

A FUNCTIONAL MODEL SUGGESTION TO IMPROVE TECHNOLOGY
MANAGEMENT IN DEFENSE PLANNING CYCLE: A CASE STUDY FOR
TURKEY

A DOCTOR OF PHILOSOPHY (PhD) THESIS

in

Modeling and Design of Engineering Systems (MODES)

(Main fields of study: Industrial Engineering & Technology Management)

Atilim University

by

HASAN UMUT AKIN

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A FUNCTIONAL MODEL SUGGESTION TO IMPROVE TECHNOLOGY
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ABSTRACT

A FUNCTIONAL MODEL SUGGESTION TO IMPROVE TECHNOLOGY MANAGEMENT IN DEFENSE PLANNING CYCLE: A CASE STUDY FOR TURKEY

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Ph.D., Modeling and Design of Engineering Systems (Industrial Engineering)

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As with all other sectors, rapid developments and changes in technologies also affected the defense domain which covers the systems of systems, and enhanced the importance of Technology Management (TM) which enables the effective planning and use of complex defense systems. Existing practices and applications in TM area are mostly focused on the TM processes of commercial business. In this thesis, TM was investigated in detail with a view on its applicability to defense domain, specifically to Turkish Defense Planning System by considering defense planning processes within the TM framework as well as activities, methods, tools and techniques constituting TM. Additionally, the mechanisms to include TM to support decision making in defense planning cycle were also covered in detail by considering technology and warfighting concepts, and future capabilities requirements. A survey was applied to the experienced participants from the Turkish MoD and the Turkish Armed Forces in electronic form to take a snapshot of TM awareness and usage level and the applicability of existing TM activities, methods, tools and techniques to defense domain was analyzed. Based on the analyses and the survey results, a functional TM model was developed and integrated into the defense planning cycle to improve its effectiveness and enable defense planners to better perform their TM roles or functions.

Keywords: Technology Management, Technology Management Processes, Defense Planning Cycle, Technology Management Functional Model

ÖZ

SAVUNMA PLANLAMA SÜRECİNDE TEKNOLOJİ YÖNETİMİNİN GELİŞTİRİLMESİ AMACIYLA BİR FONKSİYONEL MODEL ÖNERİSİ: TÜRKİYE İÇİN BİR DURUM ÇALIŞMASI

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Teknolojilerdeki hızlı gelişim ve değişim tüm sektörlerde olduğu gibi, özellikle sistemlerin sistemi yaklaşımını kapsayan savunma alanında da etkisini göstermiş, daha karmaşık hale gelen savunma sistemlerinin etkin planlanması ve verimli kullanımı Teknoloji Yönetimi (TY)'nin önemini artırmıştır. TY alanında mevcut araştırmalar ve uygulamalar çoğunlukla ticari işletmelerin teknoloji yönetimi süreçleri üzerinde durmaktadır. Bu tezde, mevcut savunma planlama süreçleri kapsamında TY'nin uygulanabilirliği; yazında yer alan ve çoğunlukla ticari uygulamalara yönelik TY çerçevesinde ele alınarak, TY aktiviteleri, yöntemleri ve araçları da dâhil olmak üzere Türk Savunma Planlama Sistemi özelinde araştırılmıştır. Ayrıca, savunma planlama sürecinde karar vermeye destek olacak, teknoloji ve operasyonel konseptler ile geleceğin yetenek ihtiyaçlarını dikkate alan işleyiş tarzları da çalışmada incelenmiştir. Tez kapsamında, Türk Savunma Bakanlığı ve Türk Silahlı Kuvvetlerinden deneyimli katılımcılara TY farkındalığı ve kullanım düzeyi belirleme anketi uygulanmış ve mevcut TY aktivite, yöntem, araç ve tekniklerinin savunma sektörüne uygulanabilirliği analiz edilmiştir. Analiz ve anket sonuçları esas alınarak, savunma planlama sürecinin etkinliğini arttıracak ve savunma planlamacılarının görev ve fonksiyonlarını daha iyi yerine getirebilmelerini sağlayacak fonksiyonel bir TY modeli geliştirilerek savunma planlama sürecine entegre edilmiştir.

Anahtar Kelimeler : Teknoloji Yönetimi, Teknoloji Yönetim Süreçleri, Savunma Planlama Süreci, Teknoloji Yönetimi Fonksiyonel Modeli

to my parents

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LIST OF ABBREVIATIONS

AF	Armed Forces
AF1	Armed Forces Function
ANOVA	Analysis of Variance
AP	Acquisition Program
CRA	Combat Readiness Assessment
CST	Critical Systems / Technologies
DoD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities
DRDPL	Defense R&D Plan
DRDPR	Defense R&D Program
DSTL	Developing Science & Technologies List
DTMFM	Defense Technology Management Functional Model
FPD	Force Planning Directive
FR	Feasibility Report
FSP	Force Structure Plan
FxPxP	Firm X Project X Product Matrix
IDEF0	Integration Definition for Function Modeling
IEEE	Institute of Electrical and Electronics Engineers
IGOE	Input, Guide, Output, and Enabler
IPR	Intellectual Property Right
IT	Information Technology
JONP	Joint Operational Needs Plan
JOP	Joint Operations Concept

KM	Knowledge Management
MCTL	Militarily Critical Technologies List
MF1	MoD Function
MoD	Ministry of Defense
MOT	Management of Technology
NIST	National Institute of Standards and Technology
OEM	Original equipment manufacturers
ONPD	Operational Needs Planning Directive
OPD	Operations Planning Directive
PD	Program Directive
PD	Project Document
PDD	Project Definition Document
PPBS	TAF Planning, Programming and Budgeting System
R&D	Research and Development
RDNP	R&D Needs Plan
STCN	Systems / Technologies to be Compulsorily National
STP	Strategic Target Plan
SWOT	Strengths, Weaknesses, Opportunities, Threats
TAF	Turkish Armed Forces
TDPS	Turkish Defense Planning System
TGS	Turkish General Staff
TM	Technology Management
TNMS	Turkey's National Military Strategy
TR	Technology Roadmaps
TRL	Technology Readiness Level

CHAPTER 1

INTRODUCTION

1.1 Background

Technology Management (TM) is an essential capability for both industrial organizations and public planning organizations as well as for technology and research establishments. All of these organizations require a robust, useful and integrated family of technology management activities and tools for supporting their technology management processes. Technology management methodologies and applications involve a broad range of research issues (Liao, 2005). One of these research issues is to provide defense planners with technology management processes through defense planning cycle.

1.2 Nature of Defense Planning Systems

Defense planning system of a nation is structured through decisions at different levels. At government level, the political intent and goals are issued as guidance to the defense planners. The defense system takes this guidance as an input and initiates a planning cycle by identifying the strategic goals and capabilities to meet them first. This planning is for long-term and it is a continuous cycle where at some points strategic decisions are made by the leaders of defense stakeholders, namely Ministry of Defense (MoD) and Armed Forces (AF).

In this respect, defense planners must consider the future operating environments which contains new contingencies and threats and in parallel to this, the technological developments which endows powerful options to eliminate these contingencies and threats enabling us to seize the superiority in future operating environments.

1.3 Turkish Defense Planning System

The main actors in Turkish Defense Planning System (TDPS) are; Government, MoD, and AF (including services). By considering the defense planning system's output which requires acquisition of defense systems, industry and academia (universities and other research establishments) are additional actors of the system.

The Turkish defense planning system is structured by several decisions at different management levels through the defense planning cycle. An overview of Turkish Defense Planning System cycle is presented in Figure 1-1.

At government level, the political intent and goals are issued by the "National Security Council" as "National Security Policy Paper". This policy paper is updated in every five years at most. It contains political, military, economic, social, and environmental assessments and analyses from global, regional and national perspectives. The policy paper includes strategic foresights for the incoming 20 to 30 years considering the past, current and future changes and developments which are analyzed according to the possible scenarios. Vision 2023 strategy requirements, national goals and interests, future potential threats, risks, and uncertainties are also included in the policy paper.

The TAF takes this guidance as an input and initiates defense planning cycle by first identifying the strategic goals and capabilities to meet the political intent. The output of this effort is "Turkey's National Military Strategy (TNMS)". Other inputs to the TNMS development are; threat analysis, military situation assessment, political/military assessment, defense technology vision, and technology foresight document. Considering the Vision 2023, TNMS's purposes are;

- to identify the national military goals,
- to define the strategic steps to achieve these goals,
- to set the bases for organizing, orientating, improving and deploying the military power for defined strategy.

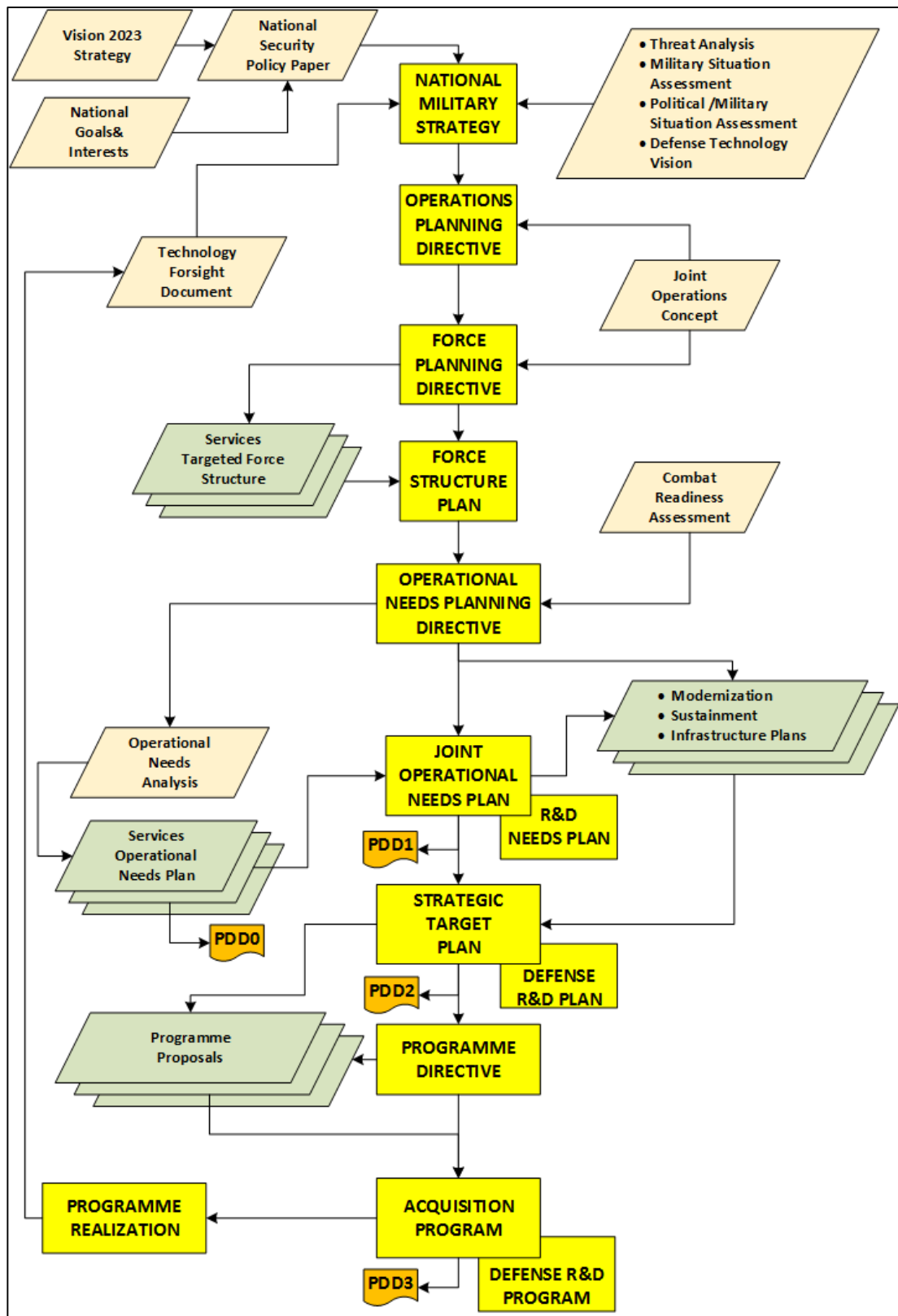


Figure 1-1 Turkish Defense Planning System

The defense planning cycle follows the steps defined by “TAF Planning, Programming and Budgeting System (PPBS)”. Conforming to the “Joint Operations Concept (JOP)”,

the “Operations Planning Directive (OPD)” and “Force Planning Directive (FPD)” are issued respectively. In the next step, services propose their targeted force structures. Considering the FPD and proposed force structures, “Force Structure Plan (FSP)” is issued. According to the FSP and the current “Combat Readiness Assessment (CRA)” the “Operational Needs Planning Directive (ONPD)” is issued to the services to initiate their operational needs planning. The services perform operational needs analysis studies, identify their operational needs in terms of systems and send them to the Turkish General Staff (TGS) along with “Project Definition Documents (PDD0)”. The TGS analyzes the services’ system needs and their contributions to the battlespace as well as their technical feasibility, and prepares the “Joint Operational Needs Plan (JONP)”. JONP includes refined PDD1s for the proposed systems and “R&D Needs Plan (RDNP)” for systems requiring research and development. For the approved system projects in JONP, services prepare modernization, sustainment, and infrastructure plans and send them to the TGS for approval. TGS analyzes and prioritizes both the system and R&D projects and finalizes the “Strategic Target Plan (STP)” and “Defense R&D Plan (DRDPL)” including finalized PDD2s. At the final step, considering the existing resources (i.e. budget, manpower, time), “Program Directive (PD)” is issued by the TGS to the services. Services prepare their program proposals within the limits of assigned resources and send them back to the TGS for approval. After a final evaluation, TGS issues “Acquisition Program (AP)” and “Defense R&D Program (DRDPR)” along with budgeted PDD3s to be realized within the 10 years.

1.4 Problem Statement

The critical issue with defense planning system is to have a dynamic response mechanism to the new contingencies and threats that may arise over time. This can be achieved through defense planning cycle by developing scenarios for the future operating environments (context), analyzing and assessing their impact on defense system and, developing appropriate operating schemas (concepts) as new contingencies and threats arise. At this point, it is important to understand the effects of emerging technologies on both the way defense system operates and the environment in which it operates.

Through the TDPS cycle, technological considerations for future operating environments and warfighting concepts are not defined explicitly in current regulations. For example; Turkish Council Of Ministers Resolution on “Turkish Defense Industry Policy and Strategy Principles” (Government, 1998), MoD Directive MSY 202-2 “MoD Duties and Responsibilities” (MoD, 2004), MoD Directive MSY 380-1 “Defense Research, Development, and Technology Activities” (MoD, 2009), Undersecretariat MoD’s “Technology Management Strategy 2011-2016” (MoD, 2010), and TGS Directive MY 369-1 “TAF Planning, Programming and Budgeting System” (TGS, 2008) documents are all defines the technology management related roles and functions of MoD and TAF implicitly. But they all lack in defining specific technology management activities explicitly. There are also no TM-assigned units to conduct technology management activities. Although Vision 2023 Strategy, Defense Technology Vision, and Technology Foresight Document are well organized to identify future operating contexts and concepts, their implications are not well integrated to defense planning cycle in a systematic way. All of the strategy and concept documents, directives, plans, and project definition documents have sections for expressing technology related issues but there is no pre-defined principles, guidelines, and standard methods for integrating technology management into the defense planning system explicitly.

Existing practices in technology management area mostly focused on the technology management processes of commercial business. There are a few specific studies on applicability of TM activities and tools to defense domain. Furthermore, existing methods and techniques for technology management activities are rather subjective. Subjective methods and techniques are mainly focused on the strategic issues whereas objective ones are focused on operational issues. In the defense domain, subjective methods and tools can be used in strategic issues to support decisions made at higher levels. But, considering the defense planning cycle and criticality of its processes, more objective methods and tools are needed for the improvement of the quality of studies of defense planners since today’s managers need more tangible results in making their decisions. There are few studies on technology management activities in the defense domain and most of them are focused on strategic issues.

1.5 Research Questions

In this study, the research questions to answer are;

- What activities constitute TM? What are their subjective or objective features?
- Being applied mostly to commercial business, can these activities also be applied to defense TM processes as a whole or with some changes where the sole client (monopsony) is MoD?
- What should be the TM activities to support the defense planning cycle?
- What are the existing TM tools to be used in TM activities and how they can be aggregated to these activities?
- How can such TM activities be integrated into the defense planning cycle to improve the quality of decisions through it by considering technology and warfighting concepts and future capabilities requirements?
- Given the task of identifying technologies for a system, how to assess the existing, new and emerging technologies related to the system and which activities should be performed to identify them?

1.6 Research Objective

The aim of this PhD study is to conduct a research on technology management and its applicability to defense domain and to develop a model driven by technology management processes to improve technology management capabilities of Turkish Ministry of Defense and Armed Forces in defense planning cycle.

1.7 Significance of the Research

The model developed by this research will help defense planners in Turkey with their defense planning studies by enabling them; to develop technology-related concepts; to better define operational needs; to utilize their resources more effectively; to invest on cutting-edge technologies; and, to obtain a competitive superiority in future operating environments.

1.8 Thesis Outline

In Chapter 1, a brief introduction to technology management is given. After explaining the nature of defense planning systems, Turkish Defense Planning System is explained. The chapter continues with statement of problem, identification of research questions, setting the research objective, and emphasizing the significance of research.

Chapter 2 summarizes the findings of the literature review on the related topics of research. It presents the TM definitions, TM history, TM models and frameworks, TM activities, tools and their generalization, and activities supporting TM. The chapter also covers the defense technology management activities and tools in the literature. The chapter continues with a discussion on technology management context in the literature considering the TM related processes, functions, activities, and TM capabilities. Next, the chapter covers defense planning system involving topics; forecasting technology trends and technological changes, defense TM framework, linking technology with military applications, defense technologies requiring special concern, defense capabilities management, and actors of defense system. At the end, function modeling and function models are discussed.

In Chapter 3, applicability of TM to defense domain is covered in detail with focus is being on; insertion of technology into defense domain, the technologies of special interest, defense TM activities and related methods, tools and techniques, and tools supporting defense TM activities. Next, defense TM activities are given and TM activities of actors in Turkish Defense Planning System are explained. Finally the conclusions on applicability of TM to defense domain and problem areas of Turkish Defense Planning System are given.

Chapter 4 presents the survey results conducted to prove the conclusions given at the end of previous chapter. It starts with stating the survey objectives, the new knowledge required by the survey, and the objectives and questions to meet these objectives in three categories, namely; TM awareness, TM usage level, and TM usage in defense planning. Next, the survey participation and participants' profile are given and survey results are given in defined three categories.

Chapter 5 is dedicated to functional model development. It starts with defining and identifying defense TM functions. It continues by giving TM functions of MoD and AF, their definitions and relations with TM activities as well as defining and relating TM them in terms of IGOE notation. In the next step, the interactions between TM functions are defined as well as the interactions between MoD and AF TM Functions. Finally, attainment of Defense Technology Management Functional Model (DTMFM) is achieved and roles of MoD and AF TM functions are explained.

The thesis concludes with Chapter 6 by presenting conclusions, contribution of the research to the problem and literature, and recommendations and future work.

CHAPTER 2

REVIEW OF RELATED RESEARCH

2.1 Technology Management Discipline and Its Scope

2.1.1 Definitions

The most common definition describes technology management as (National Research Council, 1987):

“Management of technology links engineering, science, and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization”.

This definition introduces a new term of “technological capability”, but fails to make the distinction between managerial and technical issues related with TM (Cetindamar, et al., 2009b).

Many studies in the literature considers TM as technological capabilities of a firm that it develops and exploits for achieving its strategic and operational objectives (National Research Council, 1987) (Best, 2001). Some studies explain it as a skill to explore and exploit technologies that guarantees and maintains better competitive advantage for firms (Rush, et al., 2007), whereas some simply define it as performing all of the technical and administrative functions aiming at utilizing, developing and reforming firm’s production facilities (Lall, 1990).

Another definition which merges engineering and technology management (Dhillon, 2002) is:

“Engineering and technology management is concerned with managing engineering and technologies to achieve business objectives, and it requires skills in understanding technology and engineering in addition to managing business activities of organizations.”

In an attempt to expand technology management’s scope to the strategic management of technology and innovation, another study proposed a historical approach to the definition and constitution of technology management as a discipline. (Chanaron & Grange, 2006). Although it aims at defining technology management, it prefers to use the term “management of technology” and introduces a new term “technological management”. Figure 2-1 shows the historical relationships of R&D management, management of technology, and technological management.

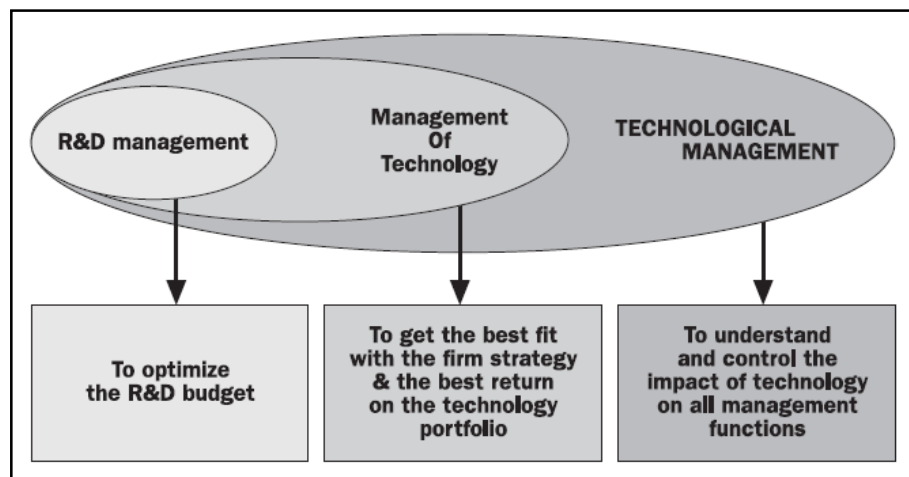


Figure 2-1 The Historical Relationship between R&D Management, MOT and Technological Management (Chanaron & Grange, 2006)

The technological management defined as (Chanaron & Grange, 2006):

“The management of innovation, whether it be a product, a process or an organization, from its conception to its diffusion, and therefore to its implementation within the company, including the consequences, advantages and disadvantages for all of the variables and actors involved in running the company.” Innovation is “any change produced by technology in an organization towards the satisfaction of its economic goals, i.e. providing an economic advantage in fine. Technological management is then the management of change, i.e. the management of technology.”

Another study defines technology management as (Jin & von. Zedtwitz, 2008) :

“The capability to make effective use of technical knowledge and skills, not only in an effort to improve and develop products and processes but also to improve existing technology and to generate new knowledge and skills in response to the competitive business environment”.

This definition highlights the difficulty of managing technology compared with developing the technology itself (Cetindamar, et al., 2009a).

Similarly, this is also stated in another study (Teece, 2007) as:

“The invention and implementation of business models and associated enterprise boundary choices involve issues as fundamental to business success as the development and adoption of the physical technologies themselves”.

A business perspective definition describes TM (Cetindamar, et al., 2010) as:

“Technology management is the management of technological capabilities for the purpose of designing and realizing the strategic and operational objectives”.

Badawy defines TM with 140-character limit of Twitter© (Badawy, 2009):

“The process of effective integration and utilization of innovation, strategic, operational, and commercial mission of an enterprise for gaining competitive advantage”.

2.1.2 History of Technology Management

Technology management discipline has over 50 years of history (Roberts, 2004), (Larson, 2007). In the last 20 years, it has been considered as a discipline of self-sustaining with increased number of practitioners and specialized organizations such as PICMET, IAMOT, and EITIM (Cetindamar, et al., 2009b).

In the early development phase of the discipline, Khalil and Bayraktar published eight essential questions to be concentrated in management of technology (Khalil & Bayraktar, 1990):

- (1) How should technology be integrated into the objectives of corporate strategy?
- (2) How can technologies be released and accessed more quickly and efficiently?
- (3) How can technology be assessed more efficiently?
- (4) How can the transfer of technology be optimized?
- (5) How does one reduce the development time of a new product, process or organization?

- (6) How should major, interdisciplinary and inter-organizational projects or complex systems be managed?
- (7) How should the internal usage of technology within the organization be managed?
- (8) How can the efficiency of technical personnel be improved?

Following these questions, initial studies covered limited TM activities/processes. They mainly focused on Research and Development (R&D) activities of organizations.

The four schools of TM and their historical evolution is presented in (Figure 2-2) (Drejer, 1996):

- the R&D management (in early 70s);
- the innovation management (in mid 70s);
- the technology planning (in 80s); and
- the strategic management of technology (in late 80s).

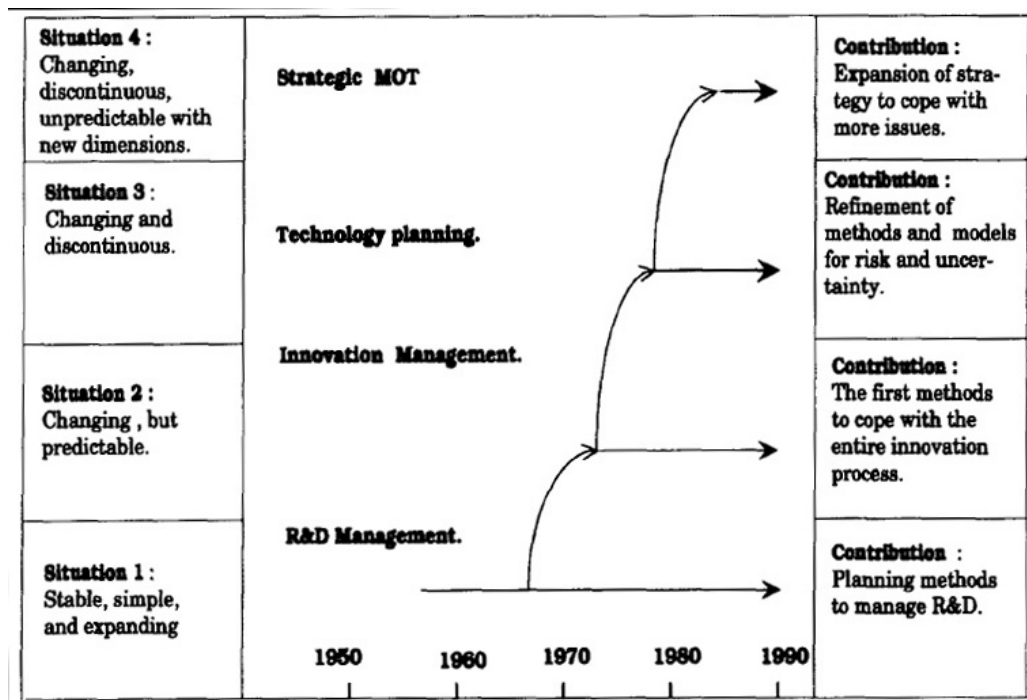


Figure 2-2 The conceptual framework for the evolution of MOT (Drejer, 1996)

The complexity of the TM discipline, considering the uncertainty and ease of TM tasks, as well as the controllability of the TM processes, has increased through the history of TM as seen in (Figure 2-3). The increased complexity introduces three

dimensions in: *scope* (strategic, corporate, and R&D levels), *view of technology* (as a system, tool, and value in practice), and related *issues* (development of products, other technologies and their integration) (Drejer, 1996).

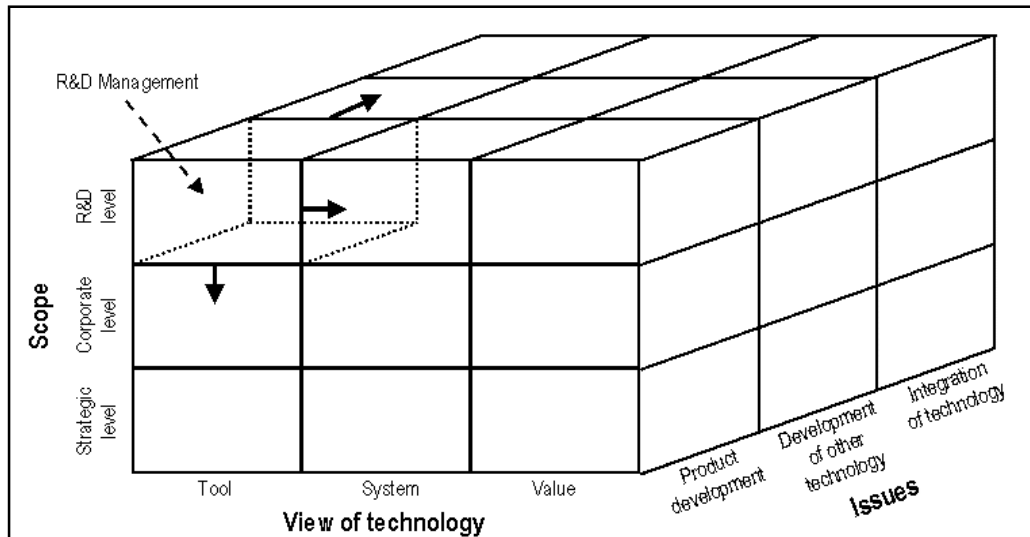


Figure 2-3 Evolution of MOT Concept (Drejer, 1996)

2.1.3 Technology Management Models and Frameworks

The most widely accepted model in the literature considers “the elements of technology management” (Gregory, 1995) which are namely:

- Competence and capability,
- R & D management,
- Innovation,
- Organizational learning,
- New product introduction.

This TM framework was developed by using a “process thinking approach” where the elements of TM were made explicit and could be converted into processes and integrated into the routine management activities gathered in five groups namely; *identification, selection, acquisition, exploitation and protection* (Gregory, 1995). Such TM Process Framework is shown on Figure 2-4.

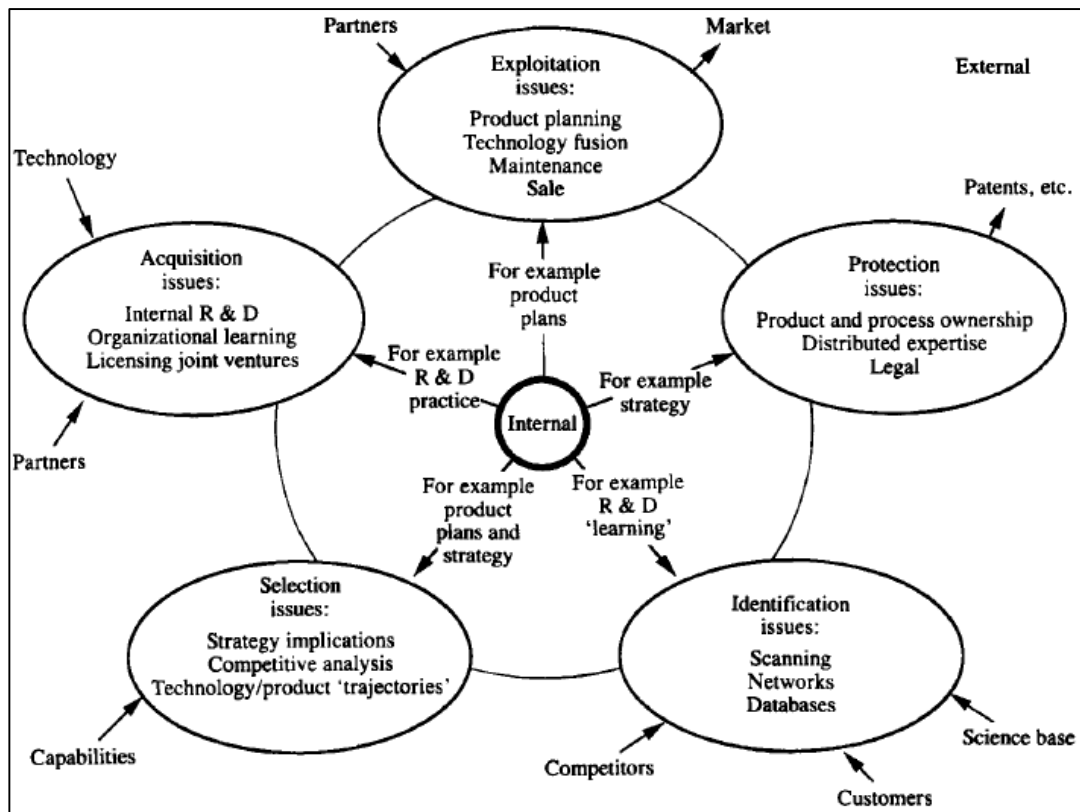


Figure 2-4 TM Process Framework (Gregory, 1995)

Another framework considers the dynamic capabilities as (Teece, et al., 2000):

“the ability to reconfigure, redirect, transform, and appropriately shape and integrate existing core competences with external resources and strategic and complementary assets to meet the challenges of a time-pressured, rapidly changing Schumpeterian world of competition and imitation”.

An alternative TM framework in the literature is shown in Figure 2-5 (Phaal, et al., 2006). The figure shows the TM specific processes (*identification, selection, acquisition, exploitation and protection*) and business processes (strategy, innovation and operations) flowing through them. The model shows the dialogue required between the technological and commercial functions within the business for supporting effective use of TM.

The framework considers technology as a resource and company technology base characterizes the technological information needs to be transformed into products, processes and services using technological capabilities established through effective management of technology (Cetindamar, et al., 2009b).

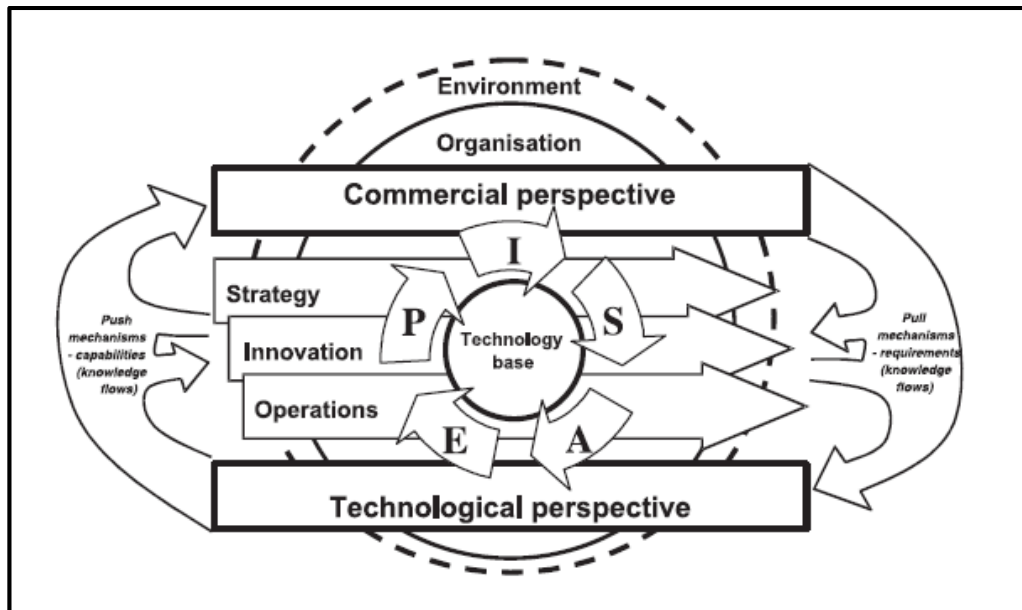


Figure 2-5 Technology Management Framework (Phaal, et al., 2004)

2.1.4 Technology Management Activities and Related Methods /Techniques

Technology management activities can be classified in 11 groups (Cetindamar, et al., 2006):

- (1) Technology utilization
- (2) Knowledge management
- (3) Technology acquisition
- (4) R&D management
- (5) Technology integration
- (6) Technology protection, license/patent purchasing
- (7) Technology transfer
- (8) Technology planning and forecasting
- (9) Technology strategy
- (10) Technology assessment
- (11) Technology commercialization and marketing

In the same study, the current TM methods and techniques based on these activities are identified as shown in Table 2-1.

Table 2-1 TM Activities vs TM Methods /Techniques (Cetindamar, et al., 2006)

TM Activities	RELATED TM Methods & Techniques
Technology strategy	Strategic Thinking Techniques (SWOT analysis, Porter's 5 forces analysis)
Technology acquisition, technology transfer	Techniques for Identification of Technologies (Value chain analysis)
Technology strategy, technology acquisition, technology planning	Market Analysis (Cost-benefit analysis, Statistical decision making models)
Technology strategy, technology transfer, technology assessment	Benchmarking
Technology planning and forecasting, technology assessment	Technology Forecast (Mathematical programming techniques, Monitoring, Simulation, Technology roadmapping, Decision trees, Methodological forecasting techniques, Trend extrapolation, Technology life-cycle analysis, Technology-product matrix analysis, Modeling, Expert opinion)
Technology transfer, technology protection, license/patent purchasing, technology commercialization and marketing, KM	Intellectual Property Rights (Licensing, patent analysis)
R&D development, technology utilization, technology integration	Portfolio Management (2-3 dimensional matrices, Value-success probability matrix, Technological position –maturity matrix, Technology efficiency analysis, Check lists, Technology analysis (technical & economical))
Technology assessment, technology utilization	Project Evaluation (Risk- return analysis, Capacity and bottleneck calculations, Reverse engineering)
R&D development, technology utilization, KM	Continuous Improvement (Brain storming)
R&D development, KM	Creativity (Promote creativity & change, Scenario building, team work, Education for professional development)

The methods and techniques shown in Table 2-1 focus mainly on subjective issues for supporting TM policies and strategic planning. The reason for this is a known debate between the perspectives of business /management community which dominates the current TM practices and engineering /science community where sometimes dissimilar subjective reasoning approaches and human decision making are against exact, objective measurements (Beard, 2002). For the management of technology at operational level, more objective tools are required for organizations.

2.1.5 Generalization of Technology Management Activities

TM activities are abundant in the literature. For the generalization of such activities, it is better to define typical routines and processes representing them to identify the essential and common tasks that are needed for TM and to develop technological capabilities.

The literature review reveals that there are several lists of technology management capabilities, activities, and processes as shown in Table 2-2. Many of them try to define technological capabilities but with different names (Cetindamar, et al., 2009b).

Analysis of Table 2-2 shows that there is an agreement on TM activities. The generic list of activities is obtained by merging two key studies (Gregory, 1995) and (Rush, et al., 2007). The final model has six generic activities (Cetindamar, et al., 2009b).

Table 2-2 TM Activities in the Literature (Cetindamar, et al., 2009b)

Terminology of the article	Gregory	Rush et al.	NCR	Sumanth	Dogson	Cotec	Roberts	Levin and Barnard
Identification	Identification	Search, awareness	Identification, evaluation	Awareness		Scan	Recognition of opp.	
Selection	Selection	Strategy, select-assess			Strategy	Focus		
Acquisition	Acquisition	Acquisition, building competencies	R&D	Acquisition, advancement	Collaborations, R&D, NPD	Resource	Idea formulation, problem solving, prototype solution	Producing knowledge and transforming into working artifacts
Exploitation	Exploitation	Implementation, exploitation	Integration, implementation, obsolescence	Adaptation, abandonment	Commercialization, operation	Implement	Commercial development, utilization, diffusion	Matching artefacts with user requirements
Protection Learning	Protection	Learning				Learn		Org support (performance, personnel, all)

- *Acquisition*: It is the acquirement of necessary technologies which are of value for the company's business. Acquisition requires several buy, collaborate, or make decisions. That is, technologies might be obtained from external providers, developed with some forms of collaborations, or through internal R&D. Based on the choice made, the acquisition management activities might differ.
- *Exploitation*: Exploitation involves commercialization of the existing technologies. It requires the realization of expected benefits through effective application, absorption and use of technologies within the firm. Technologies are incorporated through transfers in the form of either internal or external R&D to production. Basic exploitation activity modes are incremental product developments, improvements of processes in production, and marketing of products.
- *Identification*: Identification of technologies is necessary at all phases of product development and marketing. It includes both changes in market and technological advances. Identification entails search, audit, data gathering and technology intelligence processes for markets and technologies.
- *Learning*: Learning is the critical part of achieving valuable competitive advantages. It involves gathering relevant data for technology studies of the firm conducted internally or externally. Learning process is an important study area of knowledge management.
- *Protection*: This is an important process in terms of protecting intellectual assets in the firm through patenting and staff retention as well as the knowledge and expertise gained through product developments and production expertise.

- *Selection*: Selection is a strategic issue at company-level. It requires well perception of strategic goals and priorities identified at strategic level.

2.1.6 Generic Technology Management Tools

After defining a generic set of TM activities, the next task is to identify the necessary generic tools to be used for executing these activities. These generic tools are key enablers of TM activities and TM concepts whose actors are managers within business firms.

A study clearly highlights the difficulty in precisely defining what a tool is, considering the several terms which are used with different meanings, such as ‘techniques’, ‘tools’, ‘processes’, ‘procedures’, ‘models’, ‘frameworks’ and ‘maps’(Brady, et al., 1997).

Some guidelines of best practice for designing tools are (Brown, 1997):

- Founded on an objective model.
- Flexible so as to ‘best fit’ to the current situation and needs of any organization.
- Accommodating to the collection of views through all levels within the firm.
- Attentive to differences in assessments/perceptions between different groups.
- Simple in style of presentation.
- Designed in a clear graphical and visual manner.
- Linked with other methodologies and implementation aids.

Selecting necessary tools into a toolkit is a challenge since the most used or most popular tools might not fit to all TM cases. The toolkit will not make reference to the quality of tools, since there are almost no studies measuring the performance of tools (Cetindamar, et al., 2010).

It is useful to borrow the carpenter’s analogy (Straker, 1995). There are a large number of candidate tools that a carpenter might have in his toolbox. The carpenter usually carries only a small set of the mostly used tools. The carpenter also goes to the hardware store for special cases. In the case of quality improvement and problem solving the toolkit has 7 tools but, they are capable of solving 90% of all TM problems.

In addition, key tools should be dynamic in nature and applicable in all TM activities. They should also be the dominant ones across TM processes, which capture internal and external dynamics.

The basis for outlining the core tools of TM is; ease of use and elasticity, readily be available and highly standard (Cetindamar, et al., 2010). The final list consists of six tools namely patent analysis, portfolio management, road-mapping, the S-curve, stage-gating, and value analysis as presented in Table 2-3.

Table 2-3 TM tools and their applications (Cetindamar, et al., 2010)

Tools/ activities	Patent analysis	Portfolio management	Road- mapping	S-curve	Stage- gate	Value analysis
Acquisition	★					★
Exploitation			★	★		
Identification				★	★	
Learning		★	★			
Protection	★				★	
Selection		★				★

2.1.7 Activities Supporting Technology Management

Defining a simple outline to describe the essential TM activities is practical to understand the relationships between TM and other management activities, especially with project management, knowledge management and innovation management, as presented in Figure 2-6 (Cetindamar, et al., 2009b)

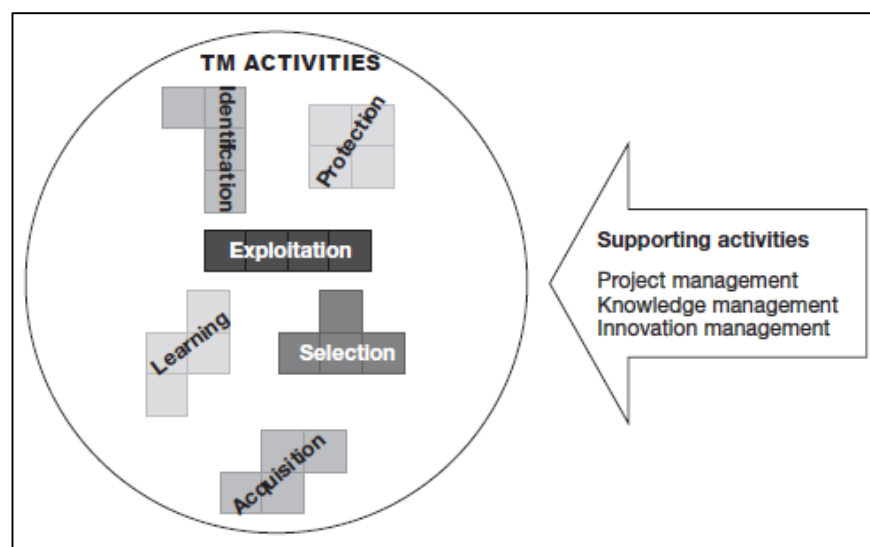


Figure 2-6 Activities Supporting TM (Cetindamar et al., 2009b)

Project management consists of management activities for all project types (e.g. product, process development). We can consider each types of TM activities being a project, which requires skills and knowledge to manage them. Likewise, knowledge management is also a required process in a company, and includes both technological and non-technological knowledge management. Innovation management, on the other hand, is needed for several types of innovations such as financial, organizational, and technological; so, it has many interfaces with TM (Cetindamar, et al., 2009b).

