DETERMINING A STRATEGY FOR FAVORABLE ACQUISITION AND UTILIZATION OF COMPLEX TECHNOLOGIES: FLIGHT SIMULATION TRAINING DEVICES (FSTD)

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Prof. Dr. Meliha ALTUNIŞIK
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Erkan ERDİL
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Serkan ÖZGEN
Co-Supervisor

Prof. Dr. Erkan ERDİL
Supervisor

Examining Committee Members

Prof. Dr. Erkan ERDİL (METU, ECON)

Prof. Dr. Serkan ÖZGEN (METU, AE)

Assoc. Prof. Dr. Teoman PAMUKÇU (METU, STPS)

Assoc. Prof. Dr. Yılmaz ÜSTÜNER (METU, ADM)

Assoc. Prof. Dr. İlkay YAVRUCUK (METU, AE)

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Ömer BOZTAŞ

Signature :

ABSTRACT

DETERMINING A STRATEGY
FOR FAVORABLE ACQUISITION AND UTILIZATION OF
COMPLEX TECHNOLOGIES: FLIGHT SIMULATION TRAINING DEVICES
(FSTD)

Boztaş, Ömer
MSc, Department of Science and Technology Policy Studies
Supervisor : Prof. Dr. Erkan ERDİL
Co-Supervisor : Prof. Dr. Serkan ÖZGEN

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The thesis investigates the elements of a consistent strategy for favorable acquisition and utilization of Flight Simulation Training Devices (FSTD), thus Full Flight Simulators (FFS) and Flight Training Devices (FTD). The primary purpose is to determine a knowledge-based strategy for the end-user, acquisition professional, aviation firms and institutions. Hence, it could be possible to shed a light for cooperative groups and main institutions of national innovation system involved in entrepreneurial and innovative efforts regarding complex technologies like FSTD.

In the sample study, 114 pilots from varied sources were administered a questionnaire and their FFS and FTD perceptions were statistically tested regarding each "technology's usefulness" in four types of training. Another variable, each "technology's ease of operation and use" was also tested additionally via agent-based model whether it had any effect on technologies' selection processes. It could be inferred that that aviation institutions and firms could acquire and utilize FTD as a complementary to both aircraft and FFS within a range of 30-60% depending upon type of the training. Moreover, FTD could be acquired and utilized as a substitute to

FFS for Instrument Flight Training (IFT). The FTD's usefulness for IFT was rated as 67% by the military pilots.

The research also asserts that the aviation institutions and firms as well as cooperative groups and organizations could favor the established strategy and policy during their FSTD related efforts at "micro and meso-level". The final aim is to create a collaborative medium and a synergy for those agents.

Keywords: Acquisition and Utilization of Complex Technologies, Consistent Strategy, Flight Simulation Training Devices (FSTD), Full Flight Simulators (FFS) and Flight Training Devices (FTD).

ÖZ

KARMAŞIK TEKNOLOJİLERDEN UÇUŞ SİMÜLASYONU EĞİTİM ARAÇLARININ AVANTAJLI TEDARİĞİ VE İSTİFADESİNE YÖNELİK BİR STRATEJİ BELİRLEME

Boztaş, Ömer
Yüksek Lisans, Bilim ve Teknoloji Politika Çalışmaları Bölümü
Tez Yöneticisi : Prof. Dr. Erkan ERDİL
Ortak Tez Yöneticisi : Prof. Dr. Serkan ÖZGEN

Eylül 2012, 138 sayfa

Bu tez, Uçuş Simülasyonu Eğitim Araçlarının (USEA), dolayısıyla Tam Uçuş Simülatörleri (TUS) ve Uçuş Eğitim Araçlarının (UEA) avantajlı tedariki ve kullanımına yönelik tutarlı bir strateji belirlemenin unsurlarını araştırmaktadır. Ana maksat, son kullanıcı, tedarikçi, havacılık firmaları ve kurumları için bilgiye dayanan bir strateji belirlemektir. Böylece, USEA gibi karmaşık teknolojilere yönelik yenilikçi ve girişimci faaliyetler içerisinde bulunan ulusal inovasyon sisteminin ana kurumları ve işbirliği gruplarına yol göstermek mümkün olabilecektir.

Örnek çalışmada, çeşitli kaynaklardan 114 pilota bir anket uygulandı ve pilotların TUS ve UEA algıları, her teknolojinin dört ayrı eğitime katkısı yönüyle istatistiki olarak ölçüldü. Diğer bir değişken olan her bir teknolojinin işletim ve kullanım kolaylığının teknoloji seçiminde etkisi olup olmadığı da ajan tabanlı bir modelde test edildi. Test sonucuna göre, havacılık kurum ve firmaları tarafından UEA'nın, eğitimin çeşidine göre, %30-60 arasında değişen oranlarla hava aracı ve

TUS'u tamamlayıcı olarak; Alet Uçuş Eğitiminde (AUE) ise %67 oranıyla TUS yerine tedarik edilebilir ve kullanılabilir olduğu çıkarımında bulunulabilmektedir.

Ayrıca araştırma, havacılık kurum ve firmaları, aynı zamanda işbirliği grupları ve organizasyonların küçük ve orta seviyedeki USEA ile ilgili faaliyetleri süresince, ortaya konan stratejiden ve de politikadan faydalanacaklarını iddia etmektedir. Nihai maksat söz konusu ajanlar arasında işbirliği ortamı ve sinerji yaratmaktır.

Anahtar Kelimeler: Karmaşık Teknolojilerin Tedarik ve Kullanımı, Tutarlı Strateji, Uçuş Simülasyonu Eğitim Araçları (USEA), Tam Uçuş Simülatörleri (TUS) ve Uçuş Eğitim Araçları (UEA).

To My Wife

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LIST OF ABBREVIATIONS

AC	Advisory Circular
BRICS	Brazil, Russia, India, China and South Africa
CBT	Computer Based Trainers
CPT	Cockpit Procedural Trainer
CTER/CTEF	Cumulative Transfer Effectiveness Ratio/Function
CTO	Cooperative Technical Organizations
DI	Domestic Investment
DIS	Distributed Interactive Simulation
DOF	Degrees of Freedom
DSB	Defense Science Board
EOTE	Evidence of Training Effectiveness
FDI	Foreign Direct Investment
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FFS	Full Flight Simulator
FNPT	Flight Navigation Procedures Trainer
FOV	Field of View
FS	Flight Simulator
FSTD	Flight Simulation Training Device(s)
FTD	Flight Training Device
HLA	High-Level Architecture
IAR	Inherent Availability Ratio
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IERW	Initial Entry Rotary Wing
IFT	Instrument Flight Training
IG	Image Generator
IP	Instructor Pilot
IPT	Integrated Product Team

ITER/ITEF	Incremental Transfer Effectiveness Ratio/Function
JV	Joint Venture
LDT	Logistics Delay Time
LOC	Line of Code
MCT	Mean Corrective Maintenance Time
MoD	Ministry of Defense
MTBF	Mean Time Between Failure
NAA	National Aviation Authorities
NTT	Negative Transfer of Training
PEU	Perceived Ease of Use
PLC	Product Life Cycle
PToT	Positive Transfer of Training
PTS/PTT	Part Task Simulation/Trainer
PU	Perceived Usefulness
SARFT	Search and Rescue Flight Training
SD	Systems Dynamics
SE/SF	Synthetic Environment/Flight
SME	Subject Matter Experts
SMEs	Small Medium Enterprises
SS	Simulator Sickness
TAF	Turkish Air Force
TAM	Technology Acceptance Model
TER	Transfer Effectiveness Ratio
TFT	Tactical Flight Training
ToT	Transfer of Training
TRF	Technology Reliability Factor
TTF	Task-Technology Fit
TUAA	Turkish Army Aviation
US ARI	US Army Research Institute
VFT	Visual Flight Training

CHAPTER 1

INTRODUCTION

1.1 Background

Commercial and military aviation organizations, having varied scales and training needs, experience a few technology management challenges. Among of those, effective and efficient acquisition and utilization of flight training technologies are noteworthy. Within the context, Flight Simulation Training Device (FSTD)[1] related matters have gained more bases recently since its use has been accepted as the most viable solution for the aviation institutions and firms to maintain aircrew training standardization and quality.

On the other hand, the rules and the regulations mandated by the aviation authorities constitute several constraints for FSTD operators and users. Those enforcements quite overlap as compared to varied authorities' applications since "the training and the flight safety" is a common concern for them. The European Aviation Safety Agency (EASA)[2] and the Federal Aviation Administration (FAA)[3], for example, are the most known and the accepted authorities which were created

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[1] FSTD is a common term used for flight simulators (as regulated by EASA and FAA). Retrieved from http://easa.europa.eu/agency-measures/docs/agency-decisions/2012/2012-011-R/CS FSTD(H)%20Initial%20Issue.pdf and http://www.faa.gov/ (01/ 08 September 2012).

[2] EASA promotes the highest common standards of safety and environmental protection in civil aviation in Europe and worldwide. The agency's responsibilities include expert advice to the EU for drafting new legislation; implementing and monitoring safety rules, including inspections in the Member States; type-certification of aircraft and components, and approval of organizations involved in the design, manufacture and maintenance of aeronautical products; authorization of non-EU operators; safety analysis and research. Retrieved from

http://easa.europa.eu/what-we-do.php (30 July 2012)

[3] Federal Aviation Administration (FAA) acts under the broad umbrella of safety and efficiency and has several major roles: regulating civil aviation to promote safety; encouraging and developing civil aeronautics, including new aviation technology; developing and operating a system of air traffic control and navigation for both civil and military aircraft; researching and developing the National Airspace System and civil aeronautics; developing and carrying out programs to control aircraft noise and other environmental effects of civil aviation; regulating U.S. commercial transportation. Retrieved from

http://www.faa.gov/about/safety_efficiency/ (08 September 2012) geographically. The International Civil Aviation Organization (ICAO)[4], however, regulates all fields of civil aviation among its members throughout the world.

In the aviation sector, the mostly used FSTD types are Full Flight Simulators (FFS)[5], Flight Training Devices (FTD)[6], Flight and Navigation Procedures Trainers (FNPT)[7]. The term, "FSTD", usually known as flight simulators (FS) will be used for all interactive flight-training tools while the primary focus will be on FFS and FTD throughout the study. Prior to elaborating more on the research and conducting sectoral analysis in Section 6.1 (Local Markets and Developing Economies), some FSTD acquisition and utilization cases will be given as introductory examples in the following paragraphs.

Today, FSTD supports almost every phase of aviation training for both commercial and military applications. The main motivation of using FSTD for the organizations participated in the sector is to generate a cost-effective and a less risky training environment while holding a competitive position among the others. According to the latest developments in military FSTD applications, up to 75% of required flight training hours in some programs are performed in the synthetic

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[4] ICAO: A specialized agency of the United Nations, was created in 1944 to promote the safe and orderly development of international civil aviation throughout the world. It sets standards and regulations necessary for aviation safety, security, efficiency and regularity, as well as for aviation environmental protection. The Organization serves as the forum for cooperation in all fields of civil aviation among its 191 Member States. Retrieved from

http://www.icao.int/Pages/icao-in-brief.aspx (05 October 2012)

[5] Full Flight Simulator (FFS): A full size replica of a specific type or make, model and series airplane/helicopter flight deck, including the assemblage of all equipment and computer programmes necessary to represent the airplane/helicopter in ground and flight operations, a visual system providing an out of the flight deck view, and a force cueing motion system. It is in compliance with the minimum standards for a specific FFS Level of Qualification.

[6] Flight Training Device (FTD); A full size replica of a specific airplane/helicopter type's instruments, equipment, panels and controls in an open flight deck area or an enclosed airplane/helicopter flight deck, including the assemblage of equipment and computer software programmes necessary to represent the airplane/helicopter in ground and flight conditions to the extent of the systems installed in the device. It does not require a force cueing motion or visual system. It is in compliance with the minimum standards for a specific FTD Level of Qualification.

[7] Flight and Navigation Procedures Trainers (FNPT): A training device which represents the flight deck/cockpit environment including the assemblage of equipment and computer programmes necessary to represent an aircraft or class/type of aircraft in flight operations to the extent that the systems appear to function as in an aircraft.

environment (Mahon, 2006, p.3) while "100% simulator flight approach" gains more bases in the commercial sector.

Private aviation sector stands out for its strong motivation towards simulator acquisitions and utilizations. While bigger simulator manufacturers like CAE, L3 (Link), Thales and few others have captured a good portion of billion-US$ global FSTD market, some companies are involved in innovative efforts to differentiate their positions in the competition. Having detected the need of regional airlines (Dallas-based Southwest Airlines) and low-cost carriers, for example, Mechtronix brought in "microprocessor-based flight training equipment" idea in 1995 (Olijnyik, 2006, 33-34). In 2006, Panama-based COPA Airlines integrated "Ascent FFS X Flight Simulator (was built by Mechtronix)" into its training system. The plan was to perform 100% of its mandatory and recurrent pilot training and 80% of its initial or transitional flight training in that FSTD at a lower cost (Olijnyk, 2006).

Source: US Army Program Executive Office for Simulation, Training & Instrumentation (2012)

Figure 1.1 Flight Simulators at FS XXI, Aviation Center of Excellence

Regarding military applications, The US Army Aviation Flight School XXI[8] (Figure 1.1) might be taken as one of a good FSTD procurement practices among

8 The FS XXI simulation capability is a long-term, contractor-provided simulation service consisting of Training Helicopter (TH-67) virtual simulators, advanced aircraft virtual simulators (UH-60A/L, UH-60M, AH-64A/D, OH-58D, CH-47D and CH-47F). It is a turn-key type operation paid for based on hours of contracted mission time (simulator availability). Systems are owned, operated and maintained by the contractor with government oversight and approval (23 April 2012). Retrieved from http://www.peostri.army.mil/PRODUCTS/FSXXI/ (31 July 2012)

the others, which was motivated to update its curriculum and incorporate more simulator flights because of a substantial cut in the availability of training funds. The stated program objectives were to make the Flight School more effective and efficient and to increase the war fighting capability of graduates (Stewart III, Dohme & Nullmeyer, 1999, p.6). The training curriculum requires FSTD-based training flights for 30% and 22-40% of all training flights for "The Common Core" and "The Advanced Track" respectively (Reese, 2012).

The last example is about the efforts in the Turkish Army and Navy Aviation. Flight training has been performed with the requirement of FSTD-based flights for 25% of all training flights in the "Army and Navy Helicopter Pilot Basic Training Program" since 1990 (Boztaş, 2006, p.9). The four UH-1 Helicopter FNPT cabins in the Army Aviation School were manufactured by CAE. In 2005, the Turkish Ministry of Defense (MoD), signed a contract for "Helicopter Flight Training Simulator Center (HELSİM)" project and selected HAVELSAN AŞ as a sole source contractor. Turkish MoD authorized the firm to establish subcontractor partnerships and agreements in domestic and international markets since the final aim is to gain FSTD developing and/or manufacturing capability. Realizing the project, the army and navy aviators could incorporate 40-60% FSTD flights in "Advanced Helicopters' Qualification Programs"[9] and maintain standardization and quality while reducing high cost of training.

Having mentioned on the few cases above, it could be inferred that the reduction in actual flight hours and the associated cost savings with the increase in flight safety and standardization seems to be the primary goal of almost every stakeholder in the sector. Either commercial or military, therefore, most aviation institutions and firms have an intention to integrate more simulator hours into their training curricula.

In addition to the benefits mentioned so far, it is significant that the developing economies and organizations get some capability from those acquisitions because of FSTD's complex technological attributes. For doing that, the

[9]The Advanced Helicopters' Transition Courses are performed to train pilots for the advanced helicopters, S-70 Sikorsky, AS-532 Cougar and T-129 ATAK, in the Turkish Army.

emerging organizations and/or economies should plan acquisition and utilization processes of those technologies cautiously. These inflows should not "weaken their indigenous industrial and technological capabilities" (Wang and Gao, 2006, p.9) and inhibit them from favoring this profitable sector because of the nature of state-of-the-art and complex technologies. This should be the main drawback of acquiring FSTD since "technological learning" and "indigenous innovation capability" may not always be attained through such acquisitions (Fu and Soete, 2010, p.8).

Previously, the global FSTD acquisition and utilization's examples and the adoption trend have been introduced. Additionally, the problem stemming from the complex technology's nature has been mentioned briefly. Prior to conducting the research and analyzing the complex technologies' primary matters in the subsequent chapters, it would be better to structure a knowledge-based mainframe and to elaborate on problem, research questions, purpose and scope as follows.

1.2 Problem

Searching the literature and examining the ongoing projects, complex technology and thus FSTD related matters seem to offer some weaknesses in their acquisition and utilization processes. The problems are mostly associated with inappropriate strategies and/or operational inadequacies.

Additionally, the efforts towards developing better innovative and entrepreneurial environment for FSTD related cooperative groups, firms and institutions might fall short in terms of creating a value added outcomes due to inconsistent policy and strategies.

1.3 Research Questions

In the thesis, the elements of favorable acquisition and utilization of FSTD are examined and a strategy is established. Aiming that, effective and efficient way of acquiring and utilizing FSTD is investigated and the following questions are addressed:

1. Is it possible to determine a strategy for favorable acquisition and utilization of FSTD?

2. Can the determined strategy shed a light for firms, cooperative groups and institutions conducting innovative and entrepreneurial efforts towards FSTD technology?

3. Is there a way to enhance technological learning and capability, and to exploit the opportunities in this profitable sector?

4. What can be the suggestions for the future study on favorable acquisition and utilization of FSTD?

1.4 Purpose

The main objective of the thesis is to determine a knowledge-based strategy for the aviation institutions, firms, end-users and acquisition professionals as they could refer while acquiring and/or utilizing FSTD.

Secondly, it is aimed to shed a light for cooperative groups and organizations conducting innovative and entrepreneurial efforts towards complex technologies and thus FSTD.

Lastly, the purposes mentioned above could help substantiating an interdisciplinary approach, a knowledge base and a synergy for the groups and the organizations acting in sectoral systems of innovation and national economy.

1.5 Scope

The research is limited to FFS and FTD since they are the most acquired and utilized FSTD technology in the market. The study is tailored to respond to the needs of emerging firms, institutions and economies as well as entrepreneurs searching for the opportunities as to favor knowledge-based systems and sectoral systems of innovation.

Sample study (Section 4. Analyzing Agents' Preferences towards FSTD Technology and Modeling Selection Process between FFS and FTD) examines technology adoption behavior based on limited variables such as commercial and military agents' perceptions towards FSTD technology's "usefulness" and "ease of operation and use" for certain flight-training tasks and needs rather than including several parameters and institution/firm specific variables.

CHAPTER 2

FSTD TECHNOLOGY AND QUALITATIVE MATTERS IN UTILIZATION

2.1 FSTD Technology

Chapter's first aim is to introduce FSTD technology via constituting a historical background and giving some explanations about its technical features and purpose of use. We have taken this necessary since the following section, "Qualitative Matters in Utilization", and FSTD technology related acquisition and utilization processes are mainly based on these technical specifications and purposes. Secondly, we consider that FSTD's validation and qualification, flight training needs and technological requirements, effectiveness and efficiency matters in FSTD utilization, and lastly FSTD-Aircraft mix training perspectives have an impact in acquisition and utilization of the technology and should be included in our final model. Hence, this chapter would be bedrock to orient the reader more easily towards recognizing FSTD technology related processes and constituted strategy.

2.1.1 Brief History

FSTD has been in use in the aviation training since the early 1900s. The primitive model was a combination of a control lever and a simple fuselage casing pilot's seat and steering pedals. It was used to make inexperienced aviators to be acquainted with flight controls and performance of an aircraft, and to transfer those skills to a real aircraft (Lafçı, 2005, p.9). The history of FSTD would go back as long as the history of a manned flight. Huff and Nagel (as cited in McCauley, 2006, p.3) mentioned on that in the study of "Psychological aspects of aeronautical flight simulation".

The initial training methods, getting the aviators to simulate as if they were on the controls and to practice via a trailed aircraft on a railroad and/or a model aircraft pulled by a balloon or a powered machine are reported in the literature. Sanders' method is also unique for being the first as to simulate aerodynamic forces on the ground. Those were the practices until the end of World War I (Page, 2000, p.2).

Since then, some mechanical and electrical training systems were introduced. Buckley developed an electrical simulator and got a US patent for it for the first time[1] in 1929 (Page, 2000). Referencing electrical systems, the "Link Trainer", accepted as the most successful and well-known trainer of its era and FSTD history was developed in 1927-1929 (Page). It was patented in 1930 and advertised as "an efficient aeronautical training aid and a novel profitable amusement device". In 1939, Link was contracted to design a crew celestial navigation trainer for UK and was motivated to manufacture electronic simulators by the end of World War II (Page, 2000, p.3).

Being parallel to the needs and technological developments in the aviation during the period of two world wars, a competition started among flight training devices' researchers and manufacturers. Moroney & Moroney (1999) reported (as cited in McCauley, 2006, p.5) that around 10,000 Link trainers were utilized and this in turn created an economy of scale at that time. In the period of 1940-1950, Curtiss-Wright Corporation, Redifon and Link were the three major simulator manufacturers. Curtiss-Wright constructed the first full aircraft simulator, which was acquired by an airline company, Pan American Airways (Lafçı, 2005, p.11; Page, 2000, p.4) when Redifon's researches on FSTD attracted some other airlines. Redifon started working with Curtiss-Wright to build simulators during that period (Page, 2000).

The number of training devices and their capabilities significantly increased especially after World War II. Visual display systems and indicators were mounted in the 1950s and computer based image generating capabilities were developed in the 1960s (McCauley, 2006). FSTD became an integral part of all commercial airline operations since then (Page).

With the exponential increase in hardware and software technologies during 1970s, the motivation towards creating identical cockpits and realistic virtual

[1] US Patent 1,865, 828 Filed 1929. J.P. Buckley.

environment has become a primary consideration. The two most common FSTD technologies; FFS and FTD, also known for their high realism levels, had been introduced to both commercial and military sector by the mid-1970s (Rosenkopf & Tushman, 1998, p.3).

Moroney & Moroney stated (as cited in McCauley, 2006) that some rules and regulations were introduced for both private and public aviation institutions, as Synthetic Environment (SE) technology and the training need for larger number of aviators improved. In the early 1980s, an improvement in the operational fidelity of FS has steadily improved with the establishment of the "Advanced Simulator Approval Program" (Dillard, 2002, p.13). Some other disciplines like aviation psychology, as Page stated, also introduced new devices as to help assessing the aptitude of prospective pilots (as cited in Boztaş, 2006, p.9) after that.

Today, FSTD's acquisitions and utilizations have become widespread for any phase of flight training in the aviation sector. Training curricula are organized according to the rules/regulations established by the internationally accepted authorities; ICAO, EASA and FAA (were mentioned in Section 1.1) although there may be some differences among countries' national and military applications.

2.1.2 Technical Aspects

The two mostly utilized FSTD types, FFS and FTD, are illustrated as selected examples in Figure 2.1 and 2.2.

Source: Robinson & Mania (2004); CAE Webpage (2012)

Figure 2.1 Full Flight Simulators (FFS)

FFS is technically more complicated than FTD since combining simulator subparts together, running and synchronizing them with motion and vision is highly complex and interdisciplinary matter. FFS also differs largely from FTD as compared to their costs, 15-20 versus 1-3 million dollars (Dillard, 2002; Stewart II, J.E., Barker C.W., Weiler, D.S., Bonham, J.W., & Johnson, D.M., 2001; Rosenkopf & Tushman, 1998).

Source: Boeing and CAE Webpage (2012)

Figure 2.2 Fligh Training Devices (FTD)

The FSTD is comprised of "interdependent components" (shown in Table 2.1) whereas "a development in one component can enable or retard progress in others" (Rosenkopf & Tushman, 1998, p.14).

Table 2.1 Interdependent Components and Associated Knowledge Base

Source: Adapted from Rosenkopf & Tushman (1998)

Components	Associated Knowledge Base
Software and Mathematical Models	Integrating Software and Aerodynamics Engineering Expertise (Core Competency/Black Box)
Computer Hardware	Enhanced Digital Computing, Image Generating and Process Engineering Knowledge
Flight Instrumentation	Combining Actual/Stimulated or Simulated Electromechanical Instruments with Simulation Software
Motion Systems	Correlating Hydraulically/Electrically Actuated Motion Platform with Control Inputs on 2 to 6-Degrees of Freedom
Visual Systems	Tuning/Overlapping Visual Imagery and Projectors, and Combining Image with the Correct Display Solutions

The main components combine and work in harmony to simulate flight and create virtual environment for the trainees. Flight instruments and controls, motion and visual systems, and computing hardware are integrated via software code and mathematical models. Associated knowledge base for each component is also shown Table 2.1.

Schroeder (1999) stated (as cited in McCauley, 2006, p.1) that FSTD is designed to reproduce the pilot-vehicle behavior of actual flight on the ground reasonably and safely. Aiming that, the researchers, end-users, aviation institutions and authorities have an insatiable intention of pushing limits towards more realistic simulations since the success is mostly related to the human perceptions, also highlighted by Galloway (2000) as follows

> Pilot's perception influenced by the combination of cues; instrument displays, flight control forces, visual imagery, motion, vibration and aural cue systems.

During the simulation, resolution level[2], iteration rate[3], latency rate[4], models and their real time effects are some commonly accepted features determining the level of fidelity[5] for a realistic training. McCauley (2006, p.4) describes two types of fidelity as follows

> Objective fidelity in a simulator refers to the physical correspondence between the flight simulator and the aircraft. Presumably, engineering techniques can be applied to measure both the aircraft and the simulator, yielding an index of objective fidelity.

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2 Resolution Level is the amount of detail or degree of aggregation employed in the model or simulation used.

3 Iteration Rate explains image generator (IG)'s speed at which the FS's visual system responds to given commands.

4 Latency Rate is the level of time lag that occurs between the control signal sent to the simulator processor and the simulation effect produced as an output.

5 The degree to which a model or simulation reproduces the state and behavior of the real world, or the perception of a real world object, feature, condition, or chosen standard in a measurable or perceivable manner; a measure of the realism of a model or simulation. Fidelity should generally described with respect to measures, standards, or perceptions used in assessing or stating it, See accuracy, precision, resolution, repeatability, model/simulation validation. This definition was developed by Fidelity Working Group for DoD Simulator Interoperability Standards Organization (1998) and quoted in Archie E. Dillard, "Validation of Advanced Flight Simulators for Human Factors Operational Evaluation and Training Programs,": (2002): 35.

> Perceptual fidelity refers to the relationship between a pilot's subjective perceptions of the simulator and the aircraft. It also refers to the comparative sets of pilot performance and control strategies in the simulator and the aircraft.

The level of fidelity is accepted as the primary determinant of the quality of FSTD and should be taken into consideration in designing, manufacturing, acquiring and utilizing FSTD. The "fidelity level" of an FSTD is also accepted as an evaluation metric, and is one of the most significant and valid prerequisites of an effective flight training simulation.

The fidelity level of an FSTD is determined according to qualitative and quantitative features of its subparts creating realism as a whole. Prasad, J.V.R., Schrage, D.P., Lewis, W.D., & Wolfe, D.'s (1991) study (as cited in Lafçı, 2005, p.39; Rehmann, A.J., 1995, p.12), "FSTD subsystems and their fidelity level characteristics", is important for assigning levels of fidelity and determining metrics to each subsystem as follows in Table 2.2.

Table 2.2 FSTD Subsystem Fidelity Characteristics

Source: Adapted from Prasad et al. (1991) cited in Lafçı (2005), & Rehmann (1995)

Simulator Subsystem	Fidelity Characteristics
Cockpit/Crew Station	- **None** - **Simulated/Generic Type Instruments** - **Partially Simulated Cockpit** - **Full Up Crew Station**
Audio	- **None** - **Significant Cockpit Sounds** - **Incidental Sounds (Precipitation, etc.)** - **Realistic**
Motion	- **None** - **2 Degrees of Freedom (Pitch & Roll)** - **3 Degrees of Freedom (Pitch, Roll and Yaw)** - **6 Degrees of Freedom (Pitch, Roll, Yaw, Sway, Surge, Heave)**
Control System/Loading	- **No Force Feel** - **Constant Force (Spring/Damper)** - **Partial Duplication of Actual Force** - **Complete Duplication**
Mathematical Model	- **None** - **3 Degrees of Freedom** - **6 Degrees of Freedom** - **6 Degrees of Freedom with Rotor**

Table 2.2 (Cont'd)

Environment	- **Clean Air** - **Discrete Gusts** - **First Order Filtered Turbulence** - **Rotationally Sampled Turbulence**
Ground Handling	- **No Gear** - **Rigid Gear** - **Simplified Gear Model** - **Comprehensive**
Mission Equipment	- **None** - **Communication Only** - **Communication/Navigation Only** - **Complete**
System Latency	- **Non Real Time (Off Line)** - **Significant Delay** - **Minimal Delay** - **Real Time**
Visual	- **Field of View (Workstation/75° Horiz.-35° Vert./90° Horiz.-40° Vert./Wider)** - **Dynamic Range (Day / Dusk / Haze-Fog / Night)** - **Detail/Resolution Level (Low / Medium / High / Very High)**

Recent developments in FSTD technologies have also introduced some novelties like roll-in/roll-out cockpits/cabins rather than dedicated systems, which provide the user with variety of cockpit configurations and aircraft types in the same module. Electrically rather than hydraulically actuated systems have started to be taken place in motion platform manufacturing sector. Such novelties could offer some favorable solutions for the end-user and acquisition professionals: less manufacturing and maintenance cost and thus less life cycle cost, higher capability of simulating ground cuing effects and control loading responsiveness etc. (CAE, 2012).

The fidelity level of an FSTD could be also evaluated according to the specified items asserted by Dillard (2002) and as listed below in Table 2.3. The interrelated features stated in both table (Table 2.2 and 2.3) could be accounted as a simplified checklist for any agent who gets involved in the acquisition and utilization of FSTD. It is expected from any stakeholder that FSTD should be acquired and utilized appropriately regarding its main and/or subpart features as well as required fidelity (McCauley, 2006; Stewart II et al., 2001) since those are the main cost-drivers sustaining the system. Based on the features and requirements mentioned above, FSTD could be classified in different styles by the aviation authorities; ICAO, EASA, FAA and National Aviation Authorities (NAA).

Table 2.3 Fidelity Evaluation Items

Source: Adapted from Dillard (2002)

FSTD Item Fidelity Evaluation Checklist
Simulator System Fidelity
Aerodynamic Database Fidelity
Realistic Motion System Performance
Realistic Visual System Performance

Taking FTD; the two certified levels (1 and 2) exist for airplane and three (1 through 3) for helicopters according to EASA while FAA asserts seven airplane/helicopter FTD certification levels.

On the other hand, the four levels of FFS classification, A through D and their specifications are identical comparing ICAO, EASA and FAA`s regulations. Those authorities all sign to the required fidelity features and approval specifications of FFS. Level D, for example, the highest level of certification with one of the features of "depicting airport environments and in flight scenes with amazing detail and fidelity" (Twombly, 1998, p.48), is common for all.

Another perspective classifying simulation and FSTD with respect to the features determining their functional areas is as follows (Dillard, 2002, p.4).

> A normal sequence for applying the different types of simulation would be the use of numerical or mathematical modeling, part task simulation/trainer (PTT), followed by an unmanned integrated model with a high level of accuracy, to a human-in-the-loop flight training device (FTD) or cockpit procedural trainer (CPT) with part of the systems operating at a high fidelity; to, finally, a human-in-the-loop advanced full flight simulator (FFS) approved under the advanced approval program with an extremely high level of fidelity

Twombly (1998) states distinguishing features of an advanced FSTD as follows: 1) Faithful replication of the performance, 2) Quality handling of a modeled aircraft, 3) Higher certified levels such as B, C or D 4) Realistic physical design and layout of the cockpit, 5) Realistic control loading and feel of the flight controls at any ground/flight configuration, 6) Appropriate information presented on instruments, 7) Quality visual and motion system.

2.1.3 Purpose of Use

Searching the literature, the two most common and essential purposes of using FSTD could be stated as being training and research (Gibson, 2000, p.157). As stated by Lones, Hennessy & Deutsch (1985), US National Academy of Sciences identified four fundamental purposes of simulation (as cited in McCauley, 2006, p.3). These are: 1) Training, 2) Systems equipment design, development, test, and evaluation, 3) Research on human performance and 4) Licensing and certification. FSTD is also used for some research on topics such as “cockpit instrument design layout, handling qualities evaluation, manning and automation, and crew resource management” (McCauley, 2006).

Regarding the second purpose of simulation use as mentioned above; aircrafts’ equipment and display systems design and development via use of FSTD is noteworthy because of its great support in reducing cost of the projects and research programs. The more the researchers and engineers rely on simulators, the less the mock-ups or actual platforms are needed in the projects. In this context, some hardware/software tests could be eliminated while redesign efforts and related costs could be reduced (Orlansky, J., Dahlman, C.J., Hammon, C.P., Metzko, J., Taylor, H.L., & Youngblut, C., 1994) and project durations are shortened.

As noted in the examination of The Defense Science Board (DSB); the potential use of simulation for many purposes of concern to defense and aviation could be listed as “training, test and evaluation, mission rehearsal and system acquisition” (Orlansky et al., 1994) which of those overlap with the ones mentioned above in many ways.

Another perspective is that the flight training methodology which holds a great place in the aviation research. The unknowns in human behavior and the complexities of human-machine interaction constitute the center of research and experimentation. The biggest motivation behind developing better flight training technologies is to understand human behavior in order to avoid human associated risks (Boztaş, 2006, p.1). Dillard (2002) mentioned on that as follows; "The time required for equipment and procedural development, and operational implementation, the use of simulation has grown importance".

