government, private sector, universities and research organizations to share information and form a database.
5. Insufficient cooperation between universities and private sector in technology creation. When the current R&D level is considered, it is observed that such a cooperation is not well developed because the potential added value of such cooperation to the industry is not fully or extensively appreciated by the private sector.
6. Private sector should have a higher participation and initiative in technology creation.

The outcomes, that Delphi survey revealed for Turkey, point at the necessity of focusing on two major sub areas: namely polymers and polymer based composites, and advanced metals. In fact, these are the same topics that automotive manufacturers in Europe and the U.S. have concentrated on for the last two decades.

Developing energy-efficient and low-emission vehicles has been the main emphasis for the automotive industry in the West because of scarce energy resources and increasing sensitivity for the environment. Reducing design and development lead times together with manufacturing costs and duration constitute a crucial point in improving the national competitiveness in this context. The major aim is implementing new materials and manufacturing technologies for achieving commercially viable innovations in current vehicles and carry out extensive research and development in manufacturing lightweight materials and meeting safety requirements for vehicles of tomorrow.

Lightweight metals and polymer based composite materials have long been in the scope of automotive industry for their exceptionally high strength to weight ratios. However, there exist problems with the commercial viability of those high-technology materials in daily use. These two classes of materials have been used in the aerospace industry extensively for many years. Nevertheless, the supply and production of those materials are not affordable in the automotive industry. Besides, safety and performance requirements should be met with the lowest possible cost level.

Emphasized topics for Turkey are consistent with the preceding discussion. In the case of polymer based composite materials:

i. improved manufacturing capabilities at low cost,
ii. discovery of a new class of polymer with high strength and temperature properties,
iii. reduction of cost of use by substituting high strength material alternatives where needed are the areas of interest.

When advanced metals are considered:

i. more extensive application of aluminum and magnesium in body frame and chassis parts,
ii. use of lightweight high strength steels,
iii. utilizing inexpensive production methods for ultra-high strength steels come into the scene.

Another crucial issue for Turkey, following the polymeric and metallic materials, is the recycling issue. As a result of environment concerns, car manufacturers have become more sensitive in increasing the amount of materials in the total car weight for re-use. As a result, a very competitive target ratio of 85% was set by governmental and private enterprises in Europe, which will further increase to 95% in two decades. Therefore, Turkey has to reconstruct her infrastructure aiming at reducing scrap and increasing re-useable materials in car manufacturing.

It is apparent that fundamental strategic policies for Turkey in advanced materials technologies should be nation specific and based on realistic information. In this context, the following concepts should be emphasized.

1. Strategic evaluation centers for technology monitoring and constructing information database.
2. Multi-disciplinary and multi-participative strategic cooperation enterprise programs including user and manufacturing companies, R&D organizations, private entrepreneurs, experts in project management and monitoring.
3. Formation of bodies within the private sector in the context of *"cooperation before competition"* principle.

The first two concepts are successfully implemented in Australia in the form of Cooperative Research Centers (CRCs). CRCs form a sophisticated network of R&D institutions, including universities, private R&D and government R&D facilities. This R&D network has a basic objective of implementation of high quality management in research, development, education, strategic planning, and human resource management [3].

Finally, the Delphi approach, which is used in this study, can be a very effective tool for constructing a reliable information database nationwide.

REFERENCES

[1] M. Ahrens, V. Mallick and K. Parfrey, "Robot-based thermoplastic fibre placement process", *Industrial Robot*, vol. 25, no. 5, pp. 326-330, 1998.

[2] *Australian Science and Technology Council Report*, "Matching science and technology to future needs: an international perspective", Australian Government Publishing Service, Canberra, 1994.

[3] Commonwealth Department of Education, Science and Training, The Cooperative Research Centers Program Home Page, www.crc.gov.au

[4] K. Cuhls and T. Kuwahara, *Outlook for Japanese and German Future Technology, Comparing Technology Forecast Surveys*, Physica-Verlag, Germany, 1994.

[5] H. Grupp and H. A. Linstone, "National technology foresight activities around the globe", *Technological Forecasting and Social Change*, vol. 60, pp. 85-94, 1999.

[6] W. Kimberley, "The light programme", *Automotive Engineer*, vol. 25, no. 2, pp. 54 – 55, February 2000.

[7] R. Langdon, D. Mann and I. Helps, "Materials", *Automotive Engineer*, vol. 22, no. 2, pp. 30 – 44, March 1997.

[8] D. Mann, "On materials for lean weight vehicles", *Automotive Engineer*, vol. 23, no. 3, pp. 44 – 56, March 1998.

[9] *Materials Foresight Panel Report*, "Materials: Shaping Our Society", UK, December 2000.

[10] J. Maxwell, *Plastics in the Automotive Industry*, Woodhead Publishing Ltd., U.S.A., 1994.

[11] M. A. Öner, A. Alsan and M. Dogru, *Ulusal Uzgörü Calismalari ve Türkiye 2023 Icin Bir Yöntem Önerisi*, Bogazici University Publications, Turkey, 2000.

[12] P. M. Pelagagge, "Product innovation programme in the field of flexible components for automotive suspension systems", *Industrial Management & Data Systems*, no. 99/5, pp. 197-204, 1999.

[13] *Science-Technology-Industry Work Group Report on Advanced Materials*, "Strategy and Policy Suggestions for Turkey", TÜBA-TÜBİTAK-TTGV Science-Technology-Industry Forum, Ankara, January 1996.