In a study conducted to better understand KM and specifically its application to R&D, KM best practices and their associated imperatives were identified (Armbrecht, et al., 2001). This study clearly shows the importance of information technology (IT) tools such as search and retrieval tools. These are: portals; web searching; taxonomy; technology yellow pages; personalization; data and textual archives; and desktop libraries.

2.2 Technology Management in Defense Domain

There are limited resources in the literature concerning defense technology management issues. Even though there were some valuable material on the topic in late 1990s and early 2000s open to the public through Internet, recently most of them have been restricted to the public access.

2.2.1 Defense Technology Management Activities in the Literature

In a book published by Springer India, containing collection of studies on emerging dimensions of technology management, one article touches defense technology management activities. Prahlada states that “There are a number of activities connected with technology, and all are to be managed either serially or simultaneously as part of technology management” (Prahlada, 2013). These are:

- (1) **Technology acquisition:** by in-house development or joint development through partner or through transfer from an established source
- (2) **Productization:** configuring a salable product incorporating a new technology
- (3) **Productionization:** carrying out essential engineering functions so that product can be produced cost effectively
- (4) **Production:** volume production of such a product

- (5) **Customization:** fine-tuning the product for a particular market or customer
- (6) **Adaptation:** modifying the technology for a slightly different product
- (7) **Upgradation:** improving the technology for higher performance of same product
- (8) **Exploitation:** complete harnessing of a technology in all its forms and nuances
- (9) **Technology integration:** integration of more than one technology in one product
- (10) **Technology control:** exercising rights and controls such that technology will not get proliferated without owner's approval.

These activities defined by Prahlada are similar to his predecessors on the subject [(Gregory, 1995), (Rush, et al., 2007), (Cetindamar, et al., 2010)]; some of them are the same, some of them are expressed with different words or with different meanings, and some of them are completely new. Activities expressed as productization, productionization, and upgradation are completely unknown words although they are grammatically correct. The comparison of Prahlada's activities versus his predecessors' generic activities is shown on Table 2-4.

Table 2-4 TM Activities (Prahlada, 2013) vs (Cetindamar, et al., 2010)

ACTIVITIES	Acquisition	Exploitation	Identification	Learning	Protection	Selection
Technology acquisition	X					
Productization		X				X
Productionization		X				
Production						
Customization		X				
Adaptation		X				
Upgradation		X				
Exploitation		X				
Technology integration		X				
Technology control					X	

In this relation, for example; acquisition and exploitation activities have the same meanings as previously described. But productization, productionization, customization, adaptation, upgradation, and technology integration are all focused on exploitation. Technology control activity has the same meaning as protection activity.

Production has no relation with the previously mentioned activities since volume production of products is a manufacturing process. Notice that none of the activities proposed in Prahlada's work are related to identification and learning. Identification is the essential activity to be able to catch the trends and technological developments in the worlds. Learning is another essential activity in the realm of technology management since it guarantees the continuity of developments and growth of workforce expertise in the field.

2.2.2 Defense Technology Management Tools

Defense technology management tools are not completely different from the tools used in commercial business technology management.

In a survey conducted by US Defense Acquisition University where the target group was a wide range of defense acquisition community with skills and high level management experience.

In the survey, participants rated some frequently used strategic planning and management methodologies, tools, and processes in defense systems acquisition activities that they thought useful. The survey showed that, the most referenced tools (and their primary use they specified) are listed below (Rosen, 2013).

- Action plans, used to establish priorities and clarify expectations;
- Root cause analyses, used to establish priorities and lower cost;
- Mission/strategy mapping, used to align the organization;
- Brainstorming;
- Program analysis/assessment, used to establish priorities;
- Needs assessment, also used to establish priorities;
- Strengths, Weaknesses, Opportunities, and Threats (SWOT) analyses, used to establish priorities;
- Stakeholder interviews, used to clarify expectations; and
- Vision statements, used to clarify expectations and align the organization.

Other rated tools were; scenario planning, Balanced Scorecard, use of consultants, and use of experts from industry and use of futurists in their activities.

2.2.3 Technology Maturity and Readiness Levels

Some of the top issues at operational levels of defense planning is to assess the technological readiness and maturity of critical technologies in system design and development studies. Since the defense systems are large-scaled and complex, the stakeholders of defense need to feel confident about successfully completing the acquisition programs having technology development and integration, but at the same time to take the minimum risk. The desired confidence levels are achieved by ensuring that development and improvement of technologies meet the system requirements well. Here, quantitative tools for assessment can give insight (Azizian, et al., 2009). One of the critical issues when initiating a defense system acquisition program is to identify the maturity and readiness of technologies which are going to be incorporated in such systems.

In recent years, a large amount of research is being conducted to develop tools and methods for technology maturity and readiness level assessments. Such tools and methods enable us gaining insight on technology readiness of a specific technology and keeping the track of its maturity through the evolution of system development life cycle and as a result, providing continuous risk management and enhanced decision making (Azizian, et al., 2009).

Developed by NASA, Technology Readiness Levels (TRLs) are one discipline-independent, programmatic performance metric that allows more effective assessment of maturity of new technologies (Mankins, 2009). It is a systematic approach to help technology planners with their technology development programs by evaluating the maturity of technologies involved along with their readiness levels for implementation. An overview of TRL is shown in Figure 2-7.

Although TRL is intended to support technology development studies, for improving the quality of decisions in system acquisition programs, literature review reveals that TRLs can in fact exposes some risks sourcing from several drawbacks such as lack of standard implementation guidelines (Azizian, et al., 2009).

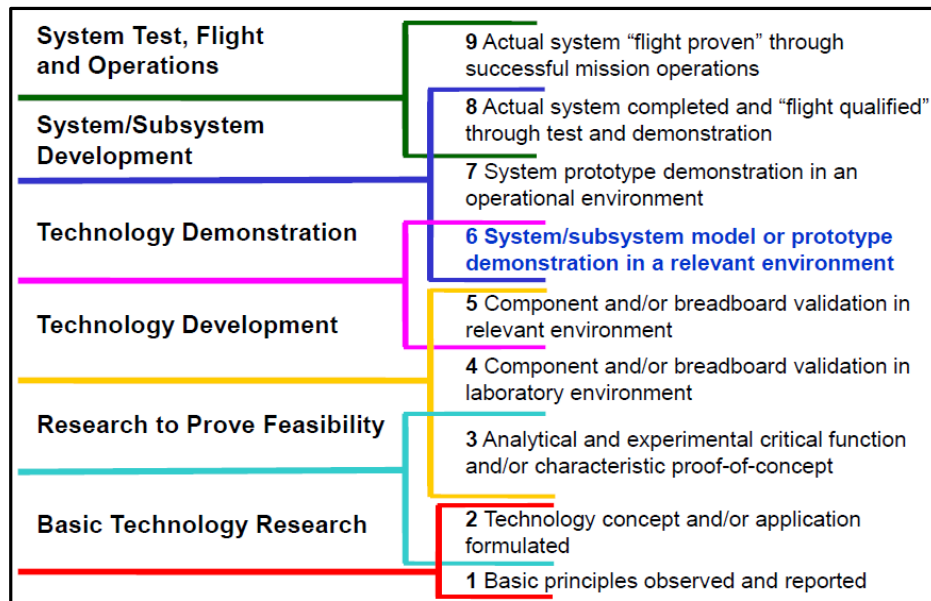


Figure 2-7 Technology readiness level scale (TRLs)

The major flaws of TRLs can be described as follows;

- *Subjective Measurement:* It is subjective since it cannot properly measure how well the development of technology meets a set of pre-defined figure-of-merits (Mahafza, 2005). This lack of objectivity results in overreliance on tacit knowledge and expected bias between its users.
- *Lack of Integration Aspect:* It does not considers the integration of different technologies within the same system. Since it lacks in providing the means for determining integration maturity between several technologies and their expected impact on a system, it is likely to have system failures at integration stage (Sausser, et al., 2008).
- *Lack of Implementation Principles and Guidelines:* Implementing the metric in a system acquisition program is problematic, since there is no well-defined "how to" guideline (Azizian, et al., 2009).
- *No Integration of Cost and Risk:* Since it's a one-dimensional technique, misleading technology readiness level assessments result in high risks and high costs.
- *Lack of Sufficient Terminology:* Each level of TRL might be vague and dependent upon interpretation of different individuals. For example, the term "relevant environment" to move technology to TRL 6 might cause a problem

since there are several environments that can be virtually simulated such as temperature, low-gravity, vacuum, radiation, etc. (Cornfor & Sarsfield, 2004).

2.3 Discussion

Although most of the literature covers TM activities and TM capabilities, some authors use different phrases such as “TM functions” (Vehkapera, et al., 2009) (Sweeney, 2008) or “TM Processes” (Kim, 2013) sometimes with the same meaning and sometimes with the different meanings. So there is a conceptual confusion when using these phrases.

In the defense domain, technology management related studies are conducted to support decision making and strategic planning in the different phases of defense planning cycle. Since it is a “cycle” and has different phases, similar activities might be performed at different phases of the cycle or at different management levels but with different focus. For this reason, it is better to define the “TM functions” within the defense planning context. For example in the early phases, technology auditing and assessment activities are performed to identify readiness and maturity of a specific technology for defining system requirements. But in a later phase same activities can be performed to identify that technology’s usability in terms of its readiness and maturity in targeted system as a part of a feasibility study. In each case the same activities’ function is different when defining the system requirements. Since the activities are generic aiming to reach a few results, the more complex studies in the defense domain can be defined with two or more TM activities to build a “TM function”. Similarly, two or more TM tools can be included in a TM activity to achieve its goal.

2.4 Defense Planning System

Defense planning system of a nation is structured through decisions at different levels. At government level, the political intent and goals are issued as guidance to the defense planners. The defense planning system takes this guidance as an input and initiates a planning cycle by identifying the strategic goals and capabilities to meet them first. This planning is for long-term and it is a continuous cycle where at some points strategic decisions are made by the leaders.

As an example, in “Handbook on Long Term Defence Planning”, NATO’s generic processes in defense planning are identified as presented in Figure 2-8.

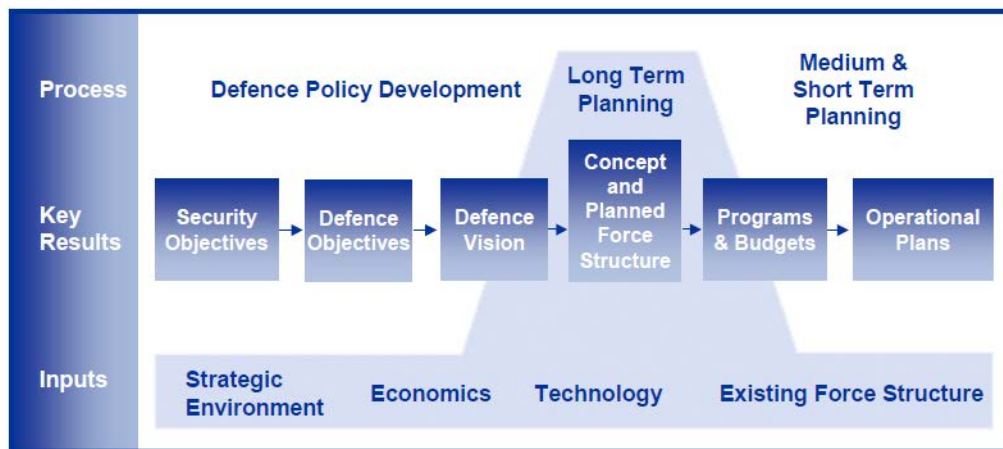


Figure 2-8 The Generic Defense Planning Cycle (RTO, 2003)

In this structure, security concerns are defined as defense goals when developing defense policies. The defense planning cycle accepts feeds input to and takes outputs from other processes. It translates the defense policies into operational concepts and required force structures and provides guidance to the medium to short term planning. As a result, the cycle links the defense policies and medium to short-term planning processes (RTO, 2003).

Since the joint force planning studies are important to NATO’s cohesiveness, the handbook is a collection of many NATO bodies’ and member nations’ best practices on long-term planning. For this reason, other nations’ defense planning systems were not included here because the NATO’s study includes all the best practices of member nations and forms a generic structure for defense planning.

The whole process begins with identifying goals of the nation to sustain and support its interests and values. Next, it identifies how defense will provide support for reaching these goals, and generate forces which have capabilities for achieving them. Through the process, new warfighting concepts influencing development of defense policies and ongoing programs affecting the formation of planned forces should also be considered.

One of the critical issues with defense system is to have a dynamic response mechanism to the new contingencies and threats that may arise over time. This can be

achieved through defense planning cycle by developing scenarios for the future operating environments (context), analyzing and assessing their impact on defense system and, developing appropriate operating schemas (concepts) as new contingencies and threats arise. At this point, it is important to understand the effects of emerging technologies on both the way defense system operates and the environment in which it operates.

In order to achieve a dynamic response mechanism against new threats, defense planning cycle should develop relevant and robust future operating concepts by; (Dortmans & Curtis, 2004)

- identifying enabling technologies for such concepts without focusing on a specific future capability;
- defining and adjusting the context in which such concepts can be evaluated and developed;
- defining the analytical framework for supporting assessment and clarification of such concepts.

2.4.1 Technology and Warfighting Concepts

The capability requirements for the long-term planning can be achieved by identifying current and emerging technologies and their applications in future operating schemas or warfighting concepts. There are reciprocal interactions between the technological concepts, ever-changing cultural contexts and warfighting concepts as indicated in Figure 2-9 (Dortmans & Curtis, 2004). Each of these develops from specific factors (such as political and strategic guidance, military expertise and operational experience for warfighting concept), and each relationship is formed via the interactions with the other elements (for example; technological concepts trigger and triggered by operational concepts through mechanisms such as operating environment, military applications, and operational needs).

Of course, the key for balancing these relationships is harmonizing the opposite associated effects of technological developments, ‘technology-push’ and ‘demand-pull’, is key to balancing the relationships as depicted in Figure 2-9 (Keller & Ledergerber, 1998).

In this structure, technology concepts are effects-based ones representing the aggregated various enabling technologies which are defined as:

- Mature - knowledge areas are well identified and the technology well understood and developed, and/or ready to use;
- Emerging - technology is still under development and/or needs further investigation, but most of the scientific research are complete;
- Speculative - recognized as a requirement or recommended as a potential future need but, requiring substantial R&D.

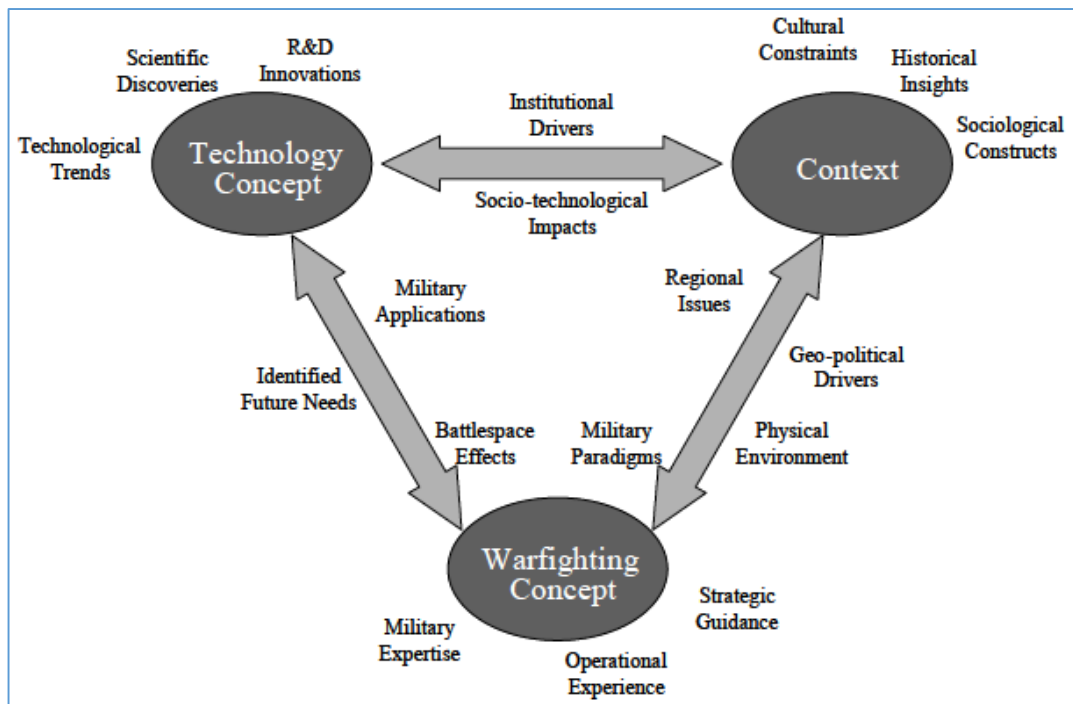


Figure 2-9 Technology & Warfighting Concepts, and Operating Contexts Relations (Dortmans & Curtis, 2004)

The key for identification of such technologies that drive technology concepts is to identify and classify technology shifts. Monitoring and identification of research findings and developments in the literature and experts' opinions provide hints on such trends. For the achievement of practical application of emerging technologies, their significance must be recognized. (Dortmans & Curtis, 2004). The next step is to identify the possible innovative combinations of the aggregated enabling technologies and develop technology concepts and their applications. Finally, the impacts, pay-offs, potential threats and opportunities of a particular technological concept is analyzed.

2.4.2 Forecasting Technology Trends and Technological Changes

Scientific research continually discovers new and unsuspected phenomena, and radical new theories have continuously been proposed by scientists (Kuhn, 1996). This mandates us to understand the impact of technological change as well as its effects on the environment involved. To focus on understanding technological change, the concepts of 'incremental' and 'disruptive' change are employed (Bower & Christensen, 1995). Technology forecasting is a way to better grasp the technological advances through monitoring their first occurrence and ensuing effects of both incremental and disruptive technologies. Since it is not possible exactly forecast everything, we could only detect and seize current trends in technology, presume their operation modes and applications, and assess their possibility of realization and effects, having an opportunity to respond accordingly (Dortmans & Curtis, 2004). The aim here is to get some insight on related technological growth as well as its application and impact, rather than focusing simply on technology forecast.

When developing inventive and perceptive future technological concepts, it is important to abstract the current paradigm and to define a new environment. One approach is to integrate current and emerging technologies into abstract systems in virtual environments and analyze their responses by applying several analytical tools.

2.4.3 Defense Technology Management Framework

Having considered the technology and warfighting concepts, technology integration into defense planning system, and TM activities grouped by generic TM activities, a possible Defense TM Framework would be the one showed in Figure 2-10.

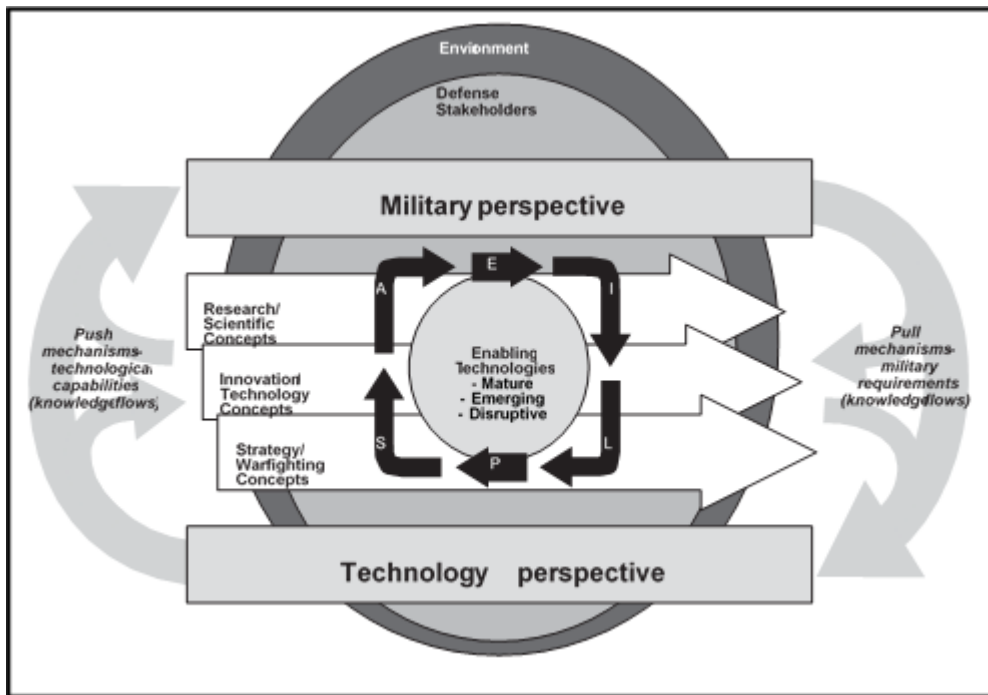


Figure 2-10 Defense TM Framework, adapted from (Phaal, et al., 2004)

2.4.4 Linking Technology with Military Applications

The starting point in developing future capabilities and their complementary technology concepts requires a systematic and structured approach for highlighting promising technologies. It is suggested to include identifying those technology concepts which are disruptive potential, and for each one (Bower & Christensen, 1995):

- (1) determine its effect and importance,
- (2) identify its application areas,
- (3) determine how to apply it,
- (4) restructure existing applications to integrate it.

The most challenging step in developing new warfighting concepts is to link them with technological concepts which propagate from scientific concepts. Figure 2-11 shows this transition with the relevant stakeholders of the process (Dortmans & Curtis, 2004).

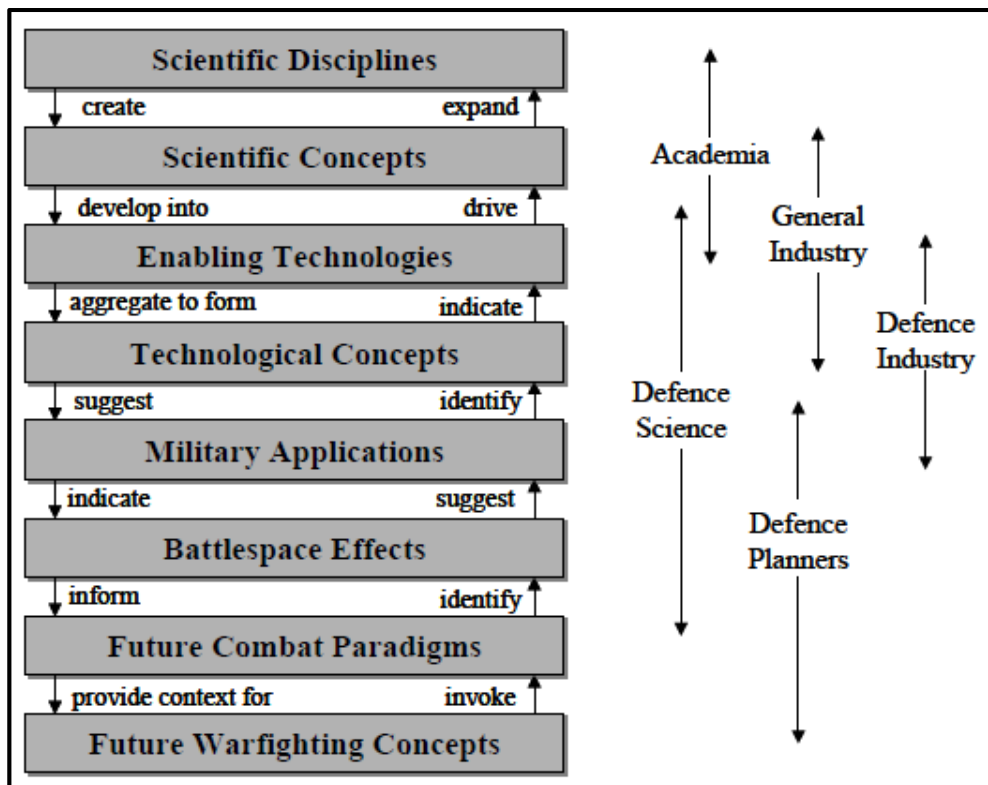


Figure 2-11 Scientific Discovery to Useable Military Technologies
(Dortmans & Curtis, 2004)

This structure has four interrelated elements: ‘Enabling Technologies’, ‘Technological Concepts’, ‘Military Applications’ and ‘Battlespace Effects’. These structure indicates the path for integrating individual technologies (enablers) into technological paradigms (technological concepts) by considering their effects on military paradigms (operational concepts) and effects in the operating environment.

The relationships between these components are reciprocal. For example, scientific concepts develop into enabling technologies from the perspective of technology-push, while enabling technologies can drive the development of innovative scientific concepts from the perspective of demand-pull (Dortmans & Curtis, 2004).

Figure 2-11 also shows the roles of scientists and defense planners in transforming technology innovation into military warfighting concepts. This structure splits the process into three:

- associating candidate scientific concepts, enabling technologies and technological concepts (led by scientists from academia);

- military applications and anticipated effects on battlespace (science- military cooperation); and
- deriving future military paradigms and operational concepts (leaded by armed forces).

2.4.5 Defense Technologies Requiring Special Concern

Considering the future warfighting paradigms might change, it is better to focus on those technologies that have potential for delivering considerable superiority to current capabilities of armed forces, known as ‘disruptive technologies’ (Gilbert & Bower, 2002). They are the technologies that radically change the current operating mode of a system. Such technologies introduces critical questions like how such technologies with their implications for complex military capabilities can be identified, accessed, employed, and supported by DoD to maintain its current state of technological superiority (Atta, et al., 2005).

Since their impact and future potential are high, such technologies require special attention in terms of monitoring and controlling them closely. For example, US DoD assesses and analyzes technologies worldwide on an ongoing basis to determine which are critical. The process determines specific values and parameters of the technologies and identifies items for addition or removal from pre-defined lists (Sellers & Wick, 2006).

The Militarily Critical Technologies List (MCTL) is a compilation of existing products and technologies that DoD considers would allow significant increases in the development, production and deployment of defense capabilities in military conflicts. It includes products and technologies that enable the development, production, and employment of weapons of mass destruction.

The Developing Science & Technologies List (DSTL) is a list of scientific and technological capabilities developing anywhere in the world and potentially will have significant military effects in future’s operating environments. It includes basic research and applied research and focuses on those technologies that have the potential for breakthrough. It uses a horizon well beyond the export control perspective of the MCTL. Application areas of MCTL and DSTL are presented in Table 2-5.

Table 2-5 MCTL and DSTL Applications

MCTL APPLICATIONS	DSTL APPLICATIONS
<p>Primary</p> <ul style="list-style-type: none"> • Formulation of export control proposals • Export license review <p>Other</p> <ul style="list-style-type: none"> • Anti-tamper determination • Software Protection Initiative • Program Protection Plans • Assessment of Worldwide Technology Capability • Counterintelligence training & operations • Counterproliferation • Foreign military assistance guidance • Freedom of Information cases • Speech and technical paper review • Technical Guide for Independent Review Teams • Committee on Foreign Investment in the U.S. (CFIUS) issues 	<p>Primary</p> <ul style="list-style-type: none"> • Monitor emerging technologies • Worldwide Technology Capability Assessments <p>Other</p> <ul style="list-style-type: none"> • Cooperative Research and Development • Independent Research and Development • Science and Technology Planning • Advanced Concepts and Technology Development • Small Business Innovative Research (SBIR) • Technical Guide for Independent Review Teams

2.4.6 Defense Capabilities Management

Capability management plays an important role in identifying the capability gaps and assessing the capability requirements to fill these gaps. Since we aim to develop technological solutions to these capability requirements, we need to link the capability management with the technology management as indicated in Figure 2-12 (Shanks, 2008).

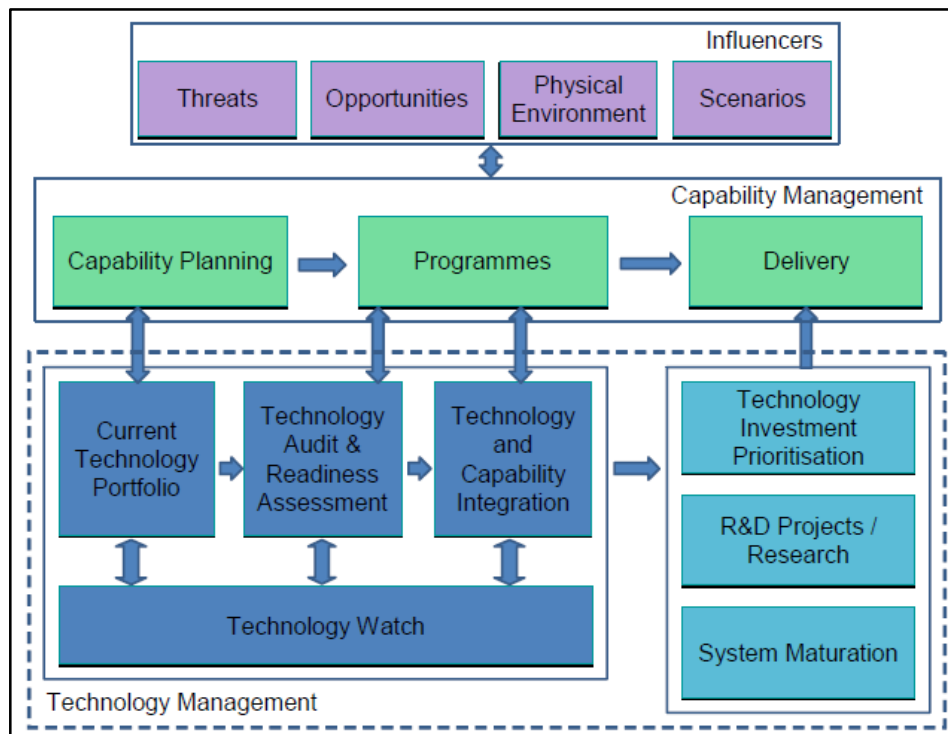


Figure 2-12 Linking TM to Capability Development (Shanks, 2008)

The interactions between technologies, capabilities and external influences are made explicit. The model can be used to identify all of the technologies available against the recognized capability gaps that needs to be filled through capability development.

2.4.7 Actors in Defense System

Related to the concept development process, we need to identify the main actors of defense community and their roles. These are, Ministry of Defense, armed forces (or military), industry and academia (universities and other research establishments). In Figure 2-11, as moved from enabling technologies to military applications, the actors focused on R&D (general industry and academia) change into those actors focused on use of such technologies (defense industry and defense planners). We can also observe a significant overlap of defense scientists and defense planners indicating that a close interaction must be set between these actors. The role of defense scientists is to connect military planners' studies with engineers in industry and academicians in the development of warfighting concepts at the very early phases. Defense industry's involvement will increase as warfighting concepts uncover the required future capabilities.

2.5 Enterprise Modeling

Organizational modeling attempts to capture the designed behavior and framework of an enterprise to measure how this structure promotes and/or inhibits the enterprise's mission. Modern industrial enterprises are generally structured in a complex manner. Enterprise modeling may be used to understand current organization, identify unneeded bureaucracy and paperwork, make optimizing changes in enterprise structure, and indicate how to accommodate expansion (Ostic & Collins, 1996).

Enterprise models are used by industry to represent different enterprise models, with no standard definition. Since the enterprise organizations are complex, many enterprise modeling approaches have been proposed by industry and academia (Petrie Jr., 1992).

Enterprise modeling is an abstract representation of a particular organization, in terms of definition and description of the structures, processes, information and resources (Leondes & Jackson, 1992). It attempts to understand the processes of an organization

and to improve its competence by constructing enterprise models. It consists of modeling relevant business context, processes involved in this context, and information technology.

2.5.1 Function Modeling

In systems engineering, function modeling is a formal representation of the functions, processes or activities of the modeled system or focused area (FIPS, 1993).

A function model, sometimes called a process model or activity model, is a graphic depiction of a business function defined in a context. The aim of using a function model is to explain the processes and functions, assisting in discovering of information requirements, help identifying opportunities, and establishing a base to determine service and product costs (DoD, 1995). A function model is produced from a perspective of functional modeling. Several perspectives available in process modeling. Other possible perspectives are organizational, behavioral, or informational.

A perspective of functional modeling focuses on describing a dynamic process. The main idea in this modeling perspective is the process, which could be an activity, a function, action, task etc.

2.5.2 Function Models

2.5.2.1 IDEF0 Function Modeling

Integration Definition for Function Modeling (IDEF0) is based on the SADT (Structured Analysis and Design Technique), (Ross & Schoman, 1977) a software analysis and design methodology. It includes both a graphical notation definition, and a detailed methodology for developing functional model (FIPS, 1993).

An IDEF0 model depicts what a system does i.e. its function, controls, inputs and outputs, and other functions and services it needs to accomplish its function. IDEF0 comprises a series of hierarchical diagrams, text, and a cross-referenced glossary. The two main modeling components are functions (represented by boxes), and the objects and data that interrelating the functions with arrows.

As shown by Figure 2-13, arrows entering the box from the left are inputs. Inputs are transformed or used up by the function for producing outputs. Arrows entering on top of the box are controls. Arrows entering on top of the box are controls. Arrows connected to the bottom side of the box characterize mechanisms. Upward pointing arrows are some of the resources that support the execution of a function. Other resources may be received from the parent box. Mechanism arrows pointing downward are call arrows. Call arrows enable detail sharing between model components (by linking them together) or between parts of the same model. The called box sends detail for the calling box. Controls define the conditions required by the function to produce desired outputs. Arrows exiting a box on the right are outputs. Outputs are the objects or data produced by a specific function.

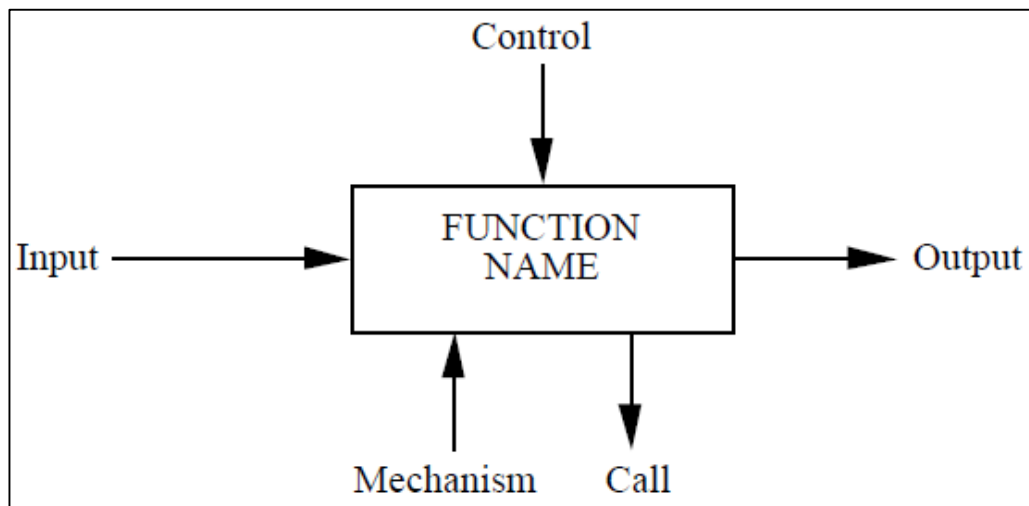


Figure 2-13 Integration Definition for Function Modeling (IDEF0) (FIPS, 1993)

The IDEF process begins by identifying the main function to get decomposed. This function is presented on a “Top Level Context Diagram” which describes the scope of a particular IDEF study. An example of a Top Level Context Diagram for an IS management process is presented in Figure 2-14.

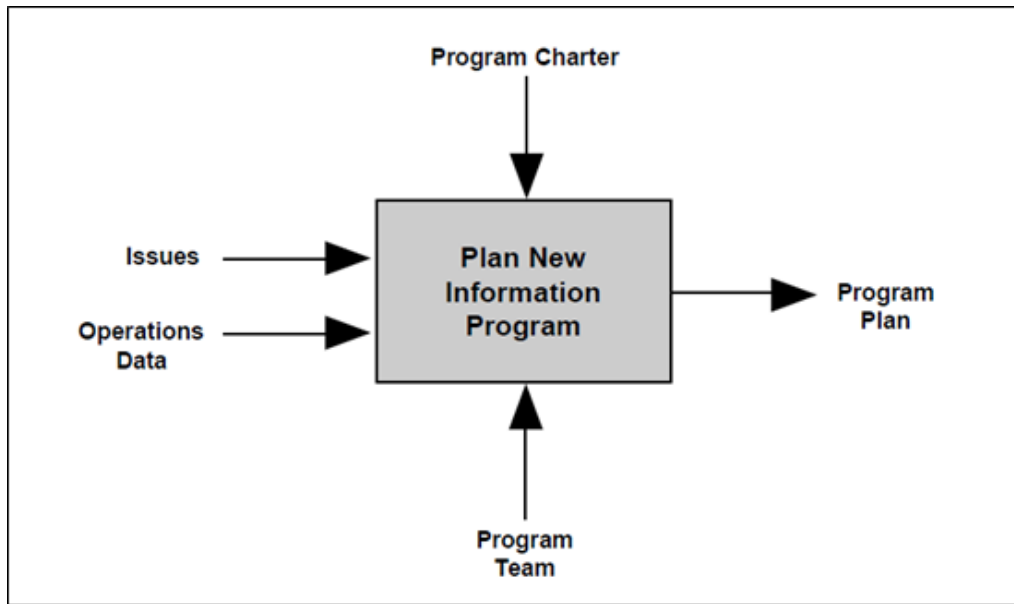


Figure 2-14 Top Level Context Diagram

Lower level diagrams are generated from this diagram. An example of a generated diagram, called a “child”, for a life cycle function is presented in Figure 2-15.

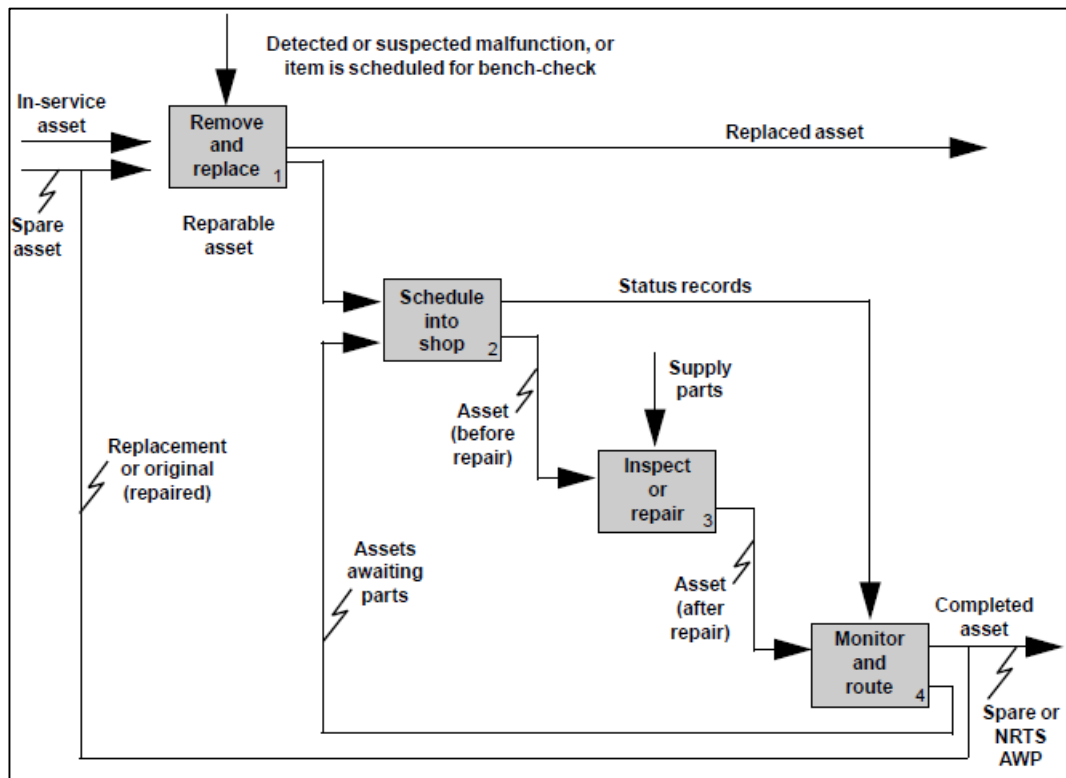


Figure 2-15 IDEF0 Diagram Example

2.5.2.2 IGOE Function Modeling

A simple form of an IDEF0 model provides the basis of the IGOE (Input, Guide, Output, and Enabler) model. These are the basic requirements for any organizational process or function. It is similar to IDEF representation, the main difference being that Mechanism is replaced by the more understandable term, Enabler as presented in Figure 2-16 (Hunt, 2013).

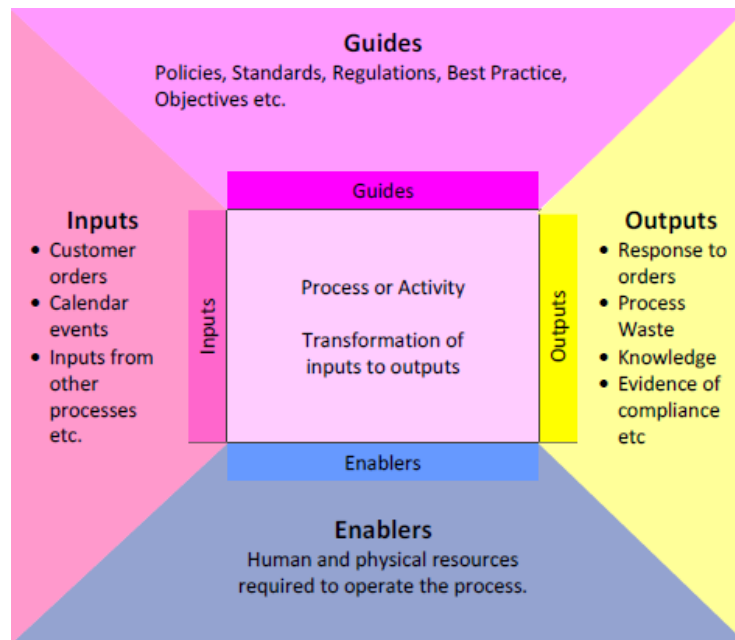


Figure 2-16 IGOE Model

CHAPTER 3

APPLICABILITY OF TECHNOLOGY MANAGEMENT TO DEFENSE DOMAIN

Although there are a few specific studies on applicability of TM activities and tools to defense systems, it can be said that a subset or superset of TM activities and related TM tools used in commercial business technology management can also be applied to the management of defense systems technologies. Apart from the commercial business technology management case, we are interested in addressing the issue of technology management within the defense domain. In other words, TM activities and tools used in defense domain should not completely be different from those used in commercial business.

3.1 Insertion of Technology into Defense System

The Turkish defense planning system is similar to the generic defense planning cycle discussed in literature review. The starting point in developing future capabilities and their complementary technology concepts is to determine how armed forces currently operates and to identify the current capability gaps considering the previous experiences and lessons learned from these experiences.

To some extent or most of the time, this capability gaps can be filled by small alterations on doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF). But when these are insufficient or inefficient, incorporating incremental technology advances into existing capabilities and defense systems be necessary. This is known as modernization or upgradation. These two solutions might be feasible and practical as long as the current warfighting paradigms are valid. But unfortunately, they change over time and filling the capability gaps with DOTMLPF and incremental technology advances become impossible.

The technological changes influence the defense planning cycle in three ways. First, the technological developments provide new opportunities for defense capabilities. Second, new technologies generate potential threats against both present and future

capabilities. Technological effects in newly developed warfighting concepts can fundamentally shift the force effectiveness balance in future potential conflicts as well as in future planned capabilities. This balance shift may occur gradually or dramatically, resulting in significant cost-effectiveness opportunities or introducing new risks like nullification of existing defense structures. Finally, new defense systems having new technologies arise new interoperability requirements in terms of both jointness within national defense forces, in an allied force, and/or in a coalition.

Understanding its importance, an indispensable part of defense planning cycle is the assessment of technological developments through forecasts on both trends and incremental changes in technologies. Such assessments contribute a lot to the cost-effectiveness of various defense capabilities.