To sum up, it is mostly agreed that a favorable use of FSTD generates valuable results for training and research purposes. Constructing appropriate and coordinated aircrew behaviors and attitudes in the cockpit; transferring those positive behaviors into actual flight mission; maintaining standardized aircrew potential; creating less risky and cost-effective training environment throughout the aviation system via use of FSTD would be the ultimate purpose of all aviation institutions and firms in the sector.

2.2 Qualitative Matters in FSTD Utilization

2.2.1 FSTD Validation and Qualification Perspective

Validation of an FSTD is an evaluation of a system itself and its utilization via employing both objective and subjective testing methods and assessing throughput outcomes at the end. Those processes include performance testing against known aircraft data; objective comparison of performance variables with the additional expert subjective testing; system certification sustainment based on qualification criteria; testing visual and motion systems together with the main and subsystems as referred to throughput latency standards (Dillard, 2002, p.4).

There are a few requirements validating FSTD so once a contract signed to develop or to acquire a validated FSTD, the "Design Goal(s)" (Galloway, 2000, p.1) should be determined at first. The design goals and the specifications should overlap and be consistent since it would help getting a validated and a qualified product. It would be otherwise waste of the resources and the efforts. Galloway (2000) mentioned on that as follows

> How well the simulator developed meets the design goals which are determined via a process called Validation. Critical elements for this process include a clear declaration of simulator requirements, appropriate data, and effective test methods. These principles apply for validating the manned vehicle simulators. Flight simulator validation compares the performance of the simulator with the

performance of the real world vehicle from the operator's (pilot's) perspective using both quantitative and qualitative measures.

"Qualification Guidelines" (Williams & Blanchard, 1995, p.5) is also significant and could be accepted as metric of functional and effective flight training in this respect. The level of FSTD utilization within the curriculum together with the transfer of training to the real aircraft and the tasks are the primary considerations while constructing task-referenced qualification guidelines.

Galloway (2000, p.2) noted on the relation between model creation and simulation realism as follows. "How close is close enough? This must be answered before the model is developed in order to establish a basis for acceptance between the model developers and users, and in certain applications, regulatory authorities". International Air Transport Association (IATA), for example, provides guidance on data requirements for airline simulators while it is highly necessary for the military that subject matter experts (SME) come into play since complexity requirements differ between the applications. The sample conceptual model illustrated below (Figure 2.3) highlights the importance of data as well as the guidelines shedding a light on FSTD validation and development processes.

Source: Galloway (2000)

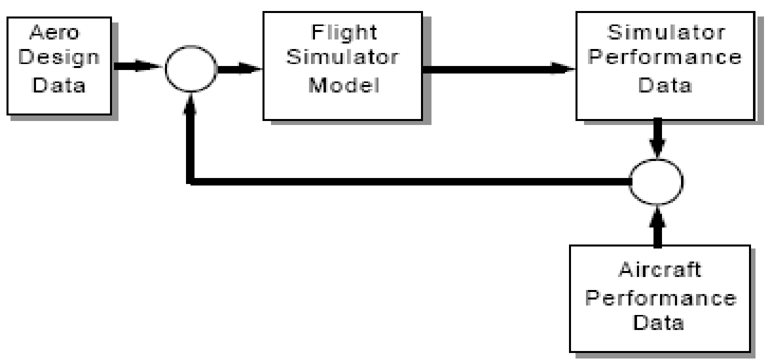

Figure 2.3 Flight Simulator Validation Elements

Regarding those processes; Galloway`s simplistic model (2000, p.3) explains well how the process should run as follows: "aero design data", an initial input for a "flight simulator model", is activated to generate "simulator performance data".

Following, the results are compared to "aircraft performance data" and any deviation is returned to the system as an adjustment/correction feedback with which the "aero design data" is adjusted/corrected.

The processes and the models used are identical when researchers, manufacturers, regulatory authorities' validation, and development methods are compared. The international regulatory authorities; ICAO, EASA and FAA enforce several rules, regulations and testing methods manufacturing, acquiring and utilizing FSTD, that in turn affect any agent involved in these costly [e.g. general guidance document published by IATA sells for $375.000 (Galloway, 2000)], complicated and heavily regulated approval processes (Olijnyk, 2006, p.33-34).

FSTD that meets Level C approval criteria, for example, can cost $15 million or more (Dillard, 2002; Rosenkopf & Tushman, 1998). In addition to the original approval, all commercial simulators must be rechecked a minimum of twice annually, over the operational life of the equipment, to maintain approval (Dillard, 2002). On the other hand, hourly FSTD costs vary from around $300 to more than $1200, depending on the aircraft type and availability (Dillard).

Mentioned on product (FSTD and their use in flight training) approvals and operational issues, it should be noted that the validation and qualification procedures could be found in the related documents of regulatory authorities. The FAA Advisory Circular (AC), for example, gives specific criteria required to obtain and maintain approval on commercial simulators used for flight crew training.

The others are given as follows. ICAO applies DOC 9625 AN/938 (Manual of Criteria for the Qualification of Flight Simulators). EASA applies JAR-FSTD A or H (Aeroplane or Helicopter Flight Simulation Training Device). FAA applies AC 120-40 C or AC 120-63 (Airplane or Helicopter Simulator Qualification), AC 61-136 (FAA Approval of BATD and AATD under Title 14 Federal Code of Regulations/CFR) and AQP AFS-230 (Advanced Qualification Program).

2.2.2 Training Needs and FSTD Requirements

The use of simulation has grown in importance to shorten the time required for equipment and procedural development as well as operational implementation. However, as Stewart III, Dohme & Nullmeyer (1999, p.viii) states, "training developers and other decision-makers might have little substantive foundation for determining what such a training system (or even a simulator) should look like". In this context, aviation institutions and firms should clearly identify and declare their needs as to determine FSTD requirements and thus specifications appropriately.

What could be the methods of determining flight training needs as well as FSTD requirements? The easiest and most effective way to explore those is to check aviation institutions training programs, curricula as well as their evaluation and standardization methods. These programs and processes are subject to regulatory authorities' regular checks and approval procedures. Either private or public, the institutions should comply with those procedures and be in accordance with the rules/regulations enforced. These requirements are also value added processes in favor of aviation institutions regarding the marketing strategies.

The primary variables shaping institution-firm/unit-department/aircrew-pilot based training programs- are determined based on the mission needs and tasks. The level of aircrew specializations and skills are also effective on those flight-training curricula. The type of aircrafts, the rules/regulations enforced by the accepted regulatory authorities could be accounted as the additional considerations tailoring flight training in an organization.

In most flight training centers, some matrices and/or software programs are used to match the appropriate FSTD (FFS, FTD, CPT, PTT and etc,) with the accurate aircrew/pilot and flight training task (will be detailed in 3.3.3 Task-Technology Fit Model). We think it is as important as a favorable FSTD acquisition. The sample matrix (Orlansky et al., 1994), illustrated below in Figure 2.4 could be valid for the military, yet could be also developed and detailed according to the tasks and training needs for any public and private aviation institution.

Using the matrix below (Figure 2.4), the training environment, the types of simulators used and the type of training could be determined simply. As Orlansky et al. (1994) states the less costly simulators should be mostly used in units rather than institutions due to operational cost and maintainability. On the other hand, more utilization and technical support could be achieved through locating costly simulators in institutions (McCauley, 2006, p.2). The recent changes in computer-based and networking capabilities have made unit based organizations able to execute interactive and collective trainings from a distance. Distributed interactive simulation (DIS) or high-level architecture (HLA) capabilities, for example, have enhanced small size simulators and/or individual FFS/FTD participate the training on a common virtual base.

Individual and collective training curricula should be identified based on training items and be detailed by type, standard and tolerance, period and duration, number of iteration and etc. Then, the type(s) of approved FSTD (FFS and FTD) together with the allowed and/or advised usable times should be accounted for each training item.

Source: Orlansky et al., (1994, III-10)

	Where Training Occurs	
Type of Training	Institutions	Units
Individual	flight simulators maintenance simulators computer-based instruction part-task trainers	on-the-job training computer-based instruction embedded trainers unit training devices part-task trainers
Collective	wargaming ENWGS, CBS, ACAAM crew training simulators networked simulators SIMNET, CCTT field training on instrumented ranges National Training Center Red Flag Marine Corps 29 Palms	command-post exercises/ combat models field exercises component and joint training Distributed Interactive Simulation STOW, MDT2 embedded trainers

ENWGS	Enhanced Naval War Gaming System
CBS	Corps Battle Simulation
ACAAM	Air Courses of Action Assessment Model
SIMNET	Simulator Networking
CCTT	Close Combat Tactical Trainer
STOW	Synthetic Theater of War
MDT2	Multi-Service Distributed Training Testbed

Figure 2.4 Types of Simulators/Simulations Used for Individual or Collective Training in Institutions or in Units

Another issue is the aircrew standardization and evaluation. The rules enforced are very strict and mandate some criterion for both initial and recurrent pilots. Based on the civil aviation authorities' regulations, the aircrew is required to have adequate knowledge, hands-on skills, and proficiency in the integration of cognitive and motor skills in operationally realistic scenarios (Longridge, T., Bürki-Cohen, J., Go, T.H., & Kendra, A.J., 2001, p.1). These evaluations are executed periodically while the skills are checked based on the specifically tailored criterion and standards. Military aviation institutions, however, have their own standardization boards. These boards are authorized to determine task-based criterion and to evaluate military pilots and units according to those criterion/standards via the examiner pilots on a permanent basis.

As mentioned above and Twombly (1998) stated, "Pilot skills require regular inspections. Abilities can decline if they are not exercised regularly and bad habits can take root if they are not corrected quickly. Periodic training, therefore, make the pilots improve their flying techniques. In this context, FSTD is a favorable asset since the training environment it provides is "stable, controllable, repeatable and adaptable" (Dillard, 2002, p.8) while being ready-to-use every time. Stable training environment, for instance, is sustained via being capable of using clear and effective communication channels inside the cabin (human-in-the-loop) since FSTD is free of actual risks and disturbances like adverse weather conditions or traffic congested airspace.

However, there are a few challenges exist meeting training needs and matching requirements with the existing technological solutions. Motion platform and simulation of realistic radio communications are the two features, which remain as an unresolved issue for the airline training due to pushing effectiveness and affordability matters of FSTD (Longridge et al., 2001, p.1). Those features are disputable matching the needs with the requirements cost-effectively since there might be some more affordable solutions such as utilizing FTD instead of FFS with a wide field of view (FOV) visual system generating a similar outcome compared to FFS with platform motion cueing (Longridge et al., 2001).

Mechtronix, for example, aimed to develop a market for an upgraded Level B instead of Level D FFS at a low cost ($2-4 million cheaper) and to meet the majority of the training needs (Olijnyk, 2006, p.33-34). The company's innovative approach of doubling the three-legged Level B simulators and converting them to six-degrees of freedom platforms via using hybrid electro-pneumatic systems for motion platforms could be found favorable in many ways. The innovation yielded better results simulating aircraft's maneuver with shorter legs and less maintenance costs (Olijnyk, 2006).

Caro (1973) pointed out "simulators` training value depends more on a proper training program than on its realism". McCauley (2006) supported Caro`s assertion as highlighting "the common belief: the more fidelity equates to better training should be welcomed with skepticism since there is little evidence supporting that" and reinforcing his statement as follows

> In an analysis of simulation by the National Academy of Sciences, the number one conclusion was, "Physical correspondence of simulation is overemphasized for many purposes, especially training" (Jones et al., p.92). And further, "...the concern with fidelity should shift from what is technically feasible in a hardware sense toward achieving greater effectiveness and efficiency in terms of behavioral objectives." (McCauley, 2006, p.2)

These arguments should not only be the primary consideration of any stakeholder involved in the FSTD acquisition and utilization processes, but should also be the sectoral systems' of innovation and national innovation systems' problem. The developing economies should search for the opportunities, shape and associate the innovative/entrepreneurial efforts for the future. Longridge et al. (2001) mentioned on the problem as follows

> If the answers to these questions can reliably and validly be obtained, the FAA may be better able to determine what level of equipment should be required for initial or recurrent training programs in the future, and whether changes to future qualification criteria for such equipment are warranted. These decisions could significantly affect the cost and availability of flight training equipment in light of future regulatory plans, particularly for small operators.

2.2.3 Effectiveness and Efficiency in FSTD Utilization

Currently, the reduction in actual flight hours and the associated cost savings via use of advanced FSTD seems to be the primary goal of almost every stakeholder in the aviation sector (Boztaş, 2006, p.3). On the other hand, maintaining effective and efficient synthetic flight training environment and utilization remains a great-unresolved issue for all.

The variables; "effectiveness and efficiency", are the two training virtues, should be measured by the appropriate metrics on a permanent basis during the flight training processes. Otherwise, FSTD practices might turn out to be the aimless or unfavorable efforts and thus a negative transfer of training to the aircraft and the additional costs should be incurred.

Stewart III et al. (1999, p.viii) states "effectiveness of training in FSTD is a function of the amount of skill that transfers" and McCauley (2006, p.2) defines "effectiveness and efficiency in flight training" while associating the matter with the "cost-benefit" issue as follows

> Simulator features that provide positive transfer of training (PToT) to the aircraft have value in terms of achieving training objectives (effectiveness) and reducing the resources required to achieve criterion performance (efficiency). If the acquisition cost of these features is within reason (cost-benefit) then there is a strong case for including them in simulator training system acquisition.

FSTD has wide variety of cost and features and are accepted as one of the value-adding attributes in the associated flight training literature, unless they are appropriately acquired and utilized. However, there are some challenges deserve to be touched which originate from the training program, the method of utilization and the features of equipment, since inappropriate applications of those might generate unfavorable results like negative transfer of training (NTT). On the other hand, it should be known that PToT is not an all-or-nothing phenomenon because every complex flight skill is composed of a number of component skills (Williams & Blanchard, 1995, p.5).

A more appropriate way to assess transfer of training (ToT) of FSTD is to determine the degree to which FSTD training can be transferred to actual mission flight or the level to which training effectiveness can be maintained. This could be measured in two ways. First is the evaluation of a trainee performance via check-rides both in FSTD and in actual aircraft. Second is the accomplishment level of a mission assigned. Here, the first challenge is the application of subjective assessment methods. Although there might be some computerized evaluation programs like automatic recorders and monitoring devices embedded and developed for both FSTD and aircrafts, the most common assessment technique is instructor pilot (IP) ratings. Hays, R.T., Jacobs, J.W., Prince, C., & Salas, E. (1992, p.66) mentioned on that as follows

> Even seemingly objective measures, such as trials to proficiency, were classified as subjective when proficiency was based on IP judgment. Only measures that were based on clearly objective indices, such as recording of instrument readings at selected points during a flight-control maneuver (Martin & Waag, 1978), were considered objective.

The second challenge is whether criterion based/performance paced training and evaluation or lock-step/class based training and evaluation procedures should be applied since they differ in terms of having flexible versus static training programs. The issue is significant as also referred to efficiency matters since criterion based training has a potential of saving time and cost (Stewart et al., 1999, p.viii).

According to the significant research conducted by Hays et al. (1992); important characteristics of flight simulator training effectiveness were identified as well as the challenges mentioned above via a meta-analysis[6]. The results are highly noticeable as follows

> 1) Simulation is an effective method of training, 2) For jet aircrafts, more than 90% of the experimental comparisons favored simulator-aircraft mix training over aircraft training alone while similar helicopter experiments were less consistent[7], 3) Simulator training

[6] In the study, some 247 articles, research reports, and technical reports were located, from which 26 experiments were identified as having sufficient information for statistical meta-analysis.

[7] According to the study of Robert T.Hays et.al (1992), jet experiments consistently found simulator training combined with aircraft training to be better than training in the aircraft alone. The findings from similar helicopter experiments were less consistent, and only slightly favored simulator training combined with aircraft training over aircraft training alone. An insufficient number of helicopter experiments (n=7) precluded any in-depth analysis involving this type of aircraft.

that allowed trainees to progress at their own pace (criterion based/performance paced) was found to be more effective than lock-step (class based) training, 4) Little support was found for the use of motion systems which is highly tentative and task dependent.

Identically, Stewart et al. (1999, p.viii) highlights the advantages of criterion-based and simulator-aircraft mix training in their study of "*Optimizing Simulator-Aircraft Mix for US Army Initial Entry Rotary Wing Training*". Having accepted these two assertions as true and integrated them into "instructional design processes" (Longridge et al., 2001); it would be easier to achieve effectiveness and efficiency in FSTD use. McCauley (2006) added on that as follows; "quality instructional design, when implemented by quality instructors, will result in PToT".

The mandated instructional design process, also enforced by the regulatory authorities like FAA, requires appropriate training program content as well as allocation of FSTD. The premises which the "FAA instructional design process"[8] is based on could be briefed as: 1) Applying quality control measures to monitor the effectiveness of curriculum, 2) Employing flexible selection criteria for the use of FSTD (FFS or FTD) according to the type of training as well as testing and checking tasks, 3) Maintaining fidelity of FSTD in accordance with FAA qualification criteria, 4) Requiring the use of FFS, and, where permitted FTD rather than aircrafts all through the training, 5) Executing all training tasks in operationally realistic scenarios.

The conclusion above is valuable for explaining that FSTD should not be taken as a substitute but a complementary to the aircraft yet some studies like Orlansky et al.'s (1994) also exist. In their study, the two methods of training are taken as if they were substitutes and a comparative analysis is made. The comparative cost and effectiveness of each method; using FSTD versus actual aircraft; and possible outcomes are illustrated in Figure 2.5 as follows.

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8 FAA AQP AFS-230 dictates "Airlines and training centers that do not maintain their flight simulators in accordance with the procedures and standards on which basis the FAA originally qualified the equipment could be subject to FAA enforcement action (2000).

http://www.faa.gov./avr/afs/aqphome.htm.

Source: Orlansky et al. (1994)

		EFFECTIVENESS		
		LESS	SAME	MORE
COST	LESS	?	+	+
	SAME	–	?	+
	MORE	–	–	?

+ ADOPT
– REJECT
? UNCERTAIN

Figure 2.5 Decision Diagram for Evaluating Effectiveness and Cost of Using FSTD versus Actual Aircraft

Additionally, Orlansky et al. (1994) mentioned on the diagram above as follows; "Cost should mean all costs, on a life cycle basis; some studies examine only the procurement costs or the operating costs". It is agreed that all those costs should be taken into account prior to computing hourly FSTD and actual aircraft costs that in turn involves efficiency of utilizing FSTD.

Regarding one of the Hays et al. (1992)'s meta-analysis results which underlines the little support for the use of motion systems is highly noticeable since it is the main feature differing FFS from FTD. Additionally, FAA's assumption of "Level D motion platform is necessary until proven otherwise" has two possible disadvantages mentioned by McCauley (2006, p.3) as follows

> (1) physical displacement limitations of motion systems mean that less than full fidelity will be provided for any unusual accelerations associated with equipment failures and emergency procedures, thus introducing the prospect negative transfer of training to the aircraft; (2) the cost of Level D simulators is beyond the budget of small regional carriers, contributing to the difficult economic basis of the industry.

Caro (1979) and Gundry (1977) respectively stated (as cited in McCauley, 2006, p.7-8) some other noticeable perspectives on motion bases and their correlation to ToT. Gundry defended "motion bases enable pilots to respond more quickly and accurately to disturbance motion while pilot-initiated maneuver motion may not contribute improved performance in the simulator". Caro, however, signed to “the potential training value of disturbance motion since it alerts a pilot to the onset of turbulence or the failure of an aircraft component”.

How much does higher fidelity level of an advanced FSTD affect ToT? In this context, Hays et al. (1992, p.64) stated that the view and objective of seeking a higher fidelity FSTD solely refrains most public and private institutions from understanding the importance of other elements, which may have an impact on effective utilization. Appropriate training methods used might pay off better and generate favorable outcomes rather than having higher physical resemblance features on FSTD. The usual TOT versus fidelity relation is depicted in Figure 2.6 as follows. Notice that incremental transfer (marginal benefit) reduces with the increasing fidelity level of simulation (Williams & Blanchard, 1995, p.7).

Source: Williams and Blanchard (1995)

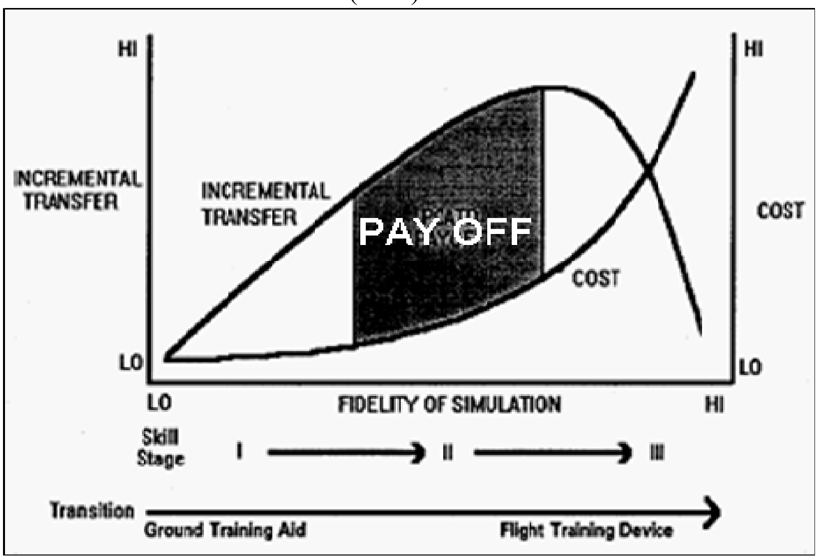

Figure 2.6 ToT versus Fidelity Graph

Once incremental transfer starts to increase, both pilots and organizations start begin rationalizing FSTD usage and its benefits in a more positive manner. This is why ToT is the most significant metric while measuring the success of training. Higher ToT is an incentive for the individual and institution to seek more opportunities towards the use of FSTD. This phenomenon could be attributed as Effect of Customization (Boztaş, 2006, p.49) and perceived usefulness (PU). “The training value of FSTD" provides organizational customization and higher adoption of technology and that is, "in large part, derived from the instructional design and content rather than simulation hardware and software that emulate functionality of the aircraft" (McCauley, 2006, p.4). The training curricula should be built over the principles as referred to virtue of effective training and favorable FSTD utilization.

2.2.4 FSTD-Aircraft Mix Training and Optimization Perspective

Studying the literature and examining the FSTD-aircraft mix training matter; few ratios or functions stands out among the others are transfer effectiveness ratio (TER), cumulative transfer effectiveness ratio/function (CTER/CTEF) and incremental transfer effectiveness ratio/function (ITER/ITEF). Those functions have hypothetical and practical usability in the domain while they are closely related to ToT. Most of the researchers; investigating optimization of FSTD-aircraft mix training as well as cost-benefit and effectiveness/efficiency matters in training, utilized and included these ratio/functions in their studies.

The hypothetical relationship between actual and synthetic flight has been studied in the literature (Rantanen & Talleur, 2005; Stewart III et al., 1999, p.13) and is shown in Figure 2.7

Source: Bickely (1980) cited in Stewart III et al. (1999)

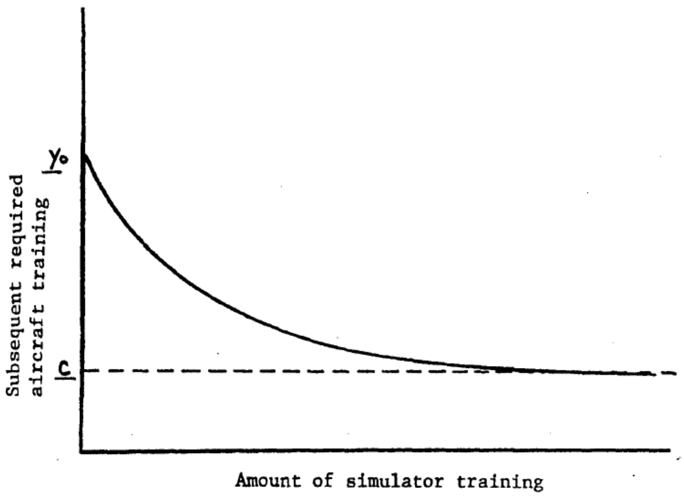

Figure 2.7 Hypothetical Relationship between Simulator Pre-Training and Required Aircraft Training

As simulator pretraining increases, the aircraft training required meeting criterion decreases, thus Yo – C represents the potential savings in aircraft costs as well as aircraft hours that will be realized as the result of simulator pre-training.

Accordingly, it is expected that the benefits derived from FSTD decreases to a point where the marginal benefit is equal to zero. Roscoe & Williges (1980) has proposed (as cited in Stewart III et al., 1999, p.11) CTER or CTEF Equations (2.1) to measure transfer effectiveness

$$CTER = \frac{(Yo-Yi)}{Xi} \quad \text{or} \quad CTEF = \frac{(Yo-Yx)}{X} \tag{2.1}$$

where Xi/X represents the number of trials, time or errors performed in a simulator, Yi/Yx is the number of iterations needed in the aircraft to demonstrate criterion performance after Xi/X simulator training, and Yo is the number of iterations that would be required in the aircraft if no simulator were available (Rantanen & Talleur, 2005, p.764; Stewart III et al., 1999, p.11).

Source: Applied by Boztaş (2006) as adapted from Roscoe (1971)

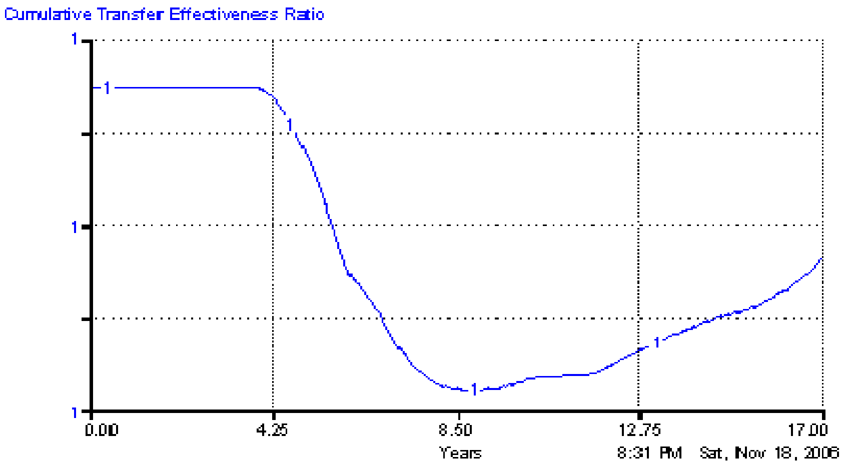

Figure 2.8 Cumulative Transfer Effectiveness Ratio (CTER) Based on Actual FNPT Use between 1990 and 2006

TUAA UH-1 Helicopter FNPT use (1990-2006) was evaluated according to CTER (Boztas, 2006). The variation depicted in Figure 2.8 could be stated as meaningful as compared to the hypothetical relationship illustrated in Figure 2.7.

Regarding the metric of effective and efficient flight training, CTER/CTEF might be also utilized since the equation yields “the savings incurred from actual flight hours for each hour of training practiced on FSTD”. Moreover, CTER/CTEF could be one of the determinants of cost-benefit analysis prior to acquiring FSTD. Examining the relationship among FSTD’ utilization, aircraft flight and CTER equation, suggests that we can adapt hypothetical CTER data to our FSTD utilization policy.

CHAPTER 3

KNOWLEDGE-BASED INNOVATION AND DIFFUSION

3.1 Knowledge and Flow Patterns

3.1.1 The Knowledge

As the developed economies get much more involved in complex technologies and the knowledge-based processes, the causality between knowledge and value-added economies gains more bases. Therefore, emerging economies are required to absorb more and be faster in capturing opportunities and generating appropriate policies. Besides, the emerging institutions and the firms involved in complex technologies should understand better, how and from whom they could acquire knowledge.

The first point is how "knowledge" differs from "information" in terms of its complexity and cognitive features (Morone & Taylor, 2010). Searched the literature, it is recognized that the one having knowledge and/or the method it could be acquired would be capable of "re-processing and/or re-engineering and/or articulating" varied types of information favorably. The notion of learning is given a great importance in that manner and is touched by several researchers like Morone and Taylor (2010, p.10) as follows

> Knowledge is generated through a cognitive process within which information is articulated with other information. This process, which can label "learning", allows actors to undertake actions which require the use of acquired knowledge

Anyone conducting a study on technology selection and adoption behavior would most likely recognize that learning and social interaction processes should be included in the model.

Knowledge and its acquisition might be very costly based on its accessibility features like tacitness and/or physical or relational proximity (Morone & Taylor, 2010). Polanyi (1967) is known (as cited in Morone & Taylor, 2010, p.12) as the first to open a discussion on tacit and codified/encoded (also stated as implicit and explicit) knowledge in the literature. Nelson and Winter (1982) defines (as cited in Morone & Taylor, 2010, p.12) “having a tacit knowledge” as follows

> ..not being fully aware of the details of the performance and finding difficult or impossible to articulate a full account of those details

Witt and Zellner (2007, p.353) assert that “encoded knowledge is accessible to commercial users as long as their training allows them to understand the context and content while tacit knowledge can only be acquired by experience on the job”. According to Morone and Taylor (2010) tacitness is a “contextual rather than an absolute situation” and their state might differ depending on the “moments in time and across different individuals”.

These classifications and features matter especially for an entrepreneur or a technology acquisition professional because of commercial issues like trade-off (Witt & Zellner, 2007, p.352). The matter of having tacit knowledge has two drawbacks. First is codifying, storing, transferring and decodifying complexities while the second is the cost of those processes. The main argument on the subject is that the codified knowledge can be stored and transferred more easily and quickly at lower costs (Morone & Taylor). These should be taken as the primary considerations while getting involved in complex technologies and their development/manufacturing, acquisition and utilization processes. It is therefore, FSTD manufacturing/developing economies and firms are quite consolidated and mainly centered in developed countries. They offer services globally via foreign direct investments (FDI), joint venture partnerships and long-term agreements.

Each FSTD is uniquely tailored based on customer needs and training requirements (tacit and/or encoded state-of-the-art knowledge). Those needs and specifications are elaborated according to the aircrafts’ features and complexity that in turn affects the pilot training and specializations. Military aircraft FSTD development and manufacturing processes are much more based on ‘state-of-the-art’ rather than ‘commercial-of-the-shelf’ products while reverse might be true for commercial aircraft FSTD. Having inspected the military and civil FSTD technology development projects and their durations would give us a more clue on the subject.

Those are mostly software-based projects. The development and manufacturing phase of a single FSTD generally last in one to two years at the earliest and might extend more depending on the aircraft complexity and the required features. The growth of the military helicopters, for example, has exponentially increased since 1970s. The line of code (LOC) generated for an ‘AH-1P Cobra Helicopter’ was 10.000 in those years while it was increased up to a 150.000 for a ‘Longbow AH-64 Apache Helicopter’ in the 1990s and it is expected to be well above a million for the recent ones[1].

On the other hand, the aviation training system itself requires the use of both tacit and codified knowledge together. The flight drills are practiced in an apprenticeship kind of training session in which the “psychomotor skills” are mostly used. FSTD is a favorable training support tool for those skills to be developed in this manner. They could be utilized as a complementary to the actual flight training with the varied optimized ratios’ (see Section 2.2.4, FSTD-Aircraft Mix Training and Optimization Perspective) determined according to the training types and pilot experience levels. That is why we applied a questionnaire and analyzed the results (see Chapter 4) regarding user perceptions and the tendencies since they have an impact on technology selection and determination processes.

The development of computer-based trainers (CBT) and its utilization require highly codified type of knowledge acquisition. Therefore, computer and software engineers together with the area experts (pilots and technicians) come together and convert all the experiences and the tacit knowledge into a codified type with which the training could be executed without instructor involvement.

Lundvall and Foray (1998) asserted (as cited in Morone and Taylor, 2010) on another knowledge classification. These are, “know what; know why; know how

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[1] Naval Postgraduate School / Graduate School of Business Public and Policy - MN3331: Principles of System Acquisition and Program Management Lecture Slides; 9-1 Software Intensive DoD Sytems.ppt. cited in Ö.Boztaş, “Modeling the Adoption Process of the Flight Training Synthetic Environment Technology (FNPT) in the Turkish Army Aviation” MBA Professional Report (December 2006): 3.

and know who” knowledge types which differs and complements each other based on what they refer to. Those knowledge kinds and what they relate to are organized in Table 3.1 as follows

Table 3.1 Reference Based Typology of Knowledge

Source: Adapted from Morone and Taylor (2010)

Kind of Knowledge	Reference	Relation
Know What?	Facts	Relates directly to the concept of information.
Know Why?	Science, Principles and	Serves as a key input for technological progress.
Know How?	Skills and Capability	Relates to a mix of division of labor and co-operation.
Know Who?	Person	Relates to a highly developed division of labor and specialized knowledge and skills.

The less complex knowledge type, “know what” is mostly related to the facts responding the questions of how much and how many while “know why” refers to the scientific knowledge, principles and law. Once the complexity and the innovative policies are referred it is time for any stakeholder or entrepreneur to talk more on “know how” and “know who” kinds of knowledge since those two specify the importance of capability, skills, specialization and briefly the unique assets what the firms and institutions or economies have.

It could be attributed that having “know how” and “know who” kind of knowledge is essential when it is interested in FSTD technologies’ acquisition and utilization processes. Lundvall and Foray stated (as cited in Morone and Taylor, 2010) that the common principle, “as the complexity of knowledge base increases, a mix or highly increased division of labor and cooperation develops”, applies for “know how” and “know who” types of knowledge related sectors. This verifies why an interdisciplinary approach and cooperation is needed for FSTD acquisitions and utilizations because they are accepted as complex technologies (Rosenkopf & Tushman, 1998).