3.2 The Technologies of Special Interest to the MoD

As explained in the literature review, some technologies require special attention in terms of monitoring and controlling them closely since their impact and future potential are high. Similar to those developed for US DoD, Turkish MoD also develops and maintain lists of technologies which need special national concern in terms of their import and national use (MoD, 2009).

Critical Systems / Technologies (CST) are systems or technologies that are not possible to import from abroad or importing them might endanger the military operations during conflicts because sustainment cannot be maintained due to various reasons. Such systems or technologies required to be at least jointly produced via licensing in and collaborative R&D when manufacturing inland is not possible due to export license and control regime (for example; software, long range missile and navigation missile technologies etc.).

Systems / Technologies to be Compulsorily National (STCN) are systems or technologies that even they could be imported and manufactured nationally, their use might violate the national security in military operations. For this reason, they must be developed and manufactured nationally.

3.3 Defense Technology Management Activities

Having considered the literature on TM Activities and TM Tools and careful examination of related regulations about Turkish Defense Planning System, a list of defense TM activities can be suggested as;

- (1) Technology Intelligence
- (2) Technology Auditing
- (3) Technology Forecasting and Technology Impact Assessment on Future Operating Environments
- (4) Technology Strategy Analysis and Development, Technology Planning and Strategic Decision Making on Technologies
- (5) Technology Related Strategy/ Concept Development & Experimentation
- (6) Technology Ownership and Competence Level Measurement
- (7) Gap and Value Analysis
- (8) R&D Management
- (9) Technology Transfer for Defense Projects
- (10) Knowledge Management (Development of Standards, Common terminology and Providing Secrecy Security for IPRs)
- (11) Documentation and Dissemination of the Technology-related Work Findings
- (12) Maintenance of the Technology Resource Base Inventory
- (13) Refinement and Maintenance of CST & STCN Lists

The TM related activities of defense stakeholders and their definitions are given in the following paragraphs. Here, the case of Turkey is being considered. The TM activities of defense stakeholders might not be an exact match with their current TM activities, but they should be.

Technology Intelligence

Technology intelligence aims at capturing and delivering technological information to enhance awareness of technologies in defense domain. It is a systematic way to support TM functions that need technology forecasting and assessment activity. It also removes the effects of noises on relevant information that refrains decision makers from reaching them. But decision makers should provide direction and define specific

intelligence needs. The effort should also be staffed with persons who have the intelligence experience and skills. All sorts of information on capturing and delivering capacities which are relevant to identify future opportunities for and threats to defense industry firms. Probable sources of information for technology intelligence are;

- Open source databases, web-searching, scientific and technological forums,
- Scientific and technological studies of academia (universities and research establishments)
- Scientific and technological study reports of international civil or military organizations and other countries,
- Technology related activities such as fairs, exhibitions and demonstrator programs.
- Reports on scientific and technological issues from intelligence agencies.

Collected data through the technology intelligence activity should be classified, verified, validated and secured in well-structured databases and be made available when needed.

The outputs of this activity are used in examining readiness of proposed systems, analyzing technological needs in pre-feasibility and feasibility studies including R&D as well as providing input to roadmap developments.

Technology Auditing

The aims of technology auditing are identifying and evaluating technical resources and capabilities at hand as well as assessing and ranking them. The activity starts with scanning for technologies for a specific system and its subsystems. The activity also considers aggregating that different technologies to build subsystems and systems. Having classified and listed the focused technologies, the activity continues with identifying their maturity levels along with their status, namely emerging, growing, mature or declining. When scanning for the required technologies, the owners who have technological capabilities and their competence level on that technologies are also identified.

Technology auditing activity outputs are provide valuable inputs to technology forecasting and assessment activity. The outputs of this activity are used mainly for identification of system readiness levels in pre-feasibility and feasibility studies, preparation of system requirements for projects including R&D and determination of competence level and competitive positions of defense industry firms. It also supports the Technology Strategy Analysis, Development, Planning and Strategic Decision Making activity by providing input on current and future technologies.

Technology Forecasting and Technology Impact Assessment on Future Operating Environments

This activity aims to predict the future impacts of technology by conducting audits and collecting internal and external data about technologies, capabilities markets. The activity needs to perform an assessment for the future impacts of technologies. This assessment covers the systematic identification, analysis and evaluation of the potential consequences of technologies in terms of its impacts on political and future operating environments as well as on social and cultural issues. The activity also needs the future visions of defense stakeholders to better analyze their expectations. Disruptive technologies which have a potential of delivering orders of magnitude enhancement to armed forces' current capabilities should also be covered with a special consideration in this activity.

Its outputs are used; to feed system definition and requirements analysis studies of defense planners including R&D; to take a snapshot of defense industry firms in terms of identifying their gaps for the future technologies; to propose advices to improve their technological capabilities on these technologies; and to prepare roadmaps for the development of future technologies. Its outputs on future technologies and trends are also valuable for Technology Strategy Analysis, Development, Planning and Strategic Decision Making activity.

Technology Strategy Analysis and Development, Technology Planning and Strategic Decision Making on Technologies

In defense technology management, several types of decisions are made at different phases of the defense planning cycle. Some types of strategic decisions made at higher

levels require strategic analysis which aims to develop potential decision alternatives. In developing decision alternatives, strategic analysis considers:

- National goals, expectations and priorities,
- Present and future operating environments.
- Technological competencies, capabilities and assets of defense industry firms as well as their strengths and weaknesses.

Technology planning is a useful approach to strategy analysis and development to realize the decisions made at higher levels. For example at higher levels, selecting a system among different alternatives affects system development approaches in terms of included technologies in it. It becomes necessary to develop strategies to acquire the required system and to plan the pathways to include cutting-edge technologies. This is why technology planning and strategy development are integrated to support strategic decision making on technologies.

One important aspect of technology strategy development and planning is to answer the question of “How current and future technologies are best utilized and deployed in required system?” Another important aspect of technology strategy development and planning is to decide on make, buy or collaborate business models for acquiring the required system. Contractor or subcontractor selection is also a strategic decision especially for acquiring large and complex systems.

One important outcome of this activity is identified future strategic R&D needs which R&D management activity take this as input. Another important output is identified disruptive technologies which motivates the technology related concept development and experimentation activity. This activity also affects most of the defense TM activities and functions which are dependent on decisions made through it. R&D management.

Technology Related Strategy/ Concept Development & Experimentation

As discussed in the previous sections, the critical issue in defense planning is to have a dynamic response mechanism to the new contingencies and threats that may arise over time. In order to achieve a dynamic response mechanism against new threats,

defense planning cycle should develop relevant and robust future operating concepts. When developing such concepts, it is important to understand the effects of emerging technologies on both the way defense system operates and the environment in which it operates.

Technology Related Strategy/ Concept Development and experimentation activity needs to perform the following steps:

- Identification of the enabling technologies, i.e. mature, emerging, speculative technologies in terms of technological concepts,
- Definition of future operating environments for developing technological concepts and analyzing their effects,
- Creation of the technical infrastructure for supporting development and analysis studies,
- Derivation of future warfighting concepts through experimentations in virtually created future operating environments and developed scenarios,
- Analyzing the experimentation results and finalizing the concept development,
- Suggestion of developed concepts to the decision makers.
- Improvement of the developed concepts by creating a feedback mechanism.

This activity uses technology related activities' outputs such as technology intelligence, auditing, strategy development, planning and decision making, forecasting and impact assessment. The outputs of this activity are used by defense TM functions such as, analysis of technological developments' effects, technological assessment of operational needs and for identification of future strategic R&D needs.

Technology Ownership and Competence Level Measurement

This activity is important in terms of identifying the defense industry firms' competitive positions as well as their competence levels and skills or capabilities on technologies. Technology ownership can be defined as a firm's level of competence and its capabilities to innovate using its ready and mature technologies. It requires the firm to have necessary assets such as IPRs, patents and licenses for that technologies. The competitive position of a firm indicates its strengths and weaknesses within the

industry. The competitive position of a firm is its innovation capability determined with respect to its technologies' status; emerging, growing, maturing or declining.

The outputs of this activity are mainly used to match the defense system needs with the defense industry firms' capabilities. They are also useful to identify the technology gaps of defense industry firms and to develop an action plan for improving their capabilities.

Gap and Value Analysis & Benchmarking

The objective of this activity is to assess the technology gaps and opportunities in light of technology strategies before making any strategic decisions. Gap analysis might be performed by identifying the competitive position of a firm with respect to technologies it has. Another way of doing gap analysis is to evaluate firm's competitive position with respect to the impact of its technologies on competitiveness. Another type of gap analysis is to measure the strengths and weaknesses of firm with respect to its technological competency. Value analysis, on the other hand is an activity that focuses on improvement of the value of business functions required to achieve the organizational goals. Strategic analysis is dependent on gap and value analysis since it identifies the strengths and weaknesses of a firm.

This activity provides valuable inputs to Technology Strategy Analysis, Development, Planning and Strategic Decision Making activity. Its outputs are also used to identify the technological gaps of defense industry firms, to improve their technological capabilities and to develop sector technology based roadmaps to fill the gaps.

R&D Management

Research and Development has two goals: research to generate new ideas and development of ideas into products. The ultimate aim of R&D management activity is to specify and realize a spectrum of R&D projects that will help achieving the strategic goals. The broad goals for technologies are decided at higher levels where technology strategy is developed. Once a system selection is made and system technology needs are specified, their readiness levels and feasibilities are determined and gaps are identified. After the analysis of these gaps and the prioritized R&D projects are selected on the basis of filling these gaps. There are three generic types of research

projects: incremental, platform and radical or disruptive. Another type is basic research that aims at generating new knowledge rather than a product. Most of R&D projects of this type are originated from the strategic needs. Applied research projects aims at developing new materials, parts or concepts to demonstrate the results of basic research. R&D projects, on the other hand, focuses on development of new products or improvement of the existing ones considering the findings of the basic and applied research.

This activity's focus is on managing the R&D projects with the resources assigned to R&D in terms of budget, manpower and time. The outputs of this activity are a selected portfolio of R&D projects, priorities of them and the resource assignments to the selected projects. These outputs are input to the TM functions which needs them.

Technology Transfer for Defense Projects

This activity aims at importing the external technologies, knowledge and know-how into the system projects which have gaps for the realization. The source is a national or international owner which might be a R&D institution, university or a commercial firm. The criteria on deciding a technology transfer to a project should consider the time to fill the gaps, costs incurred, criticality of that technology and risks associated with the project. Technology strategy also provide important clues to technology transfer decisions. When determining a technology transfer the following steps are followed:

- Technology gap analysis and identification of needs,
- Identification of technology alternatives,
- Evaluation and selection among technology alternatives,
- Determination of transfer method, modes, actors and timing,
- Contracting and realization of technology transfer.

The major methods of technology transfer are; direct acquisition, turnkey plants, Original equipment manufacturers (OEM), licensing (in or out) and collaborative R&D. Technology transfer modes in terms of receivers and developers are; over-the-wall mode, receivers-as-consultants mode, team mode and apprenticeship mode. The relationship between methods and modes are presented in Table 3-1.

Table 3-1 Methods and Modes of Technology Transfer

METHODS / MODES	Acquisition	Turnkey Plants	OEMs	Licensing	Collaborative R&D
Over-the-wall	X	X		X	
Receivers as Consultants				X	X
Team					X
Apprenticeship			X		

This activity’s outputs are mainly used by defense TM functions which have project definition, management and realization concern. The outputs of technology strategy development, planning and decision making, forecasting and assessment, gap and value analysis and R&D management activities’ affects technology transfer activity. The outputs of this activity feeds knowledge management, R&D management and technology resource base inventory maintenance activities.

Knowledge Management (Development of standards, common terminology and Providing Secrecy Security for IPRs)

Although KM is considered as a supporting activity in the literature mainly focused on commercial business, it should be considered as a main activity in defense domain which is a large and complex one in terms of both stakeholders, systems and processes involved. KM includes learning, knowledge sharing, incorporating know-how and knowledge security. KM improve creativity and learning culture among defense domain actors.

For the operation of large and complex systems jointly and synchronously, technical, procedural, managerial and administrative standards are required. For the orchestration and better communication of defense stakeholders’, a common terminology definitions are also needed. The knowledge produced by defense industry firms should also be managed in terms of providing secrecy and security for their intellectual property rights such as patents, licenses, trademarks both legally and physically.

The outputs of this activity is shared through a media which is generally in electronic form. All defense TM activities and TM functions use this activity’s outputs.

Documentation and Dissemination of the Technology-related Work Findings.

This activity involves documenting and sharing the findings of technology related work gathered as a result of several defense TM functions. This activity takes these results as an input and generates various reports to be used by the defense stakeholders. The outputs of this activity are also sent to the Technology Resource Base to be referenced in future studies.

Maintenance of the Technology Resource Base Inventory

As indicated before, knowledge management (KM) is a complementary tool to support TM activities. In this respect, a resource inventory of technological assets contribute a lot to provide required knowledge to other activities. Technology resource base contains;

- Technical data on base/ enabling, critical/ key, pacing and emerging technologies,
- Several types of technology taxonomies,
- Technology readiness level and maturity assessment study results,
- Technology forecasting and impact assessment study results,
- Technology related concept development and experimentation study results, such as scenarios, simulation outputs, technology benchmarking results, etc.,
- Systems / Technologies to be Compulsorily National (STCN) and Critical Systems / Technologies (CST) lists and their definitions,
- Technological performance data on defense industry firms' capabilities, portfolios, human resources facilities, technical equipment and their assets data including patents, licenses, IPRs, etc.

Since all the defense TM functions interacts with it, ubiquity of technology resource base inventory must be maintained. The data should be made available as needed to all of the defense stakeholders according to the pre-defined access policies. Its security and secrecy must be ensured at all levels as well.

Refinement and Maintenance of CST & STCN Lists

CSTs are a compilation of existing products and technologies that MoD considers their use could allow substantial increases for developing, manufacturing and deploying defense capabilities in military conflicts. But their import, manufacturing and use are subject to international export license and control regimes. They include technologies and products enabling the development, production, and deployment of large scale complex defense systems.

STCNs are a list of systems or technologies that even they could be imported and manufactured nationally, their use might violate the national security in military operations. For this reason, they must be developed and manufactured with national efforts. They have the potential to have significant military impact in the future. Basic and applied research is required to conduct in order to develop them.

Under the control of MoD Technology panels, technical working groups, experts from government, industry and academia, assess and analyze technologies on an ongoing basis to determine which of them are critical. The process determines specific values and parameters of the technologies and identifies items for addition or removal from the CST lists. In a similar way, STCN lists are developed with a focus on security and impact of their use in military operations during conflicts.

3.4 Defense Technology Management Activities and Related Methods & Techniques

By going one more step, we can identify the defense TM activities and related TM techniques, methods and tools in the defense domain as given in Table 3-2.

Table 3-2 Defense TM Activities and Related Methods, Techniques and Tools

Defense TM Activities	Related TM Methods, Techniques and Tools
Technology Intelligence	Information Gathering and Analysis Methods (Open Source Searching, Web Searching, Technology watch, Patent and Licence Analysis)
Technology Auditing	Maturity and Competence Assessment Methods (TRLs, Taxonomies, Patent and License Analysis, S-curve Analysis, Product/ Technology, and Technology Position/ Technology Maturity Matrices)
Technology Forecasting and Technology Impact Assessment on Future Operating Environments	Forecasting Techniques (Expert opinion, Delphi method, Technology-product-market survey, Simulation, Technology Life-cycle Analysis, Mathematical Models such as; exponential smoothing, moving averages, linear-regression causal model, and trend extrapolation)
Technology Strategy Analysis and Development, Technology Planning and Strategic Decision Making on Technologies	Strategic Thinking and Needs Assessment Methods (SWOT Analysis, Brainstorming, Knowledge Maps, Decision Trees, Impact Analysis, Stakeholder Interviews, Need Analysis, Statistical decision making , Roadmapping)
Technology Related Strategy/ Concept Development & Experimentation	Strategic Thinking and Analysis Techniques (Impact Analysis, SWOT Analysis, Brainstorming, Knowledge Maps, Mission/ Strategy Mapping, Scenario and Options Generation, Benchmarking)
Technology Ownership and Competence Level Measurement	Technological Capability Measurement Methods (Technology/ Product/ Market Matrix, Technology efficiency analysis, Check lists)
Gap and Value Analysis & Benchmarking	Evaluation and Value Engineering Techniques (SWOT Analysis, Competitive Position / Technology Matrix, Roadmapping, Value Curves, QFD)
R&D Management	Project Selection and Management Techniques (Project Selection and Prioritization Tools, Cost-Effectiveness Analysis, Value-success probability matrix, CPM/PERT, Teamwork Building, Root-Cause Analysis, Optimization, Roadmapping)
Technology Transfer for Defense Projects	Technology Evaluation and Selection Techniques (TRLs, IPR Analysis, Technology Selection and Prioritization, Reverse Engineering, Check lists, Input-Process-Output Modeling & Evaluation, Cost-Benefit Analysis, Value-Chain Analysis)
Knowledge Management (Development of Standards, Common terminology and Providing Secrecy Security for IPRs)	Continuous Improvement & Creativity Expansion Methods (Group Brainstorming, Balanced Scorecards, IP and License Analysis, Mind Mapping, Learning Curves)
Documentation and Dissemination of the Technology-related Work Findings	Data Collection and Sharing Techniques (Portals and Web Design, Automated Document Production and Sharing Tools)
Maintenance of the Technology Resource Base Inventory	Monitoring and Evaluation Methods (Technology Watch, Technology Taxonomy, Information Search and Retrieval Tools, Portfolio Analysis, Technology life-cycle analysis)
Refinement and Maintenance of CST & STCN Lists	Review and Evaluation Methods (Expert Opinion, Delphi Surveys, Analogy, Relevance Trees)

3.5 Tools Supporting Defense Technology Management Activities

Defense systems are complex in nature and contain many integrated systems which constitute “systems of systems”. When designing a system for the management of technologies related to such systems, a robust KM system is required for supporting both TM activities and TM tools of defense planning cycle.

Project management also provides an important support to TM since we can consider each types of TM activities being a project, which requires skills and knowledge to manage them.

Innovation management is also involved in defense domain with various innovations through incremental changes in defense systems and dual-uses of their technologies in commercial business.

3.6 Technology Management Activities of Turkish Defense Planning System's Actors

As stated before, managing defense technologies is not different from managing technologies in commercial business. To expand this argument, it is better to look at the technology related activities of Turkish Defense Planning System's actors.

After each list of TM activities of TDPS actors, their relation with six generic TM activities (Cetindamar, et al., 2010) are presented in matrix format at the end to see their fit into the defense domain.

3.6.1 Ministry of Defense (MoD)

The TM activities listed here were extracted from the related regulations, politic and strategic documents of Undersecretaries MoD and undersecretaries MoD for Defense Industries. These are listed as: (Table 3-3)

- Technology Intelligence (universities, trade shows, international relations, online databases, patent searches etc.)
- Technology Auditing (identifying and evaluating technological sources and capabilities as well as assessing and ranking technologies, their maturities and readiness levels)
- Technology Forecasting and Technology Impact Assessment on Future Operating Environments (future trends, future potential use of technologies and products, roadmapping technologies and products over time, impact analysis and comparisons of technology alternatives)
- Technology Ownership and Competence Level Measurement (benchmarking, evaluation and determination of capabilities)

- Gap and Value Analysis & Benchmarking (competitiveness of defense sector with respect to defense technologies, strengths and weaknesses of defense firms in terms of technological and organizational competencies)
- R&D Management (generation and selection of basic and applied research and, technology demonstration projects, portfolio management, managing, controlling and coordinating collaborations)
- Technology Transfer for Defense Projects (from creator, from either national or international universities or research organizations along with know-how and skills)
- Knowledge Management (Development of Standards, Common terminology and Providing Secrecy Security for IPRs, establishing a technology knowledge base, facilitating knowledge sharing between actors through networks, facility security, IPR management in open innovation and technology development projects)
- Documentation and Dissemination of the Technology-related Work Findings
- Maintenance of the Technology Resource Base Inventory
- Refinement and Maintenance of CST & STCN Lists

Table 3-3 MoD TM Activities vs Generic TM Activities

Defense TM Activities vs Generic TM Activities	Identification	Selection	Acquisition	Exploitation	Protection	Learning
Technology Intelligence	X					
Technology Auditing	X					X
Technology Forecasting and Technology Impact Assessment on Future Operating Environments	X		X			
Technology Ownership and Competence Level Measurement	X	X	X			
Gap and Value Analysis & Benchmarking	X	X	X			
R&D Management	X		X	X	X	X
Technology Transfer for Defense Projects	X		X			
Knowledge Management (Development of Standards, Common terminology and Providing Secrecy Security for IPRs)					X	X
Documentation and Dissemination of the Technology-related Work Findings						X
Maintenance of the Technology Resource Base Inventory	X					X
Refinement and Maintenance of CST & STCN Lists	X	X				

To review, most of the MoD defense TM activities are related to generic identification activity. This is normal since MoD is expected to identify the defense related technologies for better managing defense acquisition programs that requires cutting edge technologies. As the most referenced one, identification activity also contributes

to the other generic activities. R&D management is the most important activity in MoD in terms of both workload and its complexity since it is related to four generic TM activities namely identification, selection, exploitation and learning.

3.6.2 Armed Forces (Military)

The TM activities of armed forces are not exactly listed in a unique document. Instead, they can be extracted from different laws, regulations and other strategic and operational guidance documents (Table 3-4).

- Technology Intelligence (trade shows, international relations, online databases)
- Technology Auditing (identifying and evaluating technological sources)
- Technology Forecasting and Technology Impact Assessment on Future Operating Environments (future trends, future potential use of technologies and products, roadmapping technologies and products over time, impact analysis and comparisons of technology alternatives)
- Technology Strategy Analysis and Development, Technology Planning and Strategic Decision Making on Technologies
- Technology Related Strategy/ Concept Development & Experimentation
- R&D Management (generation and selection of basic and applied research and, technology demonstration projects)

Table 3-4 Armed Forces TM Activities vs Generic TM Activities

Defense TM Activities vs Generic TM Activities	Identification	Selection	Acquisition	Exploitation	Protection	Learning
Technology Intelligence	X					
Technology Auditing	X					X
Technology Forecasting and Technology Impact Assessment on Future Operating Environments	X		X			
Technology Strategy Analysis and Development, Technology Planning and Strategic Decision Making on Technologies		X	X			
Technology Related Strategy/ Concept Development & Experimentation	X	X				
R&D Management	X		X	X	X	X

TM related activities of Armed Forces are mainly at Strategic and operational levels where capability requirements are identified at this levels. Similar to MoD, generic identification activity related TM activities are the main focus of armed forces since it gives the vision for identifying future capabilities and developing technological

concepts and their complementary future warfighting concepts. The most complex and intensive activities are “Technology related strategy and concept development and experimentation” and “Strategic technology analysis and decision making for defense research”. These activities provide a guidance to the MoD level TM activities in terms of armed forces’ capability requirements.

3.6.3 Defense Industry

TM activities of defense industry are not different from those of general industry with the exception that the main motivation source is MoD and the armed forces since they’re the only clients (monopsony) of defense industry. But of course they are subjected to the same market conditions as general industry when they trade their products and services to foreign customers or develop products by using dual-use defense technologies (Table 3-5).

- Technology intelligence, awareness of new technologies, threats and opportunities (universities, trade shows, external technology suppliers, online databases, patent searches etc.)
- Technology auditing (identifying and evaluating technological sources and capabilities as well as assessing and ranking technologies, their maturities and readiness levels)
- Forecasting technology, market and external environment (future trends, future potential use of technologies and products, roadmapping technologies and products over time, impact analysis and comparisons of technology alternatives)
- Management of technology resource base inventory (facilities and equipment, personnel skills, management and organizational skills and, strengths and weaknesses of internal technology management infrastructure)
- Information documentation and dissemination within firm
- Technology strategy development and technology planning
- Technology ownership and competence level measurement (benchmarking, evaluation and determination of capabilities)
- Gap and value analysis (competitiveness in defense technologies, strengths and weaknesses in terms of technological and organizational competencies and, core competency requirements)

- Strategic decision making for opportunities (considering core competencies and selecting from buy-make-collaborate options)
- R&D management at firm base (portfolio management, generation and selection of new product, process and service development and marketing projects, collaborating with other companies, universities, research laboratories on R&D projects)
- Commercialization and marketing owned technology products and services (market research, preparation, targeting, positioning and execution)
- Technology integration to systems and sub-systems and improvement
- Internal evaluation and utilization of technologies for dual-use and diversification
- Knowledge management and continuous improvement (reflection of experience, conceptualization, experimentation and experience)
- Intellectual assets management (IP portfolio management, IPRs-trademarks, patent management and staff retention and, IP management in open innovation/ technology collaborations)

Table 3-5 Defense Industry TM Activities vs Generic TM Activities

ACTIVITIES	Acquisition	Exploitation	Identification	Learning	Protection	Selection
Technology intelligence	X		X			
Technology auditing	X		X			
Forecasting technology, market and external environment	X		X			
Management of technology resource base inventory			X			
Information documentation and dissemination within firm			X	X		
Technology strategy development and technology planning						X
Technology ownership and competence level measurement			X		X	
Gap and value analysis						X
Strategic decision making for opportunities	X					X
R&D management at firm base		X	X	X	X	
Commercialization and marketing technology products and services		X				
Technology integration to systems and sub-systems and improvement		X				
Internal evaluation and utilization of technology (dual-use & diversification)		X				
Knowledge management and continuous improvement				X		
Intellectual assets management					X	

Similar to MoD and armed forces, TM activities of defense industry significantly focused on generic identification activity. Another important group of activities are under the generic exploitation activity where industry makes profit by exploiting its technologies in different fields.

3.6.4 Academia (Universities and Research Establishments)

Academia’s activities are somewhat different from others that they mainly conduct basic and applied research (Table 3-6).

- Technology intelligence (awareness of new scientific achievements and technologies)
- Scientific and technological assessment (forecasting and foresighting present and long term impacts of revolutionary scientific inventions and technologies)
- Knowledge management and sharing with other stakeholders
- R&D management for basic and applied research projects
- Participating and collaborating in technology related studies with MoD and defense industry.
- Intellectual assets management (patent management and IP management in open innovation/ technology collaborations)

Table 3-6 Academia’s TM Activities vs Generic TM Activities

ACTIVITIES	Acquisition	Exploitation	Identification	Learning	Protection	Selection
Technology intelligence			X			
Scientific and technological assessment	X		X			
Knowledge management and sharing with other stakeholders				X		
R&D management for basic and applied research projects			X	X		X
Participating and collaborating in technology related studies		X		X		
Intellectual assets management					X	

In academia, TM activities are mainly focused on generic identification and learning activities. The most important activity is R&D management for basic and applied research projects which it spans generic identification, learning and selection activities that is parallel to scientific research path.

3.6.5 Comments

Notice that, some activities are listed under all of the actors, but they have different meaning for each actor. For example R&D management activity's focus is in terms of needs and monitoring for armed forces. But its focus is at sector base for MoD and firm base for defense industry respectively. For the academia, R&D management activity's focus is on basic and applied research. The same situation might be observed for generic activities. For example; generic activity "selection" is related to for all MoD, armed forces and defense industry's "technology strategy development and technology planning" activity. For armed forces, selection might be for future joint operations compatibility, for MoD, selection might be for conforming standards and for defense industry selection might be a decision on technology meeting both compatibility issue of armed forces and standards of MoD. Apart from the commercial case, MoD and armed forces' activities related to exploitation and protection are limited since they are customers of defense systems.

3.7 Conclusion

In this chapter, applicability of technology management to defense domain was investigated with a focus on Turkish Defense Planning System within the defense TM framework presented in the literature review. Considering the current regulations and their implications on defense planning cycle, the TM activities of defense system actors through defense planning cycle were identified. The identified TM activities were than compared to the generic TM activities in the literature.

It can be concluded that, TM activities in the literature used mostly in commercial business can also be used in defense domain with an exception in exploitation and protection activities because there is monopsony, MoD being the only customer of defense systems.

But TM activities alone are not sufficient enough to cover all the aspects of technology management in defense planning since the defense systems are large and sophisticated and the defense stakeholders' TM roles and functions and their interactions with each other are rather complex in defense planning cycle. The current regulations on defense

planning system are rather implicit for defining technology management processes clearly.

CHAPTER 4

SURVEY STUDY

In order to prove the TM usability in defense domain as discussed in the previous chapter, a survey was required to identify the roles and functions of MoD and armed forces, as well as defense planners' awareness and usage level of technology management in their defense planning studies.

4.1 Problem to Be Solved (Aim)

How TM can be integrated and made explicit to defense planning system in order to support decision making, and strategy and capability planning studies of defense planners?

4.1.1 What is the New Knowledge Required to Solve This Problem

- To what degree TM activities and tools for the technology management is known and used within the defense body's staff?
- Can these TM activities and tools be formed to define TM roles or functions of MoD and Turkish Armed Forces (TAF) to better support defense planners' decisions through the defense planning cycle?

4.1.2 The Objectives of the Survey

In this survey, the following questions are required to be answered with the aim of better understand the needs of defense planners and explicitly define TM roles or functions of MoD and Armed Forces which are currently defined implicitly in present regulations. The questions were grouped in three categories; TM awareness, TM usage level, and TM usage in defense planning.

4.1.2.1 TM Awareness Questions

- What is the level of awareness of defense planners about technology management as a decision aid and, strategy and capability planning tool? (Q8-14)

- To what degree the TM processes are defined in regulations? (Q11)
- Who is responsible for technology management and how they are organized? (Q12, 13)
- Are the use of TM process outputs in decision making and, strategy and capability planning processes obligatory or optional? (Q15, 16)

4.1.2.2 TM Usage Level Questions

- Are defense planners use TM processes in defense domain and familiar with TM activities and tools, and to what is their TM usage levels? (Q17, 18)
- Is there a systematic way to collect, process, and store data as needed for TM? (Q19-24)
- Is there any efforts and initiatives to improve better use of technology management within the organization? (Q25-30, Q33-42)
- What is the human resources policies and what are the training activities for the personal development of staff on technology management? (Q31, 32)

4.1.2.3 TM Usage in Defense Planning Questions

- How well the importance of future warfighting concepts and their corresponding technological concepts are known among defense planners? (Q43-49)

4.2 Survey Participation and Participant Profile

After having conversations with MoD and TAF authorities, it became impossible to conduct the survey officially within these institutions. As a result, the survey was conducted electronically by sending it to the two special Yahoo mail groups which have working and/or retired members from MoD and TAF.

A sum of 70 people responded the survey. Approximately half of the respondents are currently working and the other half are either in different institution or retired. 82% of the people are from Turkish Armed Forces. The rest of them are belonging to Undersecretariat of MoD and Undersecretariat MoD for Defense Industries as it is shown in Figure 4-1.

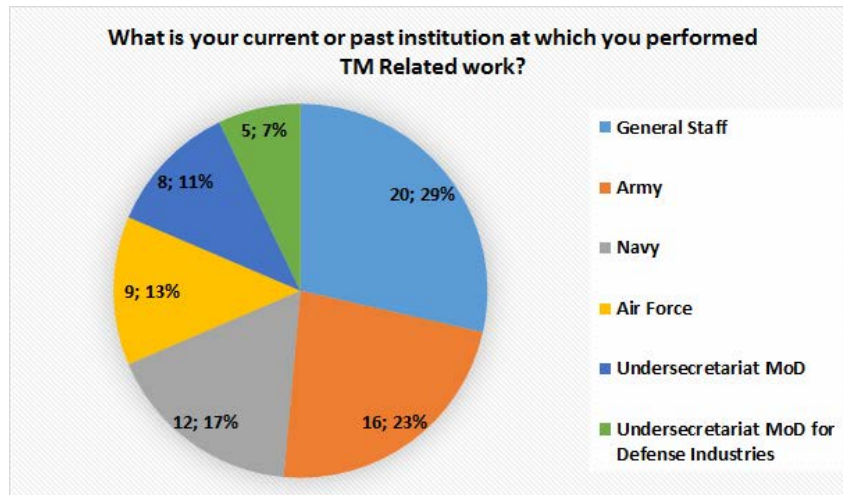


Figure 4-1 Survey Participants' Institutions

Figure 4-2 shows the education level of survey participants. 94% of the survey participants have a scientific degree of graduate level and up.

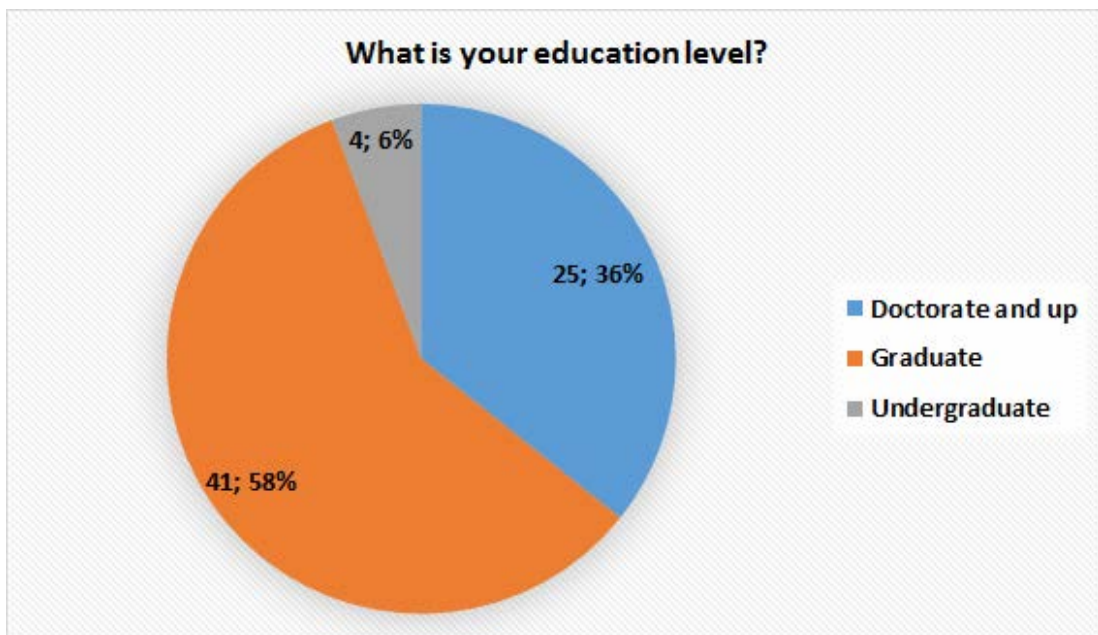


Figure 4-2 Education Levels of Survey Participants

87% of participants are from engineering field as it is shown in Figure 4-3. The rest are from Economic and Administrative Sciences, education sciences, and Arts and science fields.

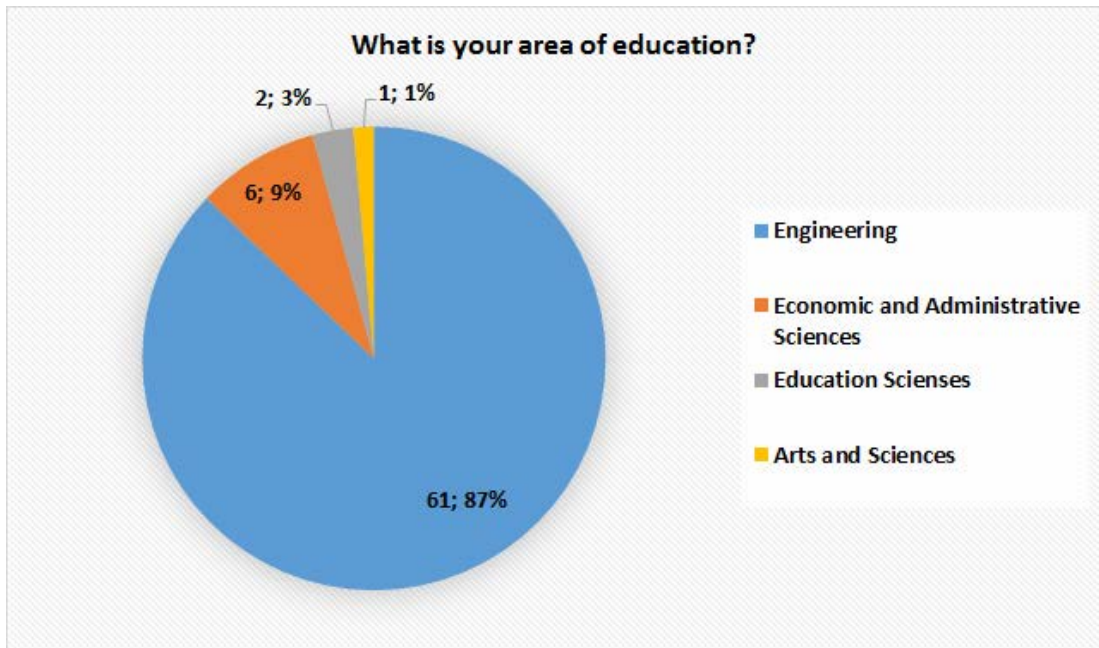


Figure 4-3 Education Areas of Survey Participants

A fair percentage of survey participants have duration of 15 years and up in their professions. The rest of the participants have a duration of 11-15 years in their professions. Figure 4-4 shows that they are all experienced people.

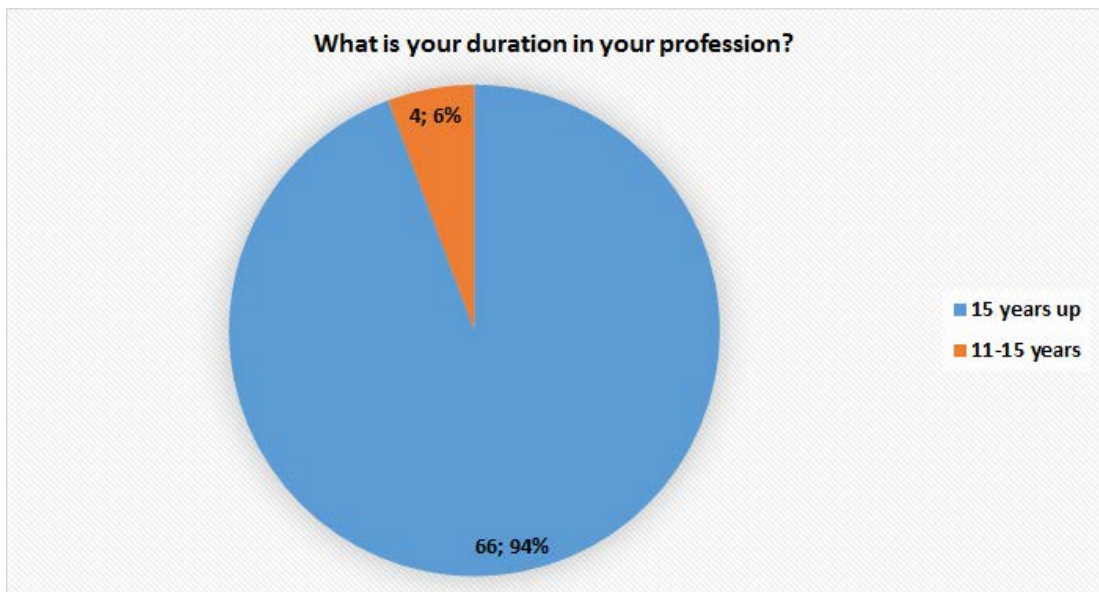


Figure 4-4 Duration in Profession

Most of the survey participants spend/spent their years of profession in their current institutions. 66% of the people are/were working in the institution more than 15 years. Only 10% of the people are/were working in the institution between 1 to 3 years as it is shown in Figure 4-5.

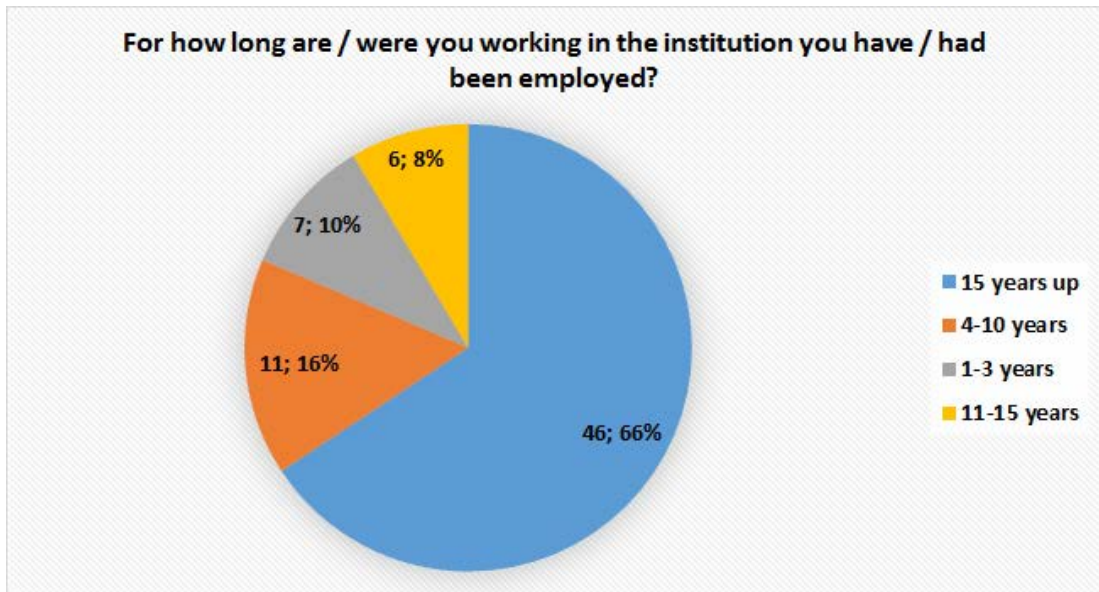


Figure 4-5 Time in Current Institution

Figure 4-6 explains the position of participants. 40% of the people are/were section head, project manager or group manager. Head of department and group has the percentage of 30. Expert, project officer and project leader are 26% and people from education and research institution are only 4%.

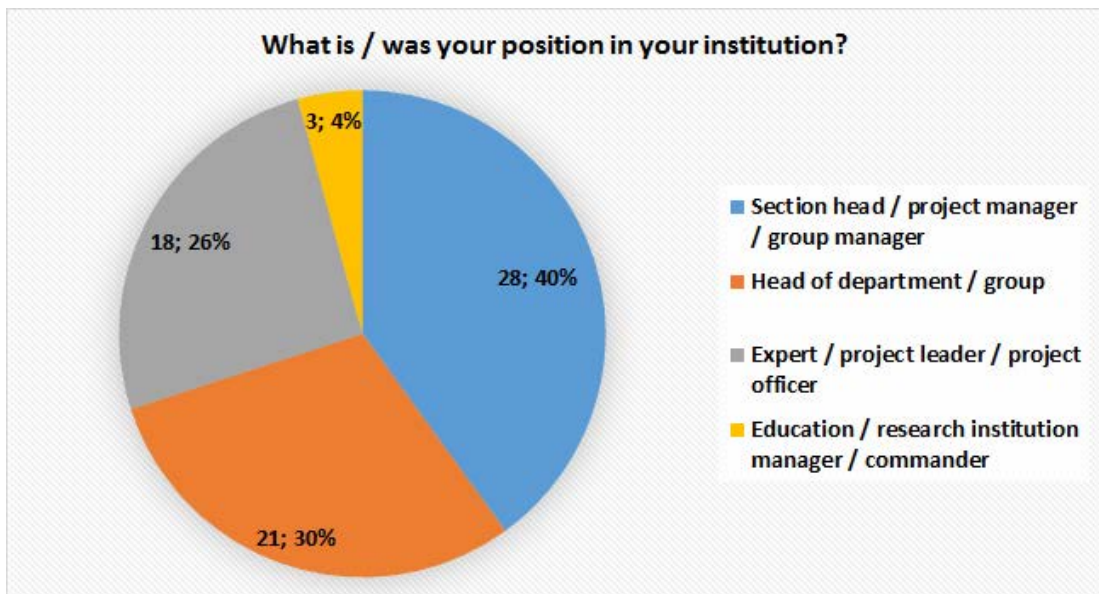


Figure 4-6 Position in Your Institution

Stability of the survey participants in the position is also important. 73% of the participants are/were working in TM position for 1-7 years in the institution. It is an important metric in terms of experience in TM areas which is poor in this case. The graph is presented in Figure 4-7.

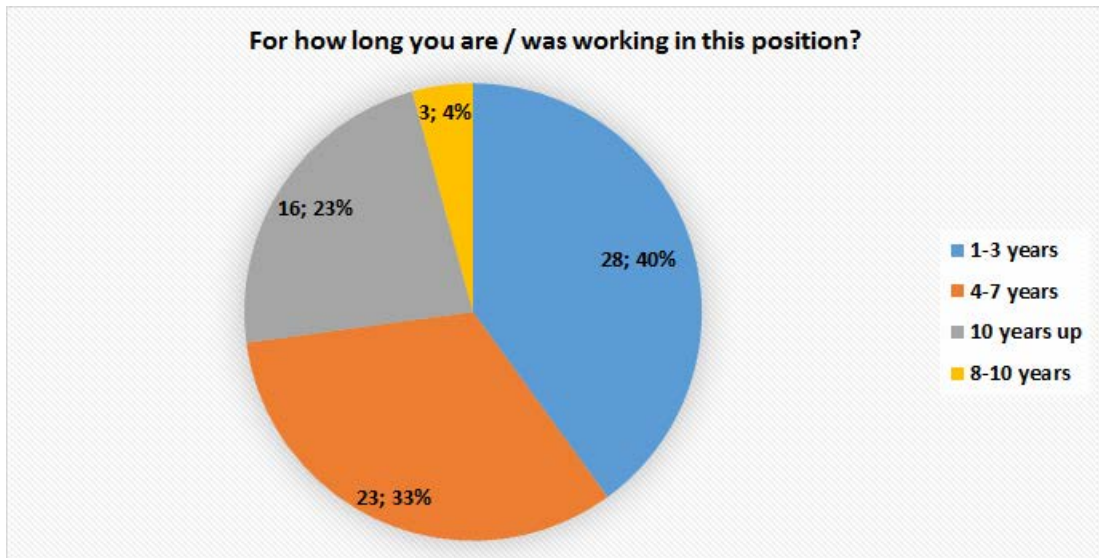


Figure 4-7 TM Position in Institution

Figure 4-8 shows the participants' durations in their positions by institutions. On average, 73% of them are/were working in their positions for 4-15 years. There is no significance between Turkish Armed Forces and Undersecretariat of MoD. The most experienced participants are belong to the Undersecretariat MoD for Defense Industries.

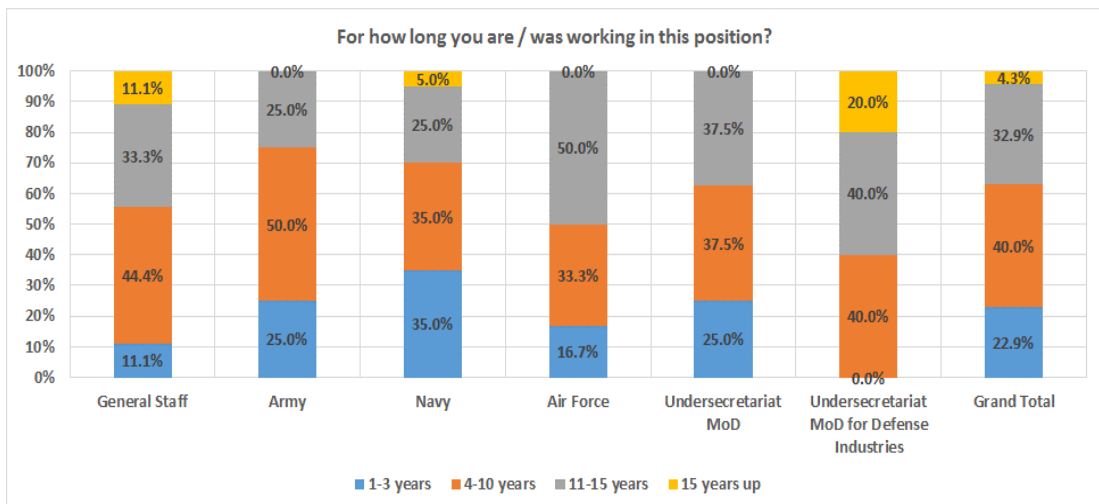


Figure 4-8 TM-Related Position in Institution by Organization

Most of the participants are more than 10 years in their professions. On average, 44% of survey participants are in technology management positions for 1 to 3 years, approximately 29% of them are in technology management positions for 4 to 7 years and remaining approximately 25% of them are in technology management positions for more than 8 years as it is shown in Figure 4-9.

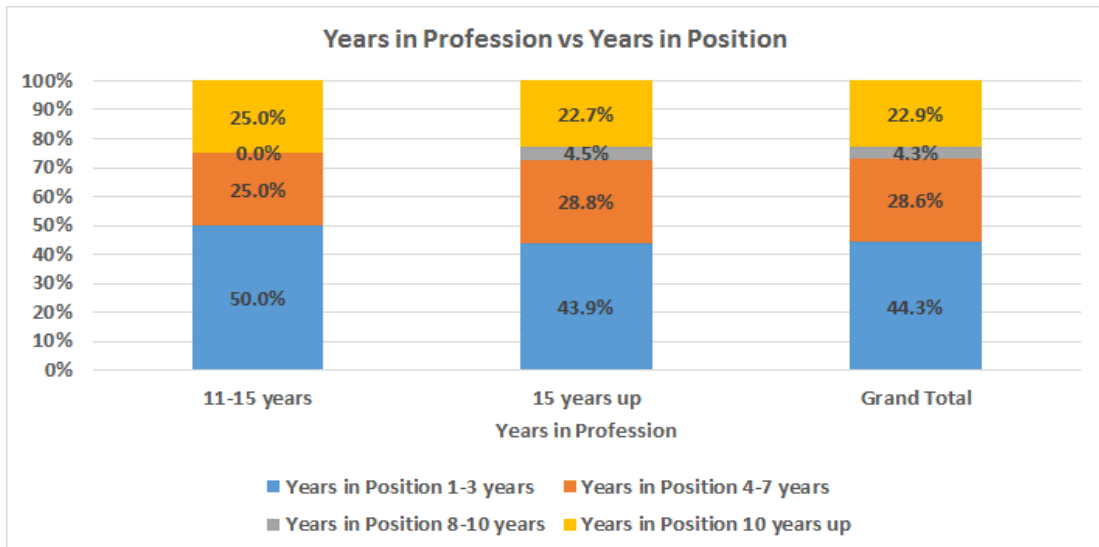


Figure 4-9 Years in Profession vs Years in Position

Approximately 44% of survey participants are in technology management positions for 1 to 3 years. 50% of participants who are in technology management positions for 4 to 7 years are in their institutions for 4 to 10 years and those in technology management positions for 11 to 15 years are in their institutions for 4 to 10 years as it is shown in Figure 4-10.

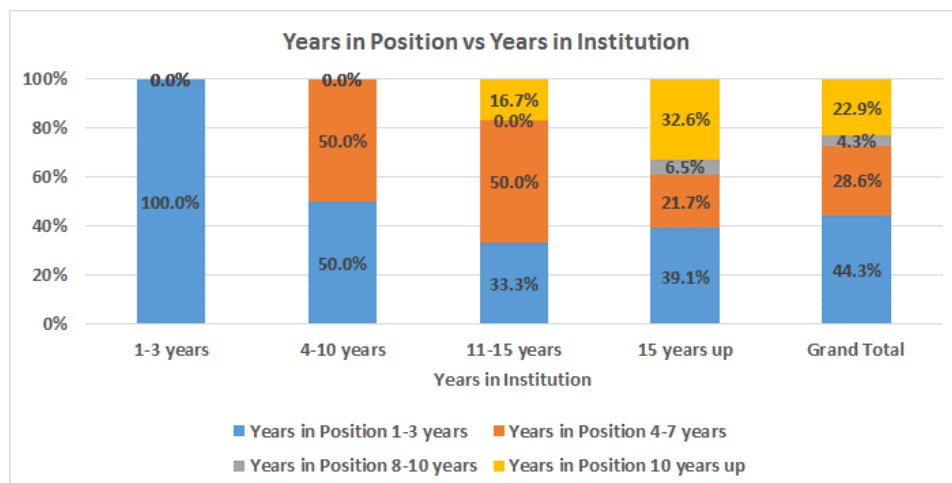


Figure 4-10 Years in Position vs Years of Institution

4.3 Analysis of Survey Results

The survey results were analyzed by considering the objectives of the survey. The comparison of survey results for several questions by institutions are also presented. In order to identify the significance of the responses, a series of statistical tests were also applied to the survey results.

4.3.1 TM Awareness

To measure the TM awareness, questions identified in the survey objectives were asked in detail to the audience as explained in the following paragraphs. Questions 8 through 16 are intended to measure the level of TM awareness in defense community.

4.3.1.1 Analysis of TM Awareness Questions

- **What is the level of awareness of defense planners about technology management as a decision aid and, strategy and capability planning tool?**

Q8 : Figure 4-11 shows that almost all of the participants are familiar to technology management studies. This is a very good percentage in terms of reaching to correct audience through the survey.

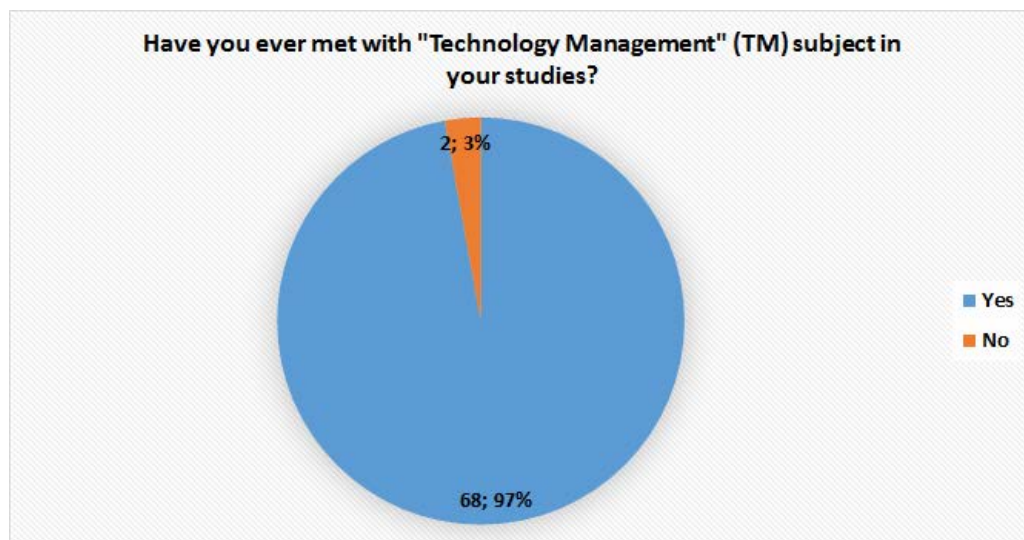


Figure 4-11 Awareness of Technology Management

Q9 : Figure 4-12 shows that 97% of the participants are/were involved in technology management studies. This is also a good percentage for the survey.

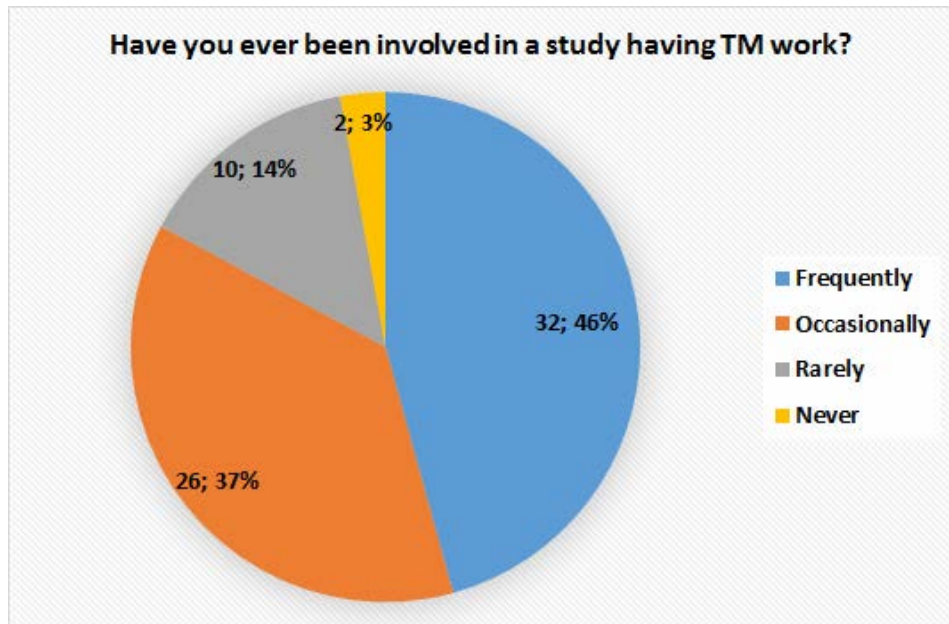


Figure 4-12 Involvement in Technology Management Studies

Q10 : 34% of participants have been worked in Project and Program Management, 22% of participants have been worked in R&D Management areas of technology management. Strategy and Capability Planning and Decision Support are the other important areas where the survey participants worked as presented in Figure 4-13. The figure shows that most of the participants are aware of using TM in their technology-related studies.

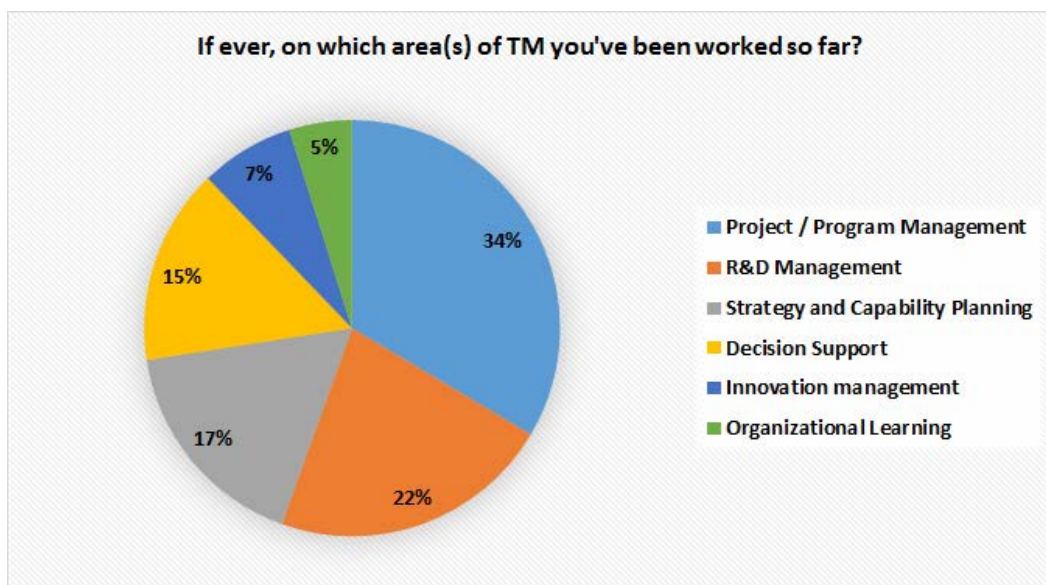


Figure 4-13 TM Usage in TM-Related Areas

Different areas of technology management are analyzed in terms of their usage among different institutions. Project/program management and R&D management are common areas in every institution. Strategy and capability management area of TM is studied by Turkish General Staff Headquarters with the biggest percentage. Decision support is one of the TM areas which were taken into account by all institutions except Undersecretariat MoD as it is shown in Figure 4-14.

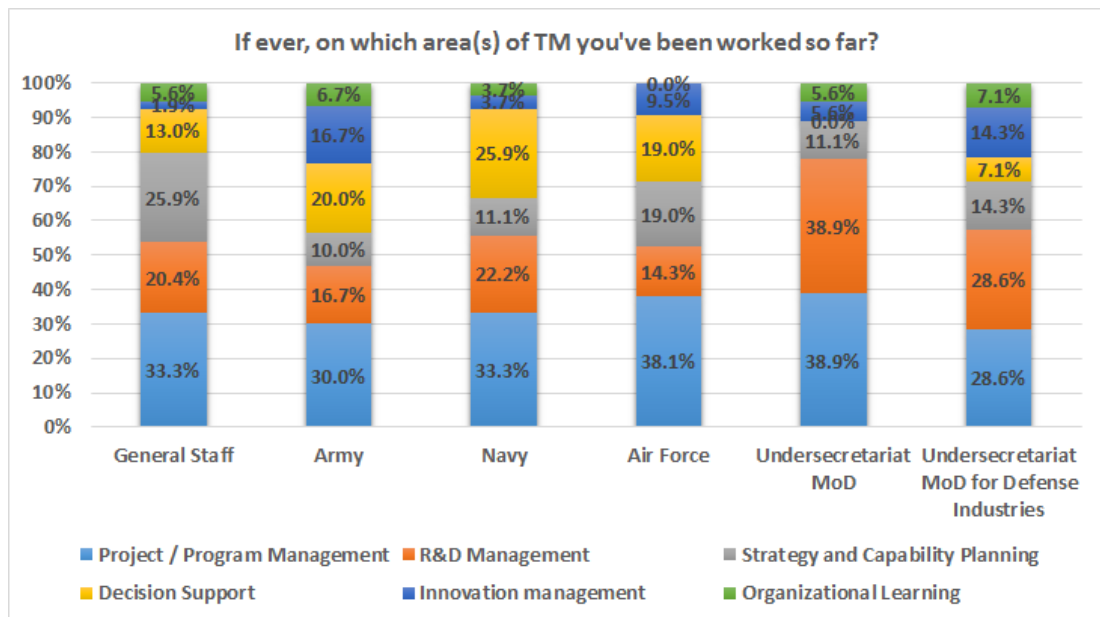


Figure 4-14 TM Usage in TM-Related Areas by Institutions

Q14 : Supporting project/program investment decisions, future strategic planning, feasibility studies for defense acquisition processes and identifying/tracing the level of national technological capabilities in defense domain are important areas that technological management processes are used as it is shown in Figure 4-15.

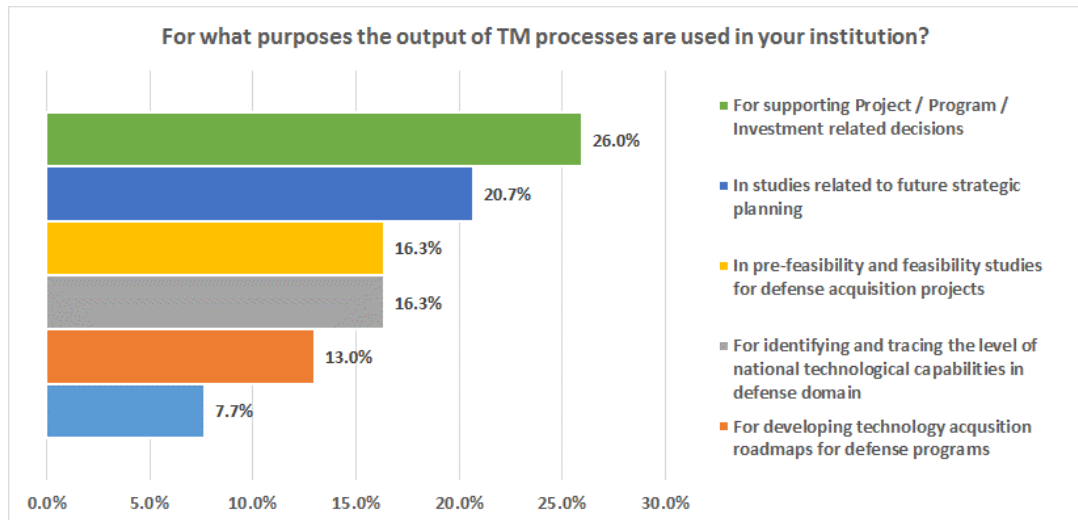


Figure 4-15 Institutional Purposes for Technology Management

TM processes usage percentage are almost the same by every institution. While TAF mostly uses TM outputs for decision making and strategic planning, MoD uses them mostly in feasibility studies and roadmapping purposes as it is shown in Figure 4-16

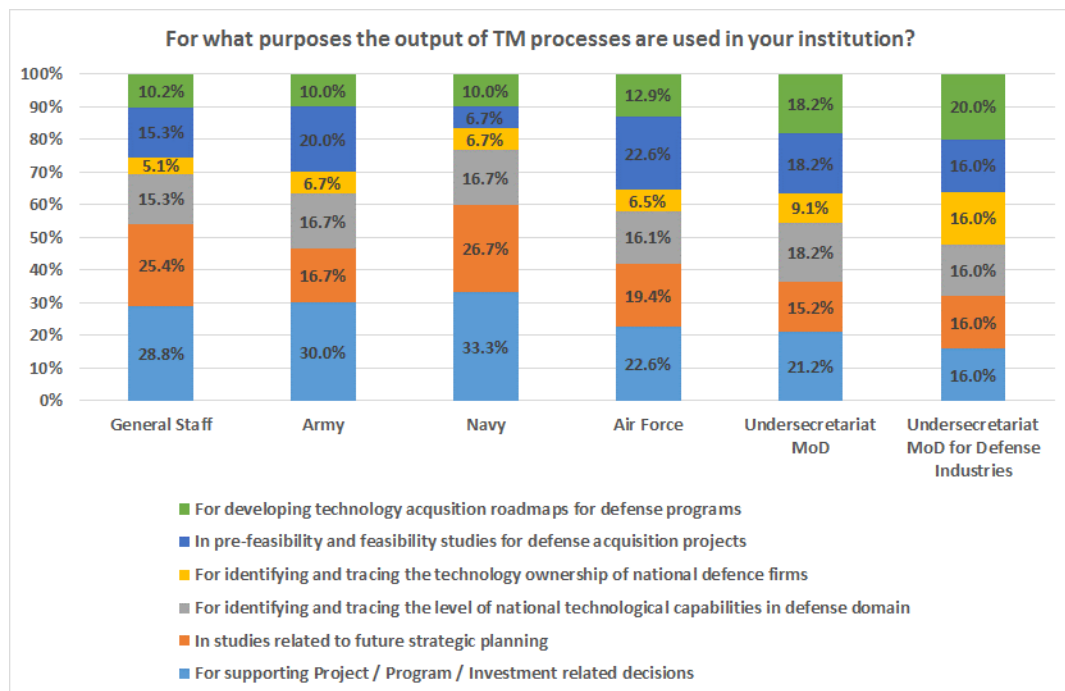


Figure 4-16 Usage Purposes of the Output of TM Processes by Institutions

The percentages of purposes for output of TM processes are almost the same for participants who have different years of profession as it is shown in Figure 4-17.

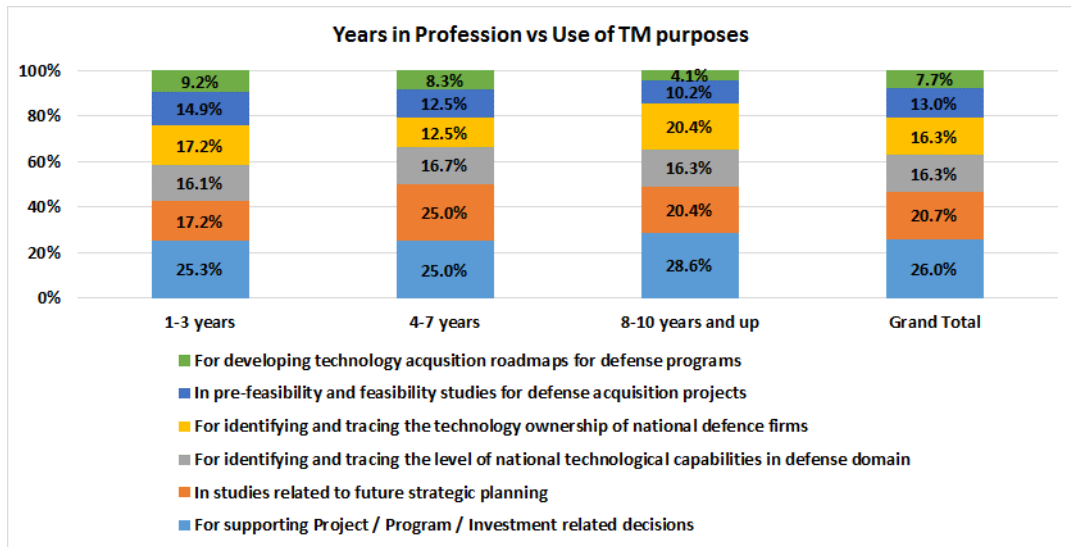


Figure 4-17 Usage Purposes of TM Process Outputs vs Years in Profession

Output of TM processes are used for supporting project/program investment related decisions and for studies related to future strategic planning almost the same by every unit. The percentages for TM purposes are close to each other for every unit and they are not changed with respect to position in institution as it is shown in Figure 4-18.

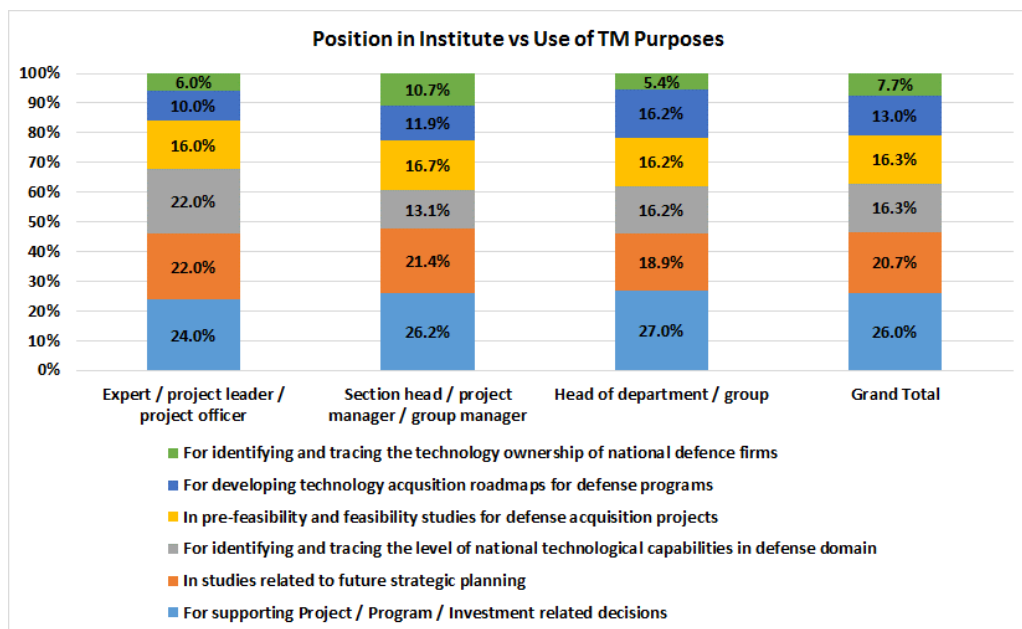


Figure 4-18 Usage Purposes of TM Processes Outputs vs Position in Institute

- **To what degree the TM processes are defined in regulations?**

Q11 : Figure 4 13 shows that 49% of the participants believe that although they are not defined clearly, there are some general principles and guidelines concerning technology management processes. 22% of participants mentioned that there are no such regulations on technology management processes or there is a study underway related to technology management processes. It means that the current regulations are not explicitly define TM processes. This is an important result since it proves the argument stated in the previous chapter concerning the regulations’ implicitness.

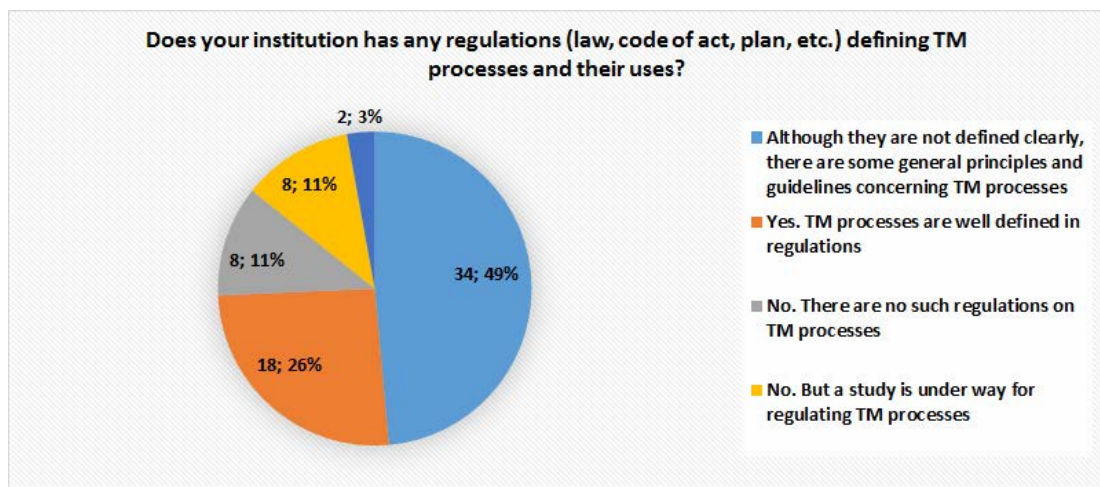


Figure 4-19 Regulations on Technology Management Processes

Participants from Undersecretariat MoD, Undersecretariat MoD for Defense Industries and Air Force mentioned that TM processes are well regulated. But in Turkish Armed Forces except Air Force; although they are not defined clearly, there are some general principles and guidelines concerning TM processes as it is shown in Figure 4-20.

To statistically test the whether there are differences between means of institutions, one-way ANOVA is used. The hypotheses are;

$$H_0 : \mu_1 = \mu_2 = \dots = \mu_m \text{ and,}$$

$$H_1 : \text{not all the means are equal.}$$

The ANOVA table is presented in Table 4-1. Since the $F > F_{crit}$, we failed to reject null hypothesis H_0 at $\alpha=0.05$ level concluding that there is no difference between intuitions in terms of regulations.

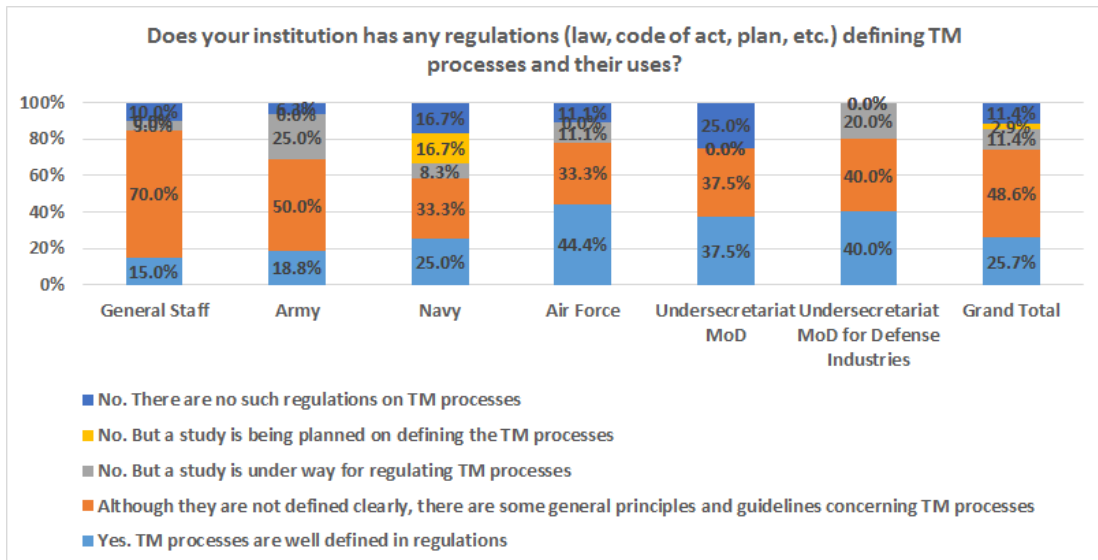


Figure 4-20 Regulations for Technology Management by Organization

Table 4-1 ANOVA Table for Existence of Regulations by Institutions

Anova: Single Factor						
α=0.05						
SUMMARY						
Groups	Count	Sum	Average	Variance		
TGS	5	1	0.2	0.088889		
Army	5	1	0.2	0.054167		
Navy	5	1	0.2	0.025		
Air Force	5	1	0.2	0.075		
UMoD	5	1	0.2	0.047222		
UMoDDI	5	1	0.2	0.04		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0	5	0	0	1	2.620654
Within Groups	1.321111	24	0.055046			
Total	1.321111	29				

- **Who is responsible for technology management and how they are organized?**

Q12 : 47% of survey participants mentioned that there are sub units and persons within units for technology management. 18% of survey participants expressed that there are no such units for technology management. 19% of survey participants mentioned that there is only one unit responsible in terms of technology management for whole institution as it is shown in Figure 4-21. This indicates that by and large some units/ persons are assigned to the TM studies.

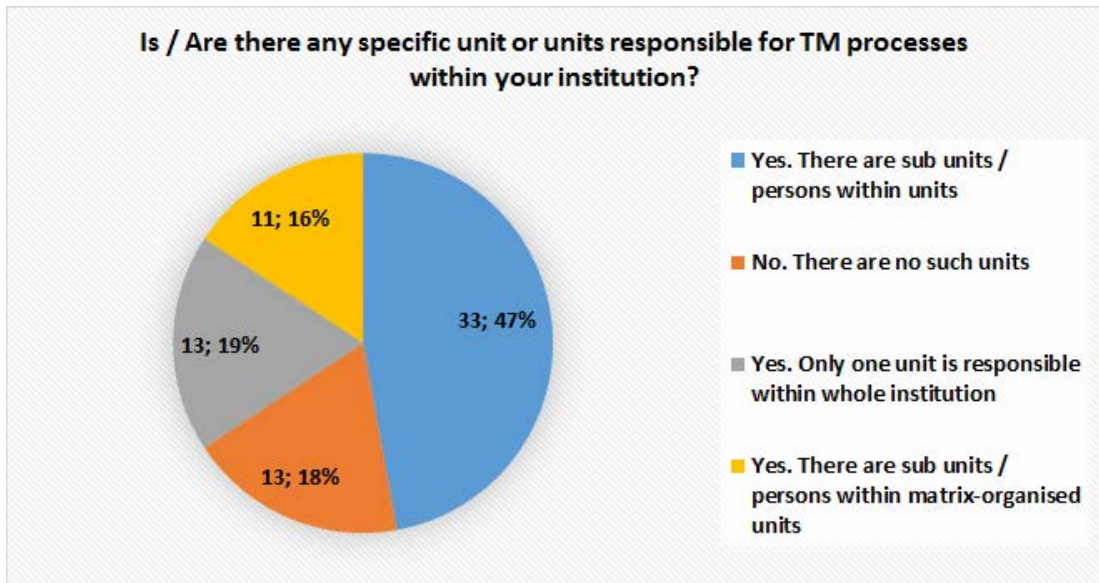


Figure 4-21 Units for Technology Management

Figure 4-22 shows that organizations have different profiles in terms of having TM units. On average, 81% of survey participants believe that there is only one unit responsible for whole organization or there are only sub units and persons within units. ANOVA test also verifies that there are no difference between institutions.

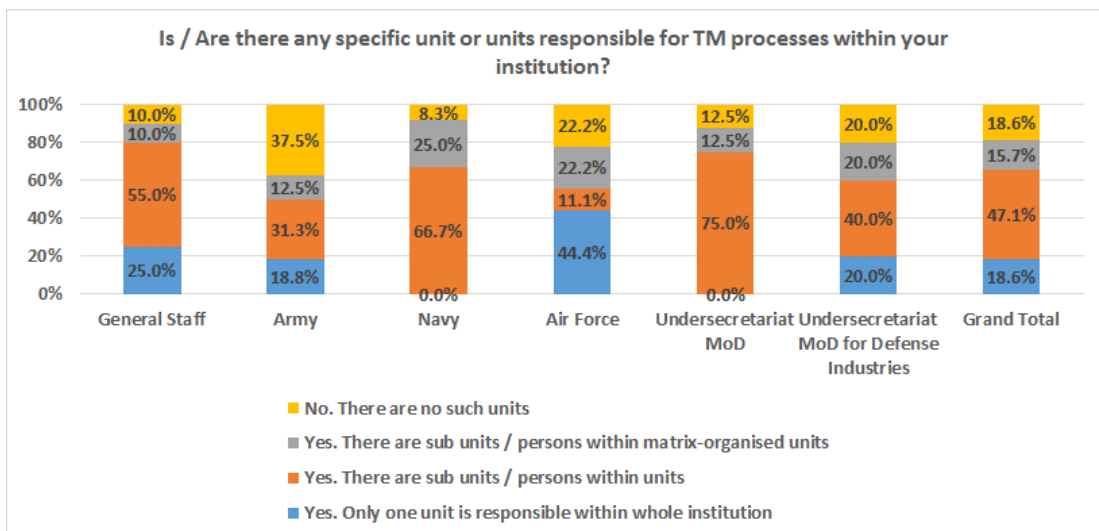


Figure 4-22 Units for Technology Management by Organization

Q13 : 71% of survey participants are in directly and indirectly responsible position for technology management processes in their organization. 19% of survey participants have no technology management responsibilities in their organization as it is shown in Figure 4-23. This result indicates that in most cases, some workforce is assigned to the TM work.

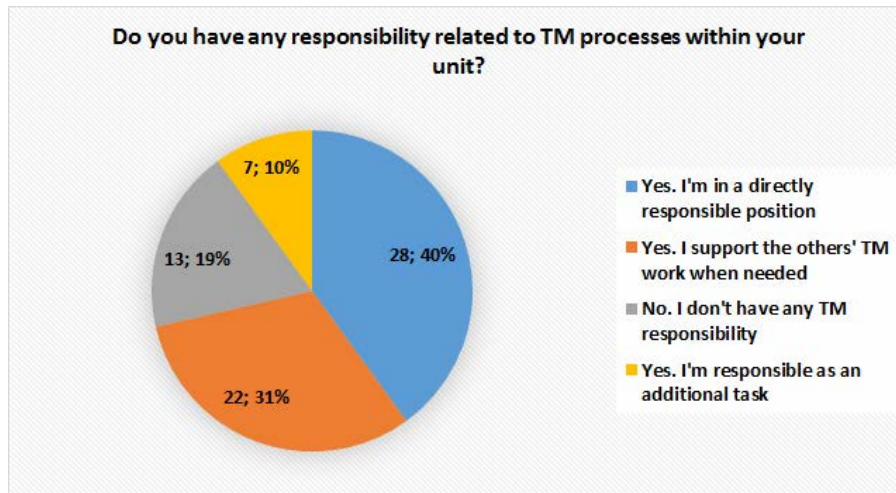


Figure 4-23 Responsibilities for Technology Management in Organization

- **Are the use of TM process outputs in decision making and, strategy and capability planning processes obligatory or optional?**

Q15 : Figure 4-24 shows that 30% of survey participants believed that technology management must be used in every project and every study. 17% of survey participants mentioned that there is no obligation to use technology management process outputs in projects and studies. This result supports the previously stated hypothesis on existing regulations' implicitness.

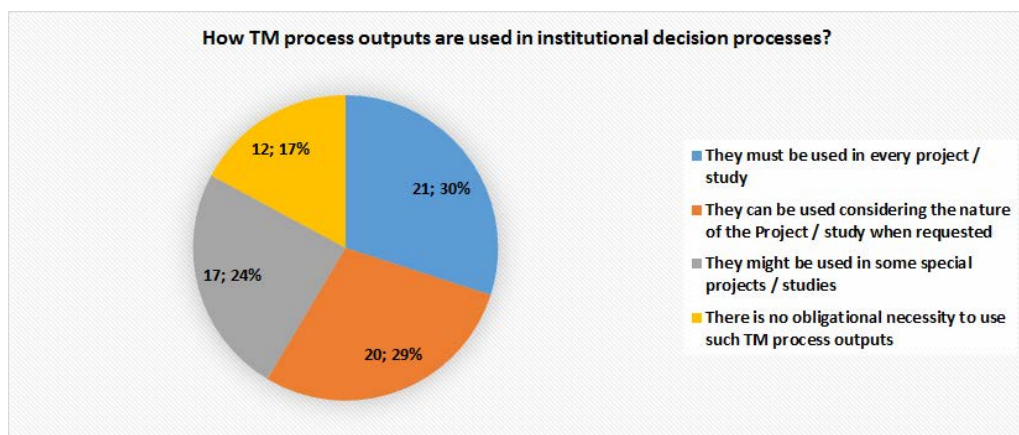


Figure 4-24 TM Outputs Usage Purposes

Use of outputs from TM processes changes by institutions. Air Force uses these results in every project and study. All institutions agree on use of TM processes results in some projects. Each unit except Undersecretariat MoD indicates that no obligational necessity to use these results as it is shown in Figure 4-25. ANOVA test also indicates that there is no difference on TM outputs usage between the institutions

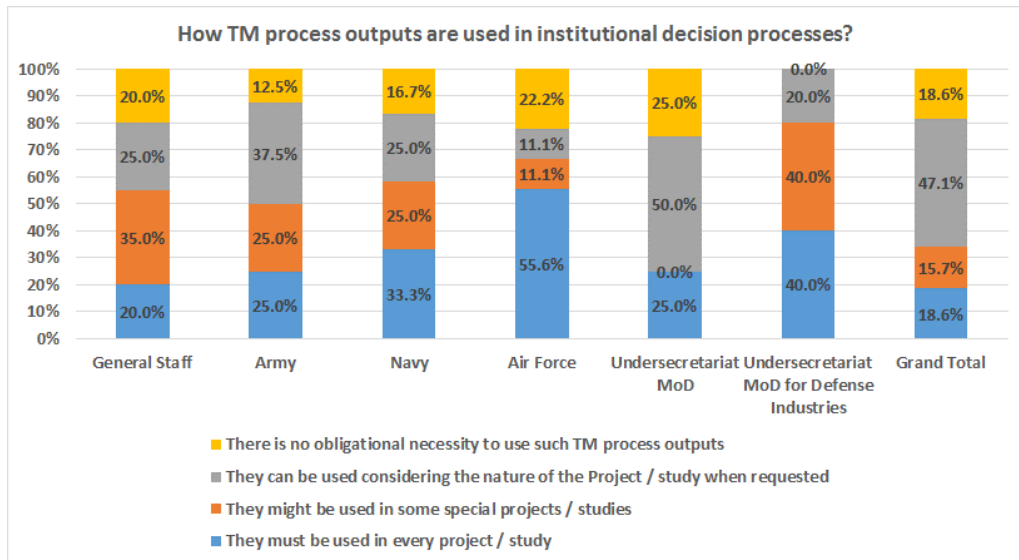


Figure 4-25 TM Outputs Usage Purposes by Institutions

Use of outputs from TM processes changes from position to position. 83.4% of head of department / group managers believes that results must/ can be used. This percentage will decrease to 46.4% for section heads, project managers and group managers. Figure 4-26 indicates that 27.8% of participants from expert, project leader and project officers will use these results in every project and study.

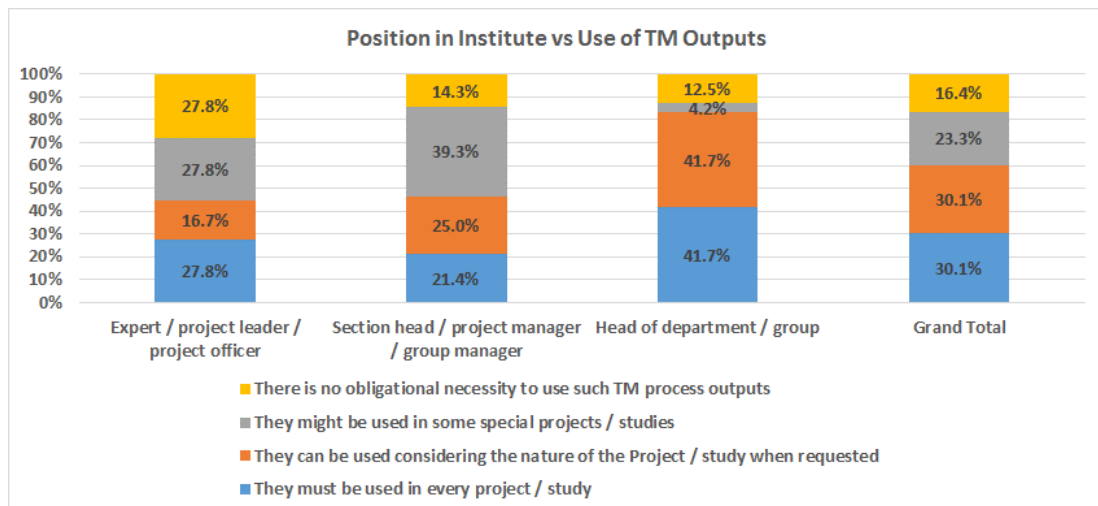


Figure 4-26 TM Processes Output Used in Positions

Q16 : 30% of participants mentioned that technology management processes outputs may be used as input to Strategic Planning studies as requested. 28% of participants think that results are directly used in strategic planning studies as it is shown in Figure 4 21. This also proves the non-existence of clear regulations, procedures and standard ways to use the TM process outputs.