3.1.2 Knowledge Flow Patterns

Knowledge-based economies tend to generate a "new knowledge" via both public and private R&D activities and studies that in turn shape and feed technological advance as well as their comparative advantage and commerciality (Witt & Zellner, 2007, p.352-53). Recognizing knowledge flow patterns is of great importance for the emerging economies and firms. Aiming that, discovering and assessing internal and external capabilities in terms of experiences and human capital, and organizational features would constitute the center of this problem for any aviation institution, firm and entrepreneur acting in a sectoral systems of innovation.

Organizational features sign to the sizes of the firms/institutions whether they are "start-up or large and incumbent ones" (Witt & Zellner, 2007). Next, knowledge and human capital feature signs to the level of expertise and the breadth of firm/institution owned capabilities to realize the knowledge transfer.

Those functions mentioned above could be accounted as the "ability to learn (absorptive capacity)[2]" determinants of the firms/institutions regarding knowledge acquisition. This is highly significant for the ones try to be involved in high technology environment since their success is associated with their capacity "to monitor and tap scientific and technological developments that have originated elsewhere" as stated by Cohen & Levinthal, 1989; Rosenberg, 1990 (as cited in Witt & Zellner, 2007, p.355).

Aggregating and/or updating private and public aviation institutions knowledge base could be accomplished via use of internal and external resources to the organizations. "Learning by using/doing" and "learning by interacting" are the two common methods of "use of knowledge and experience of other economic actors" (Oerlemans et al., 1998; Lundvall 1988 cited in Morone & Taylor, 2010,

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[2] Absorptive capacity is defined as the stock of knowledge accumulated within the firm, embodied in skilled human resources and accrued through in-house learning efforts. In Morone & Taylor. (2010). *Knowledge Diffusion and Innovation: Modeling Complex Entrepreneurial Behaviour*. UK: Edward Elgar Publishing Limited, 92-93, 102.

p.7-8). Providing R&D and interaction medium for the computer, software and aerospace engineers together with the area experts (pilots) would be a favorable strategy since the tacit and/or encoded state-of-the-art knowledge constitutes the core competency for the complex technologies like FSTD. This is quite consistent with Witt and Zellner's (2007) assertion as follows

> ..in a rapidly progressing research environment, privately held tacit knowledge is subject to relatively rapid decay unless it is quasi-automatically updated on the job in a continued involvement

Searching and covering some bases on knowledge and its acquisition, it is recognized that the existing literature offer "access or communication based" classifications mostly. The different classification like "agent-based knowledge flow patterns" suggested by Morone and Taylor (2010, p.17), also helped enhancing perspective and developing a model of agent-based technology selection processes depending on perceptions and tendencies (will be detailed in Chapter 4). The proposed taxonomy of knowledge flows is as follows in Figure 3.1. The illustration is quite helpful for any agent who gets involved in innovative and entrepreneurial efforts and develops perspective towards those activities.

Source: Morone & Taylor (2010)

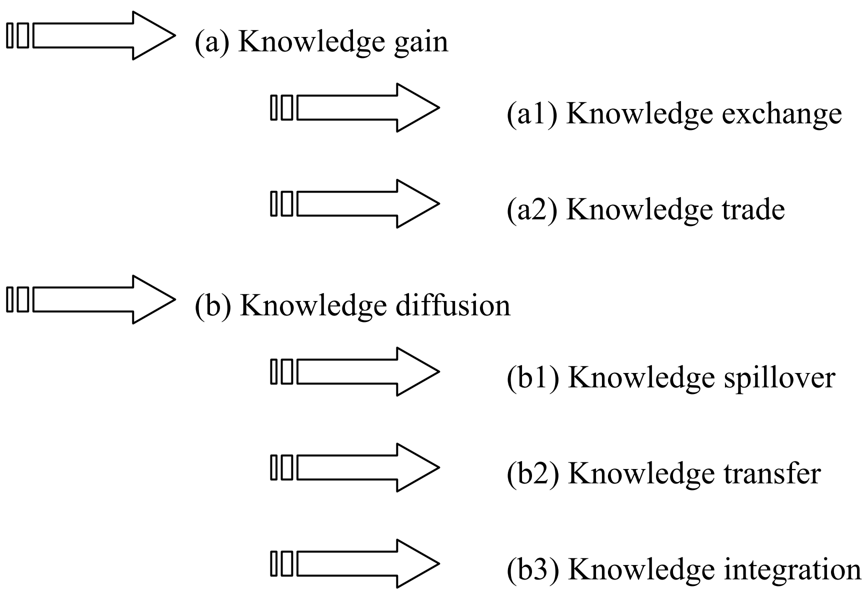

Figure 3.1 Morone and Taylor's Proposed Taxonomy of Knowledge Flows

The two main categories in Figure 3.2, “Knowledge Gain” and “Knowledge Diffusion” differ mainly depending on agents’ voluntariness. In knowledge gain there is an intention to acquire knowledge so that the agents come together to exchange or trade in a rigidly controlled domain. In a knowledge exchange, the portion of acquiring agent’s knowledge potential is used while making the payback. However, different instruments (e.g. money) might be used in a knowledge trade.

In knowledge diffusion, however, knowledge travels freely and conveyed by an absorption during the processes of “spillover and transfer” while “knowledge integration” is fulfilled by combining the scattered pieces of knowledge. Those activities result as a learning for the first two, knowledge transfer and spillover, while complementariness is the primary consideration in the knowledge integration. Those three knowledge diffusion types are subject to unintended, intended and temporary interactions successively.

Table 3.2 Agents’ Knowledge Gain or Diffusion Specialties

Source: Adapted from Morone and Taylor (2010)

	Knowledge Gain		**Knowledge Diffusion**		
	Knowledge Exchange	**Knowledge Trade**	**Knowledge Spillover**	**Knowledge Transfer**	**Knowledge Integration**
Voluntary State	Voluntary	Voluntary	Free Flow	Free Flow	Free Flow
Medium	Rigidly Controlled Domain	Rigidly Controlled Domain	Unintended Interaction/ Specific Space	Intended Interaction/ Specific Space	Temporary Interaction/ Specific Space
Tacit/ Codified	Both	Both	Both	Both	Both
Payback Instrument/ Reception Process	Knowledge	Other	No Cost/ Builds Over Previous Knowledge/ Learning Occurs	No Cost/ Builds Over Previous Knowledge/ Learning Occurs	No Cost/ Builds Over Previous Knowledge/ Learning Occurs
Drawback	Diminishes Creativity and Diversity	Diminishes Creativity and Diversity	Uncontrolled Diffusion	Uncontrolled Diffusion	Uncontrolled Diffusion

In our sample study (Chapter 4), the combination of "knowledge exchange and transfer" applies. The model is comprised of agents participating in technology selection process. They act on a voluntary/intended and a rigidly controlled medium in which the portion of their owned knowledge makes the payback and the acquired knowledge builds over the existing knowledge (accumulates). They have limited absorptive capacity since the heterogenic agents (commercial and military) varied tendencies toward FSTD technologies do not change during the simulation.

Spillovers are quite related to geographic proximity since the specific space is required for such knowledge diffusion. R&D spillovers (Geroski, 1995), for example, occur whenever a firm shares knowledge with others involved in the related R&D sectors. Baptista (1999) fortifies this assertion via adding firms, universities and government institutions for their "free of charge market transactions" in that manner.

Knowledge spillover studies and Jaffe's (1996, 1993 & 1986) studies regarding patent citations and diffusion are noteworthy in the literature. The patent citations were gathered to understand how far they were diffused. The method, "comparing the location of patent citations with that of the cited patents" showed "a strong geographical localization of spillovers". Testing for different levels of geographical matching (country, state and metropolitan area), the authors found that spillovers become more significant as the geographical area becomes smaller (Jaffe, 1986, as cited in Morone & Taylor, 2010, p.18, 24; Jaffe et al., 1993, as cited in Baptista, 1999, p.123; Jaffe et al., 1996, as cited in Geroski, 2000, p.607).

Knowledge spillovers have many favorable features on the diffusion of new knowledge though some low profile organizations and/or economies might be caught up unprepared since "unintended and no cost" knowledge diffuses very rapidly. On the other hand, this type of diffusion might accelerate organizational improvement and trigger innovative activities.

Another noticeable discussion in the literature, made by Malerba and Mani (2009) is on a changed nature of knowledge accumulation and distribution. The researchers asserted that the knowledge-based economy caused a gap in the accumulation and distribution of knowledge due to redefined sectoral boundaries as to create new dynamics and relationships among actors and to change innovative activities [major discontinuity (Malerba & Mani, 2009, p.10)].

3.2 Diffusion of Innovations

3.2.1 Innovation Process

Innovation is used as a common term in several ways. The varied attributes of innovation, product/output, process and capability (Conway & Steward, 2009) are the most frequently visited ones among the others. Innovation could be described as "the process bringing in new methods and ways to produce and manufacture" (Nelson & Rosenberg, 1993) as to have the expectation of generating outcomes that are more favorable. Conway and Steward (2009) stated the "key elements" of innovation process and it seemed preferable that we accumulated those common features of innovation in Table 3.3 rather than offering several definitions on innovation.

Table 3.3 Key Elements of Innovation

Source: Adapted from Conway and Steward (2009)

Like Invention	Unlike Invention
Concerns novelty.	Exploitation of possibilities through the bringing into practical use of an idea or concept.
A process as well as an output.	Embraces the full range of activities from discovery through to development and commercialization.

Innovation might relate to many aspects and activities around the organizations. It could be taken "like invention" while concerning a new product, process or capability; or be attributed as "unlike invention" when it relates to an idea, concept or solution that favors the internal/external opportunities inside the possibilities or beyond the possibilities frontier. Understanding the underlying dynamics and the facts that have shaped the innovative efforts through time is of great importance for the organizations and economies to make technological foresights/projections. Innovation process is explained by varied types of models comprises historical, conjectural, scientific and technological elements. We gathered those in Table 3.4 as follows.

Table 3.4 Innovation Process Models

Source: Adapted from Conway and Steward (2009)

<table>
<tr><td rowspan="3">Linear Modes of Innovation/ Conceptualize Innovation as a Linear Sequence of Events</td><td>First Generation</td><td>Second Generation</td><td rowspan="3">Science/Technology Push*
Need/Demand Pull**</td></tr>
<tr><td>Push* Models
(1950 - mid 1960s)</td><td>Pull** Models
(mid 1960s - early 1970s)</td></tr>
<tr><td>Rapid Economic Growth/
Industrial Expansion/
The Emergence of New Sectors with Technological Advances</td><td>Innovative Organizations Driving the Scientific Agenda of Universities, Governments and Research Laboratories</td></tr>
<tr><td rowspan="2">Coupling Modes of Innovation
(mid 1970s -</td><td>Third Generation</td><td>Fourth and Fifth Generation</td><td rowspan="2">Coupling of Emerging Technological Possibilities and Market Needs</td></tr>
<tr><td colspan="2">Need for the Network Perspective/Sequential Process with Feedback Loops</td></tr>
<tr><td>Innovation Networks
(1980 -</td><td colspan="3">Asymmetric Relations and Interactions Starts Motivating Agents Towards Sectoral Innovation Systems Recently</td></tr>
</table>

3.2.2 Dynamic Behavior of Systems

The dynamics of positive and negative feedbacks with/without delays and together with systems' carrying capacities and goals make the real world systems and the processes demonstrate different patterns of behaviors. From a diffusion of innovation and a technological development perspective, understanding those behaviors and underlying dynamics is of great importance since it helps us categorize the technological developments and make forecasts/projections towards selection processes.

The basic ones, also visited most frequently in innovation diffusion and technological development literature, are "exponential growth, goal seeking and oscillation" (Sterman, 2000) while the other common modes of behaviors are shown in Figure 3.2. Here, our aim is to make the reader acquainted with those modes of behaviors and relate them to the real world innovation processes and their underlying dynamics.

Source: Sterman (2000)

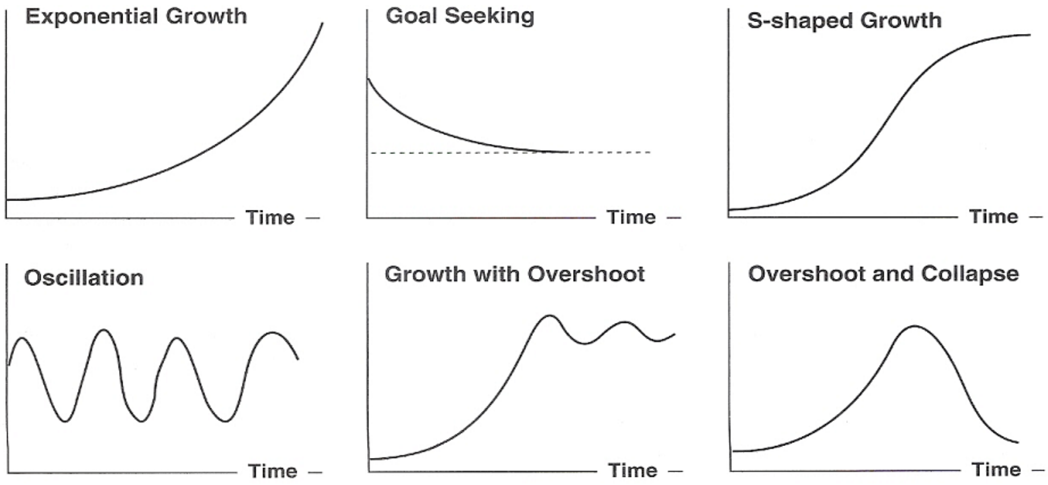

Figure 3.2 Common Modes of Behavior in Dynamic Systems

"Exponential growth" is generated by positive feedback while it is opposite (negative feedback) for "goal seeking", and "oscillation" behavior (time delays are also needed additionally for oscillation). The others; "S-shaped growth", "S-shaped growth with overshoot and oscillation" and "overshoot and collapse" behaviors are generated via basic feedback forms but with a difference. Non-linearity dominates those behaviors within which positive and negative feedbacks work together in a sequence for the S-shaped part. The overshoots and oscillations coming after S-shaped pattern, however, are concerned with time delays. Additionally, collapse behavior in S-shaped growths is a result of population/capital erosions (Sterman, 2000, p.108).

Systems' "carrying capacity" and the "goal" are also important in a sense that they could work as a determinant or as a variable both adding on the rules of the game so that they should be taken into account while thinking of dynamic system behaviors. For an S-Shaped pattern, for example, the carrying capacity must be stabilized and there should not be any significant time delays that would otherwise start oscillation. Another issue is that the "state of the system" which should be considered while interpreting existing situation and making a decision. It is determined based on the current assumptions and could be interpreted as if it were a "snapshot" of a system (Sterman, 2000).

Having examined the left part of the Figure 3.3, the one would recognize that the "net rate of change" is a function of the system itself and is generated by a positive feedback. Sterman (2000) interprets those systems as "state-determined systems" and he brings in "state variable" approach for more complex systems in which "the networks of stocks and flows, linked by information feedbacks from the stocks to the rates" (Sterman, 2000, p.202). For complex systems, however, it is required to make some assumptions such as determining constants and endogenous/exogenous variables as well as model boundaries well beforehand. It would be otherwise difficult and/or deceptive capturing the underlying mechanisms and the important feedback loop.

Taking the "goal seeking" behavior (right part of the Figure 3.3), however, state of the system serves as to melt the gap and to reach its goal. To sum up, the net rate of change is characterized by "doubling" for exponential growth and "half life" for exponential decay (Sterman, 2000, p.112).

Source: Sterman (2000)

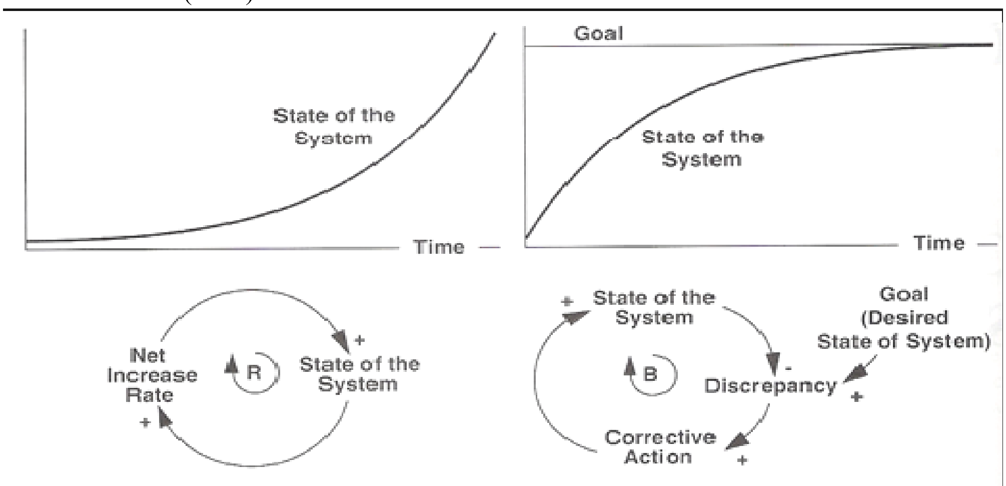

Figure 3.3 Growth and Goal Seeking Behavior

Studying the diffusion models and the behavioral patterns, the first-order linear and non-linear systems should be reviewed at first. As put by Sterman (2000, p.290), they are "the building blocks out of which all models are built and from which more complex dynamics emerge". The first-order or the linear feedback systems could generate exponential growth via positive feedback structure and goal seeking via negative feedback structure as shown in Figure 3.3.

The other basic form of dynamic behavior, “oscillation”, arises because of negative feedback with delays. It is a repeated form of behaviors stemming from goal seeking and corrections with delays. The state of the system continuously overshoots the goal or the equilibrium state (Sterman, 2000).

Equilibrium state is sustained as long the net rate of change stays zero. The “static and dynamic equilibrium” or as stated in Figure 3.4 as “stable or unstable equilibrium” are helpful for the interpreter to make some inferences towards innovation diffusion paths. The point of inflection or a turning point was defined by Conway and Steward (2009, p.131) as follows

> The point of inflection is the point on the S-curve (roughly the middle) at which the yield is at its highest. Prior to this point, the innovating organization benefits from increasing returns per unit of R&D effort; after this point, however, the firm begins to suffer from decreasing returns. Sahal explains this decline in the rate of technical progress in relation to either complexity or scale phenomena (i.e. things become too small, or too large) that arise as a technology matures.

Source: Sterman (2000)

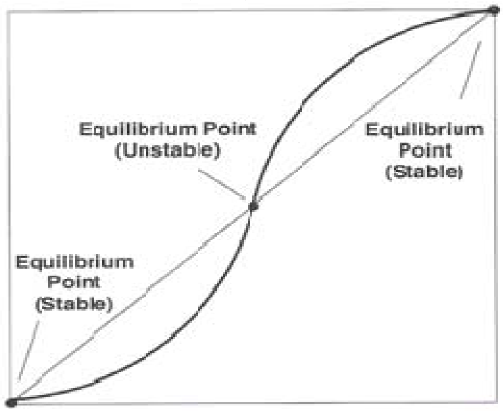

Figure 3.4 S-Shaped Growth Equilibrium States

3.2.3 Diffusion Models

Diffusion of innovation and adoption models are used to explain the dynamics of innovation processes, the adoption of new technology, as well as the escalation of epidemics in a society (Sterman, 2000; Geroski, 2000; Baptista, 1999).

The Diffusion of Innovations Model and its S-shaped growth patterns usually explain the adoption of new technologies. The phases, diffusion rates` rise and fall over time typically generate three zones (Geroski, 2000) which are also stated by Conway and Steward (2009, p.131) as "emergent, growth and maturity" states. The acceptance of new ideas and the resistance to innovation in organizations is also evaluated within this context. The diffusion model studies also help us understanding diffusion behavior as well as technology development that in turn beneficial while determining marketing strategies.

The original S-shaped diffusion curve, plotted as early as 1903 by French Sociologist Gabriel Tarde, is shown as in Figure 3.5. It could be attributed as still relevant since "most innovations have S-shaped rate of adoption" (Geroski, 2000; Baptista, 1999; Rogers, 1995). Geroski interprets three distinctive yet successive states in the S-shaped curve as "a relatively rapid adoption sandwiched between an early period of slow take up and a late period of slow approach to satiation".

Source: Rogers (1995)

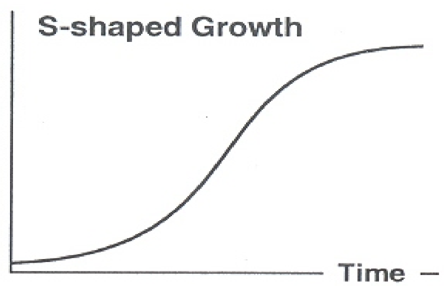

Figure 3.5 S-Shaped Diffusion of Innovations Curve

On the other hand, too much generalization towards those S-curve models should be taken as one of the main drawbacks for the researchers and stakeholders since "one size fits all" approach might distract them from their objectives. Baptista (1999) mentioned on those problematic areas as follows

> A firm, industry or nation with an impressive inventive record may still lag behind its competitors if it fails to diffuse the innovations it introduces although the frameworks used are quite general, different innovations in different industries will vary in their diffusion patterns

(Nelson and Winter, 1982). One should therefore be cautious of generalization.

The two models, “epidemic” followed by “probit” [also accepted as an alternate to epidemic (Geroski, 2000)], could be referred to as a good starting point when it comes to diffusion and innovation processes. The agents’ perfect information towards a homogenous technology is a common attribute for the neoclassical economic models and the former innovation diffusion theories (Morone & Taylor, 2010, p.24). The epidemic diffusion models are specialized with the potential adopters’ homogeneity while heterogeneity applies for the probit models (Morone & Taylor, 2010; Geroski, 2000).

Epidemic models could be decomposed as a “broadcasting (external-influence)” and a “word of mouth (internal-influence)” diffusion models (Morone & Taylor, 2010; Geroski, 2000). In “broadcasting diffusion models”, potential adopters are all exposed to the same transmission of knowledge on innovation the same way whereas the external source starts the behavior of diffusion as changing its static equilibrium state. The related depictions of “broadcasting” and “word of mouth” diffusion models, arranged in an order from left to right in Figure 3.6, are as follows

Source: Adapted from Morone & Taylor (2010)

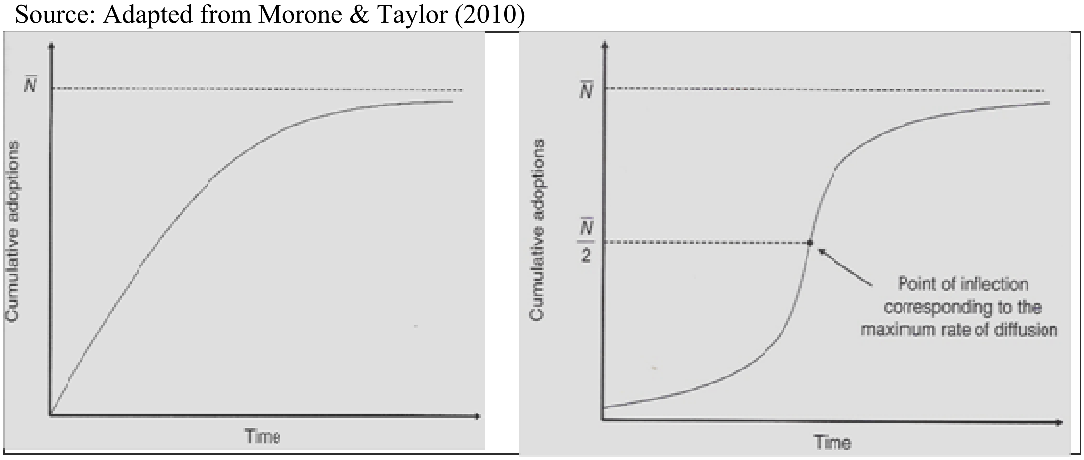

Figure 3.6 Broadcasting and Word of Mouth Diffusion Models

Searching the literature, the one can meet some differences in the methods used in explaining diffusion processes. They are common most of the time but differ slightly in their terminology, depictions and formulations towards the model behaviors. Here, we try to be simpler while highlighting commonalities. It would be favorable to move incrementally while explaining the “rate of diffusion” as well as “cumulative population of adopters” formulation for each model. The equations specified as follows are related to epidemic and probit models of diffusion and might be accepted as neoclassical (Morone & Taylor, 2010). The more recent models will also be given as stated in the existing literature. The latter ones are quite different in a sense that they are more capable of capturing complexity and the interaction dynamics of diffusion behaviors.

Broadcasting diffusion model attributes quite overlap with the “public good” assumptions of “non-rivalry and non-excludability”[3]. Here, the power of broadcasting signal determines the rate of adoption while it is personal interactions' frequency for the “word of mouth” diffusion models. The rate of diffusion equation could be stated as follows for broadcasting model (Morone & Taylor, 2010, p.26).

$$\frac{dN(t)}{dt} = a\left[\overline{N} - N(t)\right] \tag{3.1}$$

where $\overline{N}$ represents the potential adopters' population, $N(t)$ is accumulated number of adopters at time t and a ($0<a<1$) stands for infection probability or a strength of the broadcasting signal. The net rate (could be stated as a flow as mentioned earlier in Paragraph..) contributes to the adopter's population (stock).

If $a=1$ then diffusion will be instantaneous (broadcasting signal is at its maximum strength). If $a<1$, then the diffusion is slower accordingly (Morone and Taylor, 2010; Geroski, 2000). Another saying, $a>0$ parameter determines the speed of adoption (Baptista, 1999). Having mentioned on the rate of diffusion so far, it would be clearer that the accumulated adopters' population function would demonstrate negative exponential distribution since the diffusion continues till

[3] Non-Rivalry: One man's use does not reduce another's consumption; Non-excludability: Impossibility or impracticability of excluding non-contributors. In Stokey, E. & Zeckhauser, R. 1978. Achieving Desirable Outcomes. *A Primer for Policy Analysis.* New York-London: W.W. Norton & Company, 307.

reaching the last member of the potential adopters (also check Figure 3.6 for a broadcasting model diffusion curve). The equation (3.2) represents the broadcasting diffusion behavior.

$$N(t) = \overline{N}[1 - e^{-at}] \tag{3.2}$$

When the case is word-of-mouth diffusion, the rate of diffusion could be formulated as follows

$$\frac{dN(t)}{dt} = bN(t)[\overline{N} - N(t)] \tag{3.3}$$

Notice that it is very similar to the broadcasting diffusion equation. However, it differs in a way the agents' knowledge is accounted so that the diffusion arises from face-to-face interactions. Here, the coefficient $bN(t)$ stands for the "probability of receiving the relevant knowledge needed to adopt the innovation is a positive function of current users $N(t)$" (Morone & Taylor, 2010) as could be also stated as a "main source" (Geroski, 2000) or a knowledge generated via early adoptions. This kind of behavior is provided in case the coefficient of diffusion, $bN(t) > 0$.

The following function formulates that the net rate (mentioned above) adds on a stock (accumulated population of adopters) until the adoptions get less and less that in turn constitutes accumulated distribution of adopters.

$$N(t) = \frac{\overline{N}}{1 + \left(\frac{\overline{N} - N_0}{N_0}\right)^{-b\overline{N}(t - t_0)}} \tag{3.4}$$

When $t = 0$ then $N(t) = N_0 = 0$. Therefore, the diffusion behavior could solely start in case there should be early adopters in the system. This is the main drawback of the model as stated by Morone and Taylor (2010), Geroski (2000) and the others. Their agreement is that “it can not explain the diffusion of innovation from the date it is invented, but only from the date when some number, $N(t) > 0$” (Geroski, 2000, p.606). Recovering the problem, “a mixed information source model”, based on the combination of broadcasting and word-of-mouth rate of diffusion principles, has been introduced as given in a following equation

$$\frac{dN(t)}{dt} = a + bN(t))\left[\overline{N} - N(t)\right] \tag{3.5}$$

where $a + bN(t)$ is the coefficient determining shape and speed of the distribution and diffusion. The resulting pattern is also known as “logistics or sigmoid” diffusion curve (Morone & Taylor, 2010, p.29; Baptista, 1999, p.109) whereas the parameters, a as an infection probability or strength of the broadcasting signal and b as a word of mouth or face-to-face interaction intensity, have impacts in dynamic behavior of diffusion. Baptista (1999, p.109), for instance, gives varied diffusion rated logistic curves as follows in Figure 3.7.

Source: Baptista (1999)

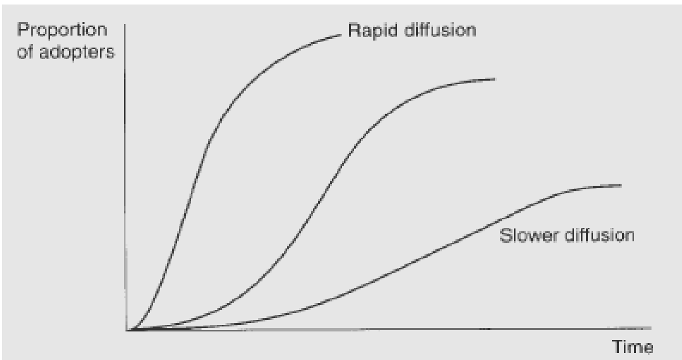

Figure 3.7 Varied Diffusion Rated Logistic or Sigmoid Curves

Since the neoclassical models were introduced, the efforts towards developing better models including parameters like knowledge base and heterogeneity have continued incrementally. The “two population model”, for example, accounts agents’ heterogeneities in a sense like being risk taking/risk averse while adopting, and being less able/more able while understanding and capturing technology and so on (Morone & Taylor, 2010; Geroski, 2000; Baptista, 1999).

The "probit model" (stated as an alternate to epidemic previously), for instance, stems from such a need since the profitability creates heterogeneity among agents' decisions. These latter models, highlighting the importance of subjectivity whereas the attitudes and perceptions as well as tendencies towards the innovations, have been started to be included in diffusion models. This heterogeneity comprises of "initial perceptions, preference characteristics and responsiveness to information" (Geroski, 2000). The probit diffusion model approach could be more solid while assessing real world parameters like cost and benefit.

In this model, the profitability is computed depending on several factors like firms' sizes and capabilities (e.g. ability to learn: absorptive capacity), technological expectation and switching costs, opportunity cost, etc. The agents with different capabilities are normally distributed in the curve (Figure 3.8). The theory states when x_i (capability of agents) exceeds x_* (threshold), then the capable agents (the lesser proportion of the population) adopt. For the ones being less capable to adopt, x_* should fall. If it continues falling, the number of adopter increases and S-shaped curve occurs.

Source: Geroski (2000)

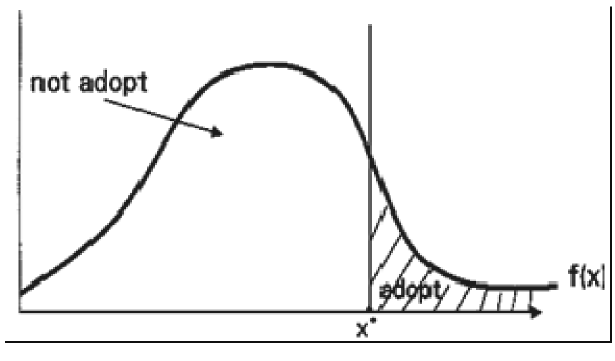

Figure 3.8 Probit Diffusion Models

Recent studies introduced some other models like "game theoretical models" These models are generally referred to as constituting a theoretical base but mostly as offering solutions for the diffusion related processes like alternate technology selections, agent interactions, neighbor growth, and social network as well as learning (Morone & Taylor, 2010, p.29-32).

To sum up, The Diffusion of Innovations Theory predicts that interpersonal contacts provide information and influence opinion and judgment (Rogers, 1995). In this context, positive attitude towards a technology is significant and is broadly discussed in the literature. For example, Agarwal et al. (1999) argued (as cited in Pagani, 2004, p.47) that individuals' perceptions towards using an innovation are considered to affect their adoption behavior. Likely, personal preferences and behavioral attitudes are influential on the use and the adoption of advanced and high fidelity complex technologies like FSTD (Dillard, 2002).

The Diffusion of Innovations Model and its S-shaped growth patterns was also proved to be a useful tool to explain the Turkish Army Aviation (TUAA) School UH-1 FNPT`s adoption processes demonstrating the similar path from 1990-2006 (Boztaş, 2006, p.59). In the study, it is argued that the conclusion of sequential phasing with different rate of adoption regions is highly compatible with the S-curve theory as shown in Figure 3.9.

Source: Boztaş (2006)

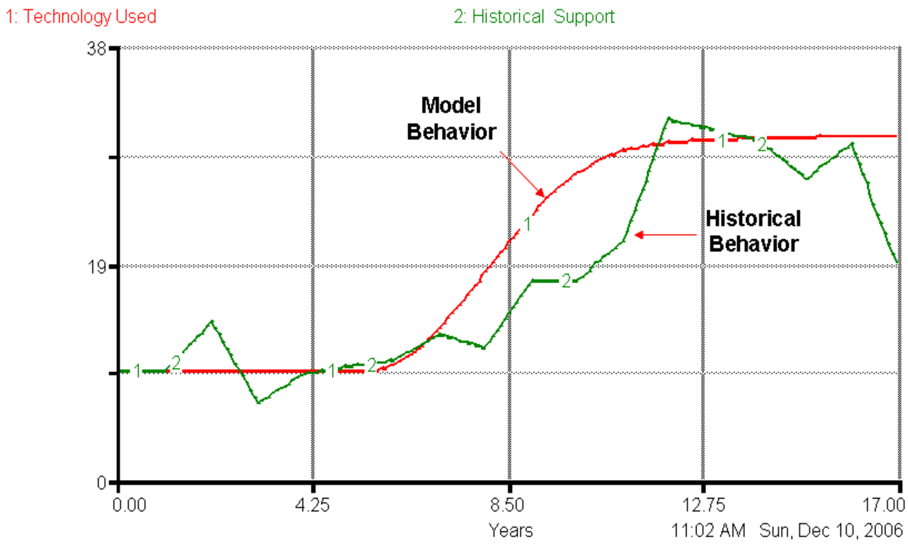

Figure 3.9 Historical-Fit of FNPT Adoption Process Model

Boztaş (2006) concluded in the research that Flight Training Synthetic Environment Technology (FNPT) usage and its adoption in the Turkish Army Aviation (TUAA) materialized over the one and a half decades and experienced a substantial increase after 1997. So, the historical behavior could be briefed as an initial phase of lower training support rates until 1997, followed by substantial increase from 1997-2001, and third phase when growth stagnated during the period 2001-2006. In the study, the dynamic hypothesis suggest that these three sequential phases can be explained in terms of an organizational culture towards the use of FNPT, organizational change in favor of FNPT usage and increasing expertise, and system's limited technical capability and its sole support for one type of aircraft respectively. Geroski (2000) also put forth "the effect that is sometimes stimulating and sometimes limiting" the diffusion of innovations in this manner.

However, the primary focus of the technology adoption processes should be on the causality affecting the rate of adoption, the diffusion behavior and the point/time of inflection rather than the shape of it solely.

Some effects like "bandwagon effect", as Mansfield (1968, p.137) brought in (as cited in Baptista, 1999, p.109), is noticeable regarding innovation adoption behavior. He discusses that earlier risk averse attitudes towards to novelty could change and innovation adoption might occur with the pressure stemming from competitive environment. He states, "As more information and experience accumulate it becomes less of a risk to begin using. Competitive pressures mount and bandwagon effect occur" (Baptista, 1999, p.109). Abrahamson and Rosenkopf (1993) tried to explain this theoretical approach (as cited in Baptista, 1999, p.120) with the "below average performers' fear" model. The researchers added on discussion as follows

> Pressures from social emulation and a localized competitive environment lead firms to adopt a new technology in order to stay in the game. This would lead to generalized adoption of innovations even when profitability is uncertain

This might be highly consistent with the FSTD market and the use of expensive FFS. As put by Rosenkopf and Tushman (1998, p.3), "aircraft manufacturers supported FFS because they generated a larger market for the sale of their cockpit instruments, aeronautical models, and flight test data". Moreover, the regulatory authorities urge the aviation community and the commercial pilots to be qualified in the advanced and expensive, Level C or D FFS.

The five phases of innovation diffusion as adapted from Morone and Taylor (2010) could shed a light on technology diffusion studies and depicted as follows in Table 3.5

Table 3.5 Innovators Pathway towards Adoption

Source: Adapted from Morone and Taylor (2010)

Knowledge	a preliminary need for acquisition of adequate knowledge of an innovation,
Persuasion	which help them in forming an attitude toward the innovation,
Decision	decide whether to adopt or reject it. Hence, adopters will,
Implementation	put the new idea into use,
Confirmation	seek reinforcement of the innovation decision already made or may reverse previous decision if exposed to conflicting messages.

Innovators pathway towards adoption explain the effect of customization and elaborate the considerations with which the stakeholders should evaluate and make some assessments prior acquisition efforts. This is highly significant for the systems like FSTD composed of state-of-the-art and high-cost components. Geroski (2000) stated (as cited in Morone & Taylor, 2010, p.25) that the diffusion studies and underlying reasons are hypothesized as follows

> ..a new technology diffuses when sufficient information on the characteristics of the new technology spreads from earlier adopters to later adopters. Hence, the technology diffusion resembles the underlying knowledge/information diffusion dynamic. Reversing the argument, since new technologies can be adopted when sufficient information is available: "one is likely to learn a lot about the time path of technology diffusion by studying the spread of information about it

3.3 Adoption Models Associating FSTD Technology

3.3.1 Background

A thorough review of the literature reveals that there are no relevant studies on adoption models associating favorable FSTD acquisition and utilization. However, the information technology (IT) domain closely models the FSTD adoption in two ways. The first concerns computer and software technologies' common and intense use in each area of technology. The second concerns the human-associated behavior towards adoption of computer-based technologies since the rejection of such technologies is a notable problem in the IT domain (Al-Gahtani, 2003, p.58). A similar resistance can be found in the literature regarding FSTD. As stated by Stewart III, Dohme & Nullmeyer (1999, p.viii-7), US Army Aviation did not adapt itself the research findings demonstrated increased training efficiencies as a result of the application of low cost simulators and automated, adaptive trainers to the Initial Entry Rotary Wing (IERW) programs

> Prior to the mid '90s, the Army Aviation training community did not acknowledge a requirement for greater training efficiencies. The general rule was to retain the same number of "blade hours" in the curriculum and to resist attempts to increase reliance on simulation

In the IT domain, one of the most important measures of implementation success is its adoption and voluntary use by managerial, professional, and operating level personnel. This use is deemed a necessary condition for success, and resistance to computer systems by managers and professionals is a widespread problem (Al-Gahtani, 2003, p.61). Based on these observations, we consider the individual user's attitude and the associated organizational culture to be the two major determinants of FSTD adoption, and incorporate these into our sample study simulation.

As noted in several IT studies (Al-Gahtani, 2003; Heslin, 1996; Rogers, 1995), there are a number of common attributes, which are the key to innovation diffusion; these include relative advantage, complexity, compatibility, observability, and trialibility. For the purposes of this study, the Rogers' studies "Diffusion of Innovations" and these five attributes are helpful in determining a favorable model for the effective and efficient acquisition and utilization of FSTD technologies. Following attributes were defined by Rogers (1995) and cited in Al-Gahtani's (2003, p.59) study of computer technology adoption as follows

> Relative Advantage; is the degree to which an innovation is perceived as being better than the idea it supersedes. The degree of relative advantage is often expressed as economic profitability, social prestige, or other benefits. Diffusion scholars have found relative advantage to be one of the best predictors of an innovation's rate of adoption.
>
> Compatibility; is the degree to which an innovation is perceived as consistent with the existing socio-cultural values and beliefs, past experiences, and needs of potential adopters. Rogers suggests that the compatibility of an innovation, as perceived by members of a social system, is positively related to its rate of adoption.
>
> Complexity; is the degree to which an innovation is perceived as relatively difficult to understand and use. Any new idea may be classified on the complexity-simplicity continuum. Some innovations are clear in their meaning to potential adopters whereas others are not. Rogers further suggests that the complexity of an innovation, as perceived by members of a social system, is negatively related to its rate of adoption.
>
> Trialibility; is the degree to which an innovation may be experimented with on a limited basis. The personal trying-out of an innovation is a way to give meaning to an innovation, to find out how it works under one's own conditions. This trial is a means to dispel uncertainty about the new idea. Rogers suggests that the trialibility of an innovation, as perceived by the members of a social system, is positively related to its rate of adoption.
>
> Observability; is the degree to which the results of an innovation are visible to others. The results of some ideas are easily observed and communicated to others. The results of some ideas are easily observed and communicated to others, whereas some innovations are difficult to observe or to describe to others. Rogers argued that the software component of a technological innovation is not so apparent to observation, so innovations in which the software aspect is dominant, possess less observability, and usually have a relatively slower rate of adoption. The observability of an innovation, as perceived by the members of a social system, is positively related to its rate of adoption.

Since the introduction of computer systems, one of the common bottlenecks to its adoption has been the complexity of the front-end interface. These computer-based systems, like FSTD, must be made easier to use to encourage faster adoption. Ease of use in turn implies that computer systems must have a well-engineered front-end interfacing as well as considerable built-in flexibility (Graham, 1982, p.45). The feature related bottlenecks towards the complexity versus faster adoption mentioned above for the computer-based technologies greatly apply to the FSTD case. In this context, user-friendly front-end interface of an FSTD instructor control station, for instance, would help effective training while giving a way towards faster adoption.

3.3.2 Technology Acceptance Model (TAM)

Technology Acceptance Model (TAM) is one of the two significant models [the other is task-technology fit (TTF) model] in the literature explaining utilization behavior and its relation with user performance (Dishaw & Strong, 1999). In addition to Rogers' five attributes, the "technology acceptance model (TAM)" is generally accepted to explain technology adoption behavior in humans. Human perception of a given technology is again the leading determinant in explaining the adoption of a technology. Two terms, the perceived usefulness (PU) and the perceived ease of use (PEU) are significant factors that should be considered in any technology adoption model (Pagani, 2004, 47-48). These terms are discussed below

> "The perceived usefulness" is defined as the degree to which a person believes that using that particular system would enhance his or her job performance while "the perceived ease of use" is defined as the degree to which a person believes that using a particular system would be free of effort.

These two factors are carefully considered in predicting the acceptance of FSTD technologies because they are perceived to be the most important factors that end-users would consider in evaluating FSTD technologies. This is because personal job performance enhancement through such technologies is attractive to aviators while FSTD's availability is accepted as an advantage to achieve that.

On the other hand, several studies like in Heslin's (1996, p.78), it is "suggested that different people exhibit varying ease of use and usefulness perceptions regarding the same system". Hence, PU and PEU could constitute the agents' heterogeneity towards the FSTD selection and utilization processes and therefore could be taken as variables in modeling those processes.

3.3.3 Task-Technology Fit (TTF) Model

The personnel and thus organizations they work for are greatly influenced by the level of utilization the technology they use (Zigurs & Kazanchi, 2008; Ammenwerth, Iller & Mahler, 2006; Dishaw & Strong, 1999; Zigurs & Buckland, 1998; Goodhue & Thompson, 1995).

Goodhue & Thompson (1995) define "task-technology fit (TTF)" as "the degree to which a technology assists an individual in performing his or her portfolio of tasks". They assert, "The technology must be utilized and a good fit with the tasks it supports to have a positive impact on individual performance". This assertion could also be used as a diagnostic tool whether to see the systems used overlap meeting the user needs since user attitudes are the predictors of utilization while TTF are the predictors of performance (Goodhue & Thompson, 1995, p.213).

Although TAM is accepted as a significant model in predicting the acceptance behavior of technologies, it is considered to be missing some points like excluding utilization inadequacies and/or fit aspects due to ineffective operations management and/or poor technical features. It is therefore appropriate utilization and/or good fit of the technology that is tailored according to the complexity of the tasks would be considered to generate favorable results.

The varied scales of commercial and military aviation institutions and firms having different level of skilled and highly specialized aircrew differentiate based on their unique training needs. Hence, TTF model should be applied prior to acquiring and utilizing FSTD technologies. The training system would otherwise generate poor TTF and causes adoption failures. TTF consideration is notable when it comes to acquire and utilize FSTD (see Questionnaire administered pilots' evaluation for "task associated FFS and FTD's support rates" in Chapter 4 and Figure 4.7 based on their perceptions and tendencies).

However, as Goodhue & Thompson (1995) noted TTF limitations should be considered while applying model to a process. Those limitations are user attitudes towards the use of technology (social norms to use a system and beliefs about expected consequences); more utilization is not necessarily lead to higher performance (poor system and/or inappropriate or extensive use might not enhance performance) and the importance of job design rather than quality or usefulness (Goodhue & Thompson, 1995, p.216).

Therefore, the tendency towards the use of technology and thus FSTD is a highly considerable matter in flight training. The resistance towards the use of FSTD technology would certainly affect the adoption behavior and effective training. The matter may have two unfolds: First is physical and second is mental.

The Simulator Sickness (SS)[4], for example, caused by FSTD should be taken seriously since its related symptoms are mostly fatigue, eyestrain, headache, and difficulty focusing, sweating, nausea, and stomach awareness (Johnson, 2005, p.22). Chappelow's research (1988) showed (as cited in Johnson, 2005, p.46) that 4% of questionnaire-administered pilots, who experienced SS symptoms. It is also reported that their experience decreased their willingness to use FSTD again. It is quite clear that pilots experience severe SS would not prefer flying in FSTD, and this would create resistance against the use of FSTD (Boztaş, 2006, p.45).

The mental resistance mostly stem from the concept of using FSTD in flight training. The responses offered in a survey (Lafçı, 2005, p.90) - applied to 145 TUAA pilots, showed that 9.7% of the pilots never agreed that they could get the same capabilities in a FSTD as they could gain in a real aircraft.

3.4 Behavior Modeling Approaches

Modeling complex behaviors has always been a matter for the scientific world. Being parallel with the development of computer processors and software packages, some modeling tools like Stella or some other platforms like C++, Java

[4] Simulator Sickness is a term used to describe the diverse signs or symptoms that have been experienced by flight crews during or after a training session in a flight simulator. M. E. McCauley (ed.), Research issues in a simulator sickness: Proceedings of a workshop (Washington, D.C.: National Academy Press, 1984) quoted in David M. Johnson, "Introduction to and Review of Simulator Sickness Research," Research Report 1832, (April 2005): 22.

etc. have been introduced. Agent-based modeling have started to be used in the domain and preferred as one of the promising tools for scientific computational studies (Morone & Taylor, 2010, p.5). Modeling selection processes of complex technologies, interaction among social systems and complex world issues have become possible via use of those advanced modeling tools. If there is heterogeneity exists among agents' perceptions and tendencies and they interact non-linearly on a complex space, the agent-based modeling is found to be useful (Zhang, 2005).

Our choice is JAVA Platform to make use of agent-based modeling. The platform is used in modeling FSTD technology selection processes based on training needs, tendencies and perceptions towards FFS and FTD. In the research, the questionnaire was constructed and the tendencies as well as perceptions towards FFS and FTD were determined. TAM and TTF variables were also used in the modeling process. The methodology, the model itself and the simulation results are given in Chapter 4.

Kirchoff, (1991) stated (as cited in Morlacchi, 2007) that "Different dynamic modeling efforts, derived from Schumpeter's theories of innovation, which were built around entrepreneurship, the core of creative destruction have been proposed". The new evolutionary economists have also introduced dynamic modeling based on deep mathematical knowledge recently.

CHAPTER 4

A SAMPLE STUDY: ANALYZING AGENTS' PREFERENCES TOWARDS FSTD TECHNOLOGY AND MODELING SELECTION PROCESS BETWEEN FFS AND FTD

4.1 Modeling Background

4.1.1 Introduction

In the sample study, we base our assumptions on the experiences of commercial and military aviation institutions as well as pilots' perceptions and ongoing discussions towards FSTD technology. FSTD's technical features such as level of fidelity and realism together with the motion platform and visual system requirements have always been a great issue since they were introduced to the flight-training sector, end-user and potential technology adopter. Within the context, objective and perceptual fidelity are the two important factors, which are to be considered in a collective manner along with the technology user's specific tasks and mission needs while acquiring and/or utilizing such technologies. Such variables mentioned above have been gathered in the model constituting a space in which the agents interact, decide the adoption of a new technology or continue with the tended via knowledge exchange. This in turn shapes the behavior of FSTD and thus FFS and FTD diffusion via adoption and/or utilization.

The potential adopter might accept some of FSTD's technical features as indispensable although there may be some false perceptions reported in the existing literature. Augmented needs and exaggerated technical requirements without appropriately tailoring training environment might lead to ineffective and inefficient outcomes. User-defined requirements in some acquisition and utilization projects/practices might turn out to be unrealized contractual specifications in some cases. When those unfavorable processes are coupled with ineffective/inefficient utilization and operations, the costs incurred multiply unintentionally. We believe that the matter is deserved to be scrutinized since the costs range widely based on

FSTD's features while there is not too much known how much they add on training effectiveness. Rosenkopf & Tushman (1998, p.3) touches FSTD acquisition and utilization processes, generating some ambiguity, as follows

> Use of FFS was supported by several constituencies: commercial airlines, whose training arms were typically run by ex-commercial pilots; regulatory bodies, typically staffed by ex-military pilots; and aircraft manufacturers. While pilots supported FFS because of their belief that "realism" was the primary dimension for measuring training effectiveness, aircraft manufacturers supported FFS because they generated a larger market for the sale of their cockpit instruments, aeronautical models, and flight test data.

Taking McCauley (2006), Rosenkopf and Tushman (1998)'s assertions as a starting point, we believe FTD could be used effectively and efficiently in case the flight training could be structured and tailored appropriately based on the needs. Rosenkopf & Tushman (1998) state, "use of FTD was supported by academic and military researches, who believed that transfer of training, could be accomplished more effectively with a specific focus on human factors and learning processes". This assertion is supported by the questionnaire results (will be discussed below) to a certain extent.

There are several opportunities in FSTD market that can be exploited to enhance cost-effective flight training, yet it is not certain, which type of FSTD could be accepted as the primary complementary or the substitute (if possible) to the actual aircraft. The degree of how much FFS or FTD flight hours could be substituted to actual flight hours is also under discussion. The questionnaire analysis and the model constituted could give a clue on the issue.

There are solid differences between FFS and FTD, especially in terms of their cost, manufacturing simplicity, maintainability, ease of use and etc. while there is little known how much they differ in terms of their usefulness as referred to as ToT (also mentioned and defined in the previous sections). Based on Rogers' technology adoption factors (1995 and 1983) and as cited by Al-Gahtani (2003, p.59) and Heslin (1996, 78-80, p.78), the two technologies might seem differ based on agents' perceptions towards the two technologies' "relative advantage, compatibility, complexity, trialibility and observability (see Subsection 3.3.1 for the discussion of those attributes' impact on technology adoption behavior).

Therefore, perceptions for a given technology are the leading determinants in explaining technology adoption processes. The Roger's five adoption attributes, TAM and TTF would help in explaining FFS and FTD adoption processes of the aviators and thus institutions/firms (Pagani, 2004, p.47-48) as well as technology diffusion in the market. Within the context, the adopter's tasks and the mission needs together with the technological tendencies and perceptions constituted because of the attributes discussed previously would deserve to be included in the model.

4.1.2 Sample Study's Research Questions

In the sample study, the analysis of agents' perceptions towards FSTD technologies and simulation of process, choosing between FFS and FTD, are executed and the following questions are addressed:

1. How much FFS and FTD technologies' adoption, thus acquisition and utilization could be attributed to the pilots' tasks, training needs and perceptions towards the technologies?

2. Will it be possible to determine a primary complementary or a substitute FSTD to the actual aircraft and how much of the flight training could be practiced in FFS and FTD?

3. Will the model built be adequate to explain the behavioral patterns demonstrated in FSTD technologies' adoption processes?

4. Can the dominant technology continue its dominance through interactions and exchange of knowledge?

4.1.3 Sample Study's Purpose

The main purpose is to show how much the FSTD adoption processes as well as its acquisition and utilization is influenced by the pilots' tasks, the training needs and the perceptions towards the technology. Secondly, it is aimed to recognize whether we could determine a primary complementary or a substitute FSTD to the actual aircraft. Next is to demonstrate the behavioral patterns of adoption processes, choosing between the technologies of FFS and FTD, via the model built. The last purpose is to understand whether there is a change in the dominance of a technology through interaction and knowledge exchange.

4.1.4 Sample Study's Scope and Evaluation of Questionnaire Administered Pilots

The sample study's scope is solely limited to the search for FFS and FTD, and their use in four types of flight training: Instrument Flight Training (IFT), Tactical Flight Training (TFT), Visual Flight Training (VFT), Search and Rescue Flight Training (SARFT).

The base data have been collected from 114 pilots (ages, 24-53), either works in commercial or military sectors, via questionnaire application (The sample questionnaire is given in Appendix 1). The 46% of questionnaire-administered pilots is commercial while 54% is military as shown in Figure 4.1.

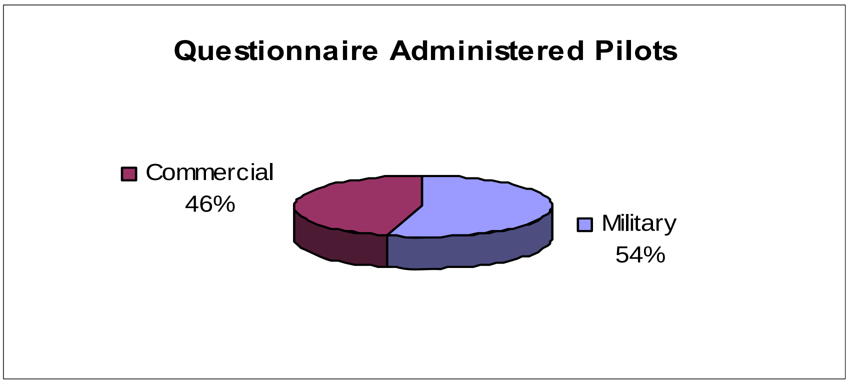

Figure 4.1 Questionnaire Administered Pilots' Status

The overview of the pilot clusters is depicted in Figure 4.2 below. Workplace and source based classification for commercial (Nc=52) and military (Nm=62) pilots are also depicted in the same figure. Please note that seven different clusters are determined according to their current workplaces and sources. The military pilots' workplaces/sources are self-explanatory while commercial helicopter pilots are mostly ex-Army pilots and work in a private firm and/or contracted by Ministry of Health, Forestry or Transportation. The airline pilots are selected from four different firms; Turkish Airlines (THY), Pegasus Airlines, Sky Airlines and SunExpress Airlines while small-size carrier pilots are from private business jet firms or contracted by Ministry of Health and Transportation. Their sources are varied depending on whether they used to work in the Army and Air Force while only 15 pilots are solely civil sourced since the military is still the biggest resource in the commercial aviation sector.

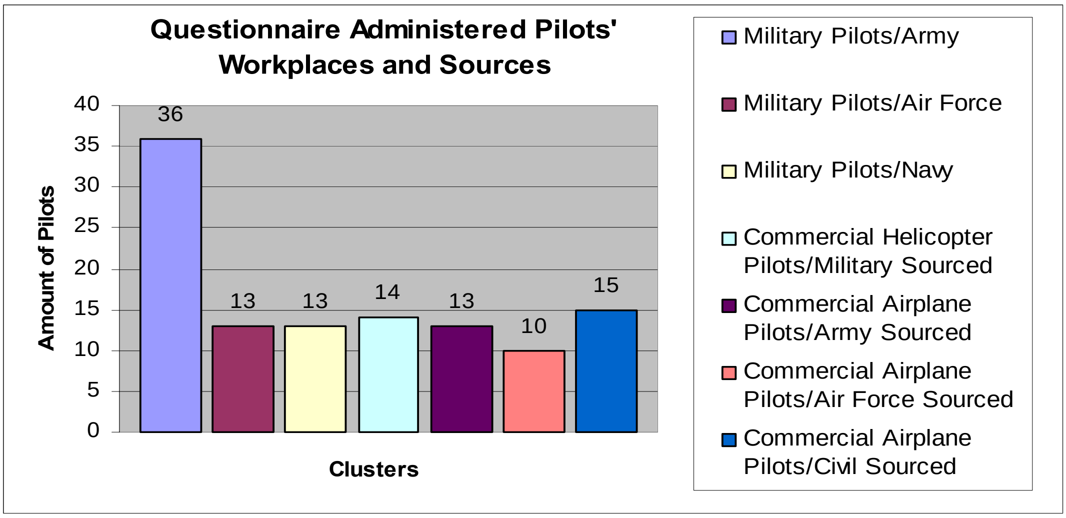

Figure 4.2 Pilots' Workplace and Source Classification

Questionnaire administered pilots' "aircraft type qualification" status percentages are depicted in Figure 4.3 as follows. Thirty three percent of those pilots are both qualified in airplane and helicopter as more pilots are only airplane qualified (above 70%).

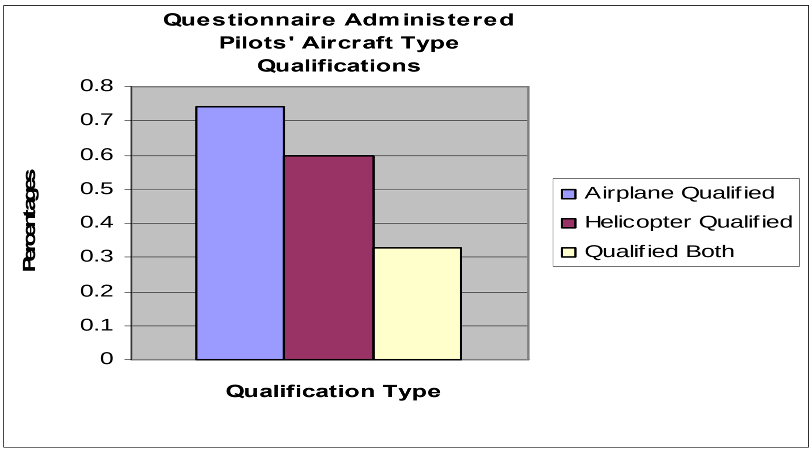

Figure 4.3 Aircraft Type Qualification Status

They are qualified in different types of aircrafts such as fighter/business jets, passenger airliners, turboprop cargo/passenger carriers, military assault/utility or commercial cargo/passenger/medivac helicopters).

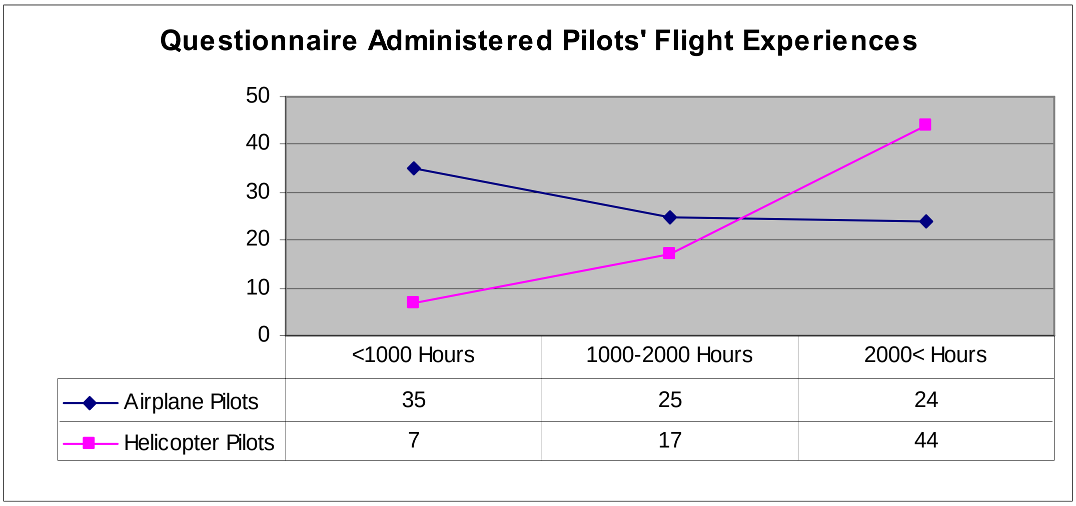

Figure 4.4 Pilots' Flight Experiences Classifications

The flight experience levels of the questionnaire-applied pilots are shown in Figure 4.4. They are classified based on their total flight hour experiences. Most of airplane pilots (35 pilots) are below 1000-flight hour experience while it is reverse for helicopter pilots as 44 of them are above 2000-flight hour experience. However, it is noteworthy that the questionnaire-administered pilots have a considerable amount of experience cumulatively, as "above 2000 flight-hour experience" segment is the most populated one (68 pilots in total) compared to other two segments (42 pilots for each).

All pilots have an experience at least in one of FSTD type while it is noticeable that 66% of them experienced in both FFS and FTD. This statistic is quite important for us since we could attribute that the sample group is adequately familiar with the two technologies and they utilize FFS/FTD actively in their flight training curriculums. Our impression is that it is identical among the pilot population in Turkey there might be also some minor exceptions. Figure 4.5 gives us a detail on FSTD experiences.

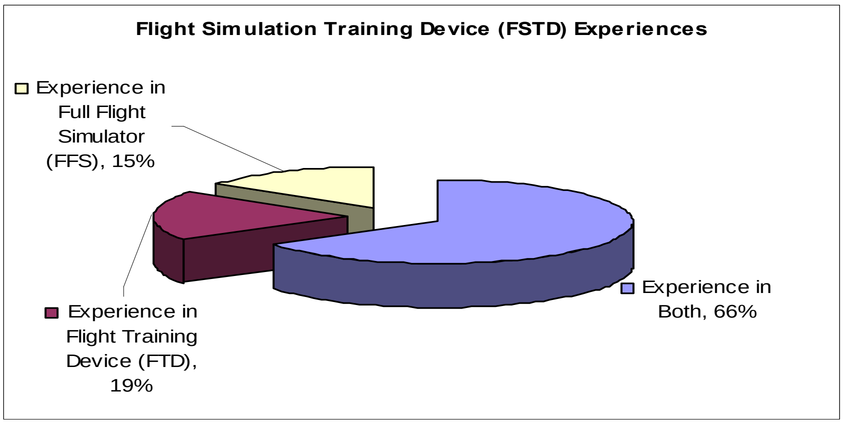

Figure 4.5 Flight Simulation Training Device (FSTD) Experience Classifications

Building the model, some endogenous variables like switching and/or training/instruction costs are not included in the model since the two reasons convinced us to discount them from our model boundary. The first is the idea to capture an important feedback loop rather than a lot of detail in the specification of the model variables (Morone & Taylor, 2010; Sterman, 2000, p.96). The second is the more the variables included, the more complex and confusing modeling processes would be experienced which might not serve any of the purpose mentioned previously.

It is expected that the variables, tendencies and perceptions [Perceived Ease of Use (PEU) and Perceived Usefulness (PU)] might be effective in assessing the technology adoption behavior in this case. It is, therefore, imperative to constitute an algorithm responding to the Roger's five attributes as well as TAM and TTF predictors. Hence, the model constituted according to this scope would help in explaining FFS and FTD adoption behavior of the aviators and the institutions/firms while determining their share in the market.

4.1.5 Questionnaire Results

The questionnaire participants were asked whether they would absolutely prefer having FFS or FTD in an effective and efficient flight training system and the result is mostly in favor of FFS as shown in Figure 4.6. The pilots tend to have FFS mostly (89%) rather than FTD. The commercial pilots add on the cumulative with 94% FFS preference while it is 87% for military as depicted below.

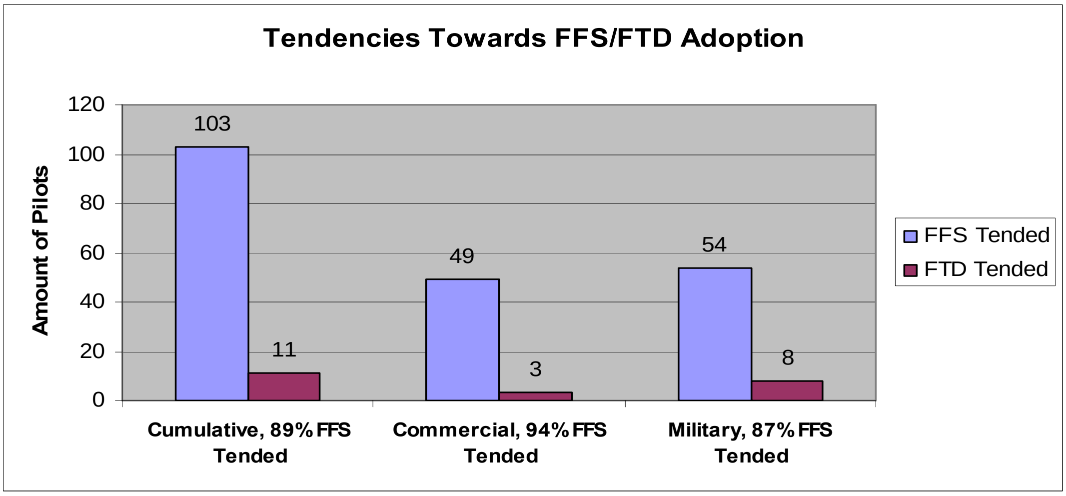

Figure 4.6 FSTD Technology Tendencies

On the other hand, we observed that the Air Force Pilots' preferences slightly differed as compared to the other pilot clusters' (Their FFS preference, 69%, is well below the average, 89%). FTD may be more appropriate for high-performed fighter jet tactical training since FFS' motion base and/or visual systems might yield negative transfer for them. In reality, Turkish Air Force has more FTD-based flight training facilities than the other clusters have.

The average PEU and PU values for FFS and FTD are computed based on the questionnaire takers' responses and are exhibited in Table 4.1 below. Taking PEU, the question "2.a" was asked to evaluate which of one; FFS or FTD is "more favorable in terms of ease of operation and use" for commercial/military flight training tasks (IFT and VFT) and military flight training tasks (TFT and SARFT). The responses, collected on a Likert-scale, constituted the PEU value for each case.

Taking PU, the question "3" was asked to determine "the percentages, FFS or FTD could meet the periodic flight training needs instead of an actual aircraft" for commercial/military flight training tasks (IFT and VFT) and military flight training tasks (TFT and SARFT). The responses, collected on a table, constituted the PU value for each case. Below is the table of all PEU and PU values for each training task. The

PEU and PU rates of technologies, FFS and FTD for each case and training task are gathered on a table below. The one could recognize FFS has an absolute advantage regarding usefulness while FTD is advantageous regarding ease of use.