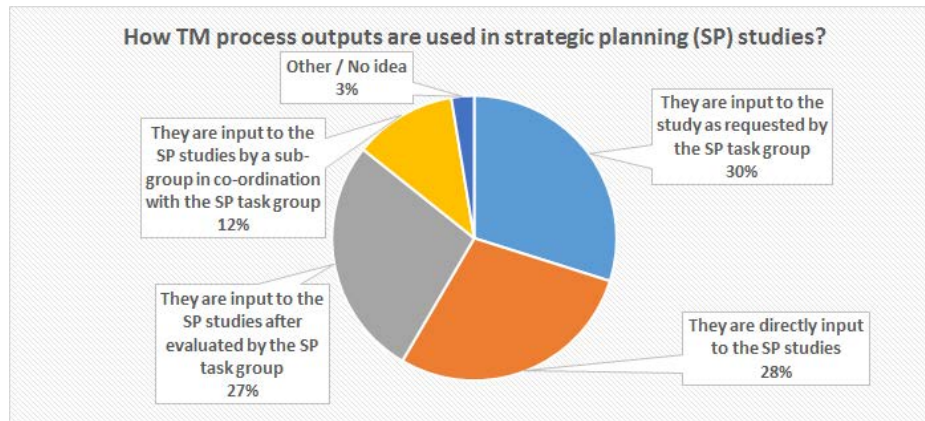


Figure 4-27 Use of TM Process Outputs in Strategic Planning

4.3.1.2 Analysis Results of TM Awareness

Survey analysis results indicate that there is a reasonable degree of awareness about defense TM within the MoD and the Armed Forces.

The implicitness of regulations as stated in the previous chapter were proved by the survey since the necessity degree of TM outputs is low and the TM roles or functions are not well understood within the institutions.

4.3.2 TM Usage Level

To measure the TM usage level, questions identified in the survey objectives were asked in detail to the audience as explained in the following paragraphs. Questions 17 through 42 are intended to measure the level of TM usage among defense community.

4.3.2.1 Analysis of TM Usage Level Questions

- **Are defense planners use TM processes in defense domain and familiar with TM activities and tools, and to what degree?**

Q17 : Technology Forecasting and Technology Impact Assessment on Future Operating Environments, Technology Auditing, Documentation and Dissemination of the Technology-related Work Findings, R&D Management, and Knowledge Management are the activities that participants mostly use as shown in Figure 4-28.

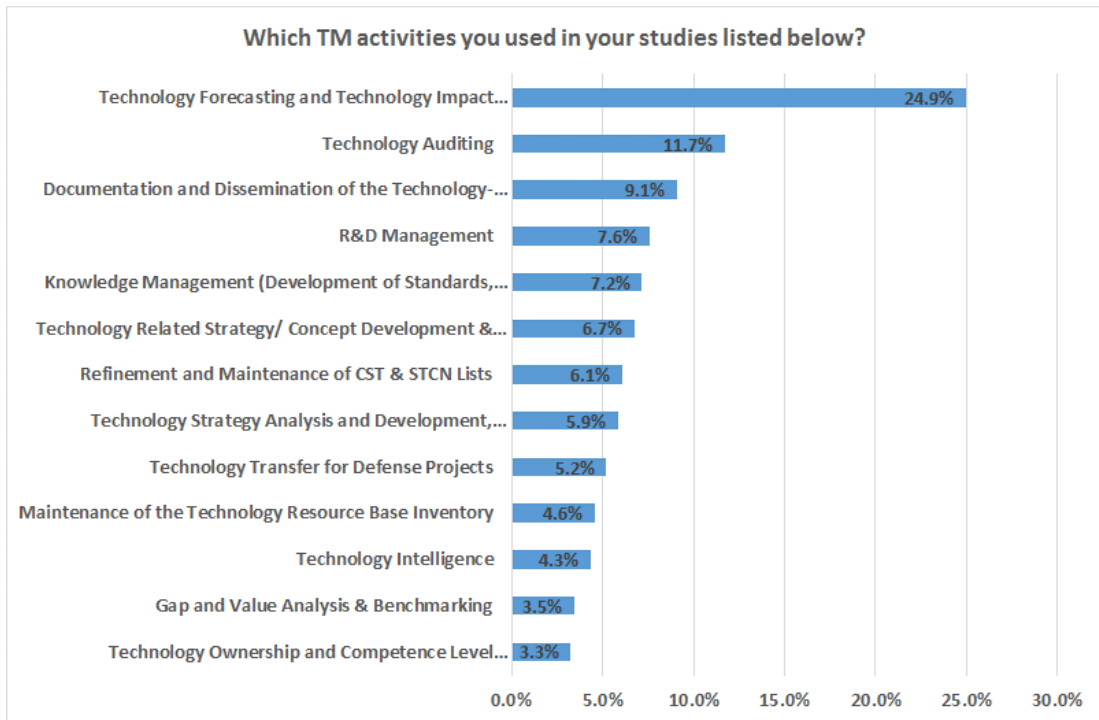


Figure 4-28 TM Activities Usage Levels

Type of TM activities used by institutions are presented in Figure 4-29. Their percentages are very close to each other.

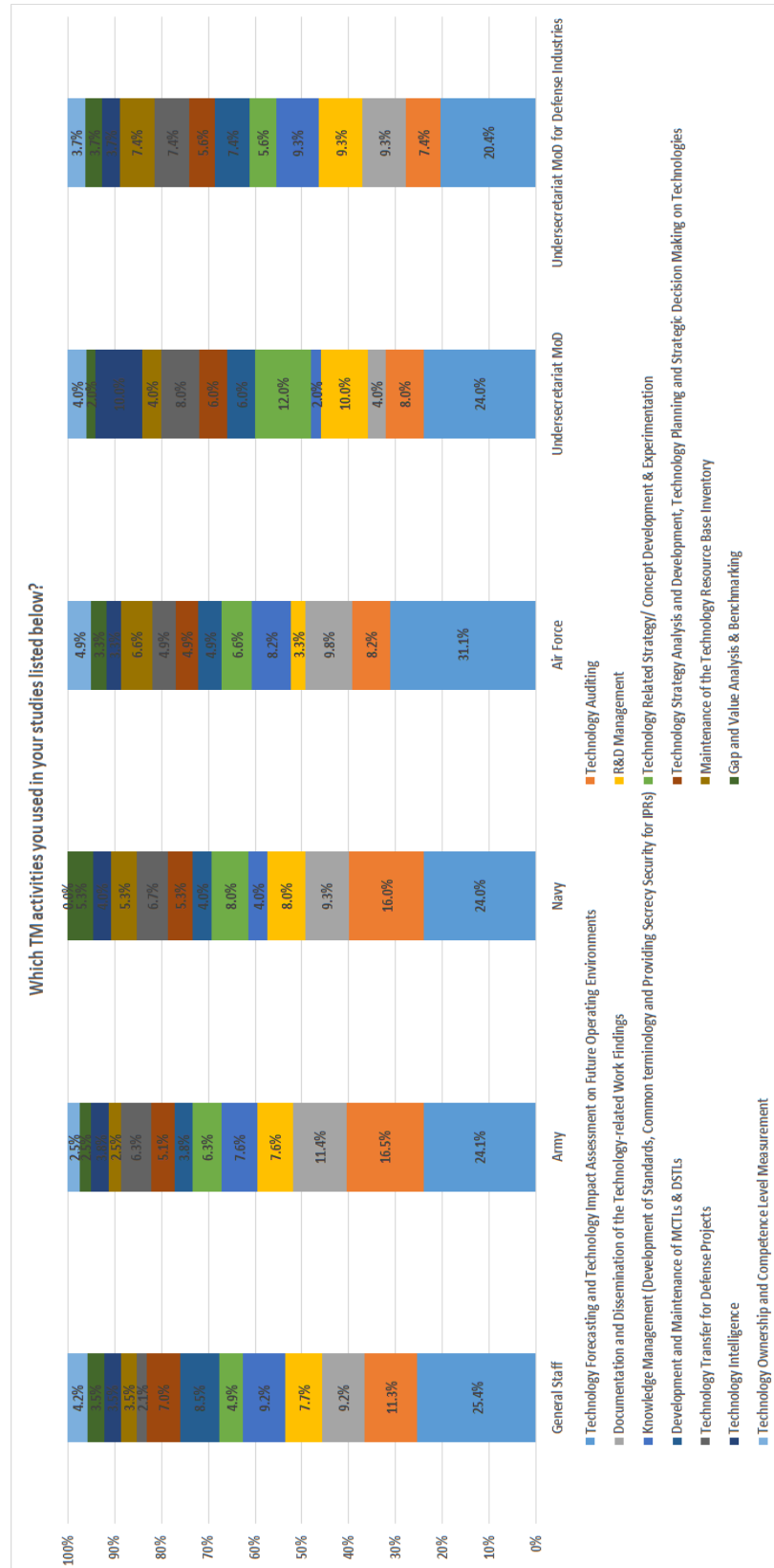


Figure 4-29 TM Activities Usage by Institution-I

Q18 : Need analysis, cost benefit analysis, brain-storming, SWOT analysis, expert opinion, technology road mapping, establishment of technology vision, project

evaluation techniques and benchmarking are main technology management tools used in TM activities according to participants as it is shown in Figure 4-30.

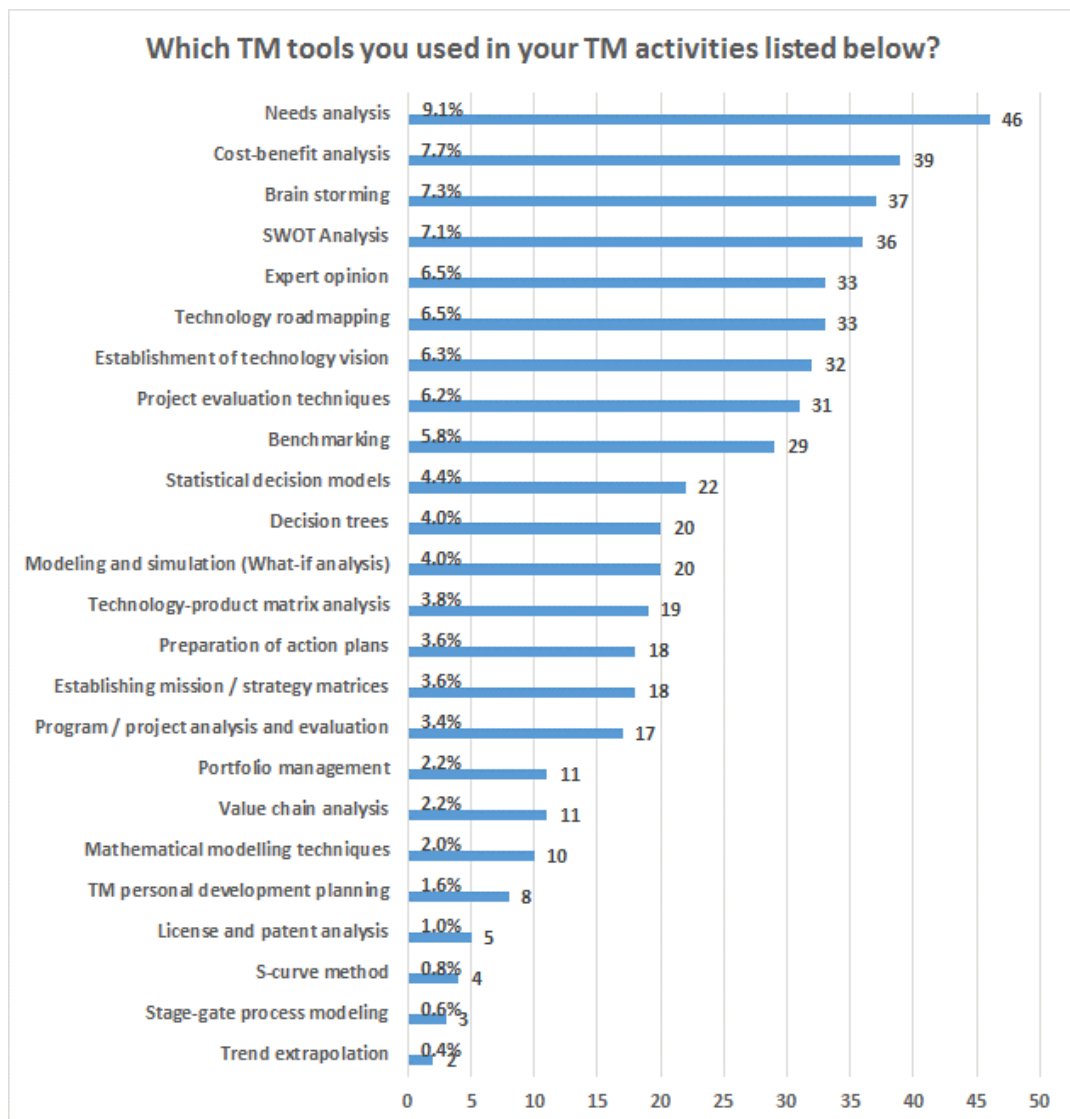


Figure 4-30 TM Tools Usage

Technology management tools can be classified as subjective and objective. Subjective tools and their usage percentages by institutions are presented in Figure 4-31. ANOVA analysis shows that there is no significant difference between institutions in terms of subjective tools usage.

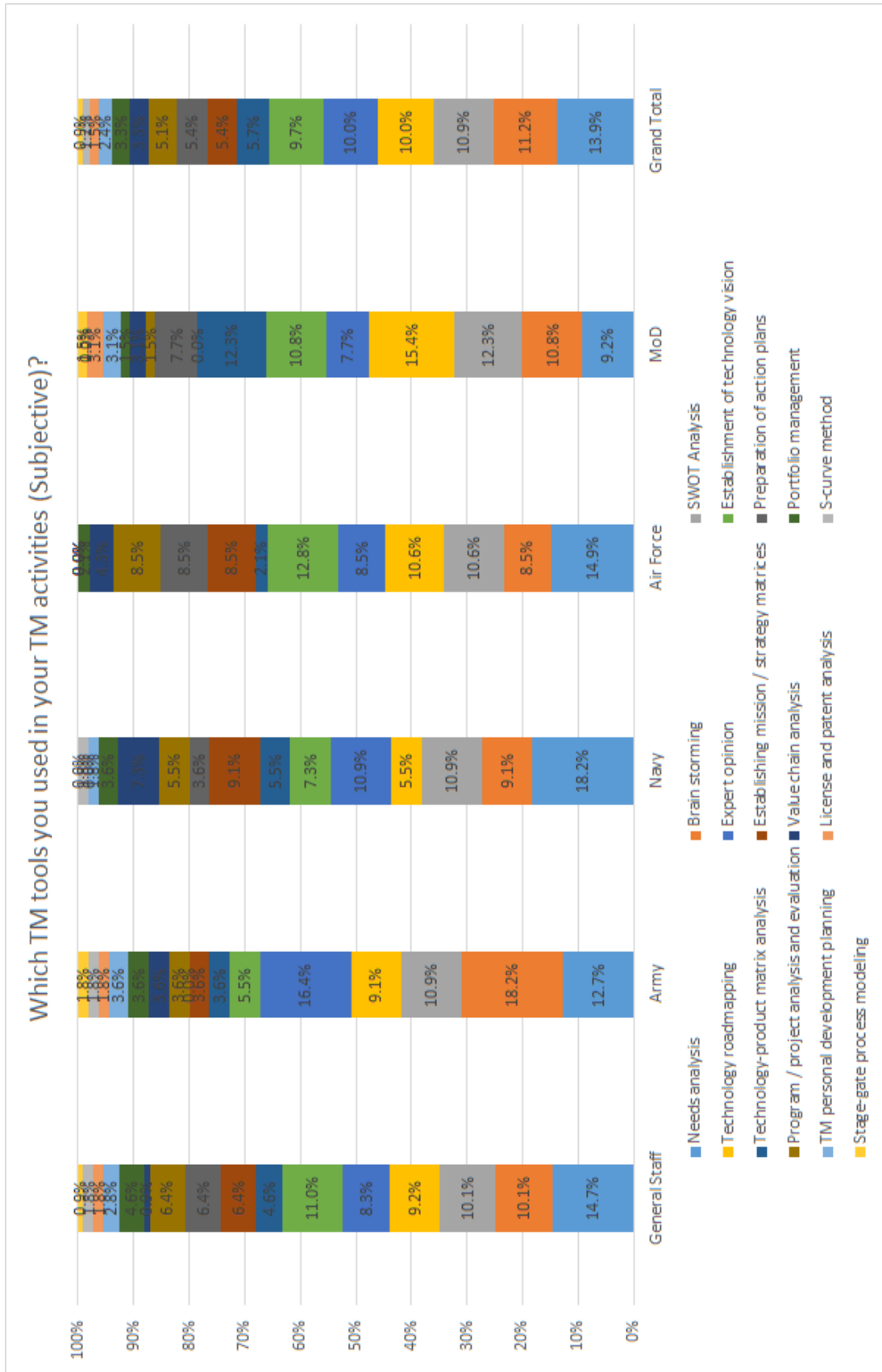


Figure 4-31 Subjective Tools Usage for TM Activities by Institution

Subjective tools and their usage percentages by institutions are presented in Figure 4-32. ANOVA analysis shows that there is no significant difference between institutions in terms of subjective tools usage.

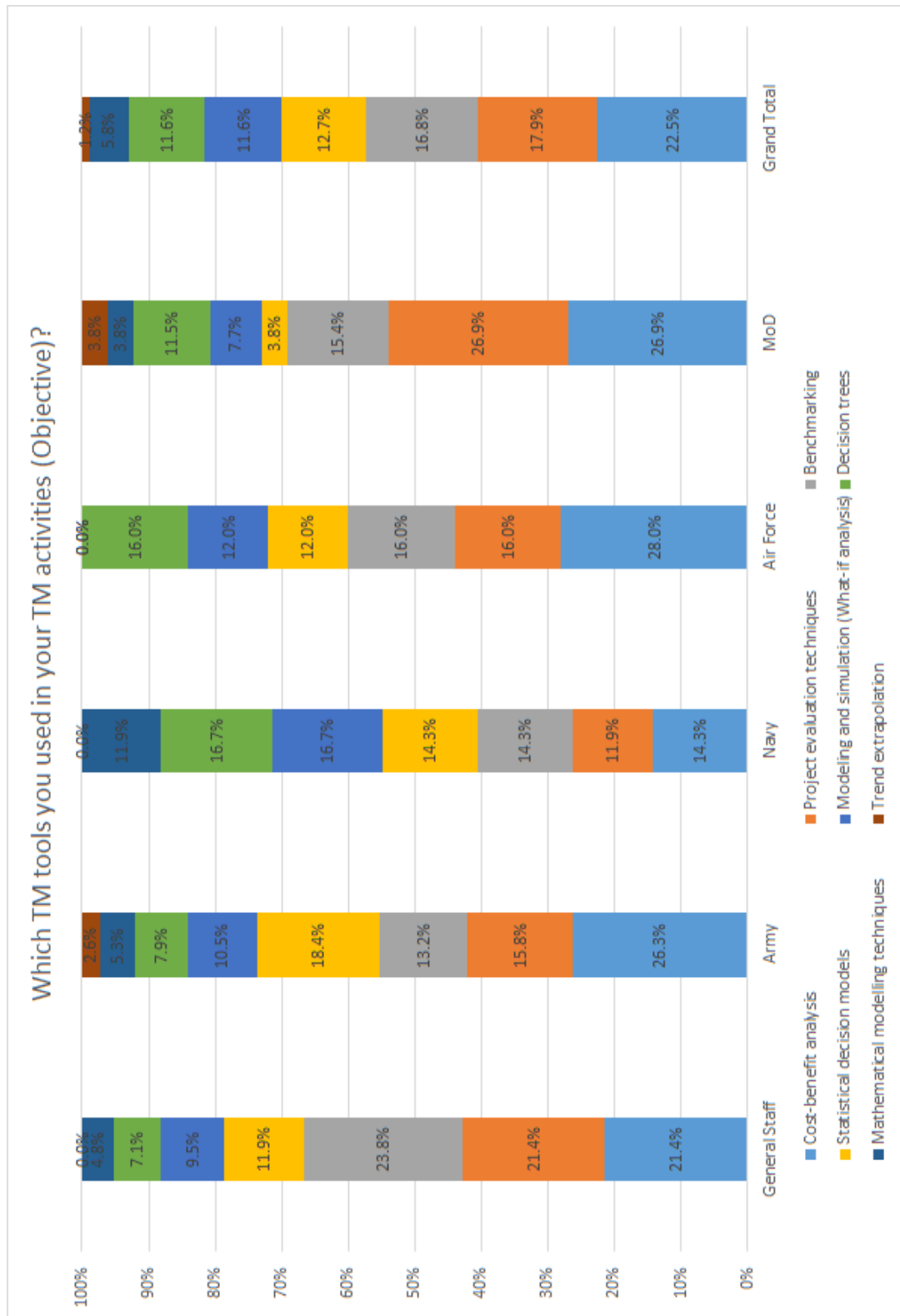


Figure 4-32 Objective Tools Usage for TM Activities by Institution

Use of subjective and objective tools in TM activities by institutions was analyzed for each institute. Approximately 66% of participants use subjective tools. The percentages are almost the same for all institutions as it is shown in Figure 4-33

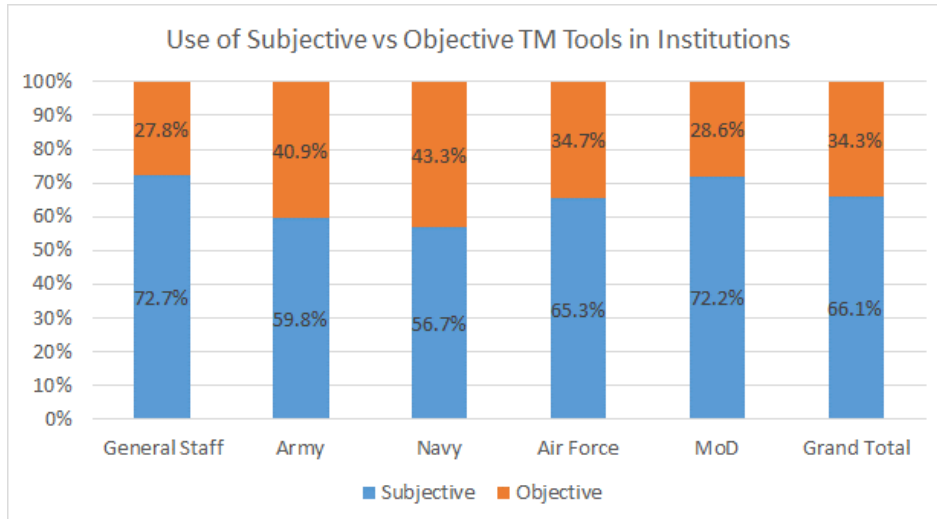


Figure 4-33 Comparison of Subjective and Objective Tools Usage for TM Activities

Usage of subjective TM tools is not changing with respect to position in institution as it is shown in Figure 4-34

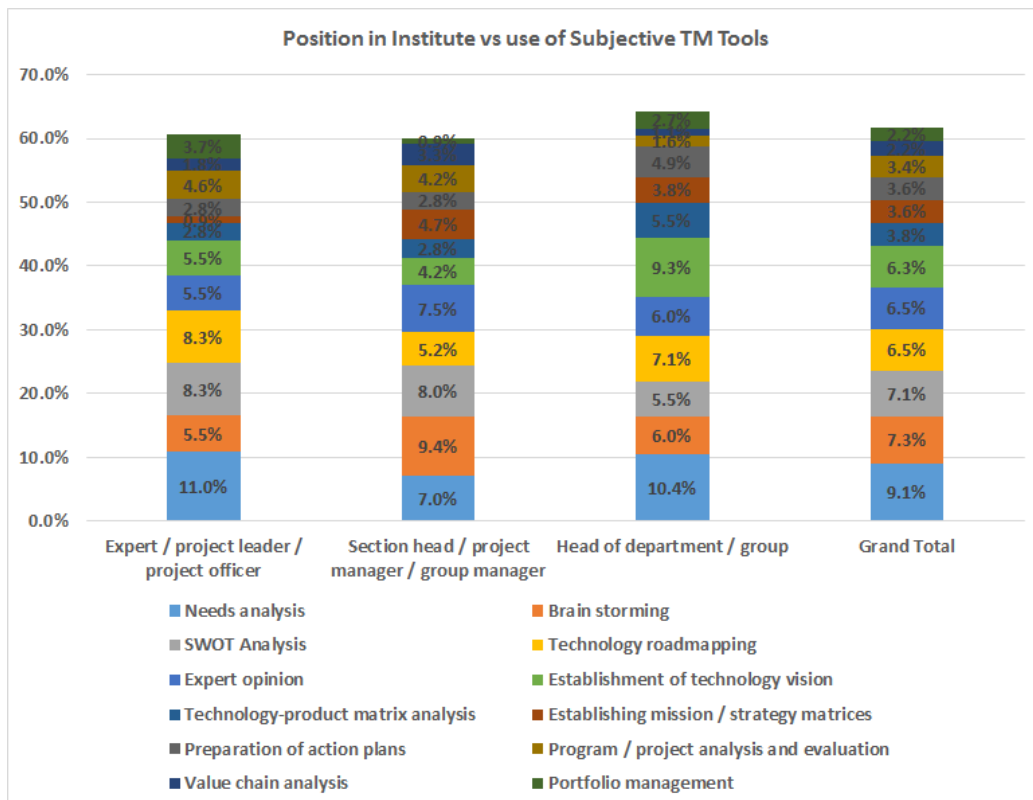


Figure 4-34 Subjective Tools Usage by Position

Usage of objective TM tools is not changing with respect to position in institution as it is shown in Figure 4-35.

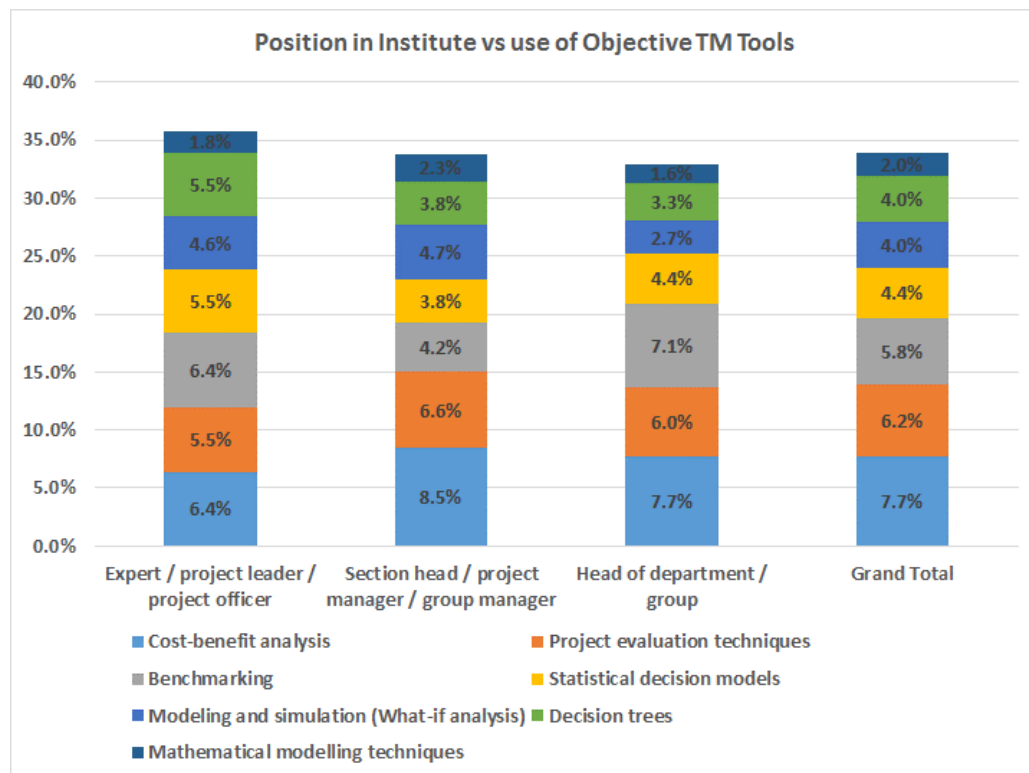


Figure 4-35 Objective Tools Usage by Position

- **Is there a systematic way to collect, process, store and, use data as needed for technology management?**

Q19 : 46% of survey participants mentioned that there is no information system related to technology management activities but it was planned. 23% of participants mentioned that there is no, but activities for development are still going on. Also 23% of participants mentioned that there is an information system which is integrated to the enterprise information system. Only 8% responded that there is a stand-alone information system for technology management activities. Results are below in Figure 4 24.

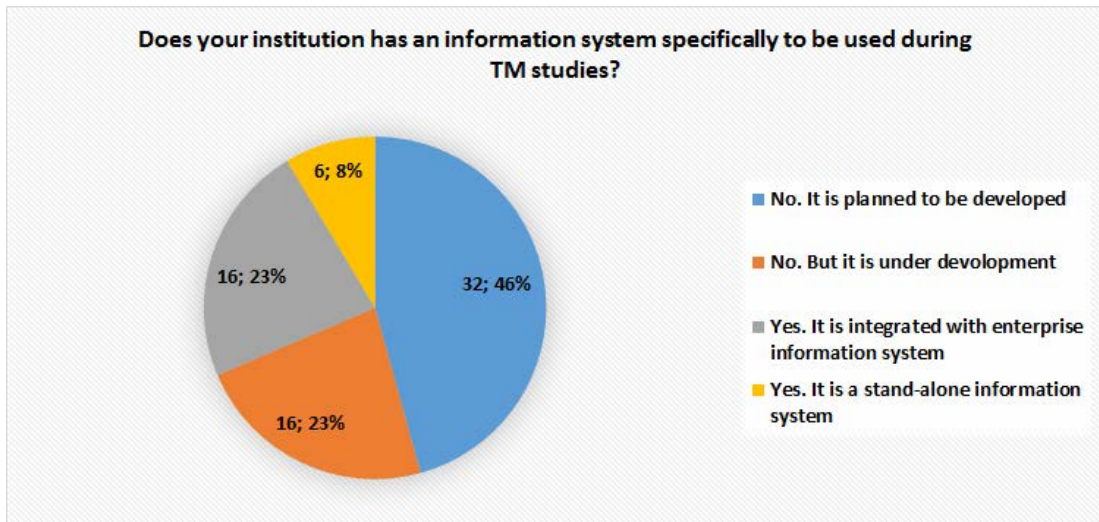


Figure 4-36 TM Information Systems

Availability of information systems especially for TM studies is analyzed. Approximately 85% of participants from Turkish Armed Forces replied that neither such systems exist nor planned to be developed. 37.5% of participants from Undersecretaries MoD and 40% of participants from Undersecretaries MoD for Defense Industries mentioned that there is an information system integrated to enterprise information system of institution as it is shown in Figure 4-37

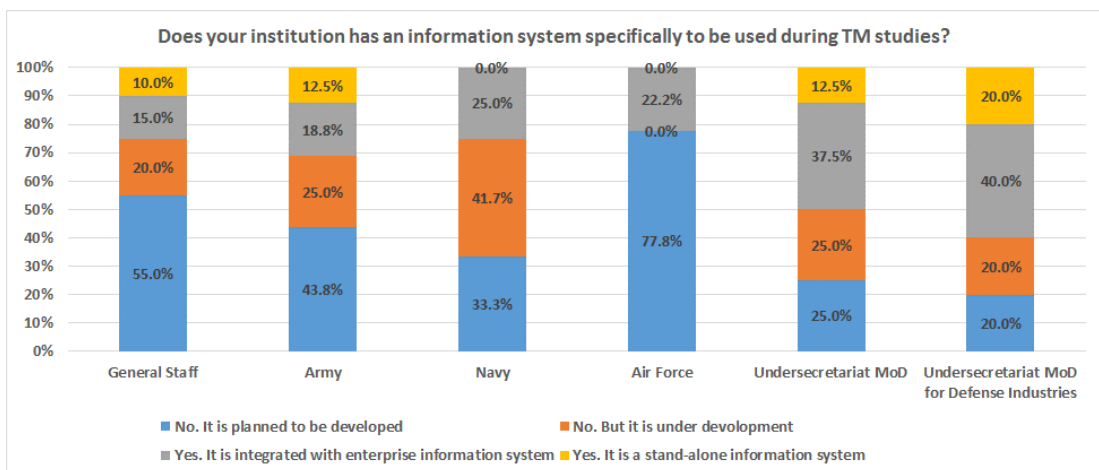


Figure 4-37 Information Systems for TM Studies.

Q20 : Figure 4-38 shows that there is no standard way to collect data according to 50% of survey participants. 37% of participants says data are collected when it is needed. Only 13% of respondents indicate that the data are collected systematically and regularly.

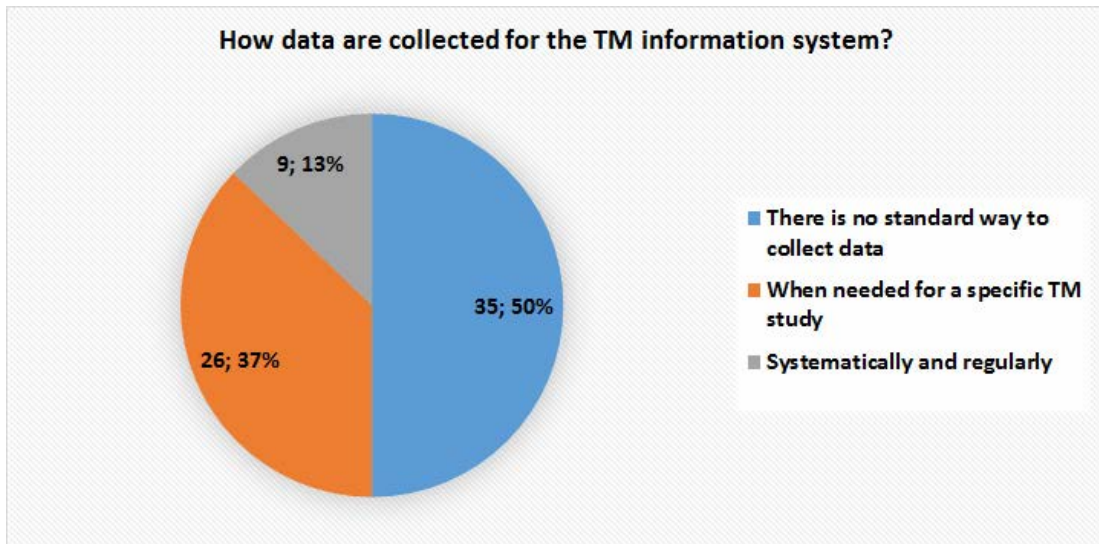


Figure 4-38 Data Collection for TM Information Systems

Among the institutions, there is no systematic and regular way to collect data for TM Information Systems. 50% of participants agreed that there is no standard way to collect data for a specific TM studies as it is shown in Figure 4-39. There is no difference among institutions.

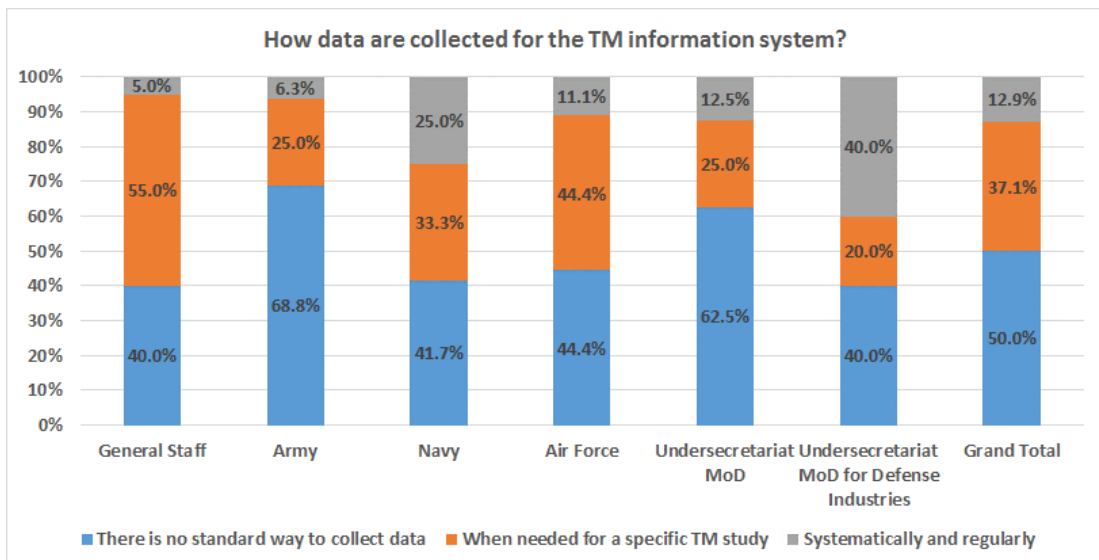


Figure 4-39 Data Collection for Information Systems by Institutions

Q21 : Almost 50% of the participants mentioned that systematic and regular data for TM system was provided by institutions within the institution and other services in Ministry of Defense. Other data resources are independent research institutions, public research establishments, private sector defense firms, academic institutions, foundations and associations as it is shown in Figure 4-40.

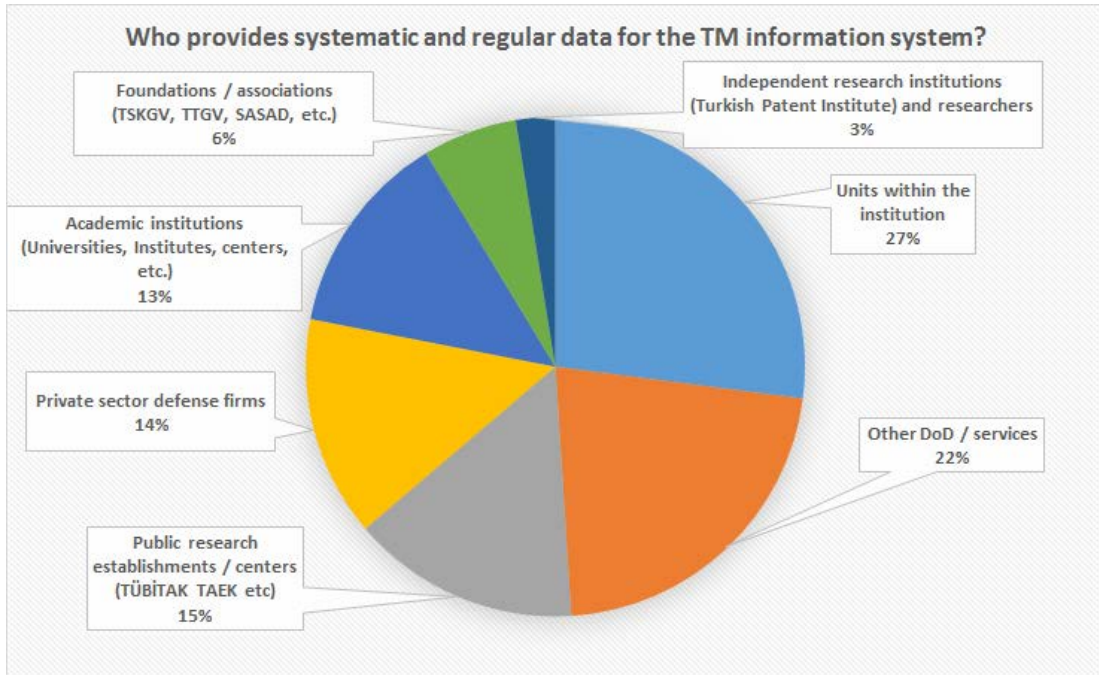


Figure 4-40 Data Sources for Technology Management

Data sources for regular data for TM information systems were analyzed and graphed by institutions as Figure 4-41. There is no difference among institutions.

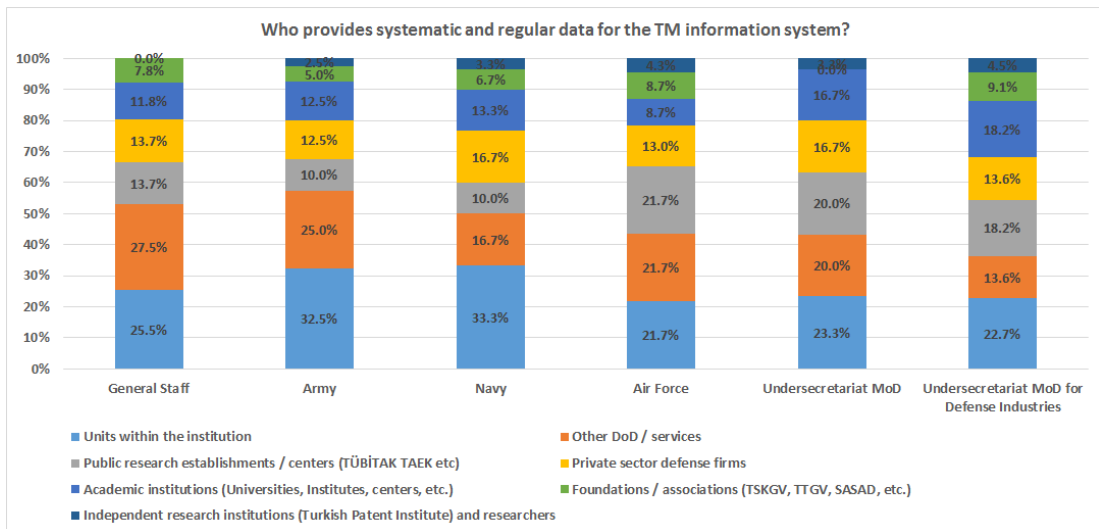


Figure 4-41 Data Sources for Information Systems in TM Studies by Institutions.

Q22 : Figure 4-42 shows that only 31% of the participants think that data stored in TM Information system are updated on a regular basis. Secrecy and security of the data is ensured according to 26% of participants. The percentage of validation and verification of the data from different sources is 29%.

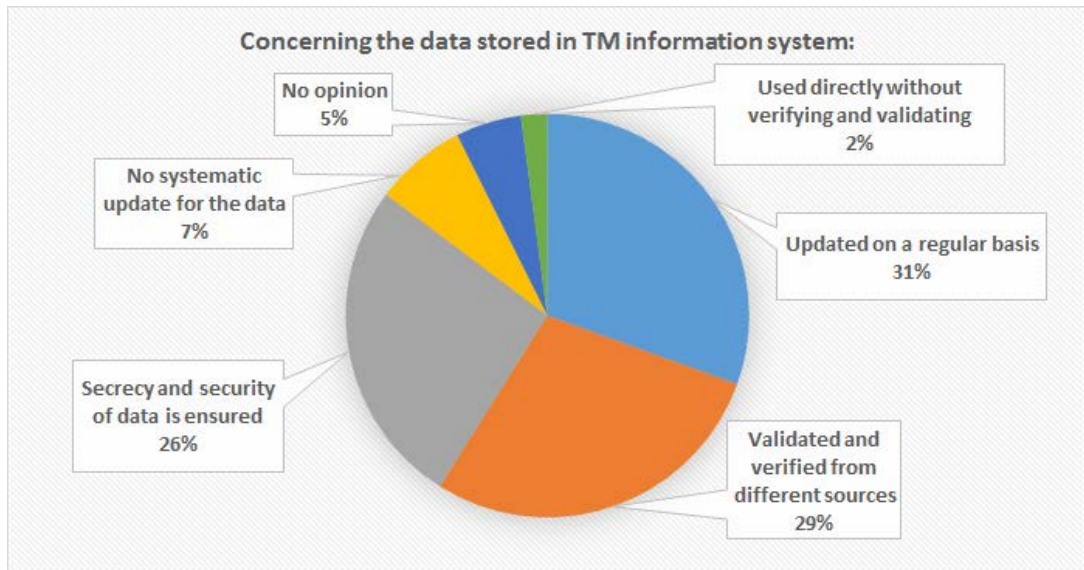


Figure 4-42 State of Data Stored in TM Information System.

Data usability for TM studies were analyzed and graphed below by institutions as shown in Figure 4-43. There is no difference among institution.