Table 4.1 The FFS/FTD Absolute PEU and PU Values Based on Questionnaire Takers Responses

TASK ASSOCIATED AGENT CLASSIFICATION	FSTD TYPE	ABSOLUTE ADVANTAGE		FLIGHT TRAINING TYPE
		PEU	PU	
Commercial/Military Case	FFS	0.21	0.8	"a", Instrument Flight Training (IFT)
	FTD	0.48	0.67	
Military Case	FFS	0.19	0.42	"b", Tactical Flight Training (TFT)
	FTD	0.5	0.27	
Commercial/Military Case	FFS	0.21	0.46	"c", Visual Flight Training (VFT)
	FTD	0.48	0.26	
Military Case	FFS	0.19	0.38	"d", Search and Rescue Flight Training (SARFT)
	FTD	0.5	0.24	

Within the context, the comparative advantage values are also computed for FFS and FTD relating each case and training task. These values are depicted in Table 4.2 below. The comparative assessment is required other than assessing solely absolute advantage values for an acquisition professional, entrepreneur, aviation institution as well as technology developers and researchers involved in FSTD related activities. This helps them analyzing possibilities frontier and assessing opportunity cost so that the rates are supportive in decision-making.

Table 4.2 The FFS/FTD Comparative PEU and PU Values Based on Questionnaire Takers Responses

TASK ASSOCIATED AGENT CLASSIFICATION	FSTD TYPE	COMPARATIVE ADANTAGE		FLIGHT TRAINING TYPE
		PEU	PU	
Commercial/Military Case	FFS	0.44	1.19	"a", Instrument Flight Training (IFT)
	FTD	2.28	0.84	
Military Case	FFS	0.38	1.55	"b", Tactical Flight Training (TFT)
	FTD	2.63	0.64	
Commercial/Military Case	FFS	0.44	1.77	"c", Visual Flight Training (VFT)
	FTD	2.28	0.57	
Military Case	FFS	0.38	1.58	"d", Search and Rescue Flight Training (SARFT)
	FTD	2.63	0.63	

The first impression is that FFS outperforms FTD regarding "usefulness" while it is reverse for "ease of use". On the other hand, it is noteworthy that FFS and FTD PU values for IFT are very close each other, "1.19" and "0.84" respectively, as compared to "1.77" and "0.57" for VFT. It could be inferred that the opportunity cost of FFS usefulness increases with the larger amount of FFS use for VFT in the market while it is lesser for SARFT and TFT successively, and the least for IFT among the training tasks.

On the other hand, it becomes clearer that TTF related matters should be involved in any technology adoption model. According to the responses offered in the survey, within a range of 18-80% FSTD use instead of sole aircraft use in varied types of training would make a sense in that manner. Inspecting Figure 4.7 below, IFT is the most supported one with 80% FFS flight among the others that is followed by 67% FTD flight for the same training.

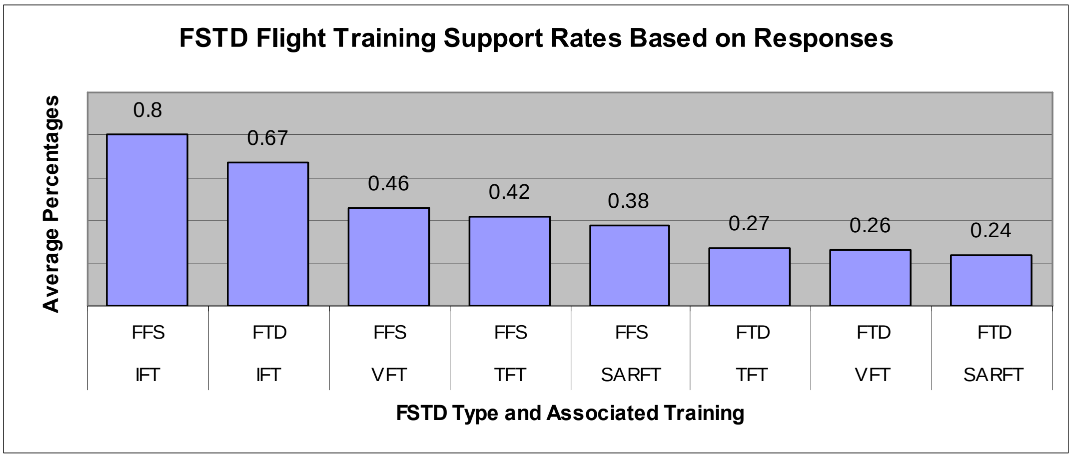

Figure 4.7 FSTD Support Percentages

This could be attributed as the most notable result in the sample study and is deserved to be analyzed since it might provide the opportunity of acquiring and/or utilizing FTD as a substitute to FFS, and thus FTD as a primary complementary of the aircraft in IFT due to three reasons. First is the opportunity cost of using FFS in IFT is not as much as the other trainings'. Second is the vast amount of difference in FFS and FTD acquisition costs. Third is FTD's ease of operation and use, which outperforms FFS largely in any case and training task. The last reason is also favorable regarding sustainment and obsolescence management since the life cycle cost would be lower in any case.

4.1.6 Statistical Analyses

Based on the primary findings above, it was decided to make a deeper analysis and to support the questionnaire results with the statistical methods. During the tests, Microsoft Excel, Data Analysis and Data Analysis Plus Tool were used. Both parametric and non-parametric tests were conducted and the clusters' preferences between FFS and FTD have been tested[1] for four types of training task, IFT, TFT, VFT and SARFT.

First, in order to check if there is any difference in pilots' FFS and FTD preferences regarding the two technologies' usefulness in four types of training task, t-test was conducted to see whether the means of FFS and FTD usefulness differ or not. It is assumed the samples are independent random samples drawn from normal populations. This requires conducting the hypothesis testing. Thus, the null hypothesis is;

$$H_0 : \mu_{FTD} = \mu_{FFS}, \tag{4.1}$$

This follows that $\mu_{FTD} - \mu_{FFS} = 0$ where μ_{FTD} and μ_{FFS} are mean values for the preferences for FTD and FFS respectively. The alternative hypothesis is;

$$H_1 : \mu_{FTD} \neq \mu_{FFS} \text{ or } \mu_{FTD} - \mu_{FFS} \neq 0 \tag{4.2}$$

However, we do not have any idea about the means of the populations, but we do know the mean values for the samples drawn from the populations. The best estimator of μ_{FTD} and μ_{FFS} are $\bar{X}_{FTD}$ and $\bar{X}_{FFS}$ respectively. Thus, it will be used $\bar{X}_{FTD}$ and $\bar{X}_{FFS}$ instead of μ_{FTD} and μ_{FFS}.

[1] Tests and analysis were executed based on "Statistical Analysis" explained in Keller's "Statistics for Management and Economics" (USA: Thomson and Brooks/Cole, 2005).

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n} \tag{4.3}$$

where X_i : preference of i^{th} pilot, n : total number of pilots in the sample.

The t-test statistic for $\mu_{FTD} - \mu_{FFS}$ depends on if the variances are equal or not. If equal then the test statistic is;

$$t = \frac{(\bar{X}_{FTD} - \bar{X}_{FFS}) - (\mu_{FTD} - \mu_{FFS})}{\sqrt{s_p^2\left(\frac{1}{n_{FTD}} + \frac{1}{n_{FFS}}\right)}}, \quad v = n_{FTD} + n_{FFS} - 2 \text{ (degrees of freedom)} \tag{4.4}$$

$$\text{where } s_p^2 = \frac{(n_{FTD} - 1)s_{FTD}^2 + (n_{FFS} - 1)s_{FFS}^2}{n_{FTD} + n_{FFS} - 2} \tag{4.5}$$

If not equal then the test statistic is;

$$t = \frac{(\bar{X}_{FTD} - \bar{X}_{FFS}) - (\mu_{FTD} - \mu_{FFS})}{\sqrt{\left(\frac{s^2_{FTD}}{n_{FTD}} + \frac{s^2_{FFS}}{n_{FFS}}\right)}}, \quad v = n_{FTD} + n_{FFS} - 2 \text{ (degrees of freedom)} \tag{4.6}$$

Since we test if the means are equal, means that $\mu_{FTD} = \mu_{FFS},$ then $\mu_{FTD} - \mu_{FFS} = 0$. According to this test:

If the variances are equal, then the test statistic becomes;

$$t = \frac{(\bar{X}_{FTD} - \bar{X}_{FFS})}{\sqrt{s_p^2\left(\frac{1}{n_{FTD}} + \frac{1}{n_{FFS}}\right)}}, \quad v = n_{FTD} + n_{FFS} - 2 \text{ (degrees of freedom) and,} \tag{4.7}$$

If the variances are not equal, then the test statistic becomes;

$$t = \frac{(\bar{X}_{FTD} - \bar{X}_{FFS})}{\sqrt{\left(\frac{s^2{}_{FTD}}{n_{FTD}} + \frac{s^2{}_{FFS}}{n_{FFS}}\right)}}, \ v = n_{FTD} + n_{FFS} - 2 \text{ (degrees of freedom)}, \quad (4.8)$$

In order to find out if the variances are equal or not we conducted F-test. Thus, the null hypothesis is;

$$H_0 : \sigma^2_{FTD} = \sigma^2_{FFS} \text{ or } \frac{\sigma^2_{FTD}}{\sigma^2_{FFS}} = 1 \text{ (The variances are equal)} \quad (4.9)$$

The alternative hypothesis is;

$$H_1 : \sigma^2_{FTD} \neq \sigma^2_{FFS} \text{ or } \frac{\sigma^2_{FTD}}{\sigma^2_{FFS}} \neq 1 \text{(The variances are not equal)} \quad (4.10)$$

Hence, the test statistic, which is conducted to test if $\frac{\sigma^2_{FTD}}{\sigma^2_{FFS}} = 1$ is;

$$F = \frac{s^2{}_{FTD}}{s^2{}_{FFS}}, F \text{ distributed with } v_{FTD} = n_{FTD} - 1 \ v_{FFS} = n_{FSS} - 1 \quad (4.11)$$

In order to employ the F and t-tests, the spreadsheets are used. The rejection region for the F test is;

$$F >_{\alpha/2}, v_{FTD}, v_{FFS} \text{ and,} \quad (4.12)$$

the rejection region for the t-test is

$$t >_{\alpha/2}, n_{FTD}, n_{FFS} - 2. \quad (4.13)$$

Examined the test results, it could be inferred that there would not be sufficient evidence to reject null hypothesis which is $H_0 : \mu_{FTD} = \mu_{FFS,}$ for the test of military pilots' FFS and FTD usefulness preferences which means that the favorability of the two technologies are same for IFT (Instrument Flight Training) while the null hypothesis were rejected for all the other cases. The result, depicted in Table 4.3, supports our primary findings (Subsection 4.1.5) towards the comparative analysis of the two technologies.

Table 4.3 "F and t-Tests": Military Pilots' FFS/FTD Evaluations for IFT

MILITARY PILOTS (α = .01)	**F-Test Two-Sample for Variances**		
		FFS	*FTD*
	Mean	0.76	0.67
	Variance	0.04	0.05
	Observations	62	62
	df	61	61
	F	0.87	
	P(F<=f) one-tail	0.3	
	F Critical two-tail	0.55	
	VARIANCES DIFFER		
	t-Test Two-Sample Assuming Unequal Variances		
		FFS	*FTD*
	Mean	0.76	0.67
	Variance	0.04	0.05
	Observations	62	62
	Hypothesized Mean Difference	0	
	df	121	
	t Stat	2.31	
	P(T<=t) one-tail	0.01	
	t Critical one-tail	2.36	
	P(T<=t) two-tail	0.02	
	t Critical two-tail	2.62	
	NO DIFFERENCE IN MEANS		

Summarizing, "F-Test Two Sample for Variances" was applied for different clusters and it was found that military pilots' preference variances differ for IFT (Table 4.3). Next, "t-Test Two-Sample Assuming Unequal Variances" was executed to understand if there is a difference between military pilots' FFS and FTD preferences in terms of their usefulness for IFT. No difference was found in the means of two samples based on the parametric tests.

In order to support our assertion and to understand whether the population distributions and their characteristics are identical, one of the non-parametric techniques, “Wilcoxon Rank Sum Test” was applied. The cluster samples regarding commercial/military case, military case and commercial case have been tested. The method requires the comparison of two populations. The data are either ordinal or interval, where the normality requirement necessary to perform the equal-variances t-Test of $\mu_{FTD} - \mu_{FFS}$ is unsatisfied and the samples are independent (Keller, 2005, p.726-749). Hypothesis testing was needed to conduct.

Thus, the null hypothesis is;

H_0 : The two population locations are the same.

The alternative hypothesis is,

H_1 : The locations of two populations are different.

Conducting “Wilcoxin Rank Sum Test” for different clusters as to understand if there is a difference between the locations (characteristics) of Pilots’ FFS and FTD preferences regarding the two technologies’ usefulness in four types of training task, it was found that the military pilots’ preferences towards IFT training do not differ. This test output is shown in Table 4.4 as follows.

Table 4.4 “Wilcoxin Rank Sum Test”: Military Pilots’ FFS and FTD Evaluations for IFT

MILITARY PILOTS (α = .01)	Wilcoxon Rank Sum Test		
		Rank Sum	Observations
	FFS	4343	62
	FTD	3407	62
	z Stat	2.3388	
	P(Z<=z) one-tail	0.0097	
	z Critical one-tail	2.3263	
	P(Z<=z) two-tail	0.0194	
	z Critical two-tail	2.5758	
	NO DIFFERENCE IN LOCATIONS		

4.2 Modeling Process

Testing the pilots' FFS and FTD preferences statistically regarding the two technologies' usefulness in four types of training task, we would test whether any variable like "technologies' ease of operation and use" could affect the adoption behavior of the technologies and to what degree it might be effective.

This is a "local environment model" comprises of highly informed agents (adopters) entering into the system. Like in *"Brian Arthur`s Competing Technologies, Increasing Returns, and Lock-In by Historical Events Model"* (Arthur, 1989). The model agents represent the potential adopters (commercial and military institutions and/or firms) decide acquiring/buying FFS/FTD or their cabin hours. They decide according to their perceptions and thus make comparative analysis in terms of ease of use and usefulness based on their tasks and training needs. They interact with the early adopter community via knowledge exchange.

The two variables, PU and PEU should be considered in any "technology adoption model" (Pagani, 2004; Davis 1989) and are used as complementary in the model. These variables are considered in predicting the adoption of FFS and FTD because they are perceived to be the most important factors evaluating the potential adopter's decision. This is because personal job performance enhancement through such technologies and having effective and efficient training environment has always been attractive to the aviation institutions and firms due to being in highly competitive environment.

The two types of agents, commercial and military, have their tendencies determined with the random probability of "0.94/0.06" in favor of FFS for commercial agents while it is "0.87/0.13" for the military agents. Those random probability rates do not change during the simulation. The random probability of having commercial agents enter into the system is 60% comparing to military agents (40%). This approximation is currently appropriate based on the real case and is subject to a change through time. Each agent has its own PU and PEU towards FFS and FTD for the selected flight training tasks, IFT, TFT, VFT, and SARFT.

Figure 4.8 exhibits the process briefly. The potential adopters/agents (commercial and military) enter the system with their previous knowledge (tendencies and perceptions towards FSTD technologies) and interact with the early adopters' community and the accumulated knowledge (knowledge exchange). An agent change or maintain its preference based on the prior tendency constituted based on the perceptions towards effective and efficient training, potential adopter's tasks and the training needs. It is compared to the FSTD choices, which are previously acquired and/or utilized by the early adopters. The process is modeled via constituting an algorithm and coding on Java Platform. "The Technology Determination Rule", applies for the each agent included in the system, is given in Equation (4.14) below;

$$\text{if} \quad PEU(Tt) < \frac{\sum_{n=1}^{100} (PEUn)}{N} \quad \text{and} \quad PU(Tt) < \frac{\sum_{n=1}^{100} (PUn)}{N} \qquad (4.14)$$

then acquires and/or utilizes the alternative technology (Ta); else decides to acquire and/or utilize the one (Tt) tended. In the Formula (4.14), PEU(Tt) and PU(Tt) represent the tended technology's determinants based on the agents' prior perceptions towards the technologies while PEUn and PUn represent the early adopters (previous agents)` final perceptions after acquisition and/or utilization of the selected technology. Here, "n" stands for the number of previous agents where N represents the number of total previous agents.

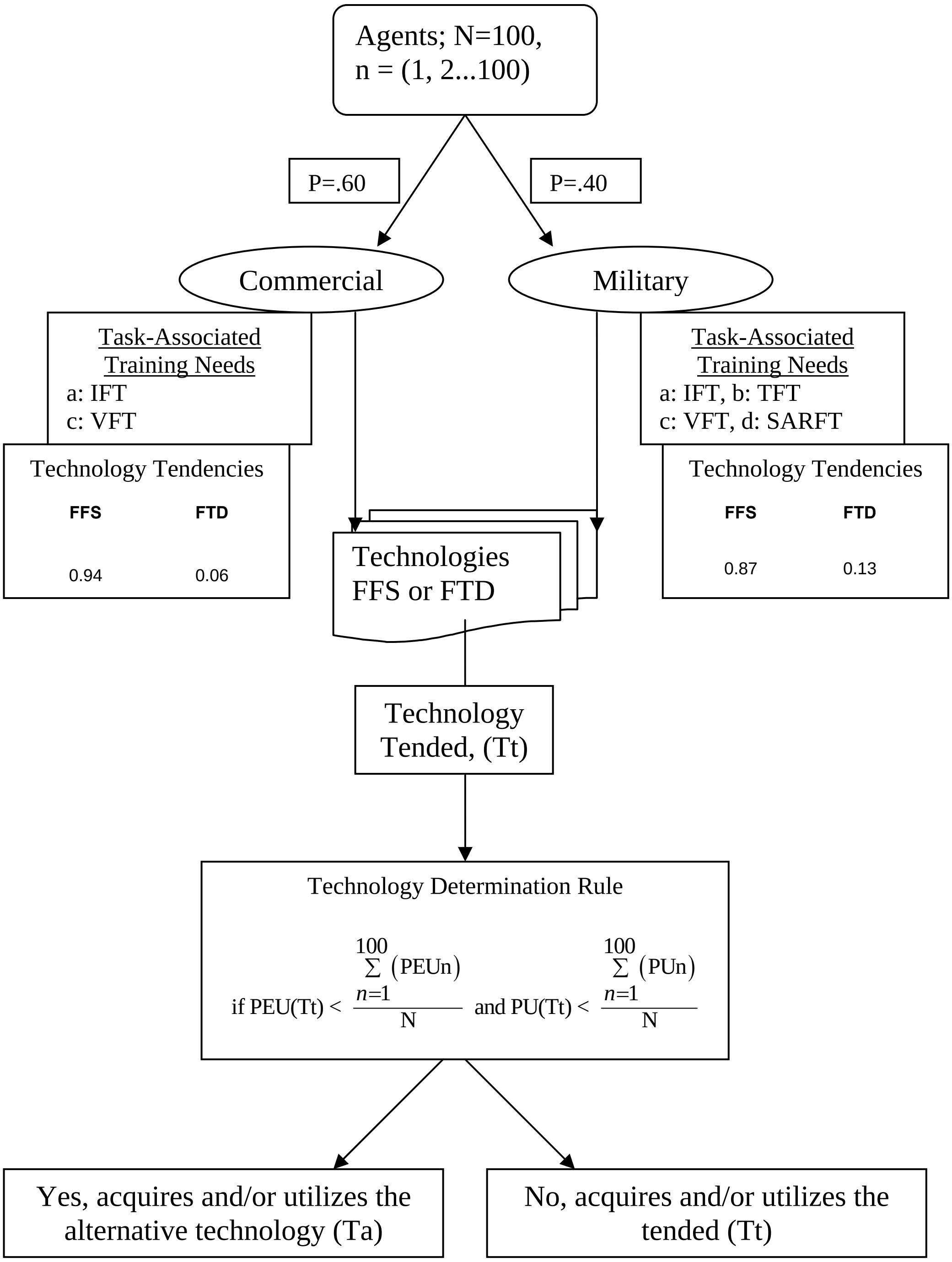

Figure 4.8 Technology Determination Process Flowchart

It is believed that "the technological cycle model" also applies to our case in quite a few ways. It is expected that the Technology Alternative (Ta) will either start dominating the market after a while (incremental change) or both technologies, Technology Tended (Tt) and Ta will reach their equilibrium and their share in the market are stabilized. We also assert that this kind of comparison comprises some effectiveness and efficiency criteria inherently since the comparative data is injected in the simulation.

4.3 Simulation Process

4.3.1 Simulation Runs and the Output

In a set of 10 simulations, FFS and FTD percent shares are observed. There are four tables, representing the percent share values of FFS adoptions that in turn also make us infer upon FTD share inherently. The values of FFS percent share for randomly chosen simulation runs are graphed for each training task, IFT, TFT, VFT and SARFT, in Figure 4.9, 4.10, 4.11, and 4.12 respectively. Briefly, each run represents the share of FTD adoptions and thus FFS inherently through time on a discrete event basis. The total number of agents is 100 and they come into play one by one as their total number increases linearly up to a 100. In Figure 4.9, for example, FTD adoptions for training task IFT are depicted.

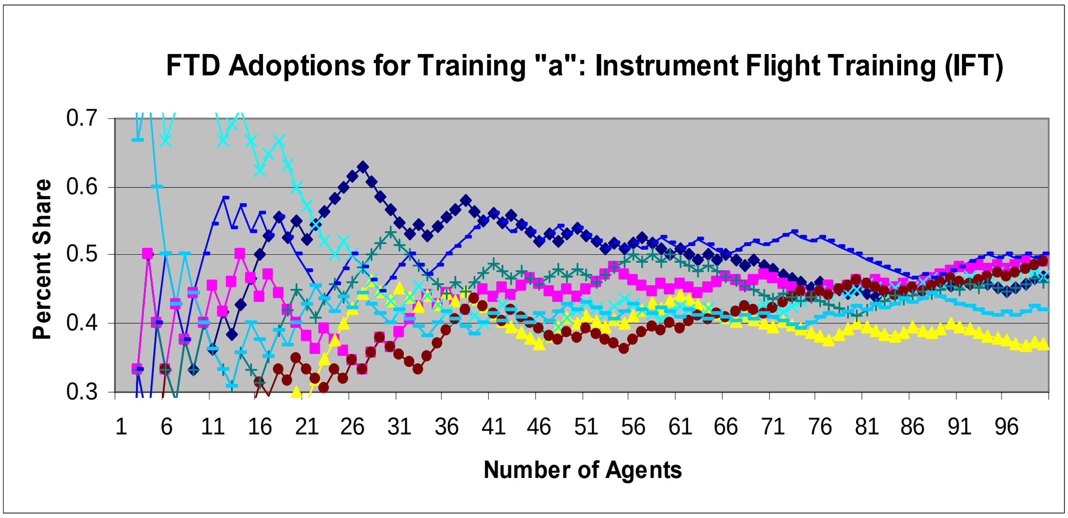

Figure 4.9 FTD Adoption Behavior for IFT

Taking Instrument Flight Training (IFT), the trend of FTD adoptions in ten randomly chosen simulations exhibits that the more institutions come into play, the more the adoption trend stabilizes, that is, an equilibrium pattern of 40-50% FTD share approximately after half of the institutions adopted. The adoption behavior seems quite consistent in that manner. The IFT is the most common and frequently executed training type in FSTD by both commercial and military pilots. We believe that the commonality in IFT needs (commercial/military case) and the accumulated FSTD experiences could have created such a consistent adoption behavior.

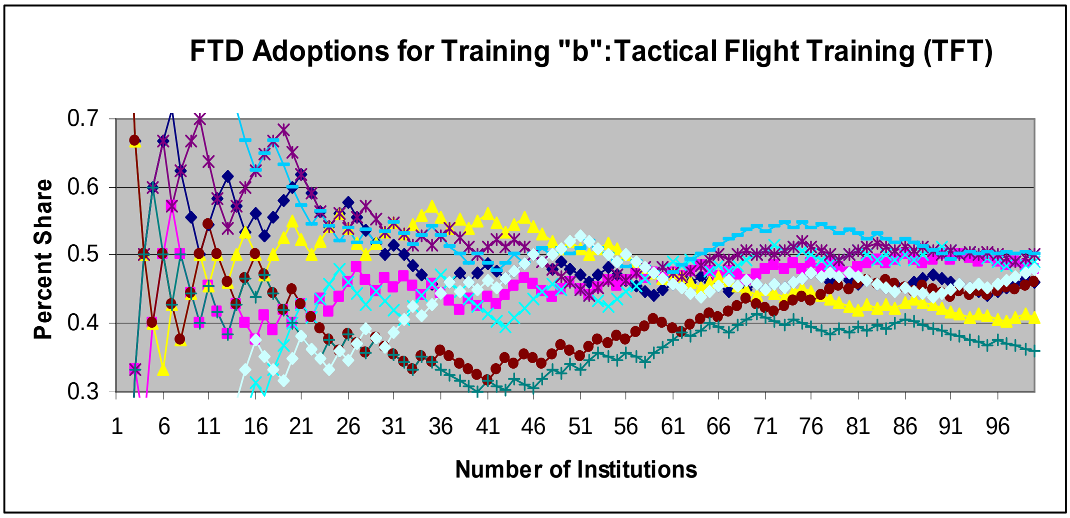

Figure 4.10 FTD Adoption Behavior for TFT

Taking Tactical Flight Training (TFT), FTD adoptions in ten randomly chosen simulations in Figure 4.10 demonstrates a quite consolidated pattern but approximately after seventy institutions. It could be attributed that the adoptions stabilize and exhibit an equilibrium behavior of 40-50% FTD share after seventy adoptions while it is between 30-55% before. This might stem from the ambiguity for some of the tactical training phases might require visual system and motion platform which could be accepted as a prerequisite for the experienced pilots. This might in turn make the potential adopters interrogate FTD's "usefulness" in tactical training since it might lack of visual system for some cases and motion platform.

The issues mentioned above could have created a delay towards the adoption of FTD at the beginning of the simulation.

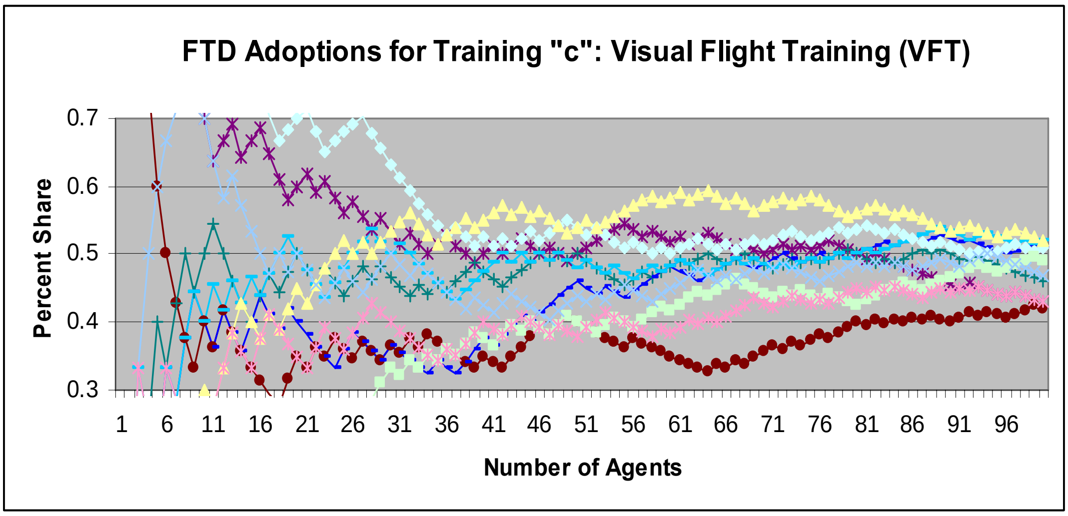

Figure 4.11 FTD Adoption Behavior for VFT

Taking Visual Flight Training (VFT), FTD adoptions in ten randomly chosen simulations in Figure 4.11 demonstrates a stabilized pattern approximately after half of the adoptions realized. The relatively loose range between 35-55% turns out to be tighter as 40-50% FTD share during the last fifteen adoptions.

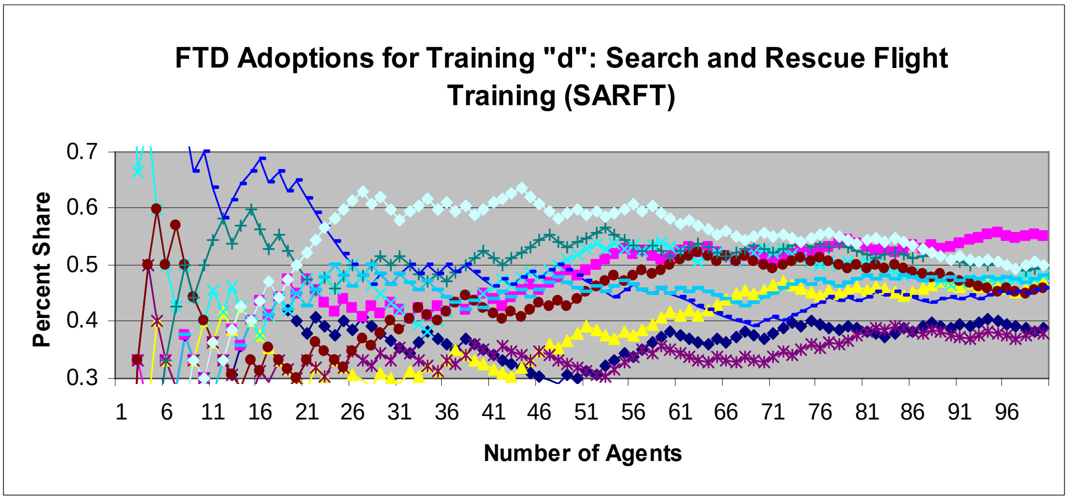

Figure 4.12 FTD Adoption Behavior for SARFT

Taking Search and Rescue Flight Training (SARFT), FTD adoptions in ten randomly chosen simulations in Figure 4.12 demonstrates a very loose range between 30-60% FTD shares for the first half of the simulation. This might stem from the type of the training and its complexity, which the potential adopters do not have adequate experience and knowledge how to acquire, utilize and make a favor of the technology for this type of training. Suspicion in “ease of operation and use” together with FTD “usefulness” (due to the lack of motion platform and visual system for some cases) might lead such a scattered adoption pattern. SARFT might certainly require specifically tailored FSTD and software code to simulate search and rescue flight-training tasks (e.g. overwater hoist operation at night) which could offer high-resolution visual system and motion cues.

4.3.2 Sensitivity Analysis

Sensitivity analyses are conducted to determine whether the model results differ significantly when the input variables are varied and the degree to which these results change. This is necessary to test the robustness of our results. Three types of sensitivity[2] are considered in testing our model and they are numerical, behavior mode, and policy sensitivity.

Having analysed the clusters’ preferences statistically and found that the military pilots perceived FFS and FTD could add on IFT equally (since the samples’ mean are equal and we could not reject the null hypothesis $\mu_{FTD} = \mu_{FFS,}$ both parametrically and non-parametrically), we decided to run the simulation solely for military although IFT is included in the commercial/military case. The objective is to analyze simulation sensitivity that in turn could help improving questionnaire and the application.

[2] Numerical Sensitivity exists when a change in assumptions changes the numerical values of the results. Behavior Mode Sensitivity exists when a change in assumptions changes the patterns of behavior generated by the model. Policy Sensitivity exists when a change in assumptions reverses the impacts of desirability of a proposed policy. John D. Sterman, Business Dynamics: Systems Thinking and Modeling for a Complex World (New York: Irwin McGraw-Hill, 2000), 883.

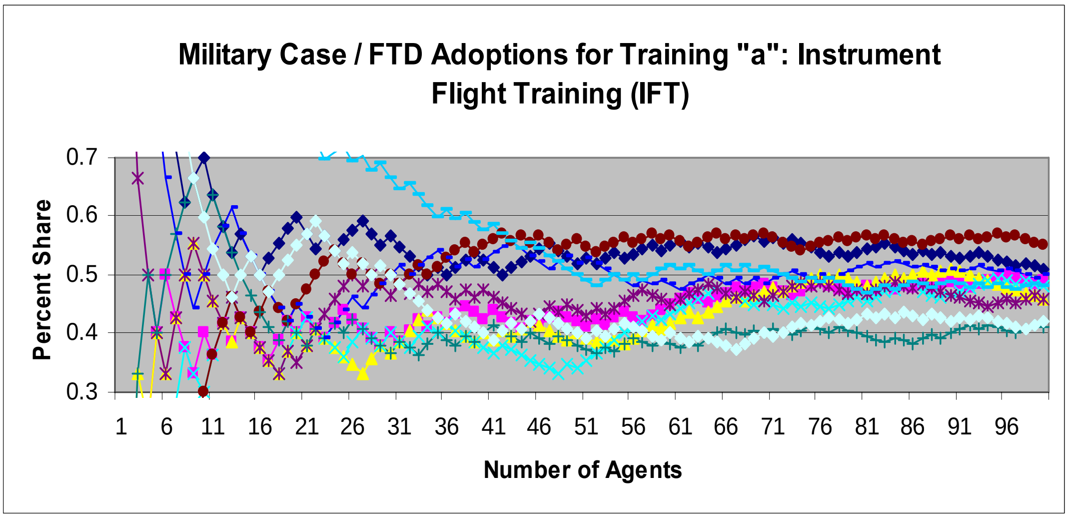

Figure 4.13 FTD Adoption Behavior for IFT/Military Case

Taking military FTD adoption behavior for Instrument Flight Training (IFT), the trend of FTD adoptions in ten randomly chosen simulations is shown in Figure 4.13. It plots a quite stabilized pattern all through the process as compared to the other adoption patterns as depicted previously. It could be inferred that it exhibits an equilibrium behavior of 40-55% FTD share and consistency after the first thirty adoptions.