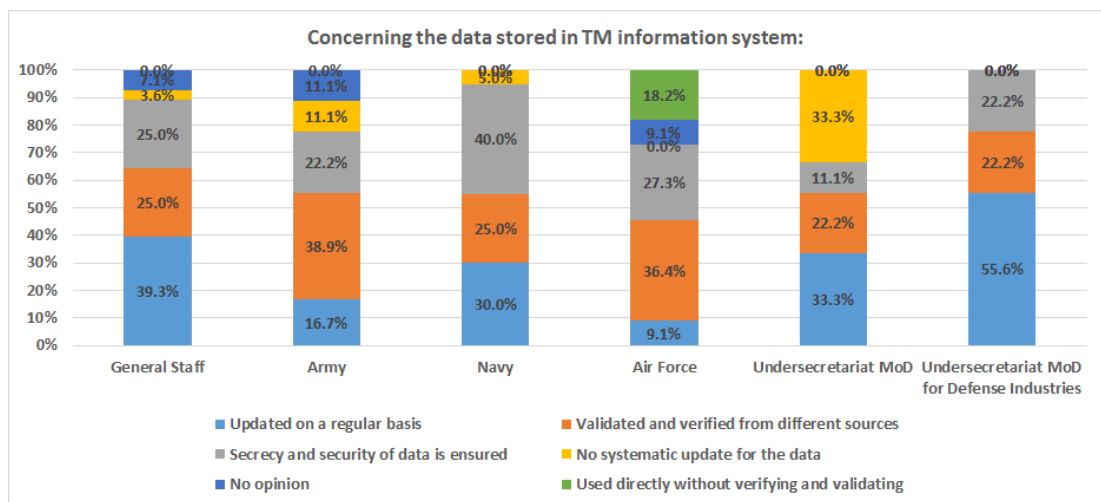


Figure 4-43 State of Data stored in TM Information System by Institutions.

Q23 : Sharing data is an important issue in defense because of the security and secrecy. For this reason participants think that 46% of data stored in their institution's unit. If there are technological management activities with the public institutions which are the stakeholders of common projects, then they share the data with them at a percentage of 36 as it is shown in Figure 4-44.

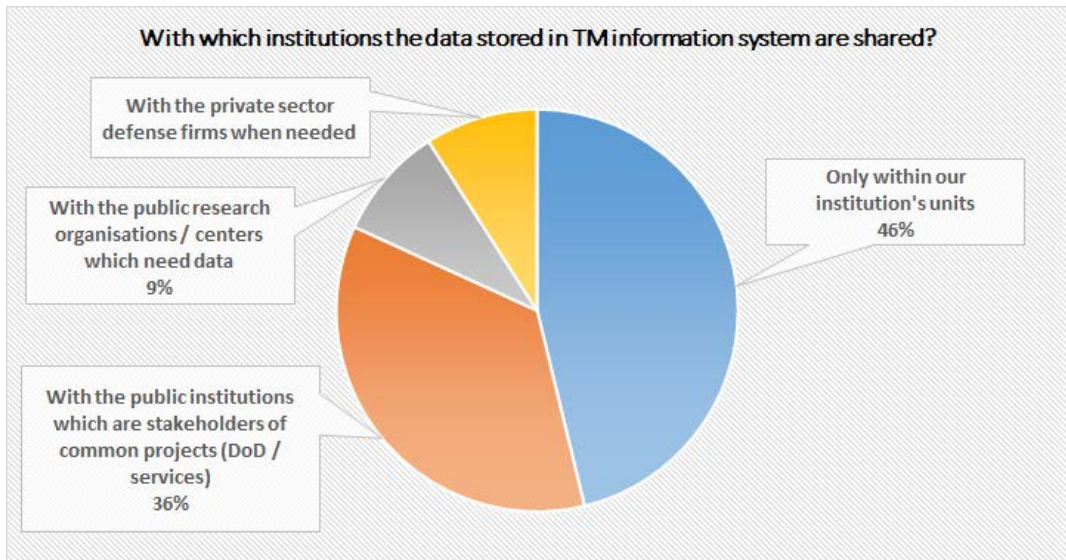


Figure 4-44 Data Sharing with Other Institutions

Data sharing in TM information systems were analyzed and graphed below by institutions as it is shown in Figure 4-45. Big percentage of participants keeps data within their organizations and there is no difference among institutions.

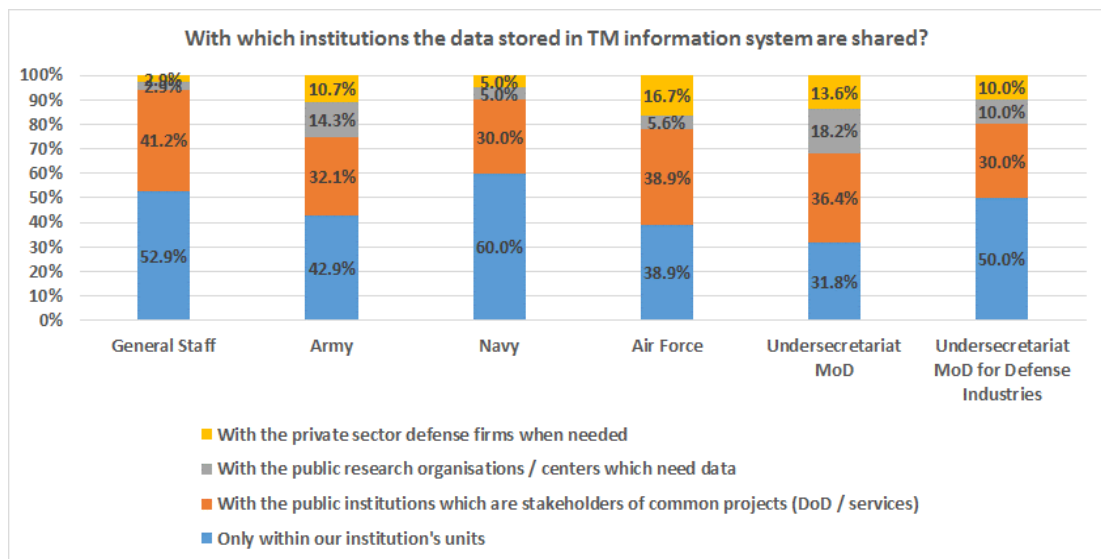


Figure 4-45 Data Sharing from Information Systems in TM Studies by Institutions.

Q24 : Figure 4-46 shows that 90% of participants mentioned that when they need data for TM processes, they obtain it manually.

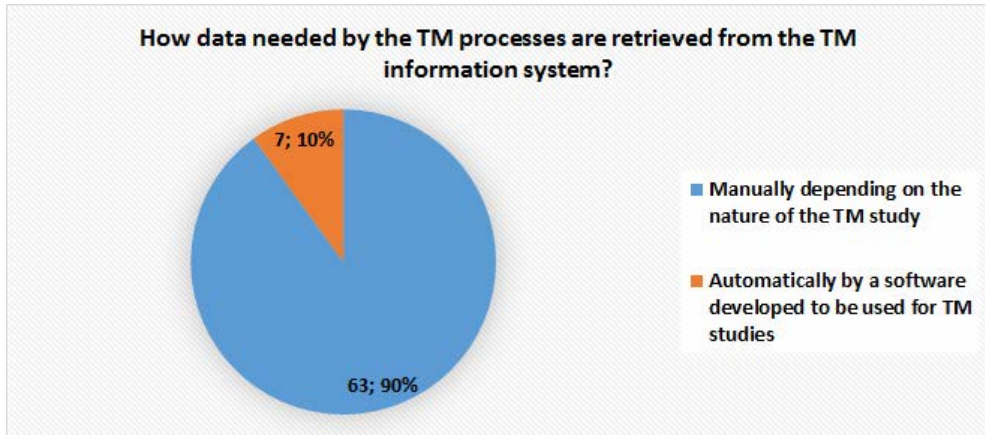


Figure 4-46 Data Retrieval from TM Information System.

Data is retrieved from TM information systems manually by institutions as it is shown in Figure 4-47. Big percentage of participants retrieves data manually and there is no difference among institutions.

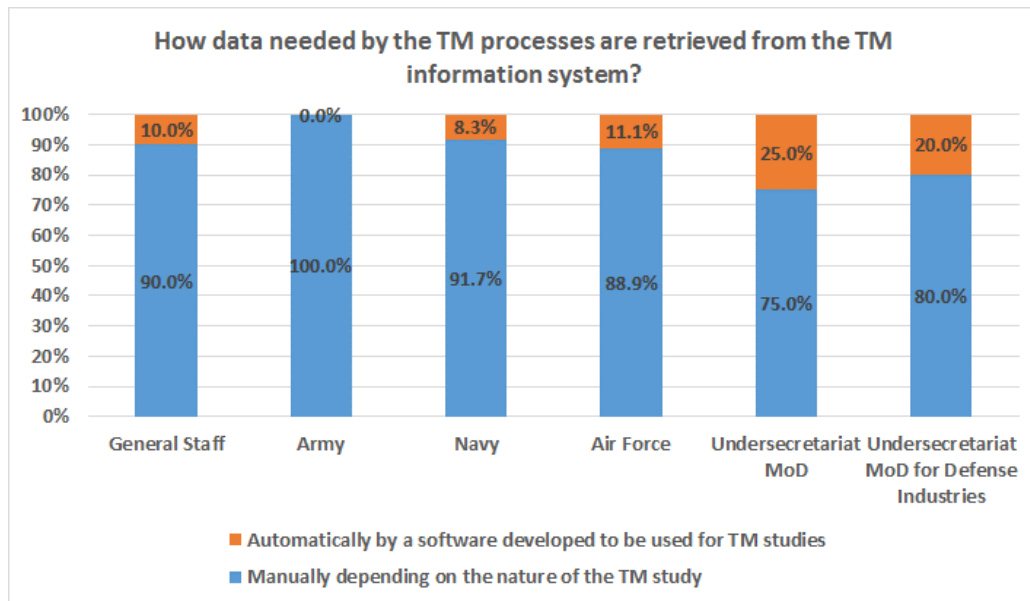


Figure 4-47 Data Retrieval Method from Information Systems in TM Studies by Institutions.

- **Is there any efforts and initiatives to improve better use of technology management within the organization?**

Q25 : Monitoring technology related studies in academia are achieved by every institutions on an average level. MoD institutions are better than Armed Forces institutions as it is shown in Figure 4-48.

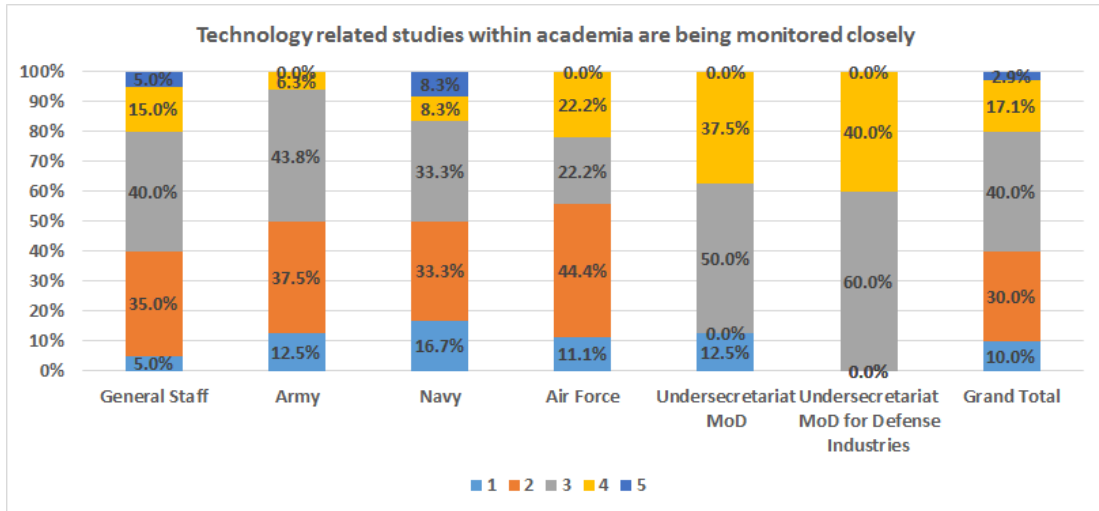


Figure 4-48 Monitoring Technology Related Studies in Academia by Institutions.

Q26 : Close co-operation and bi-lateral relations with international organizations and other countries are achieved by every unit. Undersecretariat MoD, Turkish General Staff Headquarters and Navy are better than other institutions as it is shown in Figure 4-49.

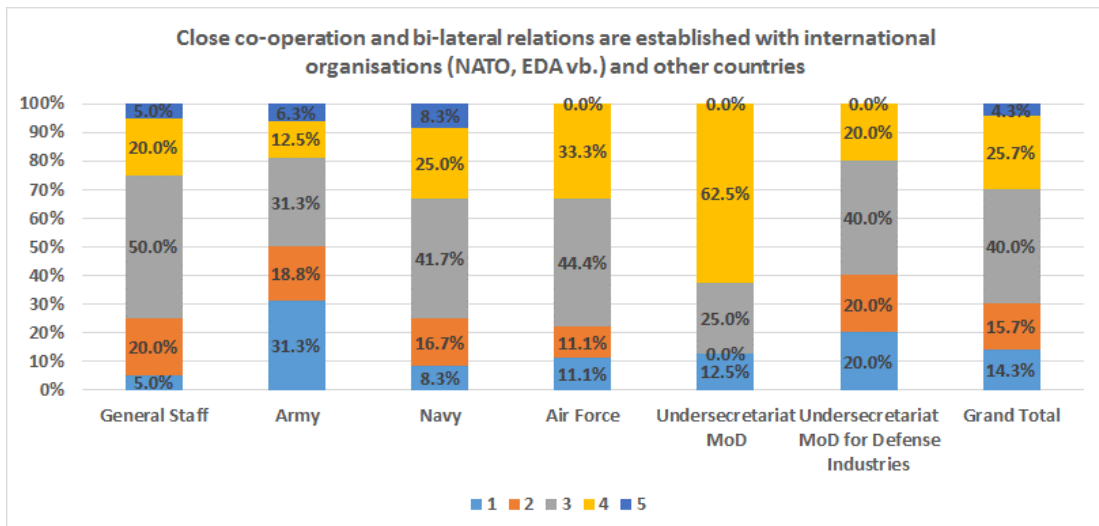


Figure 4-49 Co-operations with Other Organizations and Countries.

Q27 : Open source databases are used to collect data for TM related studies by every unit. Undersecretariat MOD, Turkish General Staff Headquarters and Navy are better than other institutions as it is shown in Figure 4-50.

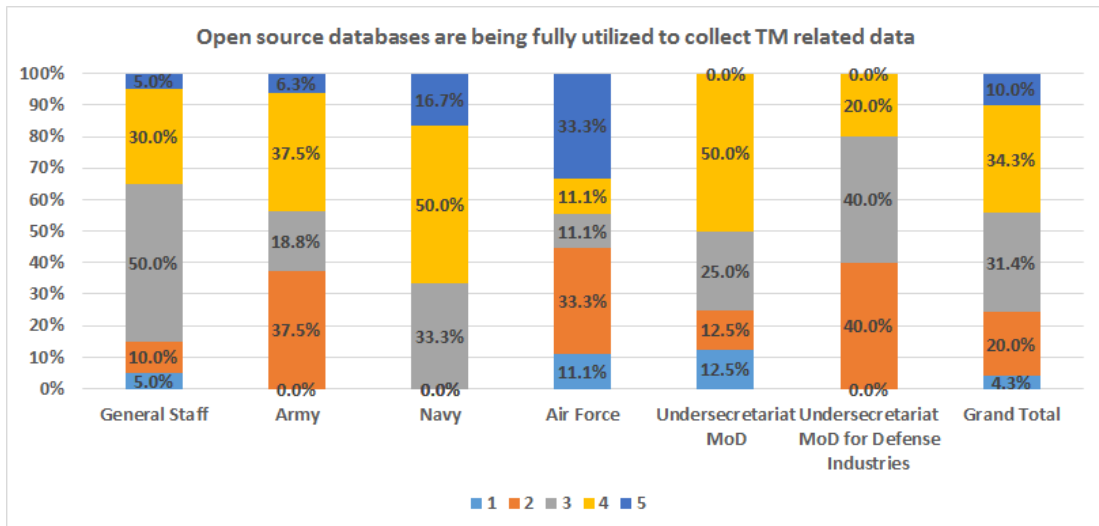


Figure 4-50 Use of Open Source Data in TM Activities

Q28 : Patent databases are being examined to search for new technologies by every unit. Undersecretariat MoD and Undersecretariat for Defense Industries are better than other institutions as it is shown in Figure 4-51.

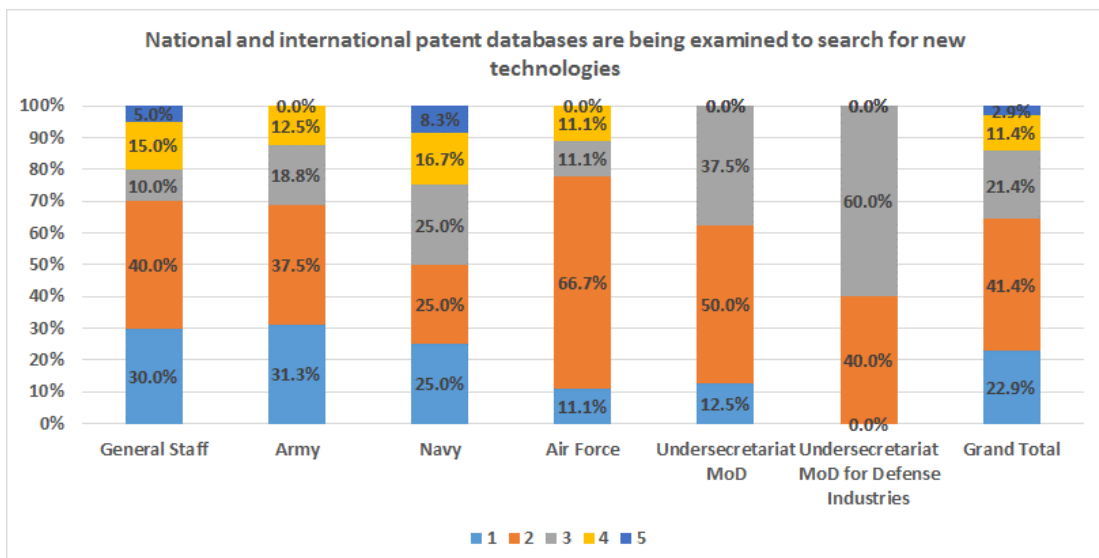


Figure 4-51 Patent Analysis for New Technologies

Q29 : Technology related activities such as fairs, exhibitions and demonstrations are being followed actively by institutions. The participants mentioned that this activity is a better activity for technology monitoring among all institutions. Their percentages are close to each other as it is shown in Figure 4-52.

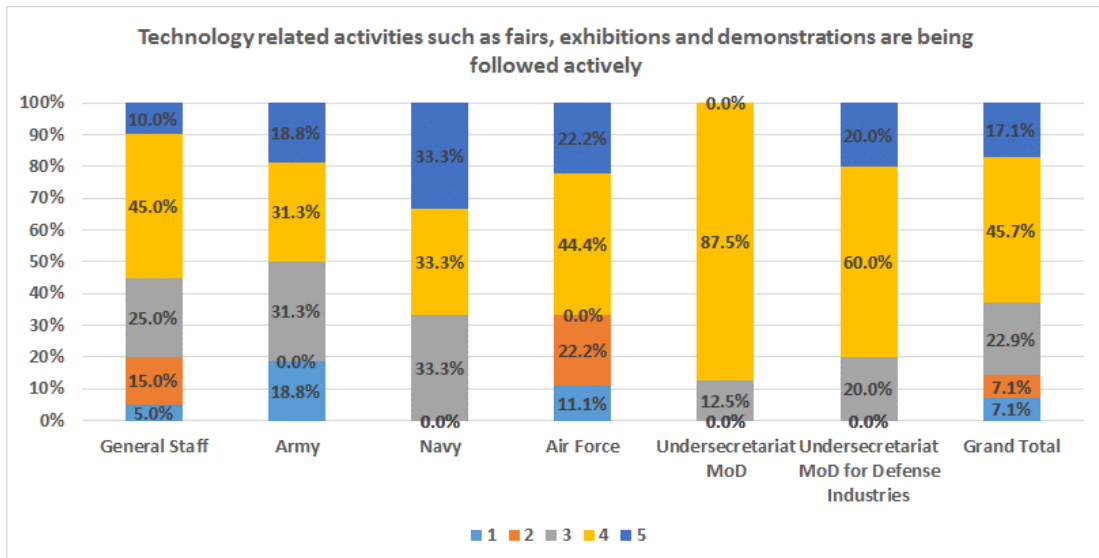


Figure 4-52 Fairs Exhibitions and Demonstrations Monitoring for New Technologies

Q30 : Technological resources and capabilities are being identified, categorized and evaluated by institutions. Their percentages are close to each other except Army as it is shown in Figure 4-53

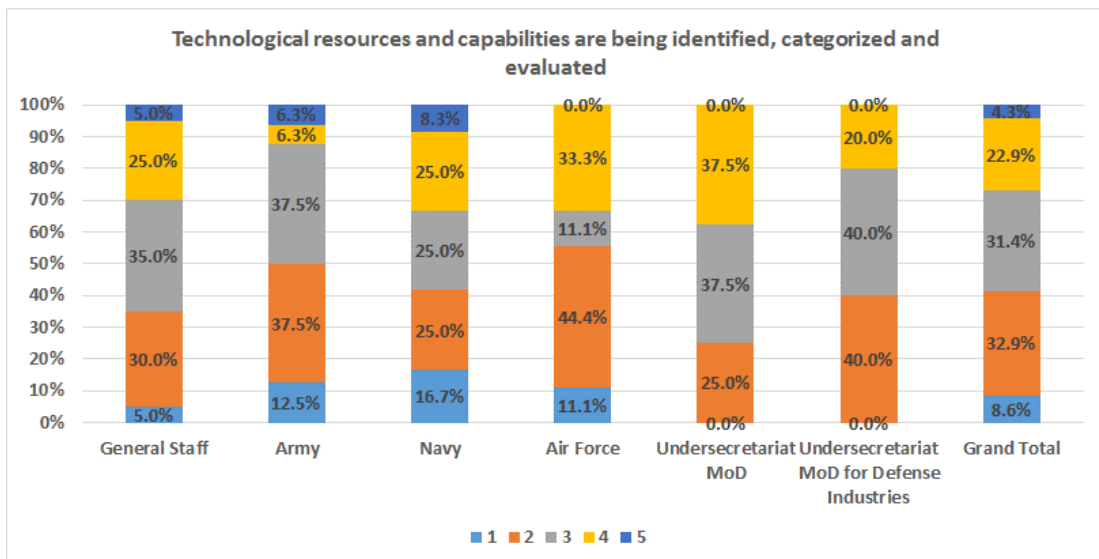


Figure 4-53 Technological Resources and Capability Estimation

ANOVA analysis of Questions 25 through 30 shows that there is no significance between the institutions.

- **What is the human resources policies and what are the training activities for the personal development of staff on technology management?**

Q31 : Manpower requirements are being planned and experts on TM are being employed by institutions. The percentages of Turkish Armed Forces and Undersecretariat Ministry of Defense are close to each other. Navy, Undersecretariat Ministry of Defense and Undersecretariat Ministry of Defense for Defense Industries are close to each other except Army as it is shown in Figure 4-54

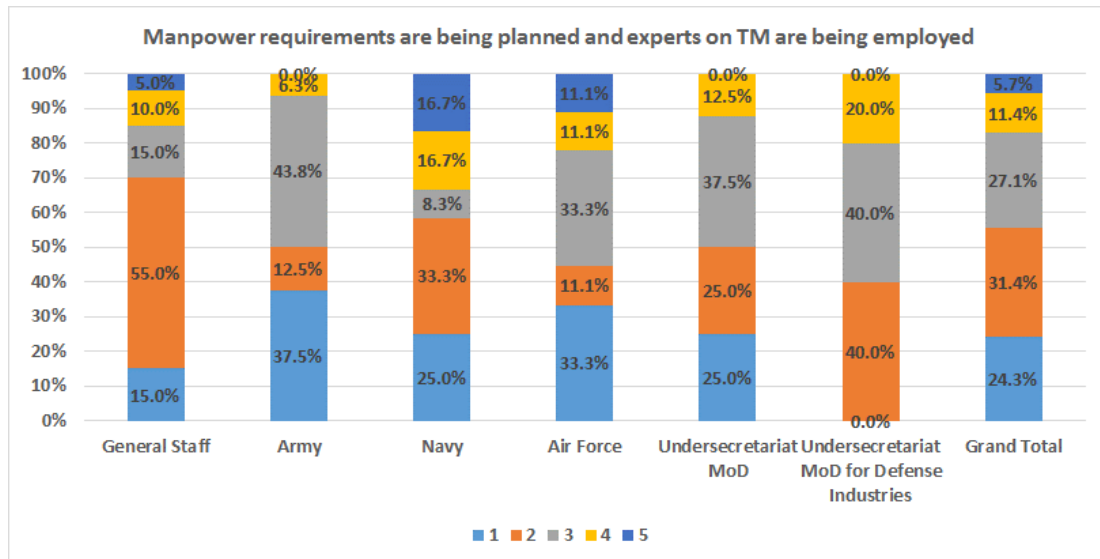


Figure 4-54 Manpower Planning for TM Positions.

Q32 : Training and education of personnel working on TM are planned and realized by institutions. The percentages of all institutions are close to each other as it is shown in Figure 4-55.

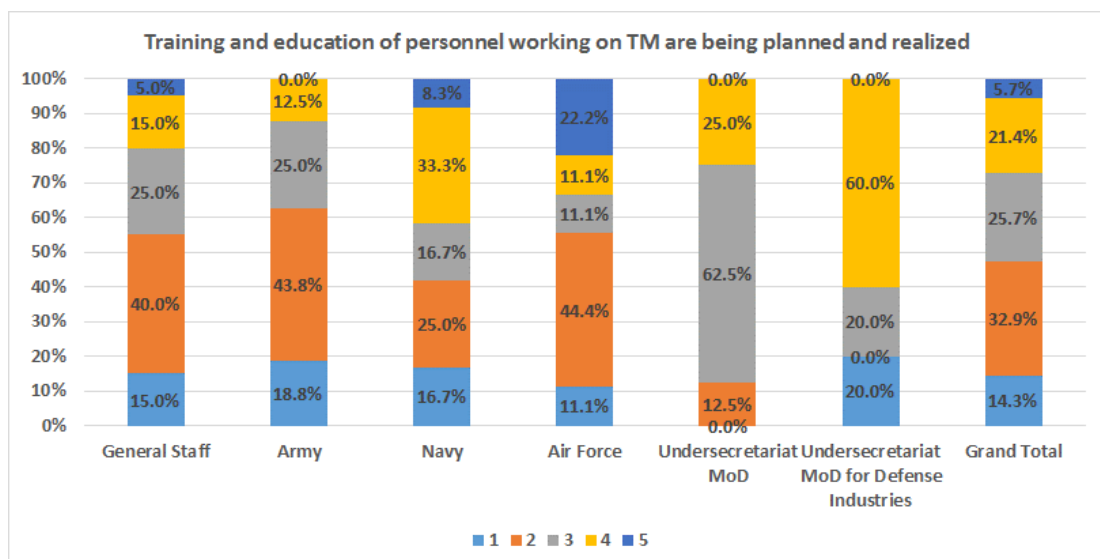


Figure 4-55 Manpower Training and Education for TM Activities.

- **How well is the TM activities usage level between the institutions?**

Q33 : Maturity levels of newly developed and emerging technologies is being determined and monitored regularly. The percentages of all institutions are close to each other as it is shown in Figure 4-56.

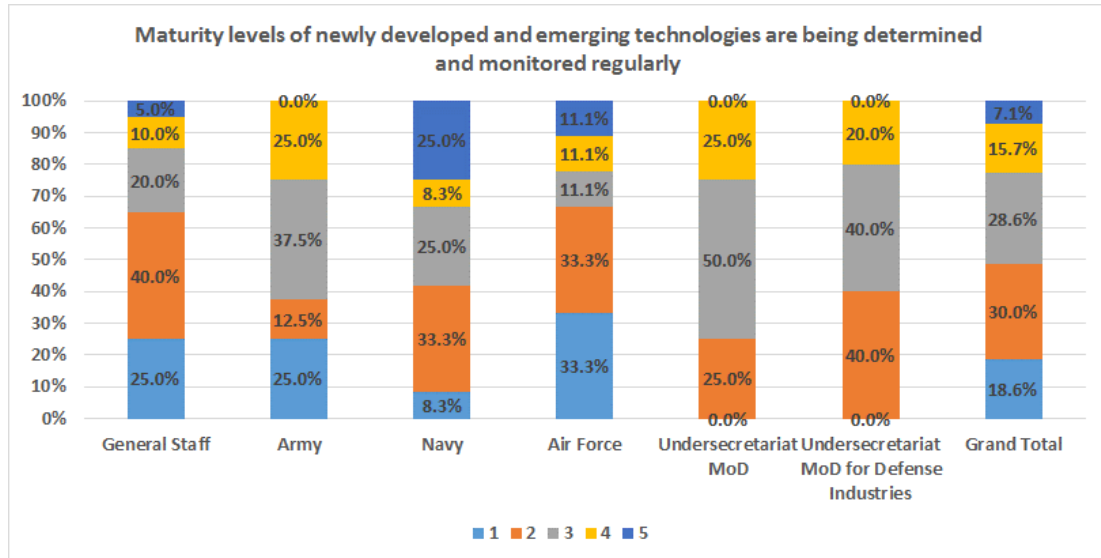


Figure 4-56 Maturity Determination and Monitoring of Technologies.

Q34 : System and technology readiness levels of planned defense systems are being determined and monitored regularly. The percentages of all institutions are close to each other as it is shown in Figure 4-57.

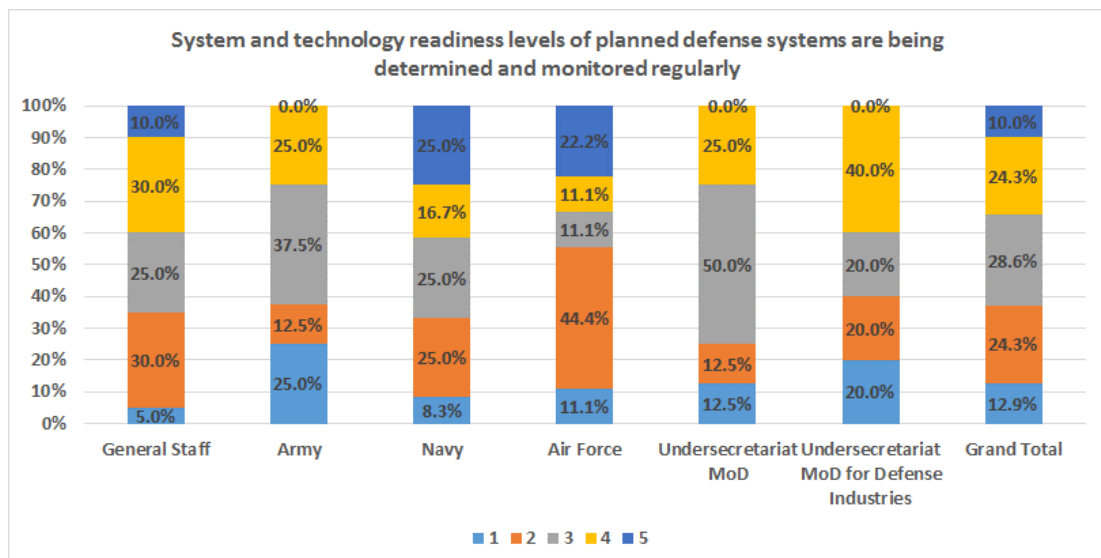


Figure 4-57 Technologies/Systems Readiness Levels

Q35 : Evaluations for the future use of technologies and technological products are being performed by all institutions. Turkish General Staff and Navy have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-58.

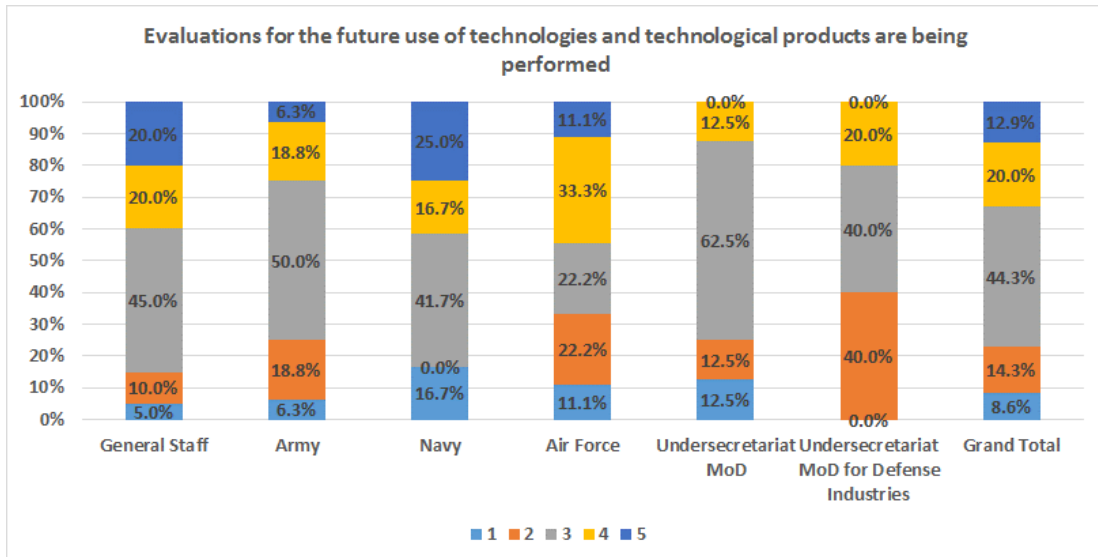


Figure 4-58 Technological Evaluations

Q36 : Roadmaps concerning the future development of technologies and technological products are being developed by institutions. Air Force and Navy have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-59.

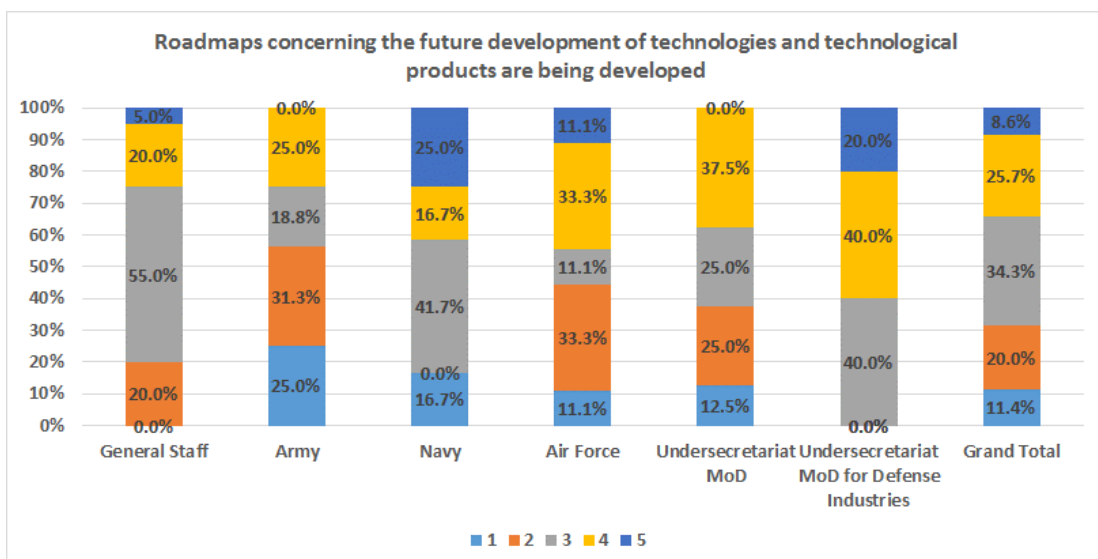


Figure 4-59 Technology Roadmaps Development

Q37 : Impact analysis for the new technologies is being conducted by institutions. The percentages of all institutions are close to each other as it is shown in Figure 4-60.

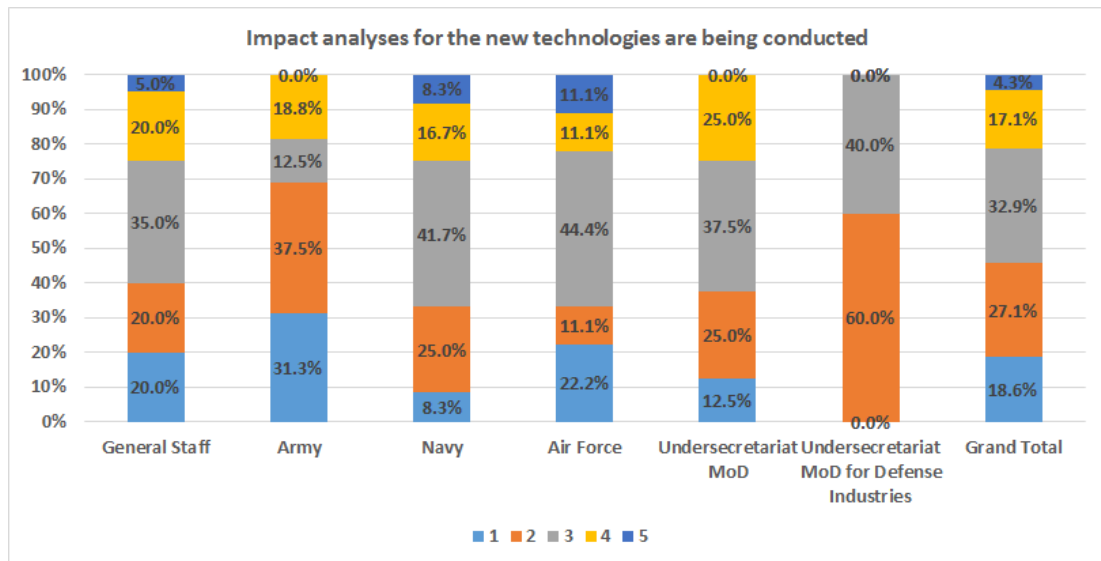


Figure 4-60 Technology Impact Analysis

Q38 : Technology options for the system development projects are being evaluated by institutions. The percentages of all institutions are close to each other as it is shown in Figure 4-61.

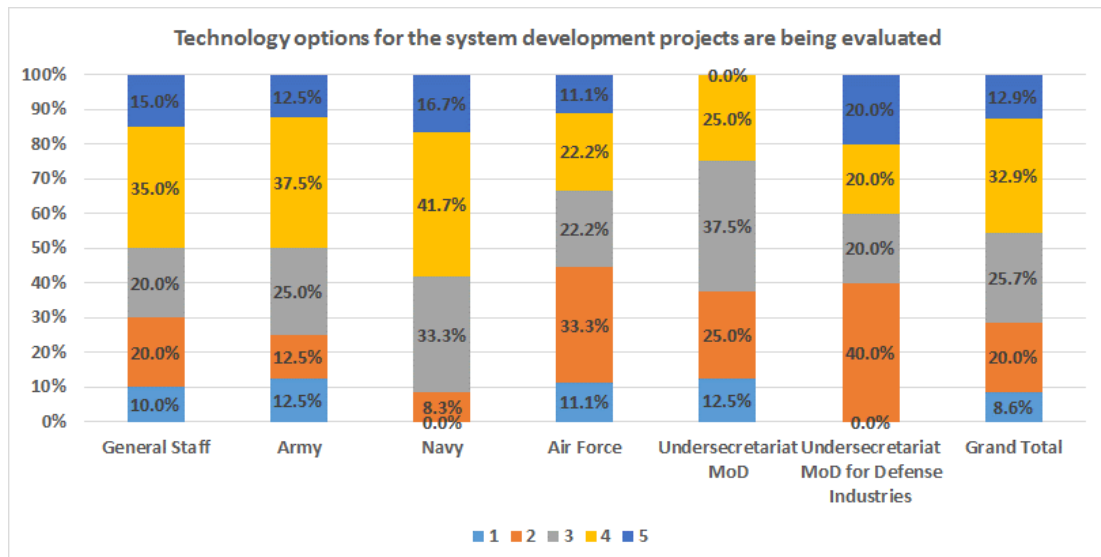


Figure 4-61 Technology Options Analysis

ANOVA analysis of Questions 33 through 38 on TM activities usage in institutions shows that there is a significant difference between institutions at $\alpha=0.1$ level as seen in ANOVA Table 4-2 since $F > F_{crit}$.

Table 4-2 ANOVA Table for TM Activities Usage by Institutions

Anova: Single Factor						
$\alpha=0.1$						
SUMMARY						
Groups	Count	Sum	Average	Variance		
General Staff	6	18.1	3.016666667	0.106666667		
Army	6	15.8125	2.635416667	0.170963542		
Navy	6	19.41666667	3.236111111	0.081712963		
Air Force	6	17.55555556	2.925925926	0.013168724		
UMoD	6	17.125	2.854166667	0.021354167		
UMoD DI	6	18.2	3.033333333	0.230666667		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.21184569	5	0.242369138	2.328484578	0.066989088	2.049246081
Within Groups	3.122663645	30	0.104088788			
Total	4.334509334	35				

To find the source of difference between institutions, paired t-tests were applied at $\alpha=0.05$ level as seen in Table 4-3.

Table 4-3 t-Tests: Paired Two Sample for Means for TM Activities Usage

t-Test: Paired Two Sample for Means			t-Test: Paired Two Sample for Means		
$\alpha=0.05$			$\alpha=0.05$		
	TGS	Army		TGS	Navy
Mean	0.603	0.527	Mean	0.603	0.647
Variance	0.004	0.007	Variance	0.004	0.003
Observations	6	6	Observations	6	6
Pearson Correlation	0.827		Pearson Correlation	0.851	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	5		df	5	
t Stat	4.008		t Stat	-3.130	
P(T<=t) one-tail	0.005		P(T<=t) one-tail	0.013	
t Critical one-tail	2.015		t Critical one-tail	2.015	
P(T<=t) two-tail	0.010		P(T<=t) two-tail	0.026	
t Critical two-tail	2.571		t Critical two-tail	2.571	
t-Test: Paired Two Sample for Means			t-Test: Paired Two Sample for Means		
$\alpha=0.05$			$\alpha=0.05$		
	Navy	Air Force		Army	Navy
Mean	0.647	0.585	Mean	0.527	0.647
Variance	0.003	0.001	Variance	0.007	0.003
Observations	6	6	Observations	6	6
Pearson Correlation	0.414		Pearson Correlation	0.892	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	5		df	5	
t Stat	2.920		t Stat	-7.187	
P(T<=t) one-tail	0.017		P(T<=t) one-tail	0.000	
t Critical one-tail	2.015		t Critical one-tail	2.015	
P(T<=t) two-tail	0.033		P(T<=t) two-tail	0.001	
t Critical two-tail	2.571		t Critical two-tail	2.571	

It is obvious that the Navy is at the best position since the p -value $< \alpha=0.05$. General Staff, Army and Air Force follows the Navy respectively.

Q39 : Technology capabilities of defense industry firms are being measured by institutions. Turkish General Staff Headquarter, Air Force, Navy and Undersecretariat MoD for Defense Industries have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-62.

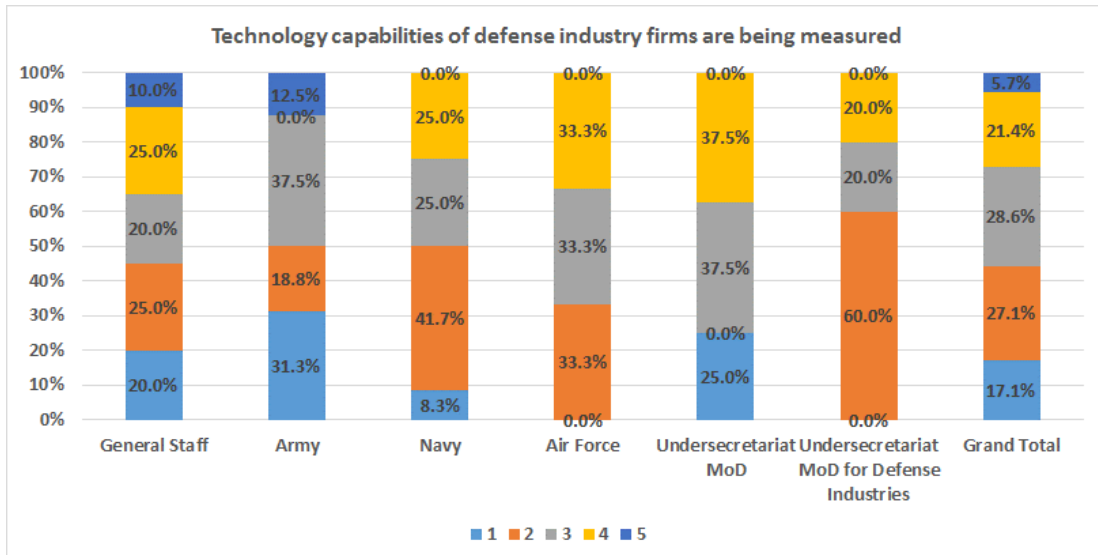


Figure 4-62 Technology Capability Analysis by Institutions

Q40 : Comparison and bench-marking of defense industry firms against other national and international firms are being conducted by institutions. Turkish General Staff, Navy and Undersecretariat MoD for Defense Industries have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-63.

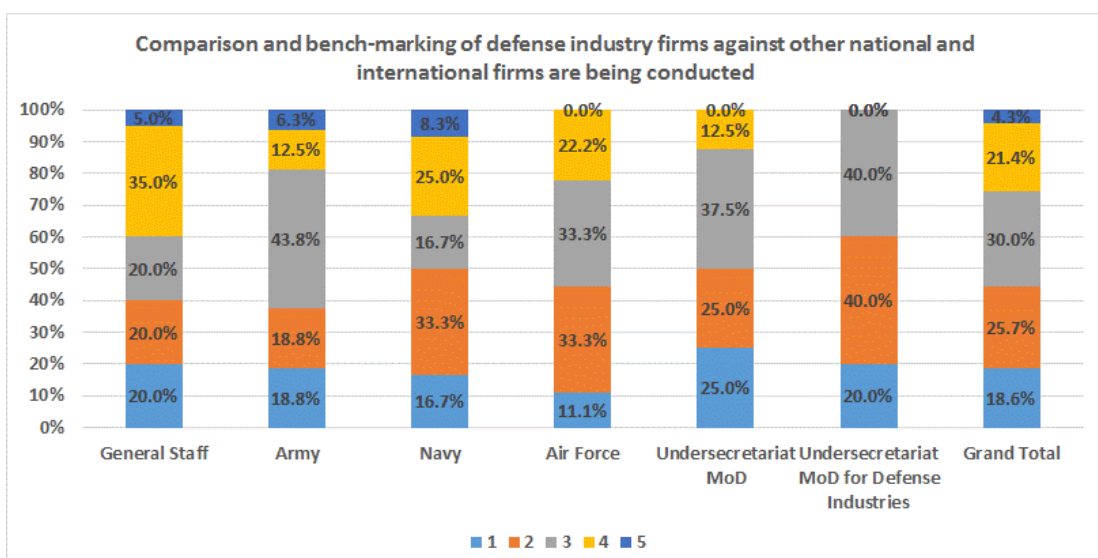


Figure 4-63 Benchmarking of Firms' Technology Capabilities by Institutions

Q41 : Inventory of technological assets of defense industry firms is being identified by institutions. The percentages of all institutions are close to each other except Army as it is shown in Figure 4-64.

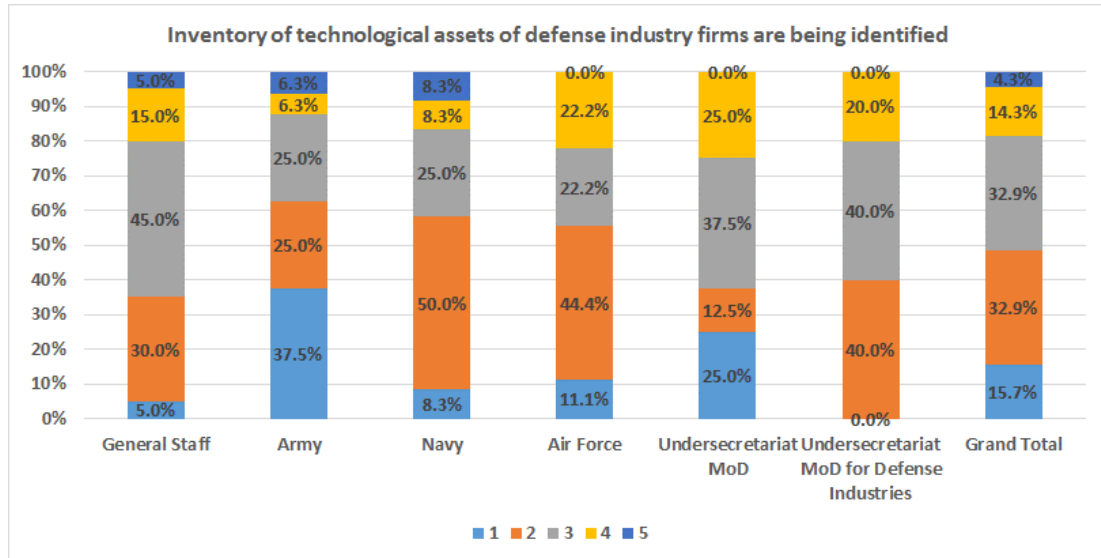


Figure 4-64 Identification of Technological Assets of Firms by Institutions

Q42 : Strength and weakness of defense industry firms are being identified and value and gap analyses are being conducted. Turkish General Staff Headquarters and Undersecretariat MoD for Defense Industries have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-65.

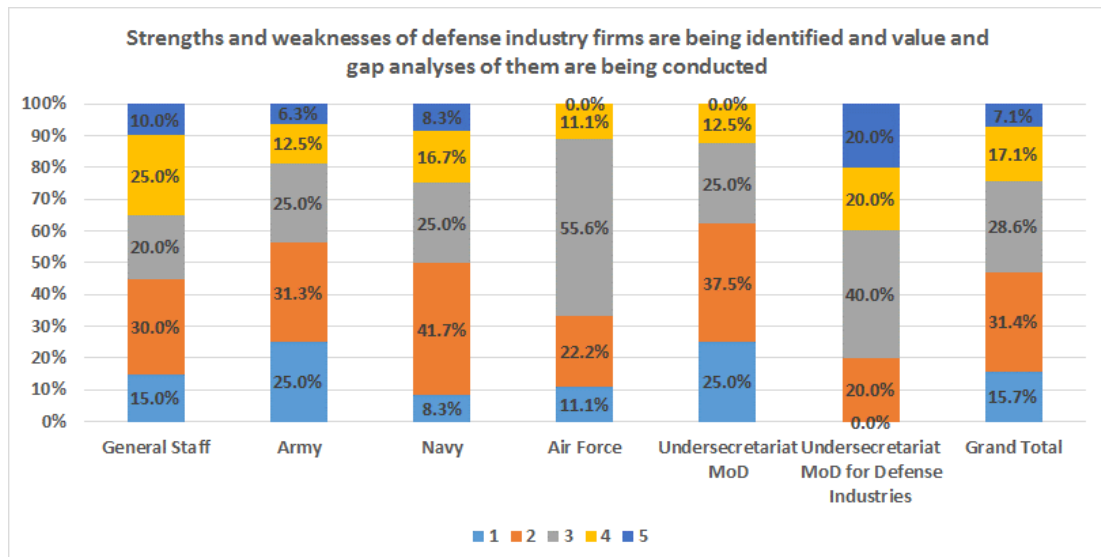


Figure 4-65 Strengths and Weaknesses and Gap Analysis of Firms by Institutions

4.3.2.2 Analysis Results of TM Usage Level

Defense TM activities and their usage levels by institutions are presented in Table 4-4.

Table 4-4 Defense TM Activities and Their Usage by Institutions

Defense TM Activities	Usage	General Staff	Army	Navy	Air Force	UMoD	UMoD for DI
Technology Intelligence		3.52%	3.80%	4.00%	3.28%	10.00%	3.70%
Technology Auditing		11.27%	16.46%	16.00%	8.20%	8.00%	7.41%
Technology Forecasting and Technology Impact Assessment on Future Operating Environments		25.35%	24.05%	24.00%	31.15%	24.00%	20.37%
Technology Strategy Analysis and Development, Technology Planning and Strategic Decision Making on Technologies		7.04%	5.06%	5.33%	4.92%	6.00%	5.56%
Technology Related Strategy/ Concept Development & Experimentation		4.93%	6.33%	8.00%	6.56%	12.00%	5.56%
Technology Ownership and Competence Level Measurement		4.23%	2.53%	0.00%	4.92%	4.00%	3.70%
Gap and Value Analysis & Benchmarking		3.52%	2.53%	5.33%	3.28%	2.00%	3.70%
R&D Management		7.75%	7.59%	8.00%	3.28%	10.00%	9.26%
Technology Transfer for Defense Projects		2.11%	6.33%	6.67%	4.92%	8.00%	7.41%
Knowledge Management (Development of Standards, Common terminology and Providing Secrecy Security for IPRs)		9.15%	7.59%	4.00%	8.20%	2.00%	9.26%
Documentation and Dissemination of the Technology-related Work Findings		9.15%	11.39%	9.33%	9.84%	4.00%	9.26%
Maintenance of the Technology Resource Base Inventory		3.52%	2.53%	5.33%	6.56%	4.00%	7.41%
Refinement and Maintenance of CST & STCN Lists		8.45%	3.80%	4.00%	4.92%	6.00%	7.41%

It can be said that TM usage level and the required TM activities tools to support this usage are not at the required level.

Therefore it's necessary to improve the effectiveness of defense planning cycle by better mounting these TM activities to enable defense planners to perform their TM roles or functions well.

4.3.3 TM Usage in Defense Planning

To measure the TM usage in defense planning, questions identified in the survey objectives were asked in detail to the audience as explained in the following paragraphs. Questions 43 through 49 are intended to measure the level of TM usage in defense planning among defense community.

4.3.3.1 Analysis of TM Usage in Defense Planning

- **How well the importance of future warfighting concepts of armed forces and their corresponding technological concepts are known among defense planners?**

Q43 : The future candidate technologies are being identified and shared with Armed Forces and Department of Defense by institutions. The percentages of all institutions are close to each other as it is shown in Figure 4-66.

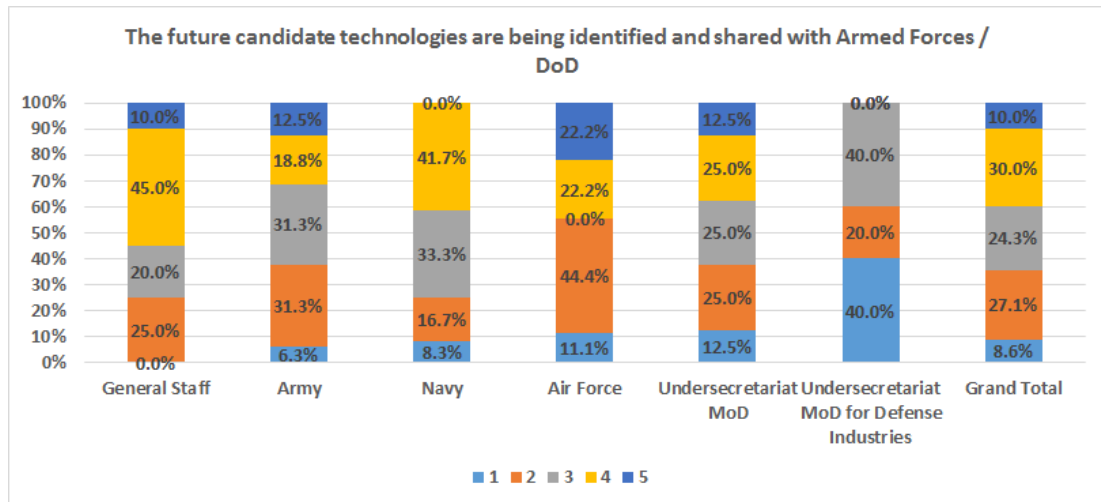


Figure 4-66 Future Candidate Technologies Identification by Institutes

Q44 : Future war-fighting concepts are being developed jointly with Armed Forces/Department of Defense by considering the future operating battlespace. Turkish General Staff Headquarters, Army, Air Force and Undersecretariat MoD for Defense Industries have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-67.

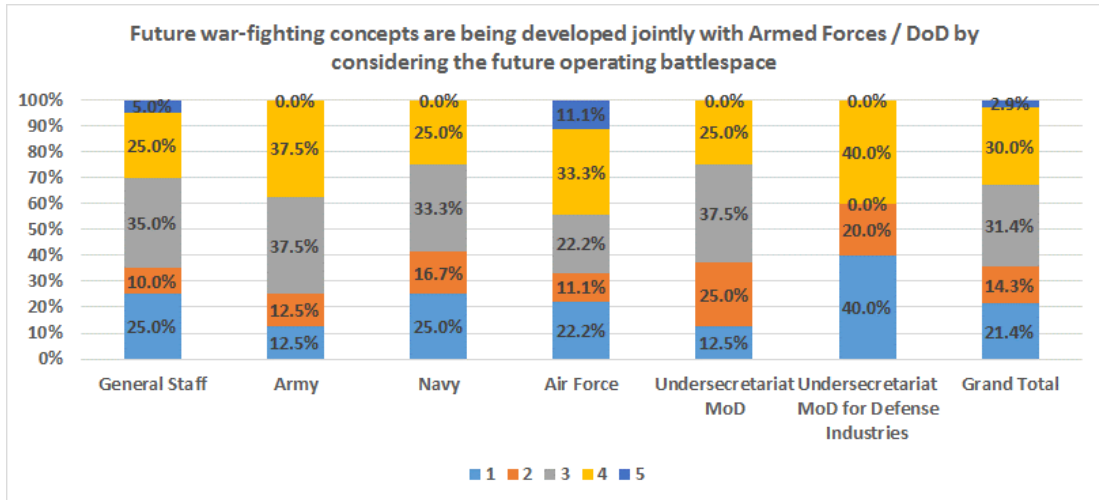


Figure 4-67 Technology Related Concept Development by Institutions

Q45 : Technological concepts involving future technologies are being developed in coordination with Armed Forces and Department by institutions. Turkish General Staff, Air Force and Undersecretariat MoD for Defense Industries have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-68.

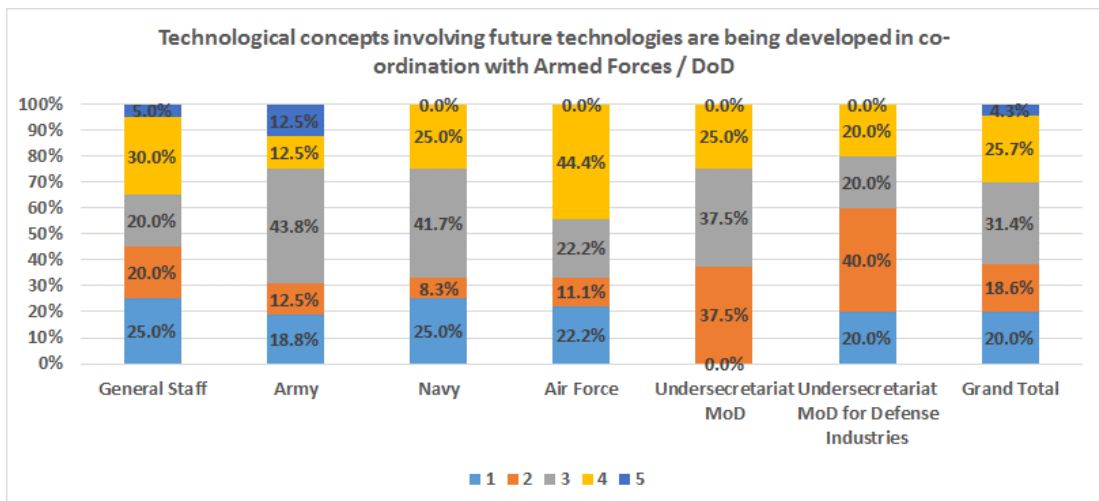


Figure 4-68 Technological Concept Development by Institutions

Q46 : Scenarios for the future operating environments are being generated by studying jointly with Armed Forces and Department of Defense by institutions. Turkish General Staff Headquarters, Air Force and Navy have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-69.

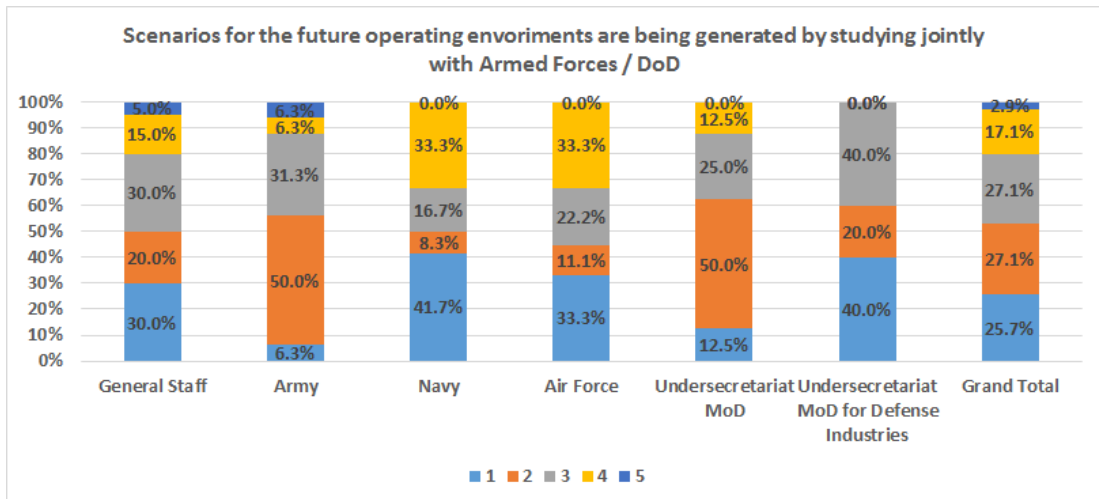


Figure 4-69 Scenario Generation for Future Environments by Institutions

Q47 : Future war-fighting concepts and technological concepts supporting such concepts are being experimented within generated scenarios and their impacts on future operating environment are being evaluated. Army, Air Force and Navy have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-70.

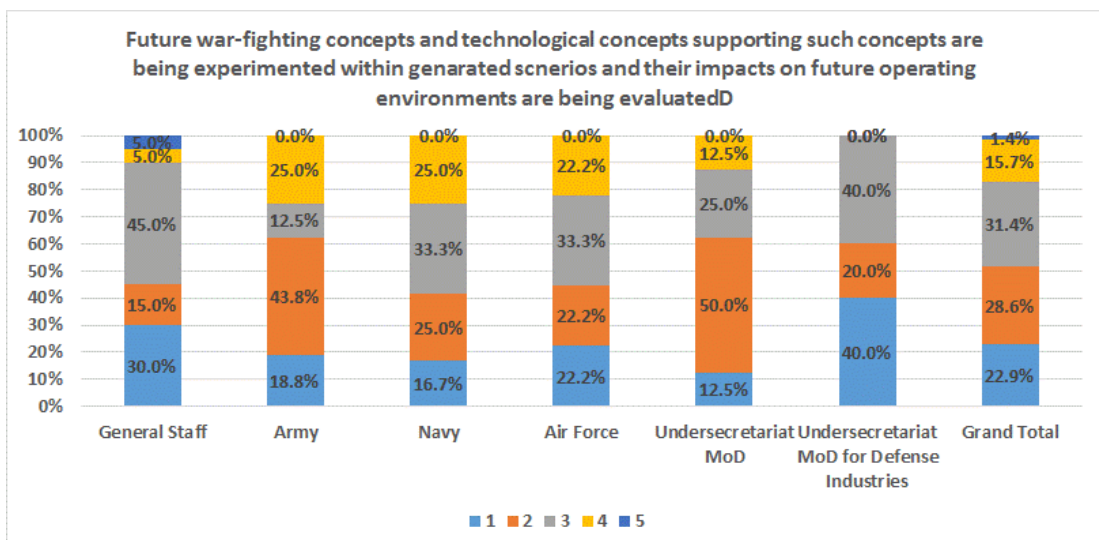


Figure 4-70 Concept Development and Experimentation by Institutions

Q48 : Future capability and system requirements are defined by considering the impact analyses results on future operating environments. The percentages of all institutions are close to each other except Navy as it is shown in Figure 4-71.

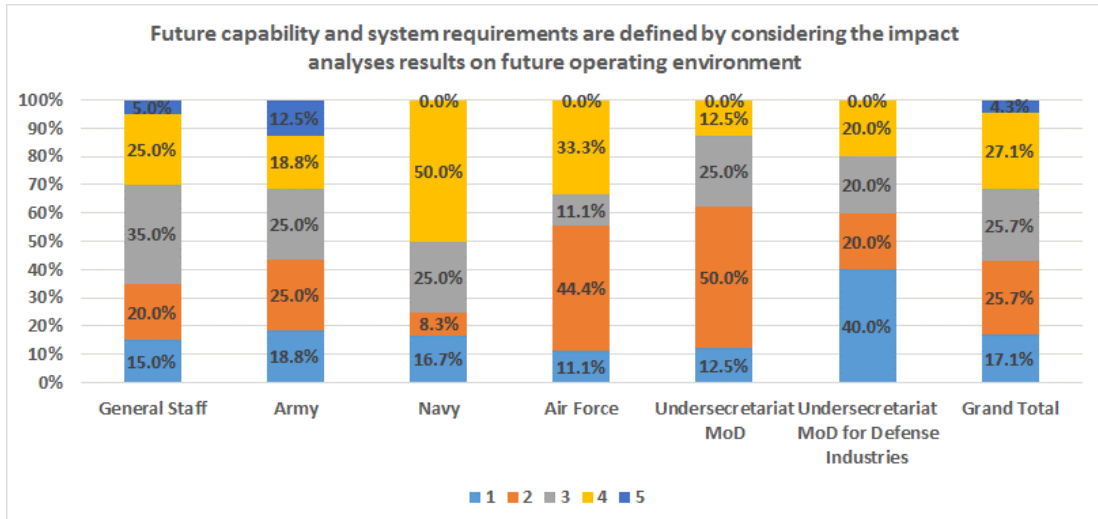


Figure 4-71 Future Capability and System Requirements

Q49 : Technology based roadmaps are being generated for the needed capability and system requirements. Air Force, Undersecretariat MoD for Defense Industries and Undersecretariat for MoD have better situation in this case. Their percentages are greater than the others as it is shown in Figure 4-72.

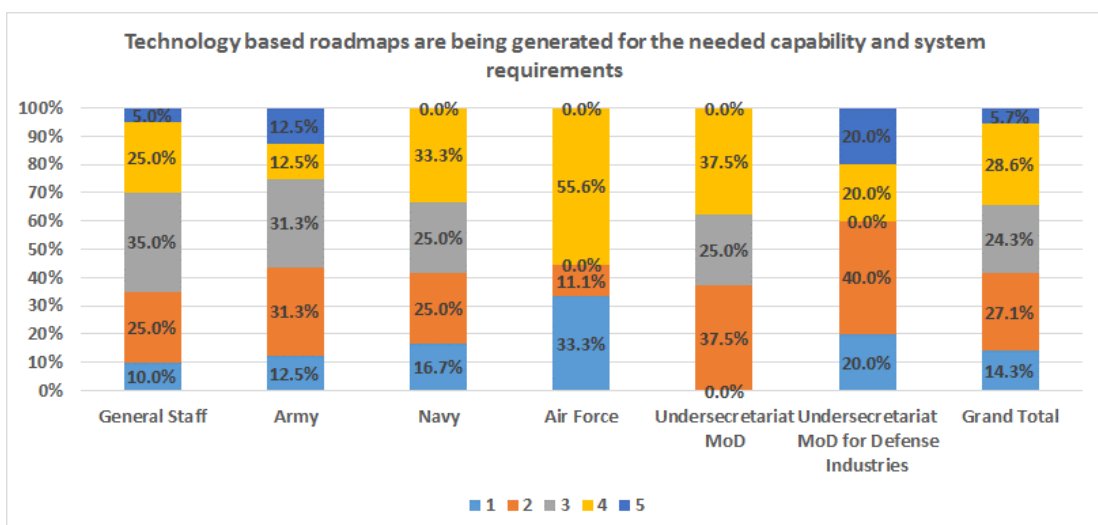


Figure 4-72 Technology Based Road Maps

ANOVA analysis of Questions 43 through 49 on TM usage in defense planning among institutions shows that there is a significant difference between institutions at $\alpha=0.05$ level as seen in ANOVA Table 4-5 since $F > F_{crit}$.

Table 4-5 ANOVA Table for TM Usage in Defense Planning by Institutions

Anova: Single Factor						
$\alpha=0.05$						
SUMMARY						
Groups	Count	Sum	Average	Variance		
General Staff	7	19.45	2.778571	0.110714		
Army	7	19.5	2.785714	0.045387		
Navy	7	19.25	2.75	0.0625		
Air Force	7	19.44444444	2.777778	0.037037		
UMoD	7	18.75	2.678571	0.087798		
UMoD DI	7	15.8	2.257143	0.089524		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.495956055	5	0.299191	4.146223	0.004464	2.477169
Within Groups	2.597757937	36	0.07216			
Total	4.093713992	41				

To find the source of difference between institutions, paired t-tests were applied at $\alpha=0.05$ level as seen in Table 4-6.

Table 4-6 t-Tests: Paired Two Sample for Means for TM Usage in Defense Planning

t-Test: Paired Two Sample for Means			t-Test: Paired Two Sample for Means		
$\alpha=0.05$			$\alpha=0.05$		
	AF	MoD		UMoD	UMoD DI
Mean	2.774	2.516	Mean	2.679	2.257
Variance	0.053	0.070	Variance	0.088	0.090
Observations	7	7	Observations	7	7
Pearson Correlation	0.563		Pearson Correlation	0.571	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	6		df	6	
t Stat	2.916		t Stat	4.041	
P(T<=t) one-tail	0.013		P(T<=t) one-tail	0.003	
t Critical one-tail	1.943		t Critical one-tail	1.943	
P(T<=t) two-tail	0.027		P(T<=t) two-tail	0.007	
t Critical two-tail	2.447		t Critical two-tail	2.447	

It is clear that the Armed Forces are better than all MoD since the p -value $< \alpha=0.05$. Undersecretariat MoD for Defense Industries is better than Undersecretariat for MoD in terms of TM Usage in Defense Planning.

4.3.3.2 Analysis Results of TM Usage in Defense Planning

TM usage levels in defense planning are at medium level. There is also significant differences among the institutions.

CHAPTER 5

FUNCTIONAL MODEL DEVELOPMENT

5.1 Definition of Defense TM Functions

As discussed in the previous chapter, it is more suitable to define the role of technology management in defense domain as TM functions rather than TM processes or TM activities. In defense planning context, technology management related studies are conducted to support decision making and strategic planning in different phases of defense planning cycle. Since it is a “cycle” and has different phases, similar activities might be performed at different phases of the cycle or at different management levels but with different intent. Rather complex processes in the defense domain can be defined with two or more TM activities and outputs of other functions to build a “TM function”. Within each activity, two or more TM tools can be included in a TM activity to achieve its goal. For this reason, it is practical to analyze defense planning cycle through the TM functions of defense actors involved within it.

5.1.1 Identification Method of TM Functions

Current regulations mentioned in the background and TAF Planning, Programming and Budgeting System (PPBS) define technology management related processes implicitly. Considering the findings of the research and survey results, TM processes were defined explicitly as technology management functions expected from defense planning cycle actors. In the development of TM Functions, existing regulations, PPBS, and interviews and discussions with senior managers and subject matter experts were considered.

5.1.2 TM Functions of Armed Forces and Ministry of Defense

TM functions of Armed Forces are;

- **AF1** Analyze Battlespace Effects of Technology Developments

- **AF2** Conduct Technology Assessments for Operational Needs
- **AF3** Analyze Pre-Feasibility Results and Verify Operational Needs
- **AF4** Prepare Project Definition Documents
- **AF5** Identify Defense Projects (Including R&D) and Plan Budget
- **AF6** Develop Capability Roadmaps

TM Functions of MoD are;

- **MF1** Examine Technical Pre-Feasibility of Candidate Alternative Systems
- **MF2** Analyze Technological Needs of Systems Requirements and Conduct Feasibility Studies
- **MF3** Develop Sector Based Technology Roadmaps
- **MF4** Manage Defense Projects (Including R&D)
- **MF5** Relate Defense Industry Firms' Capabilities and Defense System Projects
- **MF6** Identify Technology Deficiencies of Defense Sector
- **MF7** Improve Technological Capabilities of Defense Industry Firms

5.1.3 Definitions of TM Functions of AF and MoD

5.1.3.1 TM Functions of Armed Forces

Main TM functions expected from the AF are listed and explained in the following paragraphs.

AF1 Analyze Battlespace Effects of Technology Developments

Analyzing technology developments provides us with understanding the impact of technological change as well as its effects on the environment, specifically on the battlespace. In analyzing technological change, the focus is on identifying its 'incremental' and 'disruptive' nature. The aim here is to get some insight on related technological growth as well as its application and impact and respond accordingly.

AF2 Conduct Technology Assessments for Operational Needs

As operational needs become clear through the defense planning cycle, firstly this needs are analyzed with respect to; its consistency with defense policies, strategies and concepts. The next task is to analyze the candidate alternative system(s) proposals as project definition documents (PDD0s) of services meeting the operational need by identifying their contributions into operating environment in terms of several pre-defined figure-of-merits on their effectiveness by using simulations in different scenarios. The study is led by the Armed Forces and related services, but personnel from the MoD provide consultancy on technologies. The technological features of proposed systems are also considered and included in simulation analysis studies. The findings of this analysis are evaluated and reported to review groups and the higher level decision makers to select (a) candidate system(s). At the end of this study, a pre-feasibility for each candidate system is requested from the MoD to see the operational needs can be met by candidate system in terms of current technologies and defense industry firms' capabilities.

AF3 Analyze Pre-Feasibility Results and Verify Operational Needs

Once an operational need is determined to be valid in terms of its contribution to the operating environment by the armed forces, the selected candidate system(s) is/are pre-feasible in terms of technologies it is going to have by MoD, a verification is needed to see the selected systems level of fit to the operational needs. Considering the results, the operational needs are reviewed and the selected candidate system(s) is/are verified in terms of meeting the operational needs, by the armed forces and services with small additions or alterations. This study is led by Armed Forces, but personnel from services of armed forces and MoD are also participate in the study for consulting. The results of this study are reported to review groups and the higher level decision makers for the final selection among candidate systems and approval. At the end, PDD0s are modified as PDD1s and a detailed feasibility is requested from the MoD for the selected system(s). The candidate projects identified may not have a chance of selection in pre-feasibility or even the selected ones in feasibility that may have deficiencies in terms of; missing

technologies or limitations such as low maturity and readiness levels; integration and production incapacities; low competence and capability shortcomings of defense industry firms might prevent them to realize. Some of them would be the best candidates for the required operational needs. Pre-feasibility and feasibility studies might suggest complementing missing technologies required by that systems through technology development, prototype development and, technology demonstrator programs. Also the Technology Related Strategy/ Concept Development & Experimentation activity might suggest conducting basic and applied research on future promising technologies since they might change the future operating environments. For this reason, it becomes necessary to initiate R&D projects to foster the missing technologies and to better support current and future operational needs.

AF4 Prepare Project Definition Documents

After the feasibility of selected systems are proved, the next task is to detail the specific requirements of the selected system in PDD2. This detailing includes; the consistency of the system requirements with strategies, concepts and mission functions, current threats and system's performance against them, required capabilities, current capabilities and capability gaps of the system, benchmarking results of previously analyzed alternative systems versus the selected system and, technological evaluations in pre-feasibility and feasibility studies. This study is led by Armed Forces, with the participation of personnel from services and MoD. The final Project Definition Document PDD2 for both systems and R&D needs is presented to the decision makers of armed forces and services for approval.

AF5 Identify Defense Projects (Including R&D) and Plan Budget

The next step in defense planning cycle is selection and prioritization of candidate projects for realization by considering the pre-feasibility and feasibility results, and limitations on resources such as time, money and manpower as well as associated risks. After selecting projects they are

prioritized and budgeted considering the existing resources and PDD2s are updated to PDD3s.

AF6 Develop Capability Roadmaps

Roadmaps are simple, flexible strategic tools through which the progress of complex systems can be monitored equipped with supporting dialogues, alignments and consensus. The methodical multi-layered format is helpful for developing strategies over a period. Using this function, both current system projects and R&D projects, grouped by their relations are put on a multi-layered roadmap, aligning multiple perspectives such as science, technology, products, subsystems and systems and, resources assigned to them within a given timeframe.

5.1.3.2 TM Functions of Ministry of Defense

Similar to that of AF, main TM functions expected from the MoD are explained in the following paragraphs.

MF1 Examine Technical Pre-Feasibility of Candidate Alternative Systems

As several candidate systems meeting the operational needs are identified through the defense planning cycle, a pre-feasibility is requested by the armed forces to see whether the candidate systems' requirements can be met in terms of current technologies and defense industry firms' capabilities or not. The first task is to evaluate their technologies' readiness at system, subsystems, components and parts levels and, the maturity of these technologies as well as the defense industry firms' capabilities and competencies on them. The findings of pre-feasibility are sent to the armed forces along with the recommendations.

MF2 Analyze Technological Needs of Systems Requirements and Conduct Feasibility Studies

Once a system is determined to be pre-feasible in terms of technologies it is going to have and, verified in terms of its level of fit to the initial operating

needs, a feasibility study is requested by the armed forces for the selected system. The work conducted in MF1 is detailed with a focus on possibility of realizing the selected system by using national assets and resources.

MF3 Develop Sector Based Technology Roadmaps

The aim of this function is to produce several roadmaps indicating the evolutionary steps to acquire the new technologies, systems and, capabilities within a future timeframe. Since the focus is on defense industry firms, the roadmaps are designed by considering their targets in terms of technology ownership, technological capabilities and competencies and, competitive positions within a given timeframe.

MF4 Manage Defense Projects (Including R&D)

After get budgeted, defense projects are given a kick off for realization. Defense R&D projects are also initiated with the aim of; complementing missing technologies required by current system projects through prototype development and technology demonstrator programs, preparing for the future system needs and required technologies through technology development and, investigating the future strategic technologies compatible with the future operating environments through basic and applied research.

MF5 Relate Defense Industry Firms' Capabilities and Defense System Projects

With this function, requirements of defined system projects are related with the defense industry firms' capabilities to identify which firms are capable of meeting the requirements of defense system projects. Such information is needed in pre-feasibility, feasibility, roadmap development, and gap analysis studies.

MF6 Identify Technology Deficiencies of Defense Sector

The technology ownership, technological capabilities and competences and, competitive positions of defense industry firms are examined and analyzed

with this TM function, considering the several figure-of-merits in order to determine their capacities and deficiencies.

MF7 Improve Technological Capabilities of Defense Industry Firms

One of the missions assigned to MoD is to monitor and mentor defense industry firms to improve their technological capabilities. This can be achieved by guiding them in their efforts for redirecting, reconfiguring, transforming, shaping, and integrating existing core competencies on defense technologies accordingly. This guidance includes; updating them on strategic views of defense, notifying them about future operating environments and its needs, orienting them on future defense technologies (enabling, critical, pacing and emerging) trends and showing them paths for their own R&D investments on technologies.

5.1.4 Relating TM Functions with TM Activities Using IGOE Notation

Before going into the details, it is better to give the overall picture of defense TM functions and their corresponding defense TM activities. Recall the IGOE model in the literature review which defines Input (**I**), Guide (**G**), Output (**O**), and Enabler (**E**) notation. Table 5-1 shows the TM functions and corresponding TM Activities related to them which are needed to perform a specific TM function in terms of IGOE notation.

With the help of table, TM functions are defined by their Inputs (**I**), Guides (**G**), and Enablers (**E**). For example; MF1 accepts inputs from A1, A2, A3, and A8 activities; guided by A4, A10, and A13 activities; and enabled by A11 and A12 activities.

In Table 5-1, notice that, the leftmost lighter-shaded group of TM activities are used by both MoD's and Armed Forces' TM functions. All of the middle mid-shaded activities are used only by MoD TM functions. Activity A5 (Technology Related Strategy/ Concept Development & Experimentation) is only used by Armed Forces' TM functions, since Armed Forces leads this activity with the support from MoD. The TM activities shown in the table as medium shaded at rightmost position are also support both MoD's and Armed Forces' TM functions since they provide information on technological data and resources and, CST and STCN lists.

Table 5-1 TM Functions of MoD & Armed Forces and Related TM Activities

INSTITUTION	FUNCTION NO.	FUNCTIONS ACTIVITIES													
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	
MOD	MF1	I	I	I	G				I				E	E	G
	MF2	I	I	I	G				I				E	E	G
	MF3	I	I	I	G				I	E	G	G	E	E	G
	MF4	I	I	I	G				I	E	G	G	E	E	G
	MF5								I		G	G	E	E	G
	MF6			I	G				I		G	G	E	E	G
	MF7			I	G				I		G	G	E	E	G
ARMED FORCES	AF1	I	I	I									E	E	G
	AF2	I	I	I	G	G							E	E	G
	AF3	I	I	I	G	G							E	E	G
	AF4			I	G	G							E	E	G
	AF5			I	G								E	E	G
	AF6			I	G								E	E	G

5.1.5 Relating TM Functions of MoD and AF Using IGOE Notation

The relation types of MoD and AF TM functions are;

- MoD TM Functions X AF TM Functions
- AF TM Functions X MoD TM Functions
- MoD TM Functions X MoD TM Functions
- AF TM Functions X AF TM Functions

Relations between TM Functions of MoD and AF using IGOE notation are presented in Table 5-2, Table 5-3, Table 5-4, and Table 5-5 respectively.

Table 5-2 MoD Functions and AF Functions Relations

MoD FUNCTIONS \ AF FUNCTIONS		Analyze Battlespace Effects of Technology Developments	Conduct Technology Assessments for Operational Needs	Analyze Pre-Feasibility Results and Verify Operational Needs	Prepare Project Definition Documents	Identify Defense Projects (incl.R&D) and Plan Budget	Develop Capability Roadmaps
		AF1	AF2	AF3	AF4	AF5	AF6
MF1	Examine Technical Pre-Feasibility of Candidate Alternative Systems	G	G				E
MF2	Analyze Technological Needs of Systems Requirements and Conduct Feasibility Studies	G		G			E
MF3	Develop Sector Based Technology Roadmaps					G	E
MF4	Manage Defense Projects (Including R&D)						
MF5	Relate Defense Industry Firms' Capabilities and Defense System Projects						
MF6	Identify Technology Deficiencies of Defense Sector	I					
MF7	Improve Technological Capabilities of Defense Industry Firms					E	

Table 5-3 AF Functions and MoD Functions Relations

AF FUNCTIONS \ MoD FUNCTIONS		Examine Technical Pre-Feasibility of Candidate Alternative Systems	Analyze Technological Needs of Systems Requirements and Conduct Feasibility Studies	Develop Sector Based Technology Roadmaps	Manage Defense Projects (Including R&D)	Relate Defense Industry Firms' Capabilities and Defense System Projects	Identify Technology Deficiencies of Defense Sector	Improve Technological Capabilities of Defense Industry Firms
		MF1	MF2	MF3	MF4	MF5	MF6	MF7
AF1	Analyze Battlespace Effects of Technology Developments			E				
AF2	Conduct Technology Assessments for Operational Needs			E				
AF3	Analyze Pre-Feasibility Results and Verify Operational Needs	I		E				
AF4	Prepare Project Definition Documents		I	E				
AF5	Identify Defense Projects (Incl.R&D) and Plan Budget	I	I	E				
AF6	Develop Capability Roadmaps	I	I	E				

Table 5-4 Relations among MoD Functions

MoD FUNCTIONS \ MoD FUNCTIONS		Examine Technical Pre-Feasibility of Candidate Alternative Systems	Analyze Technological Needs of Systems Requirements and Conduct Feasibility Studies	Develop Sector Based Technology Roadmaps	Manage Defense Projects (Including R&D)	Relate Defense Industry Firms' Capabilities and Defense System Projects	Identify Technology Deficiencies of Defense Sector	Improve Technological Capabilities of Defense Industry Firms
		MF1	MF2	MF3	MF4	MF5	MF6	MF7
MF1	Examine Technical Pre-Feasibility of Candidate Alternative Systems			E		E		
MF2	Analyze Technological Needs of Systems Requirements and Conduct Feasibility Studies	G		E		E		
MF3	Develop Sector Based Technology Roadmaps	G	G		E	E		
MF4	Manage Defense Projects (Including R&D)		G	G				
MF5	Relate Defense Industry Firms' Capabilities and Defense System Projects	I	I		G		E	
MF6	Identify Technology Deficiencies of Defense Sector	G	G			I		
MF7	Improve Technological Capabilities of Defense Industry Firms			G	E		I	

Table 5-5 Relations among AF Functions

AF FUNCTIONS \ AF FUNCTIONS		Analyze Battlespace Effects of Technology Developments	Conduct Technology Assessments for Operational Needs	Analyze Pre-Feasibility Results and Verify Operational Needs	Prepare Project Definition Documents	Identify Defense Projects (Incl.R&D) and Plan Budget	Develop Capability Roadmaps
		AF1	AF2	AF3	AF4	AF5	AF6
AF1	Analyze Battlespace Effects of Technology Developments						E
AF2	Conduct Technology Assessments for Operational Needs	G, I					E
AF3	Analyze Pre-Feasibility Results and Verify Operational Needs		G, I				E
AF4	Prepare Project Definition Documents		G, I	G, I			
AF5	Identify Defense Projects (Incl.R&D) and Plan Budget				G		E
AF6	Develop Capability Roadmaps	G, I		G, I	E		

Table 5-6 Relations among AF Functions

5.2 Interactions between TM functions and Their Integration

The interactions between TM functions were defined as if they're feeding the defense planning processes' with their outputs. With this abstraction, it is convenient to better understand how TM functions' outputs provide input to the model. Also, there is no need to consider the organizational structures acting to perform these functions since the focus is on how the system works with TM functions rather than who is acting.

5.2.1 Interactions of TM Functions in the Model

The interactions between MoD and AF TM Functions are presented in Figure 5-1. In figure, AF TM Functions' outputs are shown as dashed lines whereas MoD TM Functions' outputs as dashed lines.