This could have been expected prior to simulation since the statistical analysis of the military cluster preferences is quite consistent for IFT. Another saying, the commonality and/or uniformity of the samples could help us making more sound inferences about the populations and thus the technology preferences. Within the context, the questionnaire should have been tailored uniquely and applied all clusters separately since it is more probable that we could get more consistent results towards the technology adoption behaviors.

4.4 The Sample Study's Conclusion

The sample study analyzed the agents' perceptions and preferences towards FSTD technologies statistically and examined the process of choosing between FFS and FTD, two major technologies in FSTD market by employing a Simulation Model. The objective of the sample study was to model aviation institutions and firms' choosing processes of the two alternative flight-training technologies, FFS and FTD, based on the features of training tasks, by constituting an algorithm, and coding the process on Java Platform.

The pilots' FFS and FTD preferences were statistically tested in terms of usefulness in four types of training task. Moreover, we tested whether any variable like "technologies' ease of operation and use" had any effect on the technology adoption behavior and how much it affected the adoptions.

The interpretation of the results and the sensitivity analyses demonstrated the model is a viable tool to model the choosing process between the two flight training technologies. We could infer that aviation institutions and firms could acquire and utilize FTD as a complementary to aircraft and FFS in Instrument Flight Training (IFT), Tactical Flight Training (TFT), Visual Flight Training (VFT), Search and Rescue Flight Training (SARFT within a range of 30-60%; and as a substitute to FFS for IFT with the FTD-aircraft mix ratio of 67%. In military case, training task "a" (IFT) showed us FFS and FTD do not differentiate in terms of usefulness and they might be accounted as substitute to each other.

We think that "technological cycle model" applies to our case in quite a few ways. It is expected that the Technology Alternative (Ta) will either start dominating the market after a while (incremental change) or both technologies, Technology Tended (Td) and Ta will reach their equilibrium and their share in the market is stabilized. Taking FSTD technology market, there seems we are in the era of technological determinism in which the technical activity is limited to information exchange and problem solving (Rosenkopf and Tushman, 1998). This also explains why FSTD market seems quite consolidated and only few firms are just involved in manufacturing and developing those systems currently.

Based on the results, it is understood that the competing technologies, FFS and FTD (To and Tt) reach their equilibrium and their share in the market are stabilized. This is also considerable regarding the Rosenkopf's "eras of technological determinism" mainly described by the incremental technological changes and information exchanges among the institutions and firms.

Although there is stabilization in the proportion of the two technologies in the market with the greater number of the institutions being included in the system, the share percentage of FFS and FTD vary based on the different training tasks and the needs of commercial and military agents. For example, the users tend to acquire/utilize FFS for the training tasks like VFT, which mostly require visual and motion cues (see Figure 4.7). The technology tended (Tt) might also change depending on the accumulated knowledge and expertise through time once the interaction and knowledge exchange begin.

Accounting different pilot clusters' training needs specifically regarding their specialties and mission tasks is necessary while constituting a model. We believe that accumulating all pilot clusters in a basket and constructing a generic-type technology selection model for them created a generalization error in this case. It inhibited us to capture an important feedback loop and the variables involving in each case (training tasks a, b, c, d) uniquely. The sample size and the questions should be determined uniquely for every cluster and the study as well as questionnaire should be designed according to these principles in the future.

Briefly, it is understood that the two competing technologies' percent share in the market could be affected by the end-user' perceptions and the tendencies. The model built is limited to represent the change in the preferences due to the exclusion of several variables such as switching and opportunity cost as well as instruction cost. Lastly, the dominant design mostly continues to keep its dominance at the beginning of the simulation despite the new adopters; however, there exists a higher tendency of converging between the two technologies (To and Tt)' trends with the inclusion of more adopter and interaction.

CHAPTER 5

FSTD TECHNOLOGY SUSTAINMENT AND ACQUISITION PERSPECTIVE

5.1 Sustainment Perspective

5.1.1 Technology Evolution and Life Cycle Matters

The frequent changes in hardware and software technologies brings in more realistic virtual environment simulations while giving a way to rapid evolutionary cycle of FSTD since the technology is closely related to microprocessor development. Conway and Steward (2009) put forth in Figure 5.1 how fast one of the few core components of FSTD technology evolves. The microprocessors have been manufactured with an "ever-greater densities of transistors" that in turn made them smaller and more capable through time since 1970s. The exponential growth in developing microprocessors that are more capable is notable.

Source: Conway and Steward (2009)

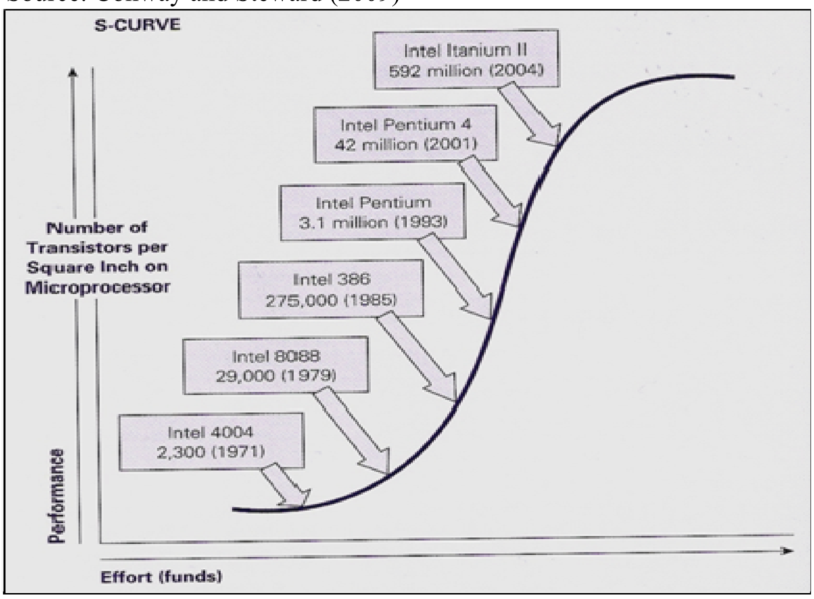

Figure 5.1 The Microprocessor Density Plot Through Time

Within the context, FSTD acquisition and integration timing is as significant as the use of realistically designed flight training environment since there is an evergrowing flight training industry. Dillard (2002) asserts, "Maximum benefit comes from the early implementation of innovative new products and applications" in the aviation. The two most important reasons are: aviation sector's competitive environment and its technology driver feature. However, growing competitive pressure in the aviation sector might also generate some adverse effects and outcomes for especially poorly organized institutions and firms. They might execute some poor acquisition practices and/or innovative efforts with the "bandwagon effect" (Baptista, 1999).

The FFS, designed for a military performing helicopter search and rescue flight training (SARFT) for example, would require much more state-of-the-art products during the manufacturing process as compared to the one for commercial airliner instrument flight training (IFT). It is because the types of commercial airplanes, flight procedures, and training tasks are quite standardized as compared to military ones and commercial-of-the-shelf components could meet the requirements of those commercial aviators. The manufacturing cost differs too much between state-of-the-art and commercial-of-the-shelf products that in turn affect the design processes and the project durations. The investment in commercial-of-the-shelf products, however, is less risky since they are already proved effective as compared to state-of-the-art products.

The evolution and life cycle of each product and the components also vary and this accounts to be a cost driver. That is why the obsolescence and sustainment perspective in each case differs and the poor acquisition practices might turn out to be obsolete easily which also creates larger opportunity costs. The technology management methodology, therefore, should include capable tools to monitor and interfere where it is needed. Herald (2005) discusses the required method as follows.

> Today's commercial and defense system-level evolution processes and tools are not structured nor rigorously optimized for sustainment-phase affordability. The challenge is to provide a sustainment-phase Technology and Product Obsolescence Management approach to forecasting that spans the entire system hierarchy and its associated elements across the system sustainment life cycle.

Dillard's (2002, p.4) assertion also supports the matter in the same way as follows.

> Modern technology delivers fully formed products in the market place with rapid wide distribution and, in many cases; a limited operating life due to forced obsolescence caused by new advances, designs, and technologies.

Dillard's assertion might be attributed as FSTD acquisition and utilization processes should be analyzed systematically since the marginal benefit of those applications may no longer be outweighing the marginal costs in few years and thus yielding diminishing returns. Hence, the challenges regarding technology evolution and sustainment should be analyzed prior to acquiring and/or developing these technologies.

The focus for FSTD acquisition and utilization should be on designing organizational structure and directing human capital within the organization as to monitor technological trend and developments, and to search for opportunities towards aircraft manufacturing and flight training market. The FSTD technology mainly depends upon the updates and/or changes in aircraft types and functions so that the dedicated FSTD are too much constrained with their existing configurations. This is why FSTD manufacturers sign contracts and establish partnerships with the aircraft manufacturers. This is a requirement for mainly software-based developing sector. Thinking of the aircraft industry forcing the obsolescence of existing systems in a very short time like three to five years (Dillard, 2002), it seems unavoidable that a firm should apply technology sustainment management on a continuous basis.

As Rosenkopf & Tushman (1998, 7:311-346) discussed in their study, eras of ferment and technological determinism are the two sequential periods in a cycle with varying levels of technological uncertainty and could be referred as "technological cycle model". As the researchers asserted and observed, flight simulation industry experiences such a technological cycle. According to them, social construction of Cooperative Technical Organizations (CTO) networks occurs and technological uncertainty exists in eras of ferment while there is incremental change and dominant design paradigm applies in eras of technological determinism.

In the second, technical activity is limited to information exchange and problem solving (Rosenkopf & Tushman, 1998, p.9).

Source: Tushman et al. (1997); Anderson and Tushman (1991) cited in Conway and Steward (2009)

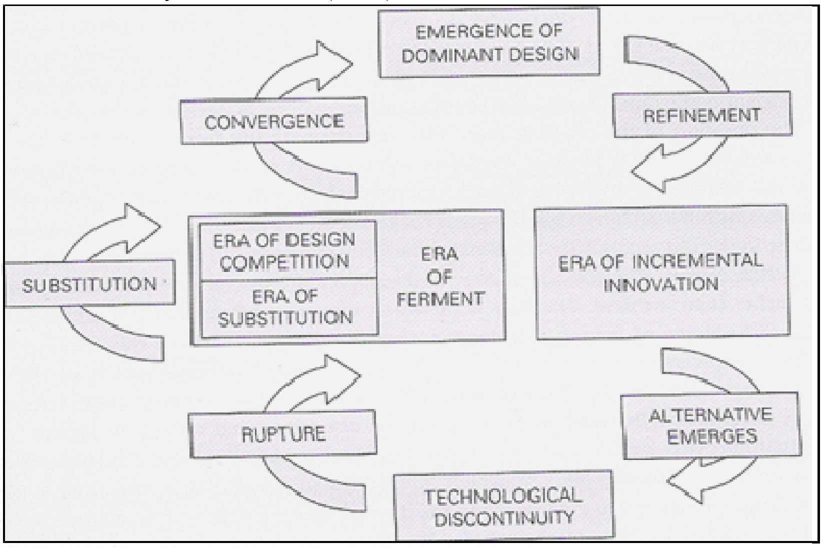

Figure 5.2 The Technological Cycle Model

As depicted in Figure 5.2 and stated by Conway and Steward (2009), incremental change is destructed once the viable alternative technology is introduced. The beginning of technological discontinuity brings in dominant design and induces an era of ferment in which R&D, design competition and substitution of technologies takes place

Taking FSTD technology market, there seems we are in the "era of technological determinism" in which the technical activity is limited to information exchange and problem solving (Rosenkopf & Tushman, 1998, 318-19). This also explains why FSTD market seems quite consolidated around "dominant design" where few firms are just involved in offering costly solutions. However, this era could also be seen as an opportunity to bring in alternative designs wherein more competition and substitution takes place regarding FSTD technologies.

Whether in commercial, military, government or international businesses, a challenge exists to determine who, what, when, where and how that a particular system of interest should evolve over its operational life cycle (Herald, 2005).

Matching appropriate innovative forms with the technological cycles would bring the organization a success. Once the literature investigated, some forms of innovation could be listed as follows (Moore, 2004, p.88)

Table 5.1 Innovation Forms and Relative Cycles

Source: Adapted from Moore (2004)

Innovation Forms	Relative Cycles
Disruptive Innovation	Gets a great deal of attention in the market when the technological discontinuities exist,
Application Innovation	Takes existing technologies into new markets to serve new purposes,
Product Innovation	Takes established offers in established markets to the next level,
Process Innovation	Makes processes for established offers in established markets more effective or efficient,
Experiential Innovation	Makes surface modifications that improve customer's experience of established products and processes,
Marketing Innovation	Improves customer-touching processes, be they marketing communications or consumer transactions,
Business Model Innovation	Reframes an established value proposition to the customer or a company's established role in the value chain or both,
Structural Innovation	Capitalizes on disruption to restructure industry relationships.

Applying an appropriate form of innovation would be sensible if there is an alignment with the market development life cycle pattern of an innovation. The commercial and military aviation organizations as well as the main institutions of national innovation could consider this alignment while determining a strategy that would shed a light for the agents involved in R&D, manufacturing, acquiring and utilizing FSTD.

Source: Adapted from Levitt Product Life Cycle (PLC) Model of Levitt (1965: 82) cited in Conway and Steward (2009)

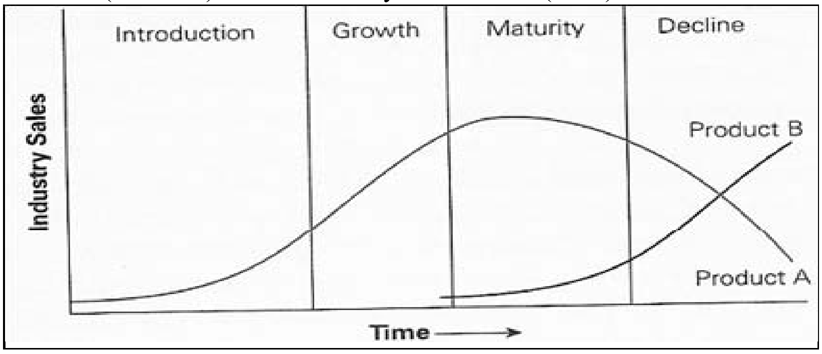

Figure 5.3 The Technology Lifecycle Model (TLC)

5.1.2 Technology Sustainment Management

The aviation institutions and firms should get involved in sustainment management of their FSTD technologies while acting appropriately as opposed to rapid evolutionary cycles of FSTD. Complex and highly technical systems like FSTD exhibit quite similar failure and/or obsolescence patterns through their life cycles and aging processes (Gill, 2001) as depicted in Figure 5.4 (shows a typical failure distribution pattern for a generic system). The main objective in logistics and/or systems management is to "remain operationally viable during the full sustainment period" (Herald, 2005).

Source: NPS/GB4450MN4470: Systems Management Lecture Slides; 8-22 Logistics: Test & Evaluation (2006)

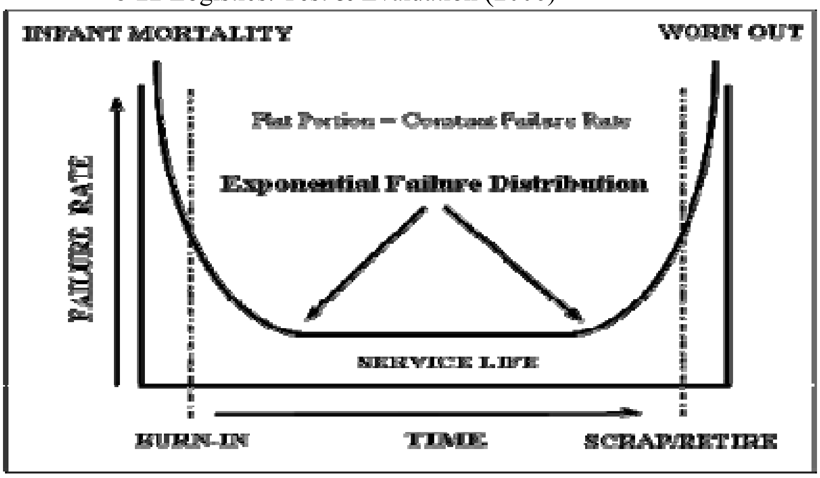

Figure 5.4 Logistics "Bathtub Curve": Failure Distribution over System's Life Cycle

The figure above is self-explanatory and highlights the importance of logistics management in terms of failure occurrences. The bathtub curve might also help enhancing organizations' understanding when technologies deserve to be retired from a system. Another saying, it is a useful model in terms of simplifying and representing the concept of obsolescence management. Thus, it would be favorable to identify the metrics helping the organizations how they could manage the technologies and thus FSTD from a logistics perspective.

In the study of determining Inherent Availability Ratio (IAR) for TUAA UH-1 Helicopter Flight and Navigation Procedures Trainer (FNPT), failure statistics of FSTD technology for four FSTD cabins were collected (Boztaş, 2006) as shown in Table 5.2. It could be a good start understanding the technique towards FSTD's sustainment management while the sample study and related assessment is subject to change for the more contemporary and cutting-edge systems.

Table 5.2 Annual Average Failure Occurrence and Mean Corrective Maintenance (Mct) Time (Units of Hours)[1]

Source: Boztaş (2006)

Failures	**Occurrence**	**Ct**	**Tct**	**Cct**
Flight Controls	1	1	1	0.25
Indicators	2	0.5	1	0.25
Motion Failures	3	48	144	72
Computer & Interface	5	48	240	240
Electrical	2	3	6	6
Visual System	3	84	252	63
Support Systems	5	48	240	240
Software	1	36	36	36
Instructor Console	2	1.5	3	1.5
Avionics	3	1	3	0.75
Mct				65.975

The final value computed as Mct, based on the experienced Ct and Tct values through the years 1990-2006, is imported from the Table 5.2 above and is

[1] Mean Corrective Maintenance Time (Mct): is the composite value of the arithmetic average of individual maintenance cycle times, Ct: Average correction time, Tct: Total Correction Time, Cct: Cabin or System Correction Time. (Mct): is the composite value of the arithmetic average of individual maintenance cycle times, Ct: average correction time, Tct: Total Correction Time, Cct: Cabin or System Correction Time.

used to find IAR in the Table 5.3 below. The main parameters[2] are; Technology Reliability Factor (TRF), Mean Time between Failures (MTBF), Mean Corrective Maintenance Time (Mct) and Inherent Availability Ratio (IAR). The computed IAR could be taken as a supportive metric for the end-user to plan training sessions and for the acquisition professionals, institutions and firms to match the organizations with the appropriate innovative efforts. These are the main considerations in applying sustainment and obsolescence management.

Table 5.3 TUAA UH-1 Helicopter FNPT Inherent Availability Ratio (IAR) over Time

Source: Boztaş (2006)

Years	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
R.F.(λ)	0.01	0.05	0.05	0.004	0.02	0.02	0.01	0.01	0.01	0.003	0.009	0.002	0.003	0.004	0.003	0.001	0.002
MTBF(1/λ)	76.9	20	21.7	250	43.5	41.7	76.9	167	200	333.3	111.1	500	333.3	250	333.3	1000	500
Mct	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66
IAR	0.54	0.23	0.25	0.791	0.4	0.39	0.54	0.72	0.75	0.835	0.627	0.883	0.835	0.791	0.835	0.938	0.883

The IAR versus years in Table 5.3 above mainly demonstrates an increasing supportive capability behavior and is plotted in Figure 5.5 below. A lower IAR converts to higher availability over time. It is obvious that greater learning has been experienced through FNPT's years of service, 2001-2006. Regarding the stagnation trend in FNPT usage between the years 2001 and 2006, we note that a system's aging and life cycle should not be a concern since inherent availability rates have remained around 80-90% between those years. This sample study sheds a light for the ones who would be in an FSTD acquisition/utilization effort. These benchmarks would give aviation institution, firm a clue for the sustainment and obsolescence

[2] Technology Reliability Factor (TRF): is the probablity (λ) that a system or component will perform a satisfactory manner for a given period of time under specified operating conditions. It is computed by dividing number of failures by total operating hours.

Mean Time Between Failures (MTBF): is the rate (1/ λ).

Inherent Availability Ratio (IAR): is the probability that a system, when used under stated conditions in an ideal support environment, will operate satisfactorily at any time. It excludes periodic maintenance and logistics delay time (LDT).

management of FSTD, and provide opportunity to make some projections about system's life cycle and maintenance costs.

Source: Boztaş (2006)

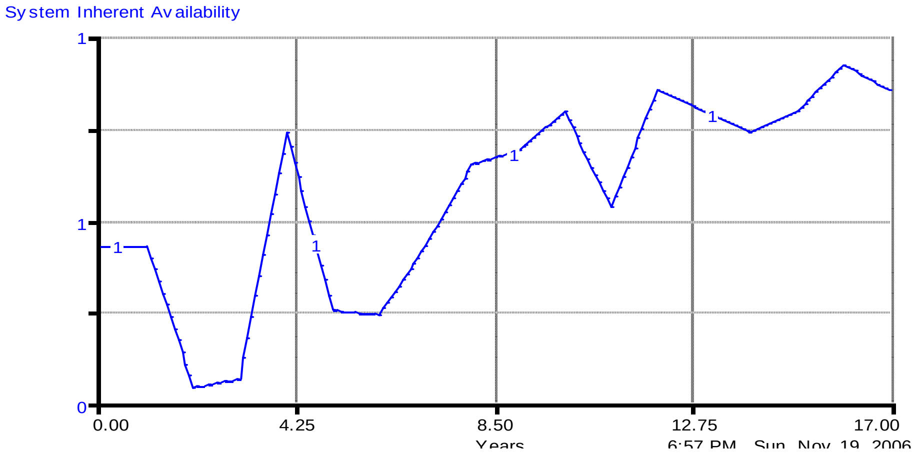

Figure 5.5 TUAA UH-1 Helicopter FNPT's Inherent Availability over Time

FSTD is ever-ready flight training tool as opposed to the aircrafts with the features of being free of adverse meteorological conditions and subject to less frequent maintenance cycles. The challenge of amortizing the invested technology as earlier as possible would provide the aviation organizations with the opportunity of making a transition to the cutting-edge technology easier. This is why FSTD is generally operated in a continuous manner with the greater IAR in this manner.

Source: Dujin (1981:266) cited in Conway and Steward (2009)

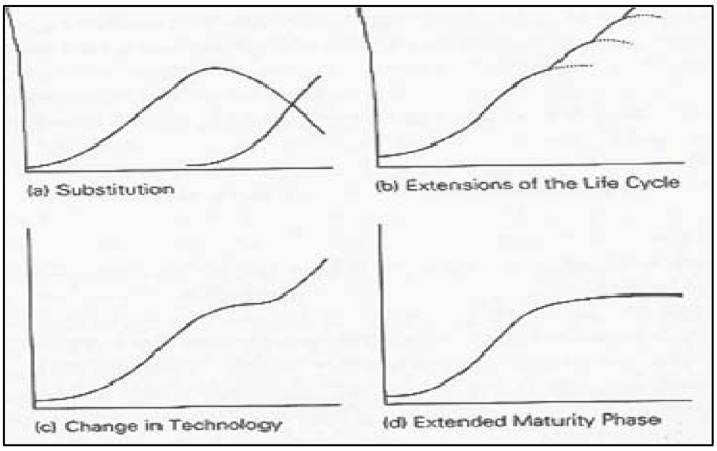

Figure 5.6 Variety of Shapes for the Product Life Cycle

As put by Herald (2005), this could be maintained via "Technology and Product Obsolescence Management" approach, which requires a continual technology obsolescence forecasting. The varied types of technological life cycle patterns as generically depicted in Figure 5.6. Those possibilities might occur based on the technological developments and opportunities, needs, organizational structures and capabilities and could solely be managed successfully and dominated by knowledge based organizations and economies.

5.2 Acquisition Perspective

5.2.1 Associating Needs and Acquisition

The identical cockpits and the highly realistic virtual environment effects are considered the two most important features of recent FSTD, and may help influence the aviation community to convert to more simulator-based flights. These developments are closely related to and parallel with the recent developments in software and hardware products.

When evaluating the required fidelity level of FSTD, both the objective and perceptual fidelity must be considered, along with the specific mission needs. For example, pilot candidates benefit from a variety of relatively low fidelity training devices and simulators, while experienced pilots receiving refresher training tend to require high fidelity simulators (Gibson, 2000, p.156). Further, military pilots also prefer higher fidelity FSTD. This stems from their need to feel as if they are flying real missions in realistic environments. The responses offered in a survey (Lafçı, 2005) - applied to 145 TUAA pilots, show that as many as 80.7%-86.4% indicate strong agreement in the importance of better fidelity, the increased quality of the visual system, and the existence of six degrees of freedom (DOF) in the motion platform.

The end-users accept some of these aspects of FFS as indispensable. This is also highly consistent with the responses offered in the sample study questionnaire showing 94% of the commercial pilots and 87% of the military pilots have a tendency towards acquiring and utilizing FFS rather than FTD. However, these aspects are cost multipliers for the organizations. McCauley (2006, p.2), for example, discusses this issue while investigating US Army helicopter training simulators' need for motion bases

> User acceptance (pilot preference) is a third perspective on the value of simulator features. How much value should be placed on simulator features that are preferred by pilots but generate no measurable training effectiveness? This is a value judgment that is not amenable to empirical research but may be important to an acquisition program manager or a military commander responsible for training and readiness.

In addition to technical features, there are several other concerns that should be taken into account in the use of FSTD. In other words, the higher technical features of FSTD might not always generate meaningful results for the end-user (McCauley, 2006). A more appropriate way to assess the favorability of using FSTD is to determine the degree to which FSTD training can be transferred to actual mission flight or the level to which training effectiveness can be maintained. Otherwise, it would be less cost-effective to install and maintain a highly expensive FSTD. The end-user should not pay excessively for a less favorable transfer of training (ToT), and/or no evidence of training effectiveness (EOTE). These two performance metrics, ToT and EOTE, are defined as follows (Stewart III, Dohme & Nullmeyer, 1999, p.1)

> A flight simulator is effective if the skills that a pilot learns in the simulator can be performed in the aircraft; that is, if the skills transfer from the simulator to the aircraft. The effectiveness of training in a flight simulator is a function of the amount of skill that transfers. Its cost-effectiveness in a pilot training program depends on the amount of skill that transfers to the aircraft as well as the ratio of simulator to aircraft operating costs (Taylor, Lintern & Koonce, 1993).

Since the introduction of advanced FSTD, the correct mix of synthetic flight (SF) versus actual flight training has been a big issue. The number of studies on optimizing the simulator-aircraft mix evidences the concept. Based on the questionnaire responses in the study (see Chapter 4), the training types are assigned with varying rates such as 80% of FFS-aircraft mix flight for instrument flight training (IFT) while it is 67% in FTD-aircraft mix.

In Dufaur (2004), the simulator-aircraft mix percentages were given as 30% for initial flight training, 80% and above for aircraft type training, 50% for instrument flight rules (IFR) training, 50% for navigation and tactical flight training, and 30-80% for mission specific training.

The TUAA and US Army Research Institute (ARI) performed two other highly visible studies for the Behavioral and Social Sciences. The TUAA study, based on an analysis of questionnaire results (Lafçı, 2005), found that the appropriate simulator-aircraft mix flight ratio for TUAA pilots was 50.82% regarding all phases of helicopter flight training. However, the ratio should be evaluated and verified over time in terms of two significant metrics, ToT and EOTE since the questionnaires naturally include subjectivity in them.

Training effectiveness of FSTD should be evaluated before integrating them into training systems. This is the most common challenge directed against FSTD integration into training curriculums and the studies on correct simulator-aircraft mix. Caro (1973) states the problem (as cited in Stewart III et al., p.2) as follows

> Most personnel who design and integrate simulators are engineers, not behavioral scientists…..Much more attention has been paid to the development of the simulator itself, than to the training program, which supports it.

In the second study (Stewart et al., 1999, p.8), US ARI proposed the analysis of the following areas for better use of FSTD:

1. The current training objectives.
2. The measurement of trainee performance.
3. The mix of aircraft and simulator (including other training devices) training.
4. The integration of academic class work and flight training.
5. The costs of each training phase and each instructional method.
6. The effect of instructor pilot attitudes and beliefs upon training effectiveness.
7. The effects of trainees' individual differences, e.g., personality, prior flight experience, attitude toward training, specific strengths and weaknesses, learning position and disposition toward feedback, upon training effectiveness.
8. The structure of the curriculum.

The results of these three studies and an understanding of the metrics, ToT and EOTE, are important in shedding light on the adoption process of FSTD. The better utilization and faster adoption of FSTD might serve as a factor in cost and time savings, risk reduction, and efficiency (McCauley, 2006, p.3) of flight training. These benefits could be maintained and improved by examining each organization's unique structure according to an overall analysis of the areas proposed by US ARI above.

There seems to be many opportunities in the FSTD market that can be exploited to enhance the development of cost-efficient flight training. Based on that, the use of FSTD is on the rise and the trend continues to grow in favor of more simulator hours. However, it is still not certain which type of FSTD should be accepted as the primary substitute for the actual aircraft, and to what degree FSTD hours should be substituted for actual aircraft flight hours. There are two reasons for this dilemma. The first concerns the complexity of military aircraft and the military-specific mission flights, and the second concerns FSTD support capability which determines how realistically complex mission and the associated environment can be simulated. A general definition for FTD proposed by the FAA is as follows (Gibson, 2000, p.157)

> A full scale replica of an airplane's instruments, equipment, panels, land controls in an open flight deck area or an enclosed airplane cockpit, including the assemblage of equipment and programs necessary to represent the airplane in ground and flight conditions to the extent of the systems installed in the device does not require a force (motion) cueing or visual system; is found to meet criteria outline in this Advisory Circular[3] for a specific flight training device; and in which any flight training event or checking event is accomplished.

Both FSTD acquisition professionals and the technology developers should take into account generally accepted EASA and FAA regulations and be aware of

[3] Advisory Circular's give specific criteria required to obtain and maintain approval on commercial simulators to be used for flight crew training. The FAA Advisory Circular (AC) 120-45A specifies the evaluation and qualification requirements for six of a possible seven-level-of-flight-training device. Level 1 is currently reserved and could possibly include PC-based training devices and in quoted in Archie E. Dillard, "Validation of Advanced Flight Simulators for Human Factors Operational Evaluation and Training Programs": (2002): 34.

the latest changes in these criteria. For now, based on the FAA's definition, it appears that training hours on computer-based training devices might not adequately substitute for actual flight hours; however, there will be steadily increasing demand for some type of certification of these hardware-software combinations for currency or refresher training (Gibson).

As defined by FAA, force cueing and motion platform are not required for FTD; however, in Lafçı (2005), the majority of the TUAA pilots' sampled (86.4%) accounted the existence of motion platform on FSTD as a significant requirement. Although, there is currently no scientific evidence explaining the training effectiveness of the motion platform, it might contribute to in-simulator performance, particularly for experienced pilots (McCauley, 2006, p.33).

FSTD is classified differently than computer-based trainers. They are both classified and certified by EASA and FAA as Level A through Level D simulators, where Level D is the highest level of certification. New training simulators that meet this level or FAA Level C approval criteria can cost $15 million or more (Dillard, 2002, p.5). In addition to the original approval, all commercial simulators must be rechecked a minimum of twice annually, over the operational life of the equipment, to maintain approval (Dillard, 2002, p.34). Hourly simulator costs vary from around $300 to more than $1200, depending on the aircraft type and availability (Dillard, 2002, p.49). These concerns force small-scale aircraft operators, who purchase training or FSTD hours, to have their pilots trained on FSTD owned by big-scale aircraft operators, rather than acquiring and operating these complex and expensive systems themselves.

The other alternative is for an organization to acquire and use FSTD without external certification or classification and apply criteria according to the organization's specific needs. This method appears more logical and preferable for military aviation organizations, since they have more complex aircraft systems and mission needs, and unique (state-of-the-art technology) FSTD requirements. For example, the US DoD is now in the process of developing its own approval process (Dillard, 2002).

Two additional examples include the TUAA School helicopter FNPT and US Army Aviation School 2B24 Synthetic Flight Training System (SFTS), of which have obtained certification from neither the JAA nor the FAA. Despite this lack of certification, they have been in use actively and successfully for tens of years. Demir (May 2001) showed that TUAA School helicopter FNPT have features, which meet FAA AC 120-63 Helicopter Simulator Qualification Document Level B criteria (Demir, 2001) from both a software and a hardware point of view.

5.2.2 Evolutionary Approach to FSTD Acquisition

Developing countries like Turkey should generate a policy to find a way acquiring and/or utilizing complex but already developed technologies like FSTD. There are not too many options that could be followed by private or public entrepreneurs and/or acquisition professionals. The first is to transfer technology externally via "foreign transnational corporations" (Heshmati, Sohn, & Kim, 2007, p.4). However, "the capacity of firms and countries to identify, to absorb, to generate, and to disperse technological competence are found crucial to the transfer of technology" (Heshmati et al., 2007). Otherwise, it might cost much more than expected with the additional costs to be incurred during utilization, maintenance, update and sustainment phases.

The considerations affecting the productivity and quality are: 1) work quality to date, 2) availability of prerequisites, out of sequence work, schedule pressure, morale, skill and experience, organizational size changes and overtime (Lyneis, Cooper & Els, 2001, 237-260, p.247). The framework should be as follows for the complex technologies' projects and/or acquisition processes;

Acquiring the systems via Foreign Direct Investment (FDI) and licensing as well as Domestic Investment (DI). Clearly, there should be mutual understanding between the investors and the policy makers that in turn generates transfer of technology wisely. The factors (as cited in Heshmati et al., 2007) have an impact for the technology transfer. They are "the ease of knowledge diffusion/imitation and the level of absorptive capacity in the recipient country".