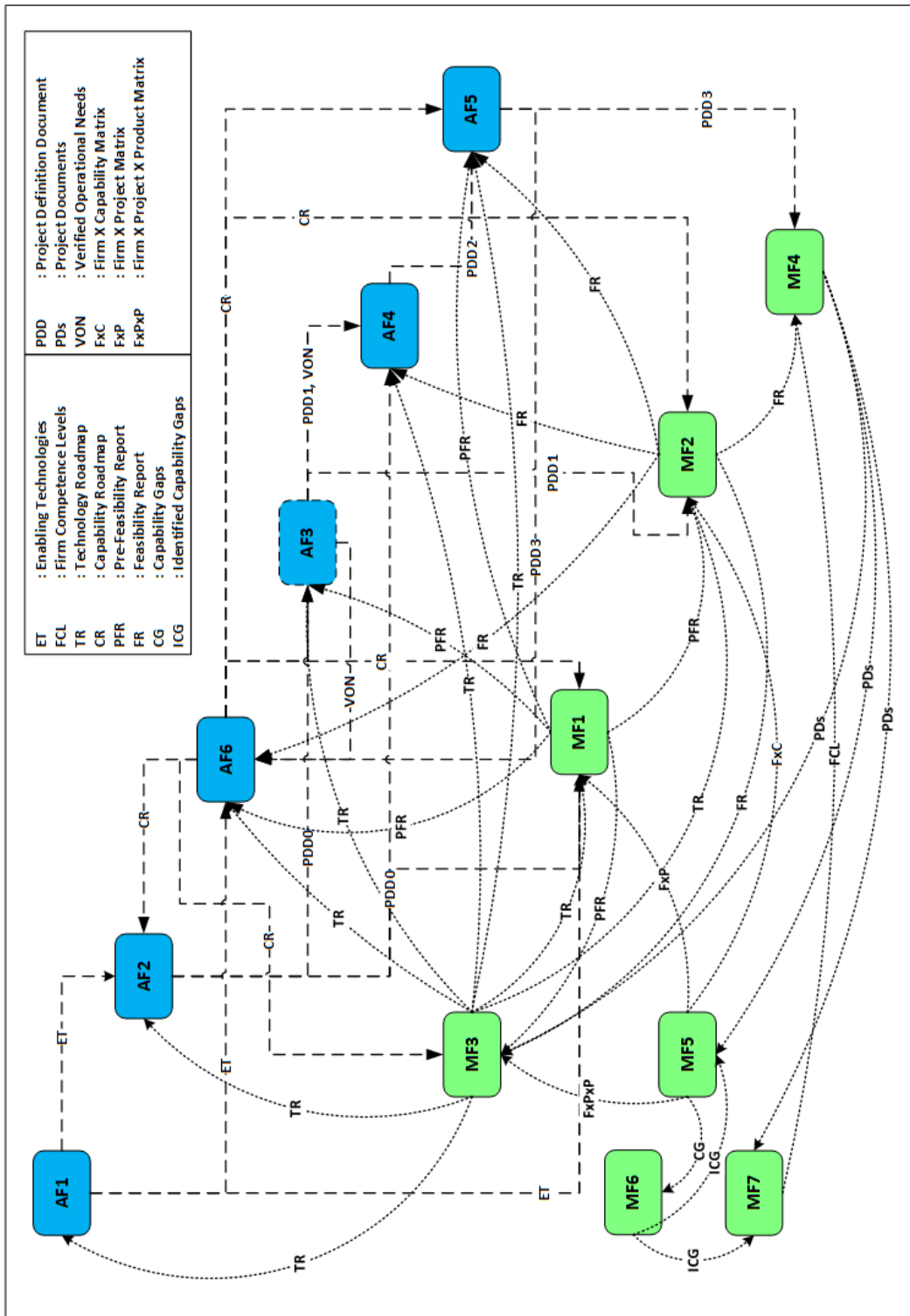


Figure 5-1 MoD and AF TM Functions' Interactions

To explain, for example; MF3 gets Pre-Feasibility Report (PFR) from MF1, Feasibility Report (FR) from MF2, Project Documents (PDs) from MF4, and Firm X Project X Product Matrix (FxPxP) from MF5 and develops Sector-based Technology Roadmaps (TR) to be used by all of the AF TM Functions, and MF1 and MF2.

5.2.2 Integration of TM Functions

As discussed in the literature review, an IDEF0 model depicts what a system does i.e. its function, controls, inputs and outputs, and other functions and services it needs to accomplish its function. In our case, a sample definition of TM function AF4 (Develop Capability Roadmaps) is presented in Figure 5-2.

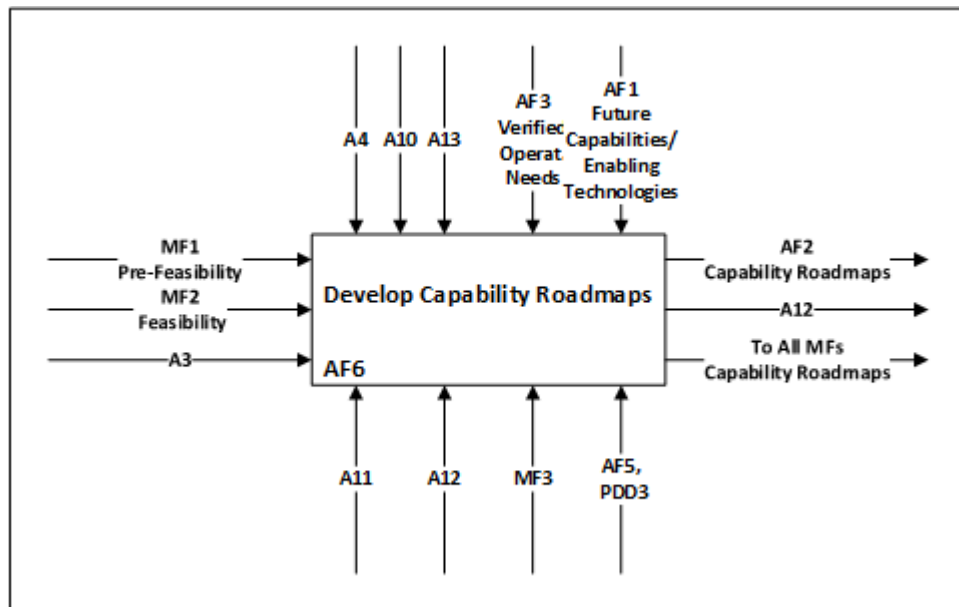


Figure 5-2 TM Function Definition

5.2.2.1 Integration of TM Functions of Armed Forces

AF TM Functions integration is presented in Figure 5-3.

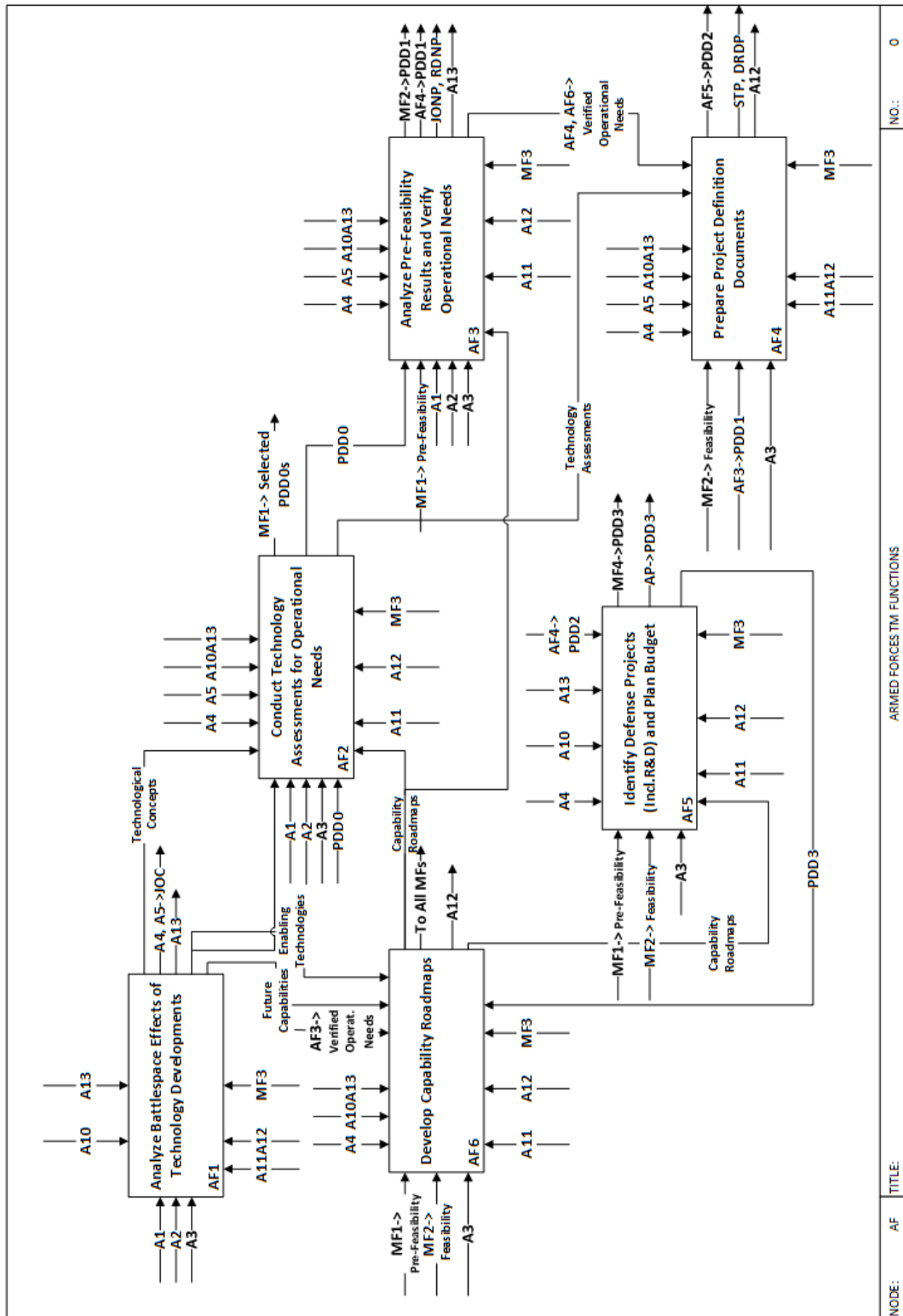


Figure 5-3 Armed Forces TM Functions and Their Relations

Definition of AF TM functions in terms of their Inputs (I), Guides (G), Outputs (O), and Enablers (E) are presented in the following paragraphs.

AF1 Analyze Battlespace Effects of Technology Developments

This function uses inputs provided by; TNMS, technology intelligence, auditing, and technology forecasting and impact assessment activities (A1, A2, A3). It is guided by KM and CST and STCN lists (A10, A13). Technology / Product Roadmaps of MF3, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technical data on base/ enabling, critical/ key, pacing and emerging technologies of A12 are enablers of this function. The outputs of AF1 are; technological concepts which guides AF2, and provides input to A4, A5 and A13; enabling technologies which guides AF6 and provides input to AF2; and required future capabilities which guides AF6.

AF2 Conduct Technology Assessments for Operational Needs

AF1 function's output of enabling technologies as well as technology intelligence, auditing, and technology forecasting and impact assessment activities' outputs (A1, A2, and A3) are inputs of this function. Technological concepts from AF1, technology strategy and technology development plans of A4, operational concepts of A5, KM ,and CST and STCN lists (A10, A13) guides this function. Capability Roadmaps of AF6, Technology / Product Roadmaps of MF3, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as scenarios, simulation outputs and technology benchmarking results of A12 are enablers of this function. PDDOs for selected candidate system(s) as input to MF1 and AF3, and technology assessments for operational needs as guidance to AF4 are the outputs of this function.

AF3 Analyze Pre-Feasibility Results and Verify Operational Needs

In addition to the pre-feasibility report of MF1, updated technology intelligence, auditing, and technology forecasting and impact assessment activities' (A1, A2, A3) outputs are input to this function. Technology strategy and technology development plans of A4, operational concepts of

A5, KM, and CST and STCN lists (A10, A13) guides this function. Capability Roadmaps of AF6, Technology / Product Roadmaps of MF3, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technology forecasting and impact assessment study results of A12 are enablers of this function. The outputs of AF3 are revised PDD1s for MF2 and AF4, JONP and RDNP, CST&STCN updates for A13, and verified operational needs for AF4 and AF6.

AF4 Prepare Project Definition Documents

The feasibility report of MF2, PDD1 of AF3, and current technology forecasting and impact assessment of A3 are the inputs of AF4. Technology strategy and technology development plans of A4, operational concepts of A5, KM, and CST and STCN lists (A10, A13) guides this function. Capability Roadmaps of AF6, Technology / Product Roadmaps of MF3, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technology taxonomies, technology readiness level and maturity assessment study results of A12 are enablers of this function. The outputs of AF4 are revised PDD2s for AF5, STP and DRDPL, and KM data for A12.

AF5 Identify Defense Projects (Including R&D) and Plan Budget

The pre-feasibility and feasibility results of MF1 and MF2, and updated technology forecasting and impact assessment of A3 are the inputs of AF5. PDD2s of AF4, technology strategy and technology development plans of A4, KM, and CST and STCN lists of A10 and A13 guides this function. Technology / Product Roadmaps of MF3, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technological performance data on defense industry firms' capabilities, portfolios, human resources facilities, technical equipment and their assets data including patents, licenses, and IPRs of A12 are enablers of this function. The main outputs of AF5 are PDD3, AP, and DRDPR.

AF6 Develop Capability Roadmaps

The pre-feasibility and feasibility results of MF1 and MF2, and updated technology forecasting and impact assessment of A3 are the inputs of AF6. Enabling technologies and future capabilities of AF1, verified operational needs of AF3, technology strategy and technology development plans of A4, KM, and CST and STCN lists of A10 and A13 guides this function. Technology / Product Roadmaps of MF3, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technology related concept development and experimentation study results of A12 are enablers of this function. The outputs of AF6 are capability roadmaps to be used by all other functions and KM data for A12.

5.2.2.2 Integration of TM Functions of MoD

MoD TM Functions integration is presented in in Figure 5-4.

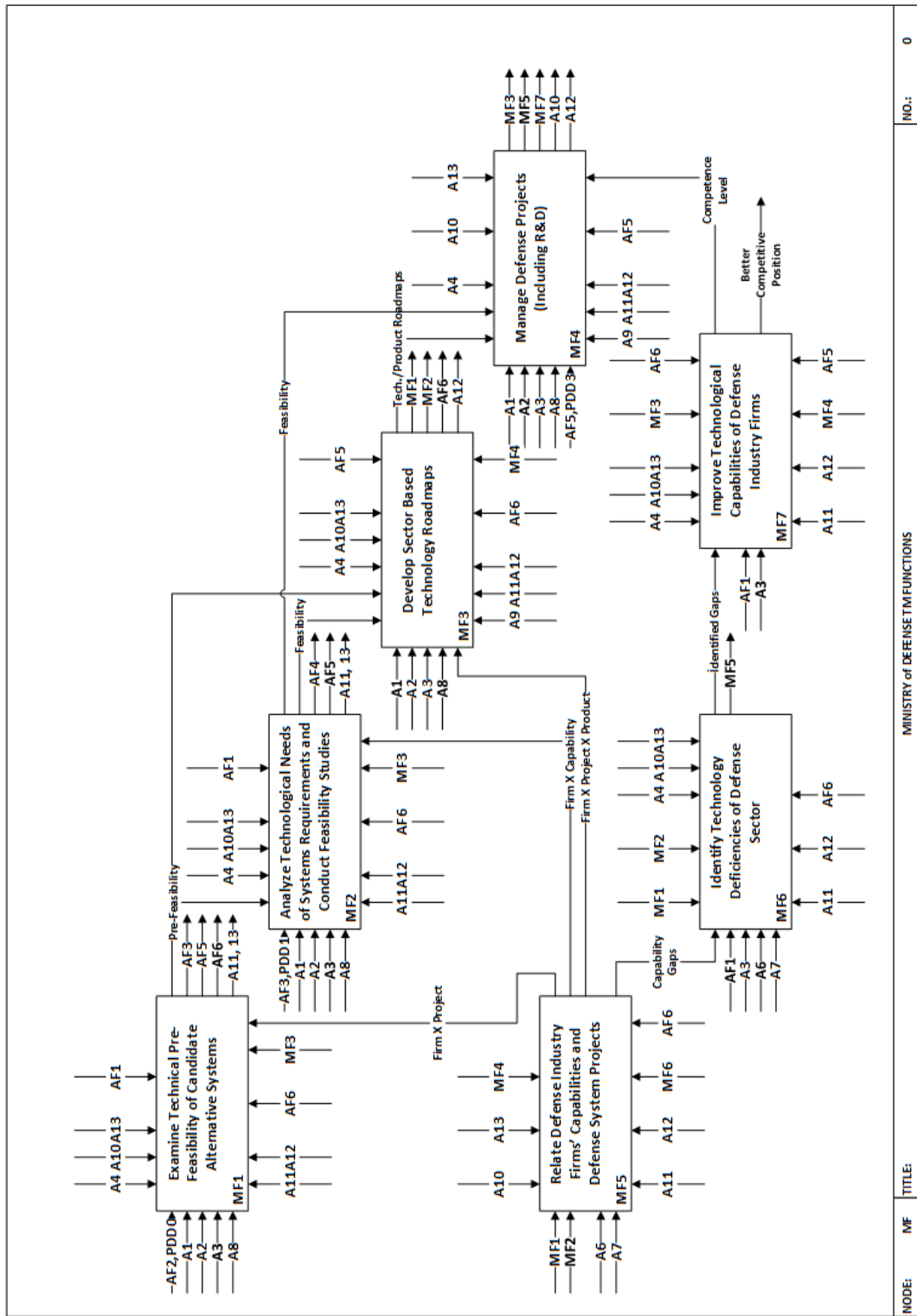


Figure 5-4 Ministry of Defense TM Functions and Their Relations

Definition of MoD TM functions in terms of their Inputs (I), Guides (G), Outputs (O), and Enablers (E) are presented in the following paragraphs.

MF1 Examine Technical Pre-Feasibility of Candidate Alternative Systems

The inputs for MF1 are PDD0s of AF2, technology intelligence, auditing, and technology forecasting and impact assessment activities' outputs (A1, A2, A3), and previous R&D projects' outputs of A8. Technology strategy and technology development plans of A4, KM, and CST and STCN lists of A10 and A13, and technological concepts of AF1 guides this function. Capability Roadmaps of AF6, Technology / Product Roadmaps of MF3, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technology taxonomies, technology readiness level and maturity assessment study results of A12 are enablers of this function. Pre-feasibility reports for AF3, AF5, AF6 and A11, and CST&STCN updates for A13 are the outputs of MF1.

MF2 Analyze Technological Needs of Systems Requirements and Conduct Feasibility Studies

The inputs for MF2 are PDD1s of AF3, technology intelligence, auditing, and technology forecasting and impact assessment activities' outputs (A1, A2, A3), and previous R&D projects' outputs of A8. Pre-feasibility reports of MF1, technology strategy and technology development plans of A4, KM, and CST and STCN lists of A10 and A13, and technological concepts of AF1 guides this function. Firm / Capability matrices of MF5, Capability Roadmaps of AF6, Technology / Product Roadmaps of MF3, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technology taxonomies, technology readiness level and maturity assessment study results of A12 are enablers of this function. Feasibility reports for AF4, AF5, AF6 and A11, and CST&STCN updates for A13 are the outputs of MF2.

MF3 Develop Sector Based Technology Roadmaps

The inputs for MF3 are technology intelligence, auditing, and technology forecasting and impact assessment activities' outputs (A1, A2, A3), previous R&D projects' outputs of A8, and Firm / Project/ Product matrices from MF5.

Pre-feasibility and Feasibility reports of MF1 and MF2, technology strategy and technology development plans of A4, KM, and CST and STCN lists of A10 and A13, and selected projects list of AF5 guides this function. Technology transfer plan of A9, Capability Roadmaps of AF6, projects list of MF4, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technology related concept development and experimentation study results of A12 are enablers of this function. Sector-based technology roadmaps for MF1, MF2, and A12 are the outputs of MF3.

MF4 Manage Defense Projects (Including R&D)

The inputs for MF4 are PDD3s of AF5, technology intelligence, auditing, and technology forecasting and impact assessment activities' outputs (A1, A2, A3), and previous R&D projects' outputs of A8. Feasibility reports and product development plans of MF2 and MF3, technology strategy and technology development plans of A4, KM, and CST and STCN lists of A10, and A13 guides this function. Firm competence levels from MF7, technology transfer plan of A9, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as portfolios, human resources facilities, technical equipment and their assets data including patents, licenses, IPRs, etc. of A12 are enablers of this function. Project status and development reports, project performance data, and technological performance data on defense industry firms' capabilities for MF3, MF5, MF7, A10, and A12 are the outputs of MF4.

MF5 Relate Defense Industry Firms' Capabilities and Defense System Projects

The inputs for MF5 are Pre-feasibility and Feasibility reports of MF1 and MF2, firm level measurements of A6, and gap analysis and benchmarking results of A7. KM, and CST and STCN lists of A10 and A13, and project information of MF4 guides this function. Capability Roadmaps of AF6, identified gaps of MF6, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base

entries such as technological performance data on defense industry firms' capabilities, portfolios, human resources facilities, technical equipment and their assets data including patents, licenses, IPRs, etc. of A12 are enablers of this function. Firm/ Project, Firm/ Capability and Firm/ Project/ Product matrices for MF1, MF2 and MF3, and capability gaps of firms for MF6 are the outputs of MF5.

MF6 Identify Technology Deficiencies of Defense Sector

Capability gaps of firms from MF5, technological concepts from AF1, technology forecasting and impact assessments of A3, firm level measurements of A6, and gap analysis and benchmarking results of A7 are input to this function. Pre-feasibility and Feasibility reports of MF1 and MF2, technology strategy and technology development plans of A4, KM, and CST and STCN lists of A10 and A13 guides this function. Capability Roadmaps of AF6, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technological performance data on defense industry firms' capabilities, portfolios, human resources facilities, technical equipment and their assets data including patents, licenses, IPRs, etc. of A12 are enablers of this function. The outputs of MF6 are identified gaps of firms to be used by MF5 and MF7.

MF7 Improve Technological Capabilities of Defense Industry Firms

Identified gaps of firms from MF6, technological concepts from AF1, and technology forecasting and impact assessments of A3 are the inputs of MF7. Capability Roadmaps of AF6, Technology / Product Roadmaps of MF3, technology strategy and technology development plans of A4, KM, and CST and STCN lists of A10 and A13 guides this function. Project information from MF4 and AF5, previously reported technology-related work findings such as scientific research reports from A11, and technology resource base entries such as technological performance data on defense industry firms' capabilities, portfolios, human resources facilities, technical equipment and their assets data including patents, licenses, IPRs, etc. of A12 are enablers of

this function. The outputs of this function are competence levels and competitive positions of defense industry firms.

5.3 Attainment of Defense Technology Management Functional Model (DTMFM)

TM functions were mounted to the defense planning cycle processes which need a specific output from them. Since the space is limited, activities and their outputs which provide inputs to the TM functions were not drawn.

The resulting functional model, DTMFM is presented in Figure 5-5.

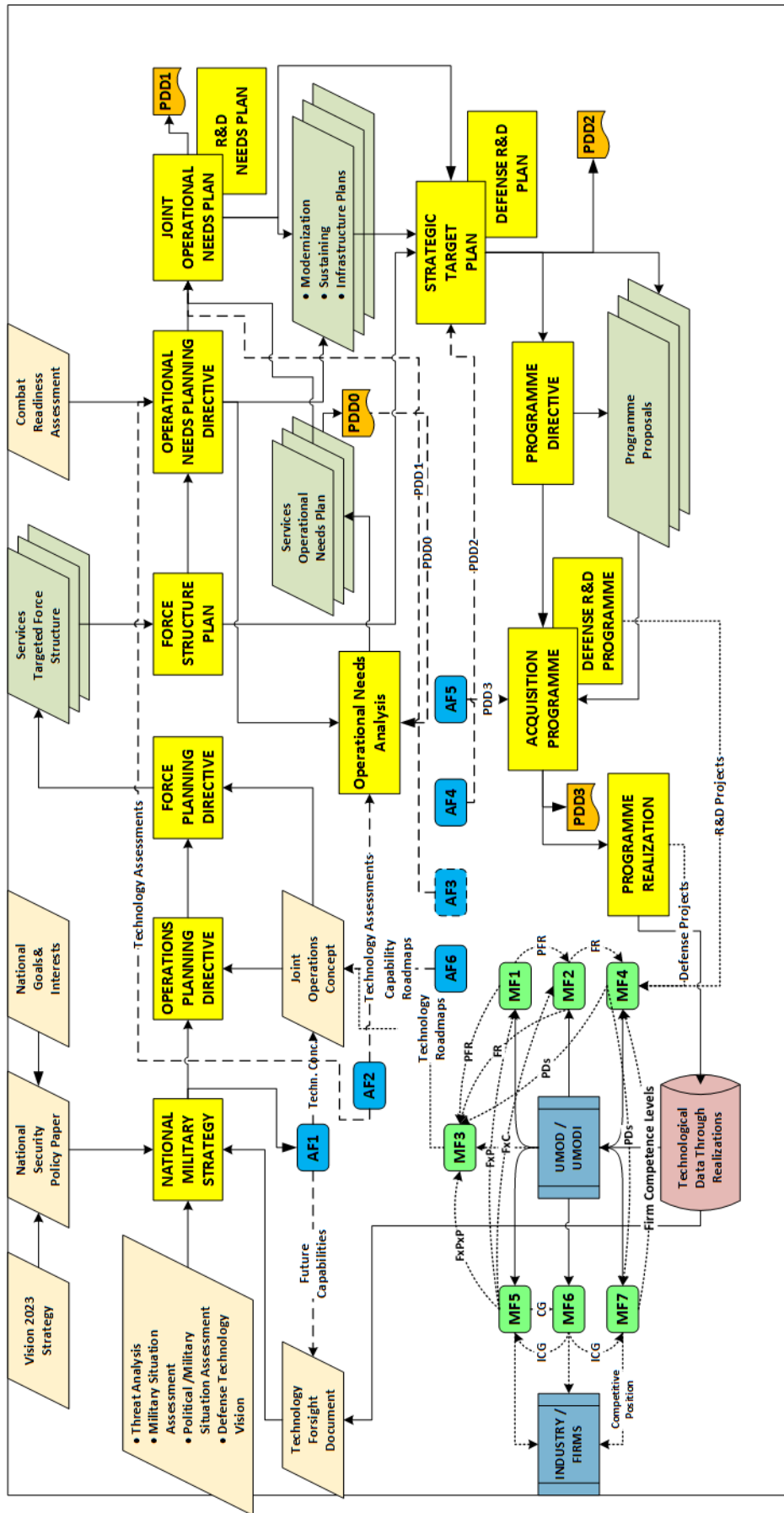


Figure 5-5 Defense Technology Management Functional Model (DTMFM)

5.3.1 Features of the Proposed Model

In the developed model, how TM functions of MoD and the Armed Forces input to the defense planning cycle processes are explained in the following sections. The TM functions integrated to the functional model are actually related to the TM processes which are parallel to those in defense planning cycle's processes. The idea behind integrating the functions into the model is to identify TM functions as black boxes and their roles in defense planning cycle rather than to identify the processes itself. With this abstraction, it is not important how processes work or who are involved in them.

5.3.2 Armed Forces TM Functions' Roles

The TM functions of Armed Forces were explained in detail previously. Their roles in the functional model are explained in the following paragraphs.

AF1 Analyze Battlespace Effects of Technology Developments

This function supports valuable inputs to JOC with technological concepts and TFD with future capabilities. It also provides functions AF2, AF6, and MF1 with enabling technologies.

AF2 Conduct Technology Assessments for Operational Needs

With its output technology assessments, this function provides input to Operational Needs Analysis, Operational Needs Planning Directive (ONPD), and AF4. The selected candidate systems PDD0s are sent to the MF1 of MoD for their Pre-feasibility, and AF3 for verification of operational needs.

AF3 Analyze Pre-Feasibility Results and Verify Operational Needs

At the end a detailed feasibility is requested from the MoD via MF2. Updated PDD1 is an input to JONP and RDNP. PDD1 is also an input to AF4 and MF2. Verified operational needs are sent to AF4 and AF6.

AF4 Prepare Project Definition Documents

The updated Project Definition Document (PDD2) is presented to the decision makers of armed forces for approval and included in STP and DRDPL. Approved PDD2s are then sent to AF5 for budgeting.

AF5 Identify Defense Projects (Including R&D) and Plan Budget

The final Project Definition Document (PDD3) is presented to the decision makers of armed forces for approval and included in AP and DRDPR. Approved PDD2s are then sent to AF6 for updating roadmaps and MF4 for realization.

AF6 Develop Capability Roadmaps

The developed technology roadmaps is synchronized with those developed by MoD's MF3 and sent to JOC, AF2, AF3, MF1, MF2 , and MF3 to be referenced in future studies.

5.3.3 MoD TM Functions' Roles

The TM functions of MoD were explained in detail previously. Their roles in the functional model are explained in the following paragraphs.

MF1 Examine Technical Pre-Feasibility of Candidate Alternative Systems

The pre-feasibility reports are used by AF3, AF5 and AF6 as well as MF2 and MF3.

MF2 Analyze Technological Needs of Systems Requirements and Conduct Feasibility Studies

The feasibility reports are used by AF4, AF5 and AF6 as well as MF3 and MF4.

MF3 Develop Sector Based Technology Roadmaps

The generated technology roadmaps provide inputs to JOC, and to all of armed forces' functions as well as to defense industry firms through MF1 and MF2.

MF4 Manage Defense Projects (Including R&D)

AP and DRDPR identifies the defense projects to be realized. Project documents during acquisition are sent to MF3, MF5 and MF7 as needed.

MF5 Relate Defense Industry Firms' Capabilities and Defense System Projects

This function provide Firm X Project Matrix to MF1, Firm X Capability Matrix to MF2, Firm X Project X Product Matrix to MF3, and capability gaps of firms to MF6.

MF6 Identify Technology Deficiencies of Defense Sector

Identified capability gaps are sent to MF5 and MF7.

MF7 Improve Technological Capabilities of Defense Industry Firms

Output of this function which is competence levels of firms is used by MF4 in evaluating firm proposals in acquisition bids. Defense Industry Firms' competitive positions are shared with firms.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In this thesis, technology management in defense domain was investigated in detail by considering defense planning processes within the TM framework as well as activities, methods, tools and techniques constituting technology management which are used mostly in commercial business in the literature. Additionally, the mechanisms to include technology management to support decision making in defense planning cycle were also covered in detail by considering technology, warfighting concepts and future capabilities requirements.

The studied topics were evaluated with a view on their applicability to defense domain, specifically to Turkish Defense Planning System. Considering the current regulations and their implications on defense planning cycle, the TM activities of defense system actors through defense planning cycle were identified and compared to the generic TM activities in the literature. It was concluded that, TM activities in the literature used mostly in commercial business can also be used in defense domain with an exception in exploitation and protection activities because there is monopsony, MoD being the only customer of defense systems.

Since defense systems are large and sophisticated, TM activities alone are not sufficient enough to cover all the aspects of technology management in defense planning. For this reason, it became clear that there is a need to improve the effectiveness of defense planning cycle by better interpreting these TM activities to enable defense planners to perform their TM roles or functions well.

TM roles, functions and their interactions with each other in defense planning cycle are rather complex and they should be defined clearly in regulations. One of the most important problem areas in Turkish Defense Planning System was identified as the

current regulations on defense planning system being rather implicit for defining technology management processes clearly.

A survey was applied to the experienced participants from MoD and the Armed Forces in electronic form to take a snapshot of the current situation awareness with the aim of answering the question of **“How TM can be integrated and made explicit to defense planning system in order to support decision making, and strategy and capability planning studies of defense planners?”**

Survey analysis results indicate that there is a reasonable degree of awareness about defense TM within the MoD and the Armed Forces. But the TM usage level and the required TM activities tools to support this usage are not at the required level.

The argument that TM activities alone were not sufficient enough to cover all the aspects of technology management in defense planning was also verified by the survey, so it was also became necessary to improve the technology related concept development capabilities of defense planners to enabling them better use technological concepts to develop warfighting concepts for future operating environments.

The implicitness of regulations were proved by the survey since the necessity degree of TM outputs usage is low and the TM roles and functions are not well understood within the institutions.

The results of the research and the survey indicated that there is a need to improve the effectiveness of defense planning cycle by better interpreting these TM activities to enable defense planners to perform their TM roles or functions well. As a solution to this identified gap, a functional model was suggested.

In order to define rather complex processes in the defense domain, two or more TM activities and outputs of other functions can be aggregated to build a “TM function”. Within each activity, two or more TM tools can be included in a TM activity to achieve its goal. For this reason, it is practical to analyze defense planning cycle through the TM functions of defense actors involved within it.

TM processes were defined explicitly as TM functions expected from defense planning cycle actors namely MoD and AF. In defining functions, TM activities, methods and

tools were aggregated to build technology management functions with the aim of making them explicit to the Turkish Defense Planning System. In this process, TM Functions, existing regulations, Planning Programming and Budgeting System, and interviews and discussions with senior managers and subject matter experts were considered.

The TM functions and corresponding TM Activities were related using IGOE notation to perform a specific TM function. Relations between TM Functions of MoD and AF, and between themselves were also defined using IGOE notation. The interactions between MoD and AF TM functions were defined as if they're feeding the defense planning processes' with their outputs. This abstraction, enables better understanding of how TM functions' outputs provide input to the model. In the next step, the integration of TM functions was performed separately within MoD and AF and their interactions in terms of IGOE model were drawn and defined.

At the final step, the functional model, Defense Technology Management Functional Model (DTMFM) was developed by mounting defined TM functions into the Turkish Defense Planning Cycle. In the developed model, how TM functions of MoD and the Armed Forces input to the defense planning cycle processes are explained in detail to improve the use of technology management in defense planning cycle.

The TM functions integrated into the functional model will produce the necessary knowledge input to the Turkish Defense Planning Cycle and create better understanding of the technology effects on defense systems. The proposed functional model will provide the decision makers with better understanding the technology impacts on the defense planning cycle and enable them to make better decisions through the cycle.

The main contributions of this research to the current practices and the literature are; synthesis of the current technology management activities which are mainly focused on commercial business and proving their applicability to the defense domain; definition of technology management "functions" which is new to the literature; and development of a functional model and integrating newly introduced technology management functions to it in the defense domain.

6.2 Recommendations and Future Work

In order to achieve a goal of acquiring state-of-the art defense systems by improving the quality of decisions made through the defense planning cycle, the following actions presented in the following paragraphs are highly recommended for future studies.

The survey results and the findings of this research should be presented to the high level decision makers of MoD and the Armed Forces requesting a pilot study initiation to use the developed model, DTMFM, for at least one planning cycle. After this period, in the light of the application results, the model should be revised.

The survey should be re-organized and repeated with increased participation from MoD and Armed Forces to track the changes, to take necessary precautions and to make improvements to the DTMFM.

It is also very important to develop a data management system for DTMFM. A detailed analyses of TM functions of DTMFM must be achieved, data needs must be identified, and finally data management model for TM must be developed, maintained and reviewed. The data sets for the model should be identified, analyzed, collected, verified, and validated and update responsibilities should be assigned to the institutions.

There may be a need to initiate and conduct an applied research on TM tools and their use in defense TM activities and develop a toolkit for defense applications, a project to develop Defense Technology Management Decision Support Model by integrating the process model and the defense TM toolkits.

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APPENDICES
APPENDIX A
SURVEY STUDY

**SURVEY ON AWARENESS AND USAGE LEVEL OF
TECHNOLOGY MANAGEMENT AMONG THE
STAKEHOLDERS OF DEFENSE ACQUISITION**

Dear Sir,

Thanks for taking your time to answer this survey which is part of my PhD study aiming at developing a decision support model for the purpose of helping the stakeholders of Defense Acquisition with their technology management activities.

The survey will take approximately 30 minutes to answer. Please read the instructions carefully before answering the survey questions.

The audience of this survey is the workers and/or the ex-workers (including retirees) of Department of Defense and Armed Forces personnel.

To answer the questions honestly and sincerely by using your experience and expertise in the past will contribute a lot to the quality and accuracy of the study and make you a part of the study.

In some questions, if you don't find a complete choice to reflect your opinion, an "other" option is included to express your opinion. You can add more than one idea in this field separated by commas.

If you get the survey link from different sources, please only answer the survey questions once.

The survey results will be used for designing a model merging the technology management activities and tools which will can used in decision support and strategic planning activities of Defense Acquisition actors.

To be informed by the survey results, please leave your e-mail address at the end of the survey.

Sincerely...

PART I

In this part, you're given the questions concerning your institution, education background and the duration of work concerning technology management. If you are currently working in a position not related to technology management, do not consider this. Only consider the work you performed in the past related to the technology management (TM).

What is your current or past institution at which you performed TM Related work?

- Undersecretaries MoD
- Undersecretaries MoD for Defense Industries
- General Staff
- Army Navy
- Air Force

What is your education level?

- Undergraduate
- Graduate
- Doctorate and up

What is your area of education?

- Engineering
- Economic and Administrative Sciences
- Education Sciences
- Arts and Sciences
- Architecture
- Law

What is your duration in your profession?

- 1-3 years
- 4-10 years

- 11-15 years
- 15 years and up

For how long are / were you working in the institution you have / had been employed?

(Answer considering your response to the first question.)

- 1-3 years
- 4-10 years
- 11-15 years
- 15 years and up

What is / was your position in your institution? Answer considering your position in the first question.

- Assistant expert / project member
- Expert / project leader / project officer
- Section head / project manager / group manager
- Education / research institution manager / commander
- Head of department / group

For how long you are / was working in this position?

- 1-3 years
- 4-7 years
- 8-10 years
- 10 years and up

PART II

In this part, you are expected to answer the questions concerning your awareness, knowledge and application level of technology management.

Have you ever met with "Technology Management" (TM) subject in your studies?

- Yes
- No

Have you ever been involved in a study having TM work?

- Frequently
- Occasionally
- Rarely
- Never

If ever, on which area(s) of TM you've been worked so far?

- Project / Program Management
- R&D Management
- Innovation management
- Strategy and Capability Planning
- Decision Support
- Organizational Learning
- Other:

Does your institution has any regulations (law, code of act, plan, etc.) defining TM processes and their uses?

- Yes. TM processes are well defined in regulations
- Although they are not defined clearly, there are some general principles and guidelines concerning TM processes
- No. But a study is under way for regulating TM processes
- No. But a study is being planned for defining the TM processes
- No. There are no such regulations for TM processes

Is / Are there any specific unit or units responsible for TM processes within your institution?

- Yes. Only one unit is responsible within whole institution Yes. There are sub units / persons within units
- Yes. There are sub units / persons within matrix organized units
- No. There are no such units
- Other

Do you have any responsibility related to TM processes within your unit?

- Yes. I'm in a directly responsible position
- Yes. I'm responsible as an additional task
- Yes. I support the others' TM work when needed
- No. I don't have any TM responsibility

For what purposes the output of TM processes are used in your institution?

- For supporting Project / Program / Investment related decisions
- In studies related to future strategic planning
- For identifying and tracing the level of national technological capabilities in defense domain
- For identifying and tracing the technology ownership of national defense firms
- In pre-feasibility and feasibility studies for defense acquisition projects
- For developing technology acquisition roadmaps for defense programs
- Other

How TM process outputs are used in institutional decision processes?

- They must be used in every project / study
- They might be used in some special projects / studies
- They can be used considering the nature of the Project / study when requested
- There is no necessity to use such TM process outputs

How TM process outputs are used in strategic planning (SP) studies?

- They are directly input to the SP studies
- They are input to the SP studies after evaluated by the SP task group
- They are input to the study as requested by the SP task group
- They are input to the SP studies by a sub-group in co-ordination with the SP task group
- Other:

Which TM activities you used in your studies listed below?

- Technology intelligence
- Technology identification
- Technology forecasts
- Technology assessment
- Technology ownership and competitive level measurement
- Building technological resources inventory
- Identification of technology readiness and maturity levels
- Documentation and publication of technological knowledge
- Determination of technology strategy and technology planning
- Determination of technology value and performing gap analysis
- Identification and selection of strategic technologies
- R&D management in defense sector
- Determination of technology standards
- Management of technology transfer
- Establishment of a common TM terminology between the stakeholders of defense community
- Promoting the knowledge sharing between the stakeholders of defense community
- Ensuring the security and privacy of stakeholders of defense community's IPRs
- Other:

Which TM tools you used in your TM activities listed below?

- SWOT analysis
- Need analysis
- Program / project analysis and evaluation
- Establishing mission / strategy matrices
- Preparation of action plans
- Establishment of technology vision
- S-curve method

- Stage-gate process modeling
- Value chain analysis
- Cost-benefit analysis
- Statistical decision models
- Benchmarking
- Mathematical modeling techniques
- Modeling and simulation (What-if analysis)
- Technology roadmapping
- Decision trees
- Technology-product matrix analysis
- Trend extrapolation
- Expert opinion
- License and patent analysis
- Portfolio management
- Project evaluation techniques
- Brain storming
- TM personal development planning
- Other:

Does your institution has an information system specifically to be used during TM studies?

- Yes. It is integrated with enterprise information system
- Yes. It is a stand-alone information system
- No. But it is under development
- No. It is planned to be developed

How data are collected for the TM information system?

- Systematically and regularly
- When needed for a specific TM study
- There is no standard way to collect data
- Other:

Who provides systematic and regular data for the TM information system?

- Units within the institution Other DoD / services
- Academic institutions (Universities, Institutes, centers, etc.)
- Public research establishments / centers (TÜBİTAK, TAEK etc.)
- Foundations / associations (TSKGV, TTGV, SASAD, etc.)
- Private sector defense firms
- Independent research institutions (Turkish Patent Institute) and researchers
- Other

Concerning the data stored in TM information system:

- Validated and verified from different sources
- Secrecy and security of data is ensured
- Updated on a regular basis
- No systematic update for the data
- Used directly without verifying and validating
- No opinion

With which institutions the data stored in TM information system are shared?

- Only within our institution's units
- With the public institutions which are stakeholders of common projects (DoD, services)
- With the public research organizations / centers which need data
- With the private sector defense firms when needed
- Other:

How data needed by the TM processes are retrieved from the TM information system?

- Automatically by a software developed to be used for TM studies
- Manually depending on the nature of the TM study

PART III

In this part, there are propositions about;

- Technology intelligence and awareness of new technologies,
- Technology identification,
- Technology and market evaluations,
- Technology ownership identification and competitive level measurement of defense industrial firms.

You are requested to scale your opinion considering these propositions' applicability within your institution.

Technology related studies within academia are being monitored closely

1 2 3 4 5
Strongly Disagree Strongly Agree

Close co-operation and bi-lateral relations are established with international organizations (NATO, EDA vb.) and other countries

1 2 3 4 5
Strongly Disagree Strongly Agree

Open source databases are being fully utilized to collect TM related data

1 2 3 4 5
Strongly Disagree Strongly Agree

National and international patent databases are being examined to search for new technologies

1 2 3 4 5
Strongly Disagree Strongly Agree

Technology related activities such as fairs, exhibitions and demonstrations are being followed actively

1 2 3 4 5
Strongly Disagree Strongly Agree

Technological resources and capabilities are being identified, categorized and evaluated

1 2 3 4 5
Strongly Disagree Strongly Agree

Manpower requirements are being planned and experts on TM are being employed

1 2 3 4 5
Strongly Disagree Strongly Agree

Training and education of personnel working on TM are being planned and realized

1 2 3 4 5
Strongly Disagree Strongly Agree

Maturity levels of newly developed and emerging technologies are being determined and monitored regularly

1 2 3 4 5
Strongly Disagree Strongly Agree

System and technology readiness levels of planned defense systems are being determined and monitored regularly

1 2 3 4 5
Strongly Disagree Strongly Agree

Evaluations for the future use of technologies and technological products are being performed

1 2 3 4 5
Strongly Disagree Strongly Agree

Roadmaps concerning the future development of technologies and technological products are being developed

1 2 3 4 5
Strongly Disagree Strongly Agree

Impact analyses for the new technologies are being conducted

1 2 3 4 5
Strongly Disagree Strongly Agree

Technology options for the system development projects are being evaluated

1 2 3 4 5
Strongly Disagree Strongly Agree

Technology capabilities of defense industry firms are being measured

1 2 3 4 5
Strongly Disagree Strongly Agree

Comparison and bench-marking of defense industry firms against other national and international firms are being conducted

1 2 3 4 5
Strongly Disagree Strongly Agree

Inventory of technological assets of defense industry firms is being formed

1 2 3 4 5
Strongly Disagree Strongly Agree

Strengths and weaknesses of defense industry firms are being identified and value and gap analyses of them are being conducted

1 2 3 4 5
Strongly Disagree Strongly Agree

PART IV

In this part there are some propositions concerning the future war-fighting concept development activities and planning and development of defense systems having cutting-edge technologies resulting from new technological concepts.

You are requested to scale your opinion considering these propositions' applicability within your institution.

The future candidate technologies are being identified and shared with Armed Forces / DoD

1 2 3 4 5
Strongly Disagree Strongly Agree

Future war-fighting concepts are being developed jointly with Armed Forces / DoD by considering the future operating battlespace

1 2 3 4 5
Strongly Disagree Strongly Agree

Technological concepts involving future technologies are being developed in co-ordination with Armed Forces / DoD

1 2 3 4 5
Strongly Disagree Strongly Agree

Scenarios for the future operating environments are being generated by studying jointly with Armed Forces / DoD

1 2 3 4 5
Strongly Disagree Strongly Agree

Future war-fighting concepts and technological concepts supporting such concepts are being experimented within generated scenarios and their impacts on future operating environments are being evaluated

1 2 3 4 5
Strongly Disagree Strongly Agree

Future capability and system requirements are defined by considering the impact analyses results on future operating environment

1 2 3 4 5
Strongly Disagree Strongly Agree

Technology based roadmaps are being generated for the needed capability and system requirements

1 2 3 4 5
Strongly Disagree Strongly Agree

Please state any other issues in the context of the survey

Please leave your e-mail to be informed on survey results