Speaking of an innovative and evolutionary approach for the National FSTD Market, it should be noted that structuring a framework is highly recognizable. The framework should comprise the elements mentioned as follows. Strategic project management involves;

Table 5.4 Strategic Project Management Elements

Source: Lyneis, Cooper & Els, (2001)

Designing the Project	Process Model Organizational Structure
Determining what indicators to measure, monitor and exert pressure on	Reward
Risk Management	Specification or Scope Changes
Incorporating learning from past projects	Benchmarking and other analyses; Cost, Schedule and Rework of Past Projects
Making mid-course corrections	Project Schedules, staffing

The category of FSTD and its main features should be tailored upfront according to requirements. Otherwise, it would be too costly to perform major updates and modifications, and is considered infeasible in the FSTD Industry. Two related attributes are mentioned in the following paragraphs.

First, technology level of the helicopter and its associated technology cycle are important determinants in FSTD level selection process. They in turn determines FSTD life cycle. However, the rapid pace of technology evolution might create a life cycle mismatch in systems where the life cycle of the system elements is much shorter than the system of interest (Herald, 2005). Recently, more rapid helicopter technology cycles have been experienced due to recent developments in software technology.

Second, FFS is more costly than their associated aircraft types, but they could pay off their design and installation costs in a very short period (e.g. two to three years) if they are used efficiently. Therefore, spending too much money for major modifications in FSTD during the life cycle of a system might not pay off in this fast pacing industry. Dillard (2002, p.25) states this point as follows

> Modern technological development is out-pacing our ability to learn and apply innovations. New systems are forcing the obsolescence of existing systems in a very short time. The airline industry is saying

> that any new system must buy its way onto the flight deck with payback in a short time, generally three to five years.

The purpose of these acquisitions is to enhance the FSTD features, and increase its maintainability and operability. Some specific application areas might be spare part inventory renewal, visual data base update, cooling system modification, uninterrupted power source modification, power generator renewal, maintenance service outsourcing, etc. These acquisitions do not consist of huge modifications that might cause any change in the current FSTD category[4].

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[4] FS are both classified and certified by EASA and FAA as Level A through Level D simulators, where Level D is the highest level of certification.

CHAPTER 6

FSTD INDUSTRY ANALYSIS AND STRATEGIC APPROACH

6.1 Local Markets and Developing Economies

Examined the local markets and developing economies, it could be clearly recognized that the aviation related industries and thus the need for flight training technologies like FSTD market demonstrate an accelerated growth pattern. Acquiring and operating an FSTD has started to be accepted as one of the metrics for being a distinguished airline in the aviation community while “only 10% of 582 airlines have been able to realize it so far” (Haybat, 2012). On the other hand, buying training or cabin hours solely rather than adopting the systems for their pilots stay recurrent may seem more reasonable for small scale companies due to FTSD’s high cost of acquisition and maintenance.

Currently, the aviation sector is in disequilibrium state since there are many opportunities to be exploited. The local market is also very fruitful for national firms as well as cross-country firms in this manner. The number of private jets and helicopters has been more than doubled in two years[1] (Aktemur, 2012). The emerging economies, however, could not create sufficient amount of comparative advantage in flight training technologies manufacturing sector and the gap always increases in favor of developed countries.

Starting with local commercial markets, The Turkish Airlines (THY), for example, could be taken as one of the few well organized company in the region, acquired several advanced FFS and FTD during the last couple of years and established a simulator center with eight FSTD. The firm signed a contract with CAE for the acquisition of Boeing 777-300ER FFS in 2010 (Turkish Airlines, 2010) and enhanced its capability recently with three additional FFS (A320, A330 and A340 type of aircrafts). THY’s policy is to be a leader capturing the big potential and directing the aviation related activities in the region. The firm tries to

1 It is 160 currently as compared to 65 two years before.

differentiate via being as one of the distinguished airlines with standardizing its services and safety operations. That is why THY invests in establishing training institutions comprising Flight Academy and cutting edge FSTD. Aiming the objective, The firm reduces training costs, maintains standardization among the flight crew and thus flight safety and markets training around the region.

Another example is Pegasus Airlines, which has established a simulator center in Sabiha Gökçen Airport in İstanbul, Turkey. The pilots' type and recurrent training have been delivered in its Boeing 737 800W FFS since 2010. The airline paid Sim-Industries a 15 million $ for one system (Pegasus Airlines, 2012).

Some cross-country firms as Holland based International Flight Training Center (IFTC), for example, also try to capture some market share in the region via foreign direct investments (FDI). IFTC was established in December 2006 as a first independent and private training center in Istanbul, Turkey and started to make dry-lease contracts (will be explained below) with the airlines in 2008. The first B737 NG FFS was flown in April 2008 in the center. The company continues marketing training and/or cabin hours via four Level C or D JAA certified FFS which of two for B737 NG and the others for A320 NG type of airplane (IFTC, 2012). Today, IFTC makes "dry and wet contracts"[2] with the FSTD customers. The potential in flight training market and the opportunities in Turkey would like to be favored by the company via establishing other simulator centers around the region. IFTC has developed a partnership with the Sunexpress Airlines as to operate a simulator center in Antalya, Turkey and signed a contract with aircraft manufacturer, Boeing, to diffuse its training service more throughout the Middle East (IFTC, 2011).

Continuing with military, the several FFS and FTD are utilized in the Turkish Army, Air Force and Navy to make the pilots develop their combat skills, reduce training cost, and increase overall quality and standardization. The FSTD is basically utilized for helicopter flight training in the Army [(UH-1 and S-70 types of FFS/FTD are in use), (AS-532 and T-129 types of FFS/FTD are in manufacturing process)] and in the Navy (S-70 type of FFS/FTD is in use) while the FFS/FTD

[2] Dry Contract: to sell cabin hours solely, Wet Contract: to sell both cabin and instruction.

types for F-16, F-4 and F-5 fighter jets and CN-235 cargo airplane are all in use in the Air Force. Those types of FSTD used in the military are mostly motion-based in the Army and Navy while it is FTD for the half of the systems in the Air Force. The reason is the difference between mission needs and training tasks of helicopter and fighter jet pilots. Some of the studies found in the literature states that FFS' motion base might yield a negative transfer for the high maneuver training of the fighter jets.

Searched the developing countries, it is mostly seen that FSTD technology flows are realized via big firms' joint venture establishments and/or FDIs. The deficiency in the amount of pilots especially in Asian Pacific countries like India and China (Air Türk Haber, 2012) and all over the world signs to a "biggest surge expectation in pilot hiring history with a need forecast of more than 400.000 commercial pilots by the year of 2029" (Davis, 2012).

As stated by Fu and Soete (2010), the "experiences of the BRICS, have important implications for the world and will provide valuable lessons to other developing countries with regard to industrial, technological and trade policies". That is why we have taken the two of the BRICS[3] Countries, India and China, as the two notable examples in terms of FSTD acquisition and utilizations within the context. The FSTD manufacturer CAE, for instance, has been a leader around the globe and thus in India with having 81% of share for the installed base FFS (10 FFS for commercial airlines and 11 for military) and in China with having 68% of share for the installed base FFS (62 FFS). The company also differentiates its activities in those countries via operating training facilities/pilot training schools and establishing joint ventures with governments as well as commercial airlines like China Southern Airlines and Brazilian Embraer (CAE, 2012). The latter one, one of the largest Brazilian passenger airplane manufacturers world-wide is also referred to as a good example of sectoral innovation approach in the literature (Malerba & Mani, 2009).

[3] BRICS: The emerging economies, Brazil, Russia, India, China and South Africa, also called as Golden BRICS cited in X.Fu and L.Soete, "The Rise of Technological Power in the South (UK: Palgrave Macmillan, 2010), 1.

Having examined the following Table 6.1, the one could infer that the FFS technology acquisitions and utilizations through the regions mostly comprised of developing/emerging economies are quite consolidated around one company, CAE. On the other hand, annual growth in air travel as depicted below will also lead those emerging economies and markets acquire and utilize more FSTD cabins each year since the more air travel executed the more pilots are trained.

Table 6.1 CAE Manufactured FFS Diffusion in Emerging Markets

Source: Adapted from CAE's Webpage: Company Profile (June 2012)

	India	Middle East	Latin America	Southeast Asia	China
Annual Growth in Passenger Air Travel	9.2%	6.8%	5.5%	8.3%	7.1%
Share of FFS Installed Base	61%	55%	44%	40%	60%
Sales of Defense Simulators	11	12	2	19	-
Joint Ventures / Long Term Agreements	- Gov't of India - HAL	Emirates	- LAN, TAM, Gol - Lider Aviaçao	Air Asia	China Southern Airlines
First Sale	1970	1974	1978	1979	1988
Training and Services	- Commercial - Helicopter - Ab Inito - Defense	- Commercial - Business - Helicopter - Defense	- Commercial - Business - Helicopter	- Commercial - Business - Defense	- Commercial - Helicopter - Ab Inito

Taking developing countries and BRICS, the impact of knowledge diffusion on technology transfer via Foreign Direct Investment (FDI) or licensing has been the focus of great attention in the literature. FDI has a number of benefits beyond domestic investment regarding "balance of payments, spill-over benefits, technology transfer and labour force trianing" (Heshmati, Sohn & Kim, 2007, p.14).

Giroud (2003) asserts (as cited in Heshmati et al., 2007, p.3) that the countries in the "Association of Southeast Asian Nations (ASEA) seek to encourage foreign investment and domestic investment: to promote economic growth and development" as "foreign-owned multinationals are generally outperformed by domestic multinationals in R&D and innovation engagement (Heshmati et al., 2007, p.14)

6.2 Sectoral Systems of Innovation Approach

The dynamic behavior of knowledge and its flow patterns have revolutionized "innovation approach and its processes" since the underlying dynamics are more associated with the asymmetric features in which the firms could interact and add on their knowledge base in an unprecedented manner and speed. "Firms, their related capabilities and learning processes accepted as the major drivers of innovation and production" and their "interplay with the national systems" in a "competitive, exchangeable, cooperative and coevolutionary environment" constitutes the center of "sectoral systems of innovation" approach (Malerba & Mani, 2009, p.3). Hence, we could account main elements of this new approach as follows

> Firms in the sector, other actors, networks, demand, institutions, knowledge, basic processes of interaction, variety generation, selection and coevolution (Malerba & Mani, 2009, p.5)

Taken the elements above, the one could recognize that the "evolutionary approach introduced formal and informal networks that emerge not because the agents are similar but varied in their expertise and abilities" (Morone & Taylor, 2010; Malerba & Mani, 2009, p.7) and hence "the networks integrate complementarities in knowledge, capabilities and specialization. This makes the networks favorable structures because of the medium they provide for knowledge transfer, spillover and integration in this respect.

The groups and the institutions involved in the process of technological evolution also develop different patterns of adoption behavior like individuals. Rosenkopf & Tushman's (1998) research, for example, showed how inter organizational networks coevolve with flight simulation industry. They assert that the “industries characterized by complex technologies, like flight simulation, rely on cooperative groups such as technical committees, task forces and standards bodies to decide on the process of technological evolution” (Rosenkopf & Tushman, 1998, p.311). This is parallel to the existing situation experienced in the aviation world today because of rigidly regulated trainings and high-cost of FSTD.

Bes’ (2008, p.44) socio-technical networks discussion is noticeable in a manner which the emerging and consolidated networks are proposed. According to the assertion, “emerging knowledge and know-how circulates within open and unstable organizational formations in research and development projects while consolidated networks are dominated by routine activities and of groups of stabilized members”.

FSTD manufacturing, research and development-network is very much consolidated due to very few firms and limited know-how type of knowledge existence in the global FSTD market. The know-how (black-boxed software) and know-who (highly developed division of labor) type of knowledge in the sector is mostly captured by few firms. That is why emerging economies could solely participate as subcontractors in these projects or be the acquirer (preferably) due to being free of contractual responsibilities. This mainly stems from FSTD’s core component, software and mathematical models, which are kept as a black box by the few firms (e.g. CAE, Thales, and L3). Generally, they prefer acting with the aircraft manufacturers (e.g. Boeing, Airbus, Lockheed Martin, Sikorsky, Eurocopter) as a joint venture, partner or alliance. They also make direct investment into the emerging markets and build flight training centers and/or FSTD. That time, the joint venture might be the domestic firm or a public institution like MoDs [e.g. Indian Defense Forces run CAE flight training facilities, (CAE, 2012)].

The organizational structures, experiences and policies of the BRICS could shed a light for the developing economies to clarify and adapt the approach for themselves (Fu & Soete, 2010; Malerba & Mani, 2009). The different sectors in developing countries like in BRICS might vary in terms of “their distances from the global innovation frontier”[4]. Aircraft manufacturing industry in Brazil, for instance, is well developed and accounted as having “little or no” distance from global innovation frontier (Malerba & Mani, 2009, p.192), however the country has not any well established FSTD manufacturer in the global market. On the other hand, Brasilian Embraer has a comparative advantage in aircraft manufacturing that in turn helps the firm constitute a joint venture with CAE and transfer FSTD technology more easily into the country.

Notice that it was mentioned in the previous section that the other BRICS Countries like India and China also have some joint venture (like China Southern Airlines) and/or long-term agreements with the same FSTD manufacturer. This also implies that a sectoral system of innovation approach provides several opportunities especially for the developing countries and the firms that might have comparative advantage in some sectors.

Those countries’ similarities; large population (43% of the world population), huge landmass (30% of the global surface area), high growth rates (South Africa’s 5.1% is the lowest while China’s 13% as the highest among the BRICS), high gross domestic products (13% of world GDP) and high foreign direct investment (FDI) inflows (12% of global net) (Fu & Soete, 2010, p.1) are frequently mentioned in the literature. Their policy is mostly based on utilizing the varied types of tools acquiring the foreign knowledge and these elements are as follows (Fu & Soete, 2010, p.20)

> ..trade, FDI, technology licensing, foreign education and training, use of the diaspora, copying and reverse engineering, accessing foreign technical information in print and, now, through the Internet. On all these counts, China has been more aggressive and systematic than Brazil or India.

China’s comparative advantage lies in the “attractiveness of its larger and richer market which in turn constitutes a pull factor for the foreign investments

[4] Global production frontier; Firms at the global technological frontier are more likely to report that their main source of innovation is their own R&D since they have already incorporated existing technology. Firms behind the frontier are not likely to have that much R&D capability. The most important source for them is existing technology obtained from others (Dahlman, 2010, p.1-2)

(Malerba & Mani, 2009, p.23). That is why it is largely preferred by the foreign agents via FDI such the number of CAE manufactured FFS in the country is 60. However, one of the main drawbacks of having FSTD technology via FDI lies in the difficulty of capturing the core competency and the knowledge due to the technology's state-of-the-art nature. As Aitken & Harrison (1999) and Wang & Gao (2005) state (as cited in Fu & Soete, 2010, p.9) "it is difficult to acquire state-of-the-art technology through inflows of FDI and imports, and that huge inflows of FDI may even weaken indigenous industrial and technological capabilities".

As Nelson & Rosenberg (1993) assert (as cited in Malerba & Mani, 2009, p.7) "Relationships between firms and non-firm organizations (such as universities and public research centers) have been a source of innovation and change in several sectoral systems" where in "the types and structures of relationships and networks differ greatly" among them.

Taking emerging economies/institutions/firms and assessing their positions based on networks and co-evolution of complex technologies, it is required to touch on their sociological development and interaction capabilities since those processes closely related to human capital and organizations. The co-evolution of networks involves "economic sociology" which also tries to explain some of "Schumpeter's insights into sociological analysis of the whole economy" (Morlacchi, 2007, p.334) as well as human interaction, networking and learning processes in terms of generating value-added activities.

6.3 Developing Innovative and Entrepreneurial Perspective for FSTD Technology

Having mentioned on the innovation process and technology diffusion behaviors previously, it is appropriate to touch on technological innovativeness and entrepreneurial behaviors regarding flight-training industry. We think it would be better starting with reviewing Schumpeterian perspective and understanding its importance for a capitalist environment. Capitalism applies unless the new innovations are continued to be realized "in the form of new consumer goods, new production techniques, new modes of transportation, and new forms of industrial organization" (Lanzillotti, 2005, p.13).

Within the context, Schumpeterian assumption of “creative destruction”, comprised of “to create” and “to destruct” as the two reverse phenomena, could be accepted as the primary processes constituting an environment in which the global market and economic growth as well as entrepreneurs act as “equilibrium-disturbing figures” (Zhang, 2005, p.76) and disequilibrium determines the dynamics as follows

> ..-a process he described as “creative destruction”-creative in the sense that it creates new value (i.e., what contemporary economics characterizes as increased consumer welfare) and destructive in the sense that the economic returns to capital/labor producing obsolete products are lowered or eliminated entirely (Lanzillotti, 2005)

In this context, Schumpeter assumes role of an entrepreneur as “combining new things or innovating, that is, introducing a new product or new quality in a product, a new method of production, a new market, a new organizations within an industry”. Inherently, this interpretation also comprises the dynamics of an “interaction among social agents” (Morlacchi, 2007, p.341).

The technological capabilities and the firms’ knowledge level should be determined and assessed well prior to starting the entrepreneurial activities since there is heterogeneity among the firms and human capital that also determine the agents’ “absorptive capacity”. On the other hand, the main institutions of the economies might differ widely in their formations, customs and behaviors that in turn create differences in terms of their institutions/firms’ technological innovativeness and the entrepreneurial behaviors (Dosi, 2007, p.172-173).

Many scholars in the literature sign to the “differences or asymmetry in the ability to innovate and/or adopt related with the product characteristics and production processes; varied organizational interests and production processes’ efficiencies’ (Dosi, 2007). We think that it is necessary that developing countries’ policy makers and strategists generate some metrics as to understand how the technological innovativeness and the entrepreneurial behaviors evolve and have an impact on the national economies. That is why we are interested in and search for a favorable strategy demonstrated during the processes of acquisition and utilization of FSTD technology. Our final aim is to establish an innovative and entrepreneurial model with which the agents could communicate and interact through the processes of flight training.

Searched the literature, it is recognized that developing/manufacturing and/or innovating complex technologies like FSTD could be accepted as one of a value added attributes for the aviation institutions and firms while constituting a positive input for the emerging economies. To us, the main reason is that many people from variety of geographies and expertise share their competencies for this, "extremely complex, low-volume and strongly regulated" (Rosenkopf & Tushman, 1998, p.312) and state-of-the-art products. Hence, being capable of managing FSTD projects would require "highly absorptive human capital" from several disciplines such as software, computer, aeronautical, electrical/electronic, mechanical engineers as well as aviators, regulatory agents, acquisition professionals and entrepreneurs.

We could attribute that knowledge diffuses via specialized knowledge pooling and experience sharing within the sectoral system of FSTD innovation. Therefore, the national institutions of innovation and the firms should work in a harmony to create an innovative and entrepreneurial stand favoring the opportunities in this high-technology sector.

6.3.1 Government's Role

The appropriate policy and the vision for the future term regarding FSTD technologies should be determined and highlighted by the Government. Those policies are not supposed to give an exact roadmap for FSTD related innovations. However, they might shed a light for the software-based institutions, firms, university departments, researchers, patent organizations and the other stakeholders to determine their positions and, if possible, direct their R&D efforts towards developing aerodynamic models for the aircrafts. "Technology Foresight" is one of the main instruments of the countries and should be used effectively by our main institutions of national innovation and aviation system whereas it is necessary.

Within the context, some public institutions: economy, industry and business related ministries; and organizations involved in science, technology, and standards should relate their innovative efforts to the studies of the universities and the external experts: economists, sociologists, cultural anthropologists, psychologists, scientists and all kinds of markets including labor.

The government's intervention is unavoidable for some required activities to make the FSTD market closer to a perfectly competitive since we need the government facilitating market processes by maintaining law and order, establishing property rights, and enforcing contracts. In spite of these regulating efforts of the government, "the efficient outcome might not be reached since some high technology markets like FSTD market is still away from being perfectly competitive" based on the reasons stated by Stokey & Zeckhauser (1978, p.292). The problematic areas where the government might take actions for a favorable outcome in FSTD market are as follows

Table 6.2 Related Market Failures

Source: Adapted from Stokey and Zeckhauser (1978)

Unsatisfactory Market Conditions
Information is not shared costless among all prospective participants in the market.
Transaction costs significantly impede the conduct of beneficial trades.
The relevant markets do not exist.
Some of the participants in the market exercise market power.
Externalities are present, so that the actions of one individual (whether a person or an organization) affect the welfare of another.
The commodity involved in the policy choice is a public good.

6.3.2 Creating a Common Base

The management of national innovation and aviation system in a society is a highly complex issue in which many key players are involved. The causal and complex relationships among those players determine the behavior of that society. Understanding that behavior and generating appropriate policies is a very difficult problem. One of the premises, on which the Systems Dynamics (SD) philosophy based, is as follows (Abdel-Hamid & Madnick, 1991, p.9).

> The behavior (or time history) of an organizational entity is principally caused by its structure. The structure includes not only the physical aspects, but also the policies and procedures, both tangible and intangible, that dominate decision-making in the organizational entity.

Accordingly, professionals should be capable of understanding aviation industry's solutions and the end users' needs. Absent these two requirements, the diffusion profile of an innovated technology will not meet expectations. Moreover, instead of helping for an expected outcome resources would be consumed inefficiently.

It becomes more apparent that the complex technology related industries "require institutions/firms establish research laboratories, staffed by scientists and engineers, and focused of the firm's technological needs and the needs dictated by its competitive environment (Nelson & Rosenberg, 1998, p.47). R&D costs incurred might be still overwhelming for most aviation firms in developing countries, which in turn increases the number of imitators, is highly recognizable. The one successful solution is to have regulated R&D environments, collaboratively shared by the universities and the industry. Some tax exclusions and/or subsidies could be applied to make the national innovation and innovation system work more effectively.

However, "the links between universities and aviation industry makes sense only to the extent that the growth of knowledge can be made to assume a form and a content that would be a direct assistance to the changing needs of other sectors (Nelson & Rosenberg, 1998, 48).

The authorized institutions involved in R&D, program/project management, procurement/acquisition and contracting should reorganize the instruments of the main institutions to create "mission-teaming opportunities such as Integrated Product Team (IPT) Approach, instead of having preoccupied functional groups. It would be otherwise impossible for the national innovation and aviation system to compete globally.

A team of government and industry people coming together shares the common objective of solving a difficult technical challenge in a breakneck race against everything (cost, risk, performance) is of great importance in terms of complex technologies' development. Two efforts, should be exercised in the public sector procurements, have a great importance in creating a common base and a motivation for the industry. First is to enforce a full and open competition that values equity but with one exception: acting appropriately to protect and to include small and disadvantaged businesses into the project. Second is to encourage dual use FSTD technologies' (they could both serve in public and private sector) development which would reduce the costs noticeably.

6.3.3 Communicating the Right Language

Communication established with the institutions and the firms would provide consistency towards innovative and entrepreneurial efforts. Marketing and advertising techniques, for instance, are accepted as a part of source-centered innovation adoption models. Market pattern forecasting for a technology, its expected life cycle, and its expected technology adoption level are the determinants in estimating the amount of capital investment and the correct timing for the introduction of a new FSTD. "Technological differentiation is practiced in market growth phase whereas advertising serves to stress the relative merits of differing products, to determine most adoptable design and to enhance product utility" (Forrester, 1981, p.201).

In this context; while predicting the future state of FSTD, exploratory technological forecasting techniques may be used as stated by Roberts (1981, p.375) as follows

> Formal trend extrapolation to either a straight-line fit or an S-shaped expectation …Using statistical "best fit" procedures, a growth-of-technology line is drawn through the data points and extended into the future. An assumption of technology saturation effects produces the biological growth pattern with its S-shaped curves; an assumption of no saturation leads merely to longer straight lines

Technology foresight, technology obsolescence forecasting, technology surveillance and road mapping might be attributed as some communication techniques establishing a link and a medium to communicate among institutions and firms. Establishing innovation related standards are also significant to communicate the right language, to reduce the costs and to promote the innovative efforts. "The standardization processes are strongly influenced by the specific set of productive and technological characteristics such as the technological diversity of firms and the localized character of the innovation processes (Antonelli, 1998, p.96).

6.3.4 Protecting Innovative Efforts

Regarding FSTD technologies, one of the biggest challenges of a national innovation system is property rights and the encoded tacit and/or tacit knowledge required to manufacture such complex technologies. Some of the innovations, serving as public goods and/or the processes, which are abstract in nature, should be protected. The desirable outcomes expected from the innovative efforts and the protective measures against uncontrollable diffusion create a great dilemma and long lasting discussions. This dilemma is the main barrier for the innovations to be diffused and transferred since the leader's advantage could turn out to be the leader's disadvantage easily.

The policies; enforcing law and order, establishing property rights, monitoring the professionalism on contracts should be the first and the most important concern for the state-of-the-art technologies. In that way, uniquely developed FSTD systems and innovations would be encouraged and start creating a value added steps.

First, it is necessary that we assign some metrics to any effort demonstrated by the main institutions of national innovation and aviation system. These metrics should be valuable in economics, common to majority of the society since the communication and the accountability is highly significant for the institutions, and the firms participated in innovative efforts. Every institution and firm participates in FSTD related innovative and/or entrepreneurial effort should at least;

1. Investigate whether "the institutional vision" is still valid or not. The metric is maintaining the internal and external consistency on a national and global scale.

2. Overview the organizational structure and search for the possibilities to create mission-teaming opportunities instead of having preoccupied functional groups. The metric is the level of professional responsiveness in case of confronting extreme conditions or unprecedented missions.

3. Examine the processes and determine the bottlenecks. The metric is the cycle time in which the response given and the outcome generated in different cases.

4. Search for the links with the end-users, suppliers, academicians, legislators, executives, judicial branches from public, private or quasi-private institutions. The metric is the frequency of contact, the speed and the level of access to those actors,

5. Search for the prudence among the program/project managers and the firms. The metric is how many national and global scale project has been created to be customized by the national private competitors and how much value added to the economy via these programs?

6. Investigate the ethical concerns in the activities. The metric is how much importance is assigned to a fair and equitable competition while creating projects for the private market.

7. Review and update the educational curricula to increase organizational learning and absorptive capacity of the human capital. The metric is the impact of those educational programs on the outcome.

Once these concerns are started to be searched in the aviation organizations' innovative/entrepreneurial efforts, the strategies generated by the institutions/the firms would yield value added programs/projects, and more importantly, the standards encouraging the private market towards FSTD technology manufacturing/developing.

CHAPTER 7

CONCLUSION

The thesis examines favorable acquisition and utilization of complex technologies and thus FSTD while investigating the elements for generating a consistent strategy at micro and meso-level. Aiming that, the processes of constituting such a strategy and a collaborative medium for firms, cooperative groups and institutions participated in innovative and entrepreneurial efforts towards FSTD technologies are studied. Additionally, the way of enhancing technological learning and providing capability to exploit the opportunities in this sector and national innovation system is scrutinized.

Conducting the study, the stages, proceeded through systematically in seven chapters are as follows: 1) Introduction Chapter is mainly designed to provide a background about the problem and a framework followed during the study. 2) Second Chapter aims to enhance reader's background about FSTD technology and to explain qualitative matters of FSTD utilization. 3) Third Chapter is structured to give details on knowledge-based innovation notion as well as diffusion and adoption processes. 4) In the Fourth Chapter, the commercial and military pilots' FSTD preferences are analyzed statistically. The analysis constitutes an input for the model designed to simulate agents' technology selection behavior. 5) Fifth Chapter aims to give some FSTD specialized details towards FSTD technology acquisition, maintenance and sustainment. 6) Sixth Chapter is designed to provide the reader with the knowledge towards FSTD industry and the applications in local and developing markets. 7) Conclusion Chapter is tailored to integrate analysis and previous chapters' selected items while exhibiting a combined strategy for aviation institutions, firms and entrepreneurs.

Throughout the study, the methodology is based on finding the bottlenecks in FSTD related processes and improving the weaknesses. The aim is to make every innovative effort investigate itself in terms of efficiency, maintain operational effectiveness and thus overcome the inertia.

At the same time, it is expected that the main institutions of national innovation system and FSTD related policies should be based on consistent strategy since such efforts could increase national aviation institution/firms' competitiveness. Competitive organizations could develop value added programs/projects for complex technologies like FSTD, with which the nations' resources are consumed prudently and knowledge-based learning occurs. Based on this framework; complex technology manufacturers/researchers, universities, academicians, entrepreneurs, public/private aviation stakeholders would start searching for more opportunities to enhance their production possibilities since those innovative solutions could help them make a leap in the sector. Next, the beneficial innovative solutions would be favored (willingness to pay) by more institutions and firms. Lastly, the effect of customization, the different applications of the innovation and overall impact of those activities would generate economies of scale and could be referred to as a successful outcome (Figure 7.1) for the national aviation and innovation sector.

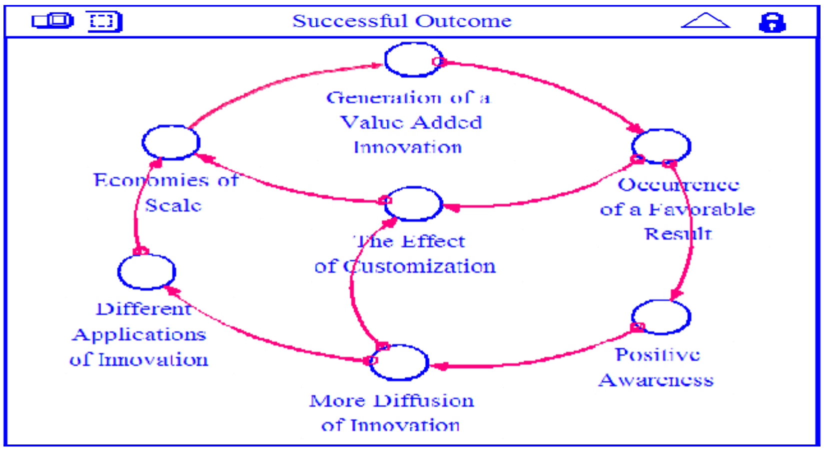

Figure 7.1 Dynamic Behavior of Generating Successful Outcome

The four considerations (Section 6.3); government's appropriate intervention policies, creating a common base between public and private sector, communicating the right language using the appropriate tools, and protecting innovative efforts and determining the appropriate metrics are suggested to be made while managing main institutions for FSTD sector and national innovation system. These considerations would lead to transparency and create mutual accountability for the actors participating in FSTD market. Briefly, it is mentioned that the national innovation system generates desirable outcomes if the efficient competitive FSTD market works and the consistent innovative strategy is set forth as a result of the collaboration created by the private and the public sector.

This exploratory research has established a model serving as a policy maker for FSTD related processes. The policy and a consistent strategy are required for the ones who get involved in FSTD acquisitions and utilizations. The strategy determined for micro and meso-level FSTD related innovative efforts is depicted in Figure 7.2. Micro-level serves for the aviation institutions, firms, organizations and aviators. The suggestions at this level is mostly operational and aim how to get a better flight training curriculum and environment, increase human standardization and quality, and maintain continuous improvement, competitiveness and flight safety. Meso-level, serves for the collaborative groups/efforts, government policies, regulatory authorities, universities, R&D organizations, public and private entities and the others participate in national innovation system, and sectoral systems of innovation related activities.

Micro-level strategy is called as "FFS and FTD Need Assessment Cycle" while it is "Collaborative Value Chain" for meso-level. The cycle and a value chain could shed a light for firms, cooperative groups and the institutions conducting innovative and entrepreneurial efforts in the domain. Hence, these two could help constituting an interdisciplinary approach and a synergy towards generating knowledge-based efforts for sectoral systems of innovation and national economy. It is asserted that the main findings of the study would support aviation institutions and firms as well as cooperative groups involved in FSTD technology associated management and development processes. However, it is significant that those entities enhance their absorptive capabilities and improve their technological learning to exploit the opportunities in FSTD sector.

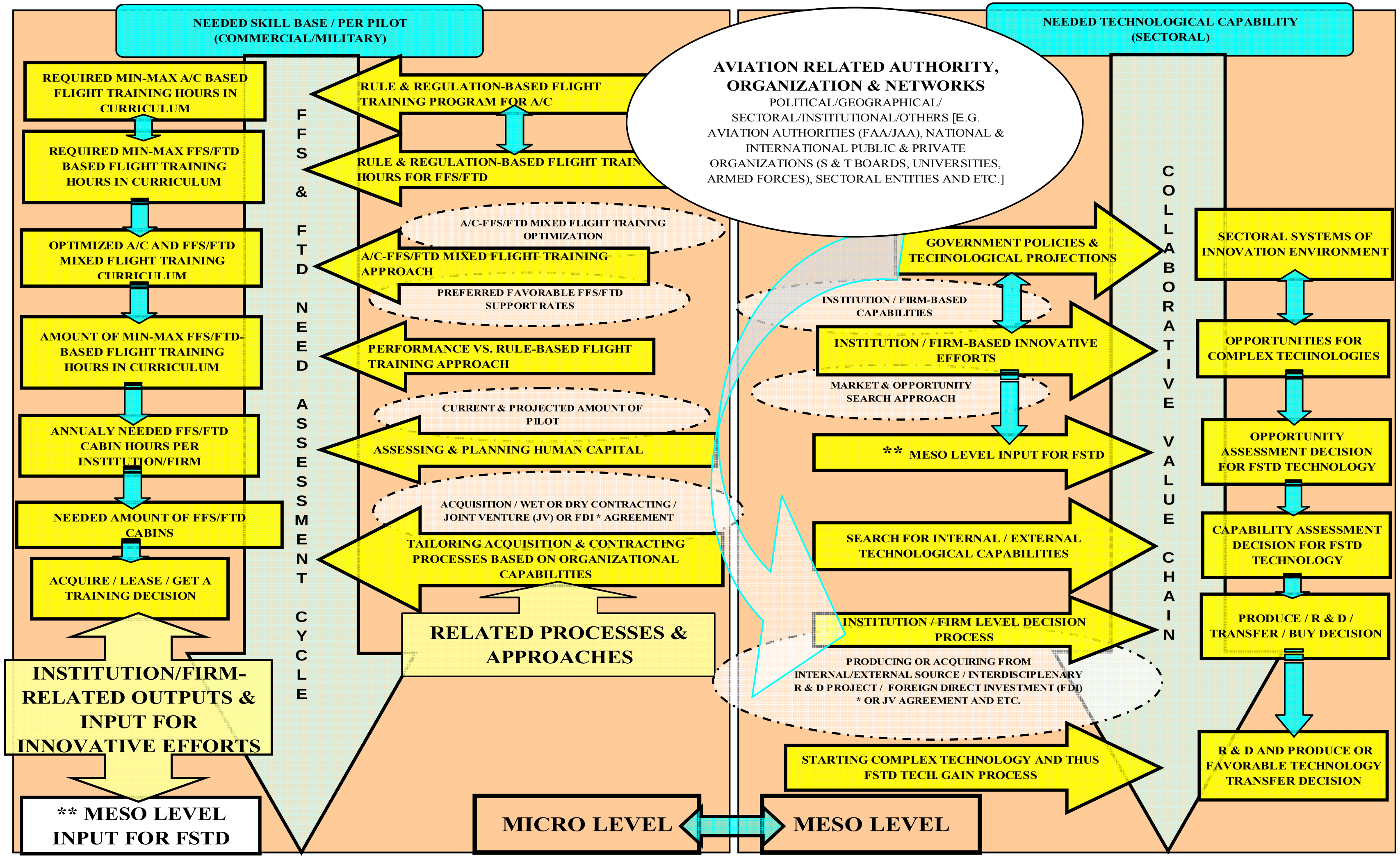

Figure 7.2 Micro-Level FFS and FTD Need Assessment Cycle and Meso-Level Collaborative Value Chain

Additionally, the meso level collaborative value chain examines the way the main institutions of national aviation and innovation system should work for a successful outcome. The objective of this part is to discuss the metrics of a successful outcome and to suggest a favorable model for the main institutions of national economy.

The interpretation of the sample study (Chapter 4) demonstrated the model (Analyzing Agents' Preferences towards FSTD Technology and Modeling Selection Process between FFS and FTD) is viable. It could be inferred that aviation institutions and firms could acquire and utilize FTD as a complementary to both aircraft and FFS within a range of 30-60% based on type of the training [Instrument Flight Training (IFT), Tactical Flight Training (TFT), Visual Flight Training (VFT), Search and Rescue Flight Training (SARFT)]. Additionally, FTD could be acquired and utilized as a substitute to FFS for Instrument Flight Training (IFT). The FTD's usefulness for IFT was scored 67% by 62 military pilots.

It is verified that the comparative assessment is required other than assessing solely FFS and FTD's absolute advantage values for their "usefulness" since "ease of operation and use" has an impact in those technologies' adoption. Hence, acquisition professionals, entrepreneurs, technology developers and researchers should consider the end users' perceptions and make use of those inferences in their efforts.

On the other hand, acquiring and/or transferring FSTD technology should be performed in a favorable way with which the core competency of the technology could be captured. It could be succeeded via enhancing organizational structure and human capital's absorptive capacities. This is highly significant for the ones involved in complex technologies' acquisition and utilization. R&D and interaction medium provided for the computer, software and aerospace engineers together with the area experts (pilots) would be a favorable strategy since "state-of-the-art tacit knowledge" is seen as a core competency for FSTD related technologies.

The Diffusion of Innovations' Theory, The Technology Acceptance and Task Technology Fit Model are the noteworthy theories and the models to support the considerations to be taken into account in determining the way the for the FSTD selection processes. The innovation forms and their alignment with the technology development cycles are also addressed in the research.

The following matters, involving acquisition and utilization of FSTD, have been addressed with the research. The true training needs and appropriate FSTD specifications have been determined. Appropriate technology and cycle time match have been investigated. The underlying dynamics of FSTD technology diffusion and adoption behavior have been explored. The effective and efficient FSTD acquisition and utilization have been examined. Logistic concerns, obsolescence and sustainment management have been explained. The opportunities for national economy and sectoral systems of innovation have been searched. The way of "Technological learning and upgrading the structure of FSTD manufacturing capability" (Fu and Soete, 2010) has been scrutinized.

Briefly, the elements of a consistent strategy for the favorable acquisition and utilization of FSTD, thus FFS and FTD, have been studied. The established strategy and the determined policy tools have been explained in the related chapters throughout the thesis. Our assertion is that the applications and the strategy determined could support developing economies, aviation institutions, firms and cooperative groups in their FSTD related activities.

LIST OF REFERENCES

Abdel-Hamid, T.K., & Madnick, S.E. (1991). *Software Project Dynamics: An Integrated Approach* New Jersey: Prentice Hall.

AirTurk Haber. Retrieved from http://www.airturkhaber.com/haber_detay.asp?haberID=5519 (01 September 2012)

Aktemur, K. (27 August 2012). *Kokpit Haber.* Retrieved from http://www.kokpithaber.com/haber/714-pilotaj-20-yil-icerisinde-465000-pilota-ihtiyac var.html#ixzz251Y4N7FH (01 September 2012)

Al-Gahtani, S.S. (2003). Computer Technology Adoption in Saudi Arabia: Correlates of Perceived Innovation Attributes. *Information Technology for Development.*

Ammenwerth, E., Iller, C., & Mahler, C. (2006). IT-Adoption and the Interaction of Task, Technology and Individuals: A Fit Framework and a Case Study. *BMC Medical Informatics and Decision Making.* Retrieved from http://www.biomedcentral.com/1472-6947/6/3

Antonelli, C. (1998). Localized Technological Change and the Evolution of Standards as Economic Institutions. In A.D. Chandler, P. Hagström & Ö. Sölvell (Eds.), *The Dynamic Firm: The Role of Technology, Strategy, Organization, and Region* (p.78-82). New York: Oxford University Press Inc.

Arthur, W.B. (1989). Competing Technologies, Increasing Returns, and Lock-In by Historical Events. *Economic Journal, 99*, 116-131.

Baptista,R. (1999). The Diffusion of Process Innovation, A Selective Review. *International Journal of the Economics Business, Vol.6, No.1*, 107-129.

Bes, M.P., (2008). The Division of Scientific Labor and the Sharing of Knowledge. In L.Perche et al. *The Genesis of Innovation: System Linkages Between Knowledge and the Market.* UK: Edward Elgar Publishing Limited.

Boztaş, Ö. (December 2006). "Modeling the Adoption Process of the Flight Training Synthetic Environment Technology (FTSET) in the Turkish Army Aviation". MBA Professional Report.

Caro, P.W. (1973). Aircraft Simulators and Pilot Training. *Human Factors, 15,* 502-509.

CAE Company Profile. (June 2012). Retrieved from http://www.cae.com/en/sim.products/_pdf/brochure.cae.sim.products.pdf (20 June 2012)

Clubb, G.D., (1996, Fall). Blinding Speed Equals Competitive Advantage. *Acquisition Review Quarterly*.

Conway, S., & Steward, F. (2009). *Managing and Shaping Innovation.* New York: Oxford.

Demir, M. (2001). Simulation/Simulator Applications in Training: Investigation and Qualification of Helicopter Flight Training Simulator with Motion System; a Sample Computer Simulation Application. *M.S. thesis,* Gazi University Institute of Science and Technology.

Diffusion of Innovations Theory. Retrived from *University of Twente Online* http://www.tcw.utwente.nl/theorieenoverzicht/Levels%20of20theories/macro/Diffusion (12 October 2006).

Dillard, A.E. (2002). Validation of Advanced Flight Simulators for Human Factors Operational Evaluation and Training Programs. *Foundation'02 V&V Workshop, John Hopkins University*.

Dishaw, M.T., & Strong D.M. (1999) *Extending the technology acceptance model with task-technology fit constructs.* Research Abstract.

Dosi, G. (2007). Statistical regularities in the evolution of industries: a guide through some evidence and challenges for the theory. In F. Malerba & S. Brusoni (Eds.), *Perspectives on Innovation.* UK: Cambridge University Press. 172-173.

Forrester, J.W. (1981). Advertising: A Problem in Industrial Dynamics. In E.B. Roberts (ed). *Managerial Applications of Systems Dynamic* .MIT Press. 201.

Fu, X., & Soete, L. (2010). *The Rise of Technological Power in the South.* Great Britain: Palgrave Macmillan.

Galloway, R.T. (2000). *Model Validation Topics for Real Time Simulator Design Courses.* Aerospace Engineering, Naval Air Warfare Center Training Systems Division.

Geroski, P.A. (2000). Models of Technology Diffusion. *Research Policy 29.* 603-625.

Gibson,,R.S. (2000). Certification of Training. In *Human Factors in Certification* Mahwah: Lawrence Erlbaum Associates, Publishers.

Goodhue, D.L., & Thompson, R.L., (1995, June). Task-Technology Fit and Individual Performance. *MIS Quarterly,* 213-236.

Graham, A.K., (1982, March). Software Design: Breaking the bottleneck. *IEEE Spectrum.*

Haybat, S. (n.d.). Pegasus Airlines Webpage. Retreived from http://www.pegasusucusakademisi.com (22 July 2012)

Hays, R.T., Jacobs, J.W., Prince, C., & Salas, E. (1992). Flight Simulator Training Effectiveness; A Meta Analysis. *Military Psychology, 4(2)*, 63-74.

Herald, T. (2005, August 11). Integration of Technology Assessment and Management Methodology for System Sustainment Determination. *International Council on Systems Engineering, INCOSE*. Retrieved from <http://www.incose.org/practice/research/seanet_herald.aspx> (2011, August 7)

Heshmati, A., Sohn, Y.B., & Kim, Y.R. (2007). *Commercialization and Transfer of Technology: Major Country Case Studies*. New York, Nova Science Publishers, Inc.

Heslin, J.A. (1996). *How Critical Ease of Use in Adopting an Information Technology: An Emprical Study*. IEEE.

International Flight Training Center (IFTC). Retrieved from http://www.iftc.aero/en/about-us (25 July 2012)

International Flight Training Center (IFTC) Webpage. (09 December 2011). Retrieved from http://www.iftc.aero/blog/2011/12/iftc-istanbul-and-boeing-partnership/ (20 June 2012)

Johnson, D.M. (2005, April). Introduction to and Review of Simulator Sickness Research. *Research Report 1832*. 46.

Keller, G. (2005). *Statistics for Management and Economics*. USA: Thomson and Brooks/Cole. 726-749.

Kirchoff, B.A. (1991). *Entrepreneurship's Contribution to Economics', Entrepreneurship Theory and Practice 16(2)*: 93-112.

Lafçı, A. (2005). "The Importance of Simulator Usage in TUAA Flight Combat Readiness Training and Determining the Optimum Usage Rates" *M.S. thesis,* Turkish Military Academy Defense Sciences Institute of Technology Management.

Lanzillotti, R.F. (2005). Schumpeter, product innovation and public policy: the case of cigarettes. In U.Cantner et al. (Eds.), *Entrepreneurship, the New Economy and Public Policy: Schumpeterian Perspectives*. Germany: Springer. 13

Longridge, T., Bürki-Cohen, J., Go, T.H., & Kendra, A.J. (2001). Simulator Fidelity Considerations for Training and Evaluation of Today's Airline Pilots. *Proceedings of the 11th International Symposium on Aviation Psychology, Columbus, OH.* 2.

Lyneis J.M., Cooper, K.G., & Els, S.A. (2001, Fall). Strategic Management of Complex Projects: A Study Using System Dynamics. *System Dynamics Review Vol.17*, No.3, 237-260.

Mahon, T. (2006, June 19). Sims with Service. Integrated Training Services Dominate European Helo Scene. *Training and Simulation Journal*. Retrieved from http://www.tsjonline.com/story.php?F=27865576US (2011, June).

Malerba, F., & Mani, S. (2009). *Sectoral Systems of Innovation and Production in Developing Countries; Actors, Structure and Evolution.* UK: Edward Elgar Publishing Limited.

McCauley, M.E. (2006, February). Do Army Helicopter Training Simulators Need Motion Bases. *Technical Report,* 1176.

Moore, G.A. (2004). Innovating Within Established Enterprises. *Harvard Business Review*: 88.

Morlacchi, P. (2007). Schumpeterian legacies for entrepreneurship and networks: the social dimensions of entrepreneurial action. In F. Malerba & S. Brusoni (Eds.), *Perspectives on Innovation.* UK: Cambridge University Press.

Morone, P., & Taylor, R., (2010). *Knowledge Diffusion and Innovation: Modeling Complex Entrepreneurial Behaviours.* UK: Edward Elgar Publishing Limited.

Nelson R.R., & Winter, S. (1982). *An Evolutionary Theory of Economic Change.* Cambridge, MA: Harvard University Press.

Nelson, R.R., & Rosenberg, N. (1998). Science, Technological Advance and Economic Growth. In A.D. Chandler, P. Hagström & Ö. Sölvell (Eds.), *The Dynamic Firm: The Role of Technology, Strategy, Organization, and Region* New York: Oxford University Press Inc. 47-48.

Olijnyk, Z. (2006, February 27-March 12). Mechtronix Systems finds a niche in flight simulation. *Canadian Business.* Toronto: Vol.79, Iss.5.

Orlansky, J. Dahlman, C.J., Hammon, C.P., Metzko, J., Taylor, H.L., & Youngblut, C., (1994). The Value of Simulation for Training. *Institute for Defense Analyses IDA Research Program Paper*, P-2982.

Pagani, M., (2004). Determinants of Adoption of Third Generation Mobile Multimedia Services. *Journal of Interactive Marketing* 18.

Page, R.L. (n.d.). *Brief History of Flight Simulation.* R.L. Page and Associates.

Pegasus Airlines. Retrieved from
http://www.pegasusucusakademisi.com (22 July 2012)

Purvis, C.D. (2001, March). Estimating C-17 Operating and Support Costs: Development of a System Dynamics Model. *M.S. Thesis,* Air Force Institute of Technology.

Rantanen, E.M., & Talleur, D.A. (2005). Incremental Transfer and Cost Effectiveness of Ground-Based Flight Trainers in University Aviation Programs. *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting,* 764-768.

Reese, M.L. (2012, May 30). *Increasing Role of Simulation in FS XXI.* Retrieved from
http://65.18.194.107/~admin1/images/pdf/Magazine/July2011/ReeseJuly2011p12.pdf (2012, July).

Rehmann, A.J. (1995). A Handbook of Flight Simulation Fidelity Requirements for Human Factors Research. *Technical Report, DOT/FAA/CT-TN95/*46.

Davis, C. (Boeing Chief of Pilot Services). Review. *USA Today*. Retrieved from http://www.cae.com/ (23 June 2012)

Roberts, E.B. (1981) Exploratory and Normative Technological Forecasting. In E.B. Roberts (ed). *Managerial Applications of Systems Dynamics* MIT Press, 375.

Robinson, A., & Mania, K. (2004). Flight Simulation: Research Challenges and Flight Crew Assessments of Fidelity.

Rogers, E.M. (1995). *Diffusion of Innovations.* 4th ed. Retrieved from University of Twente Online Retrieved from
http://www.tcw.utwente.nl/theorieenoverzicht/Levels%20of20theories/macro/Diffusion (2011, October 12).

Rosenkopf, L., & Tushman, M.L. (1998). The coevolution of community networks and technology: Lessons from the Flight Simulation Industry. *Industrial and Corporate Change*, *7*:311-346.

Sterman,J.D., (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. New York: Irwin McGraw-Hill.

Stewart II, J.E., Barker, W.C., Weiler, D.S., Bonham, J.W., & Johnson, D.M. (2001). Assessing the Effectiveness of a Low-Cost Simulator for Instrument Training for the TH-67 Helicopter. *Research Report* 1780.

Stewart III, J.E., Dohme, J.A., & Nullmeyer, R.T. (1999). Optimizing Simulator-Aircraft Mix for US Army Initial Entry Rotary Wing Training. *Technical Report* 109.

Stokey, E., & Zeckhauser, R. 1978. Achieving Desirable Outcomes in *A Primer for Policy Analysis*. New York-London: W.W. Norton & Company, 1978.

Twombly, M. (1998, June). High Fidelity: Safety Training for Pilots. *Risk Management Periodical*. Vol.45. Iss.6: 46, 4 pgs.

Turkish Airlines Webpage Bulletin. (19 February 2010). Retrieved from http://www.turkishairlines.com/tr-TR/kurumsal/basin_odasi.aspx (09 January 2012)

Williams, K.W., & Blanchard, R.E. (1995, February). Development of Qualification Guidelines for Personal Computer-Based Aviation Training Devices. *Civil Aeromedical Institute, Federal Aviation Administration, Office of Aviation Medicine, DOT/FAA/AM-95*/6.

Witt, U., & Zellner, C. (2007). Knowledge-based Entrepreneurship: The organizational side of technology commercialization. In F. Malerba & S. Brusoni (Eds.), *Perspectives on Innovation.* UK: Cambridge University Press.

Zhang, J. (2005). Growing Silicon Valley on a Landscape: An Agent Based Approach to High-Tech Industrial Clusters. In U.Cantner et al. (Eds.). *Entrepreneurship, the New Economy and Public Policy: Schumpeterian Perspectives* Germany: Springer. 76.

Zigrus, I., Khazanchi, D. (2008). From Profiles to Patterns: A New View of Task-Technology Fit.In *Information Systems Management, V.25, Issue 1*, 8-13.

APPENDICES

Appendix A: Sample Questionnaire

WORK QUALIFICATION DATA :
Workplace (Public/Private) and Pilot Status :
Qualified Aircraft Types :
Total Flight Hours (Airplane and Helicopter) :
Experienced Simulators in Training : **a)** FFS* **b)** FTD** **c)** Both **d)** None

QUESTION 1: Taking the most widespread Flight Simulation Training Devices (FSTD); **a)** FULL FLIGHT SIMULATOR (FFS)* and **b)** FLIGHT TRAINING DEVICE (FTD)**, which of one would you think that could add more on "**effective and efficient"** flight training so that it should be included in the training system primarily? Please sign "a" or "b".

QUESTION 2: a) Please evaluate FFS and FTD's **"ease of operation and use"** in training and mark one of the choices "a through e" below which is more likely to realize?

b) Please also evaluate "f" choice in addition to your recent assessment in Question 2.a and **mark the "f" choice "as is"** if you agree on the statement completely; if not, correct the word(s) in the statement **and sign "f" choice as you corrected.**

a. FFS's ease of operation and use is little favorable as compared to FTD.
b. FTD's ease of operation and use is little favorable as compared to FFS.
c. FFS's ease of operation and use is quite favorable as compared to FTD.
d. FTD's ease of operation and use is quite favorable as compared to FFS
e. Both are equal regarding ease of operation and use.
f. FFS ve FTD are equal or more favorable than the aircrafts regarding ease of operation and use.

<u>QUESTION 3:</u> In case the flight simulators are used in place of the aircrafts for the training types below;

a. INSTRUMENT FLIGHT TRAINING, b. TACTICAL FLIGHT TRAINING,

c. VISUAL FLIGHT TRAINING, d. SEARCH AND RESCUE FLIGHT TRAINING, **how much do you think that you could meet your periodic flight training need on FFS or FTD?** Please, fill in the spaces in the table below with the ratios you determined for each training type (a, b, c, d) and simulator (FFS, FTD). Based on your prior experiences and observations, fill all the spaces in the table.

(For example; for "d"/search and rescue flight training, you think that you could meet your training need 40% on FFS in place of aircraft, fill in the blank as follows).

	FFS (Full Flight Simulator)		FTD (Flight Training Device)	
Flight Training Need Meeting Ratio	a.	b.	a.	b.
	c.	d.(e.g.: % 40)	c.	d.

*** FFS has a realistic and functional cockpit and flight controls; and a motion platform, and generally, high-resolution visual system working in compliance with those functionalities.**

****FTD has a realistic and functional cockpit and flight controls; and based on the needs, some of them have visual system working in compliance with those functionalities. FTD has no motion platform.**

Appendix B: Örnek Anket

MESLEKİ BİLGİ :

Çalıştığı kurum/firma ve pilot statüsü :
İntibaklı olduğu tüm hava araçları :
Toplam uçuş saatleri (uçak ve helikopter) :
Eğitim yapılmış simülatör(ler) : **a)** FFS* **b)** **F**TD** **c)** Her ikisi de **d)** Hiçbiri

SORU 1: En yaygın uçuş eğitim simülatörlerinden: **a)** FULL FLIGHT SIMULATOR (FFS*-Tam Uçuş Simülatörü) ve **b)** FLIGHT TRAINING DEVICE (FTD**-Uçuş Eğitim Aracı) kullanımından hangisinin, **"etkin ve verimli"** uçuş eğitimine daha çok katkı sağlayacağı ve uçuş eğitim sisteminde öncelikle bulundurulması gerektiğini düşünürsünüz? Lütfen a veya b'yi işaretleyiniz.

SORU 2: **a)** FFS ve FTD'leri, **"eğitimdeki işletim ve kullanım kolaylığı"** kapsamında değerlendiriniz: Aşağıdaki **"a**'dan **e**'ye**"** kadarki şıklardan gerçekleşme ihtimali daha yüksek olanı işaretleyiniz.

b) Ayrıca, bir önceki değerlendirmenize ilave olarak **"f"** şıkkını da değerlendiriniz ve bu ifadenin tamamına katılıyorsanız **"f" şıkkını da mevcut haliyle işaretleyiniz**. Katılmıyorsanız, kısmen veya tamamında katılmadığınız kelime(leri)yi çizerek **"f" şıkkını düzeltilmiş haliyle işaretleyiniz**.

a. FFS'ler, işletim ve kullanım kolaylığı olarak FTD'lere göre biraz daha avantajlıdır.

b. FTD'ler, işletim ve kullanım kolaylığı olarak FFS'lere göre biraz daha avantajlıdır.

c. FFS'ler, işletim ve kullanım kolaylığı olarak FTD'lere göre oldukça avantajlıdır.

d. FTD'ler, işletim ve kullanım kolaylığı olarak FFS'lere göre oldukça avantajlıdır.

e. Her ikisi de işletim ve kullanım kolaylığı olarak birbirine eşittir.

f. FFS ve FTD'ler, işletim ve kullanım kolaylığı olarak hava araçlarına eşit veya daha avantajlıdır.

<u>SORU 3:</u> Uçuş eğitimlerinden;

a. ALET UÇUŞ EĞİTİMİ, **b.** TAKTİK UÇUŞ EĞİTİMİ,

c. GÖREREK UÇUŞ EĞİTİMİ, **d.** ARAMA-KURTARMA UÇUŞ EĞİTİM'lerinde simülatörlerin kullanılması halinde; **periyodik uçuş eğitim ihtiyaçlarının yüzde kaçının, gerçek hava aracı yerine FFS veya FTD'yle karşılanabileceğini değerlendirirsiniz?** Lütfen, eğitim çeşitleri (a, b, c, d) ve simülatörler (FFS, FTD) için belirlediğiniz oranları tablonun ilgili bölümlerine kaydediniz. Geçmiş tecrübe ve izlenimlerinizi de dikkate alarak tablonun tamamını doldurunuz.

(Örneğin; "d"/arama-kurtarma uçuş eğitimi ihtiyacının, gerçek hava aracı yerine FFS'le % 40 oranında karşılanabileceğini düşünüyorsanız tablonun ilgili bölümünü aşağıdaki gibi doldurunuz).

	FFS (Tam Uçuş Simülatörü)		FTD (Uçuş Eğitim Aracı)	
Uçuş Eğitim İhtiyacı Karşılama Oranı	a.	b.	a.	b.
	c.	d.(örnek: % 40)	c.	d.

*** FFS'ler; gerçekçi ve fonksiyonel kokpit ile kumanda sistemine; bu fonksiyonlarıyla uyumlu çalışan hareket sistemi ve genellikle yüksek çözünürlüklü görsel sisteme sahiptir.**

**** FTD'ler; gerçekçi ve fonksiyonel kokpit ile kumanda sistemine; ihtiyaca göre bazıları, fonksiyonlarıyla uyumlu çalışan görsel sisteme sahiptir; hareket sistemine sahip değillerdir.**

Appendix C: Java Code

```
import javax.swing.*;
import java.util.*;
public class Deneme2{
        public static final int techFFS = -1;
        public static final int techFTD = 1;

        public static final int militaryAgent = -1;
        public static final int commercialAgent = -2;

        public static final double agentMTendencyToChooseFtd = 0.13;
        public static final double agentMTendencyToChooseFfs = 1 -
agentMTendencyToChooseFtd;

        public static final double agentCTendencyToChooseFtd = 0.06;
        public static final double agentCTendencyToChooseFfs = 1 -
agentCTendencyToChooseFtd;

        public static final double aFfsPeou = 0.44;
        public static final double bFfsPeou = 0.38;
        public static final double cFfsPeou = 0.44;
        public static final double dFfsPeou = 0.38;

        public static final double aFfsPu = 1.19;
        public static final double bFfsPu = 1.55;
        public static final double cFfsPu = 1.77;
        public static final double dFfsPu = 1.58;

        public static final double aFtdPeou = 2.28;
        public static final double bFtdPeou = 2.63;
        public static final double cFtdPeou = 2.28;
        public static final double dFtdPeou = 2.63;

        public static final double aFtdPu = 0.84;
        public static final double bFtdPu = 0.64;
        public static final double cFtdPu = 0.57;
        public static final double dFtdPu = 0.63;

        public static final int trainingTypeA = 1;
        public static final int trainingTypeB = 2;
        public static final int trainingTypeC = 3;
        public static final int trainingTypeD = 4;
```

```
public String trainingChoiceStr = "";
public int trainingChoice = 0;
public int techType = 0;
public int agentType = 0;

public String repetitionStr = "";
public int repetion = 0;

public int numberOfFFS = 0;
public int numberOfFTD = 0;

Random randomProb;
public ArrayList<Agent> agentList;

public static void main(String[] args) {
        FlightSimulatorAdoption adoption = new FlightSimulatorAdoption();
        adoption.start();
}

public void start () {

        randomProb = new Random();
        agentList = new ArrayList<Agent>();

        repetitionStr = JOptionPane.showInputDialog("Please Type The
Number Of Repetion To Run The Model : ");
        repetion = Integer.parseInt(repetitionStr);

        trainingChoiceStr = JOptionPane.showInputDialog("Choose
Training Type To Run The Model (a, b, c or d): ");

        if (trainingChoiceStr.equals("a")) trainingChoice = trainingTypeA;
        else if (trainingChoiceStr.equals("b")) trainingChoice =
trainingTypeB;
        else if (trainingChoiceStr.equals("c")) trainingChoice =
trainingTypeC;
        else if (trainingChoiceStr.equals("d")) trainingChoice =
trainingTypeD;
        System.out.println("Tech Type:" + " PEOU: " + "PU: " + "FFS%: " +
" FTD%");

        for (int i = 1; i < repetion; i++) {

        switch (trainingChoice) {
        case trainingTypeA:
```

```
				militaryCommercialCase(trainingTypeA);
				break;
			case trainingTypeB:
				militaryCase(trainingTypeB);
				break;
			case trainingTypeC:
				militaryCommercialCase(trainingTypeC);
				break;
			case trainingTypeD:
				militaryCase(trainingTypeD);
				break;
			default:
				JOptionPane.showMessageDialog(null,    "You    Have    Not
Chosen A Proper Training Type!!!");

				System.exit(-1);
			}
			}
		}

		public void militaryCommercialCase(int trainingType) {
			if (randomProb.nextDouble() <= .4)
				agentType = militaryAgent;
			else
				agentType = commercialAgent;

			switch (agentType) {
			case militaryAgent:
				if          (randomProb.nextDouble()          <=
agentMTendencyToChooseFtd) {
					techType = techFTD;
					TechnologyDeterminationRule(trainingType,
techType);
				} else {
					techType = techFFS;
					TechnologyDeterminationRule(trainingType,
techType);
				}
				break;
			case commercialAgent:
				if          (randomProb.nextDouble()          <=
agentCTendencyToChooseFtd) {
					techType = techFTD;
					TechnologyDeterminationRule(trainingType,
techType);
				} else {
```

```
					techType = techFFS;
					TechnologyDeterminationRule(trainingType,
techType);
				}
				break;
			default:
				JOptionPane.showMessageDialog(null, "Error!!!");
			}
		}

		public void militaryCase(int trainingType) {

			agentType = militaryAgent;
			if (randomProb.nextDouble() <= agentMTendencyToChooseFtd) {
				techType = techFTD;
				TechnologyDeterminationRule(trainingType, techType);
			} else {
				techType = techFFS;
				TechnologyDeterminationRule(trainingType, techType);
			}
		}

		public void TechnologyDeterminationRule(int trainingType, int techType) {

			double PEOU = 0;
			double PU = 0;
			double oppositeTechPEOU = 0;
			double oppositeTechPU = 0;
			double allAgentsPEOU = 0;
			double allAgentsPU = 0;

			if (trainingType == trainingTypeA) {
				if (techType == techFTD) {
					PEOU = aFtdPeou;
					PU = aFtdPu;
					oppositeTechPEOU = aFfsPeou;
					oppositeTechPU = aFfsPu;
				} else if (techType == techFFS) {
					PEOU = aFfsPeou;
					PU = aFfsPu;
					oppositeTechPEOU = aFtdPeou;
					oppositeTechPU = aFtdPu;
				}
			} else if (trainingType == trainingTypeB) {
				if (techType == techFTD) {
					PEOU = bFtdPeou;
```

```
                PU = bFtdPu;
                oppositeTechPEOU = bFfsPeou;
                oppositeTechPU = bFfsPu;
            } else if (techType == techFFS) {
                PEOU = bFfsPeou;
                PU = bFfsPu;
                oppositeTechPEOU = bFtdPeou;
                oppositeTechPU = bFtdPu;
            }
        } else if (trainingType == trainingTypeC) {
            if (techType == techFTD) {
                PEOU = cFtdPeou;
                PU = cFtdPu;
                oppositeTechPEOU = cFfsPeou;
                oppositeTechPU = cFfsPu;
            } else if (techType == techFFS) {
                PEOU = cFfsPeou;
                PU = cFfsPu;
                oppositeTechPEOU = cFtdPeou;
                oppositeTechPU = cFtdPu;
            }
        } else if (trainingType == trainingTypeD) {
            if (techType == techFTD) {
                PEOU = dFtdPeou;
                PU = dFtdPu;
                oppositeTechPEOU = dFfsPeou;
                oppositeTechPU = dFfsPu;
            } else if (techType == techFFS) {
                PEOU = dFfsPeou;
                PU = dFfsPu;
                oppositeTechPEOU = cFtdPeou;
                oppositeTechPU = cFtdPu;
            }
        }

        if (agentList.isEmpty()) {
            Agent agent = new Agent(PEOU, PU, techType);
            agentList.add(agent);
            // TEST
            System.out.println(agent.techTypeStr + " \t" + agent.PEOU +
" \t" + agent.PU + " \t" + (double) numberOfFFS/agentList.size() + " \t" + (double)
numberOfFTD/agentList.size());
        } else {
            Iterator iterator = agentList.iterator();
            while(iterator.hasNext()) {
                Agent agent = (Agent)iterator.next();
```

```
                    allAgentsPEOU += agent.PEOU;
                    allAgentsPU += agent.PU;
                }
            }

            if ((PEOU < allAgentsPEOU/agentList.size()) && (PU <
allAgentsPU/agentList.size())) {
                Agent agent = new Agent(oppositeTechPEOU,
oppositeTechPU, techType * (-1));
                agentList.add(agent);
                // TEST
                System.out.println(agent.techTypeStr + " \t" + agent.PEOU +
" \t" + agent.PU + " \t" + (double) numberOfFFS/agentList.size() + " \t" + (double)
numberOfFTD/agentList.size());
            } else {
                Agent agent = new Agent(PEOU, PU, techType);
                agentList.add(agent);
                // TEST
                System.out.println(agent.techTypeStr + " \t" + agent.PEOU +
" \t" + agent.PU + " \t" + (double) numberOfFFS/agentList.size() + " \t" + (double)
numberOfFTD/agentList.size());
            }
        }

        public class Agent {

            double PEOU;
            double PU;
            int techType;
            String techTypeStr = "";

            public Agent(double PEOU, double PU, int techType) {
                this.PEOU = PEOU;
                this.PU = PU;
                this.techType = techType;
                if (techType == 1) {
                    techTypeStr = "FTD";
                    numberOfFTD++;
                } else {
                    techTypeStr = "FFS";
                    numberOfFFS++;
                }
            }
        }

}
```

Appendix D: Tez Fotokopisi İzin Formu

TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü ☐

Sosyal Bilimler Enstitüsü ☐

Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

YAZARIN

Soyadı : Boztaş
Adı : Ömer
Bölümü: Bilim ve Teknoloji Politika Çalışmaları Bölümü

TEZİN ADI : Determining a Strategy for Favorable Acquisition and Utilization of Complex Technologies: Flight Simulation Training Devices (FSTD)

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ☐

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
3. Tezimden bir bir (1) yıl süreyle fotokopi alınamaz. ☐

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: