CHARPTER IV

RESULTS OF THE BENCHMARKING STUDY

4.1 A View of Air Traffic Control

Strande (1995) addresses a view of air traffic control that can be shown in Fig 4.1 and explained as follows:

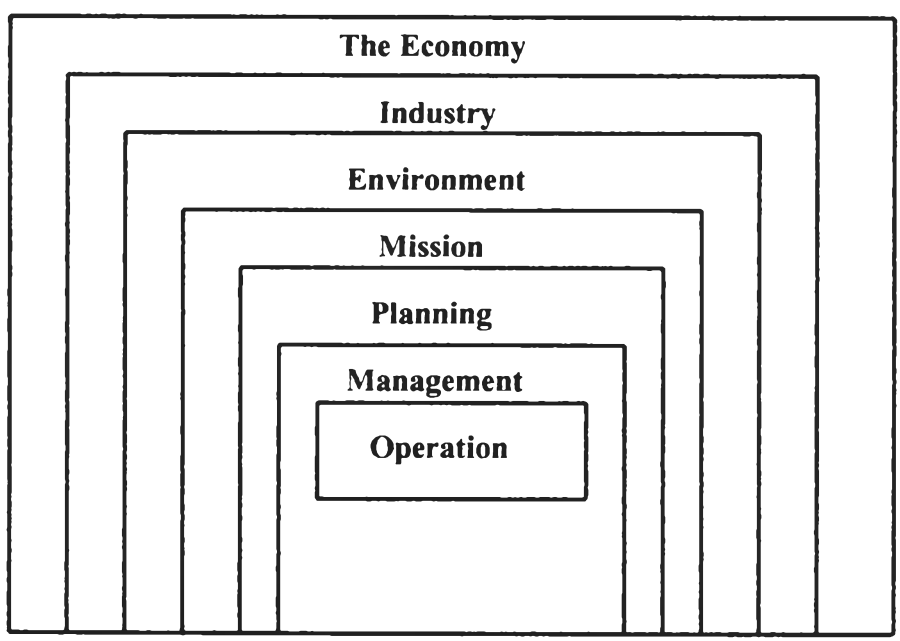


Fig. 4.1 A view of ATC

The Economy : Defined on a national basis and regional basis for example, the European Union, the North American Free Trade Alliance.

The Industry : Composed of all commercial aircraft operators, shippers, forwarders and passenger, private aviation and military, air traffic control organization, aircraft manufacturers and airport authorities.

Environment : For ATC providers, is defined by the need to establish a safe, orderly, economic and expeditious flow of traffic, the environment include the airspace definition, demand and capacity parameters, procedures, organizational division of responsibility, international resources , aircraft performance characteristic, equipment affecting air traffic control (ATC) providers and system users.

Mission : Defined by the ATC's provider's role, responsibility, authority and accountability

Planning : How each organizational elements will fulfill its current and future mission in a future air traffic control environment.

Management : Planning, monitoring and controlling of current operations

Operations : The execution of current procedures with existing operational capabilities and resources.(see Fig 4.2)

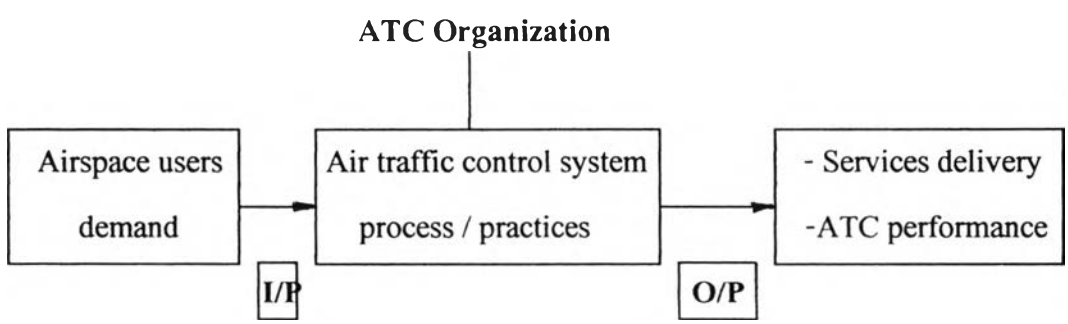


Fig 4.2 I/O Analysis of ATC Operations

Air Traffic Control's Missions

To provide safe, expeditious, orderly and efficient operations of the air transportation system.

Air Traffic Control's Objectives

- To prevent collision between aircraft , between aircraft and obstructions on the maneuvering area. This is accomplished by separations assurance.
- To maintain on orderly and expeditious flow of traffic.

The air traffic control (ATC) organizations will manage, plan and control its own airspace and air traffic control system that consists of infrastructures, facilities, resources and primary operational services to fulfill its missions and objectives to meet the airspace user requirements.

Air traffic control system consists of two main issues, hardware and software.

Hardware: Technology & system, human factor, equipments , ATC facilities and resources.

Software: Methods, manuals, checklists, procedures and operating concept.

In the current air traffic control system environment, there are three main critical factors support air traffic control services as follows:

Air Traffic Controllers who assign and conduct a separation assurance to guide the pilots to active the flight safety that is the main objectives of air traffic control.

Air Traffic Control Technology that assists the controllers to communicate with pilots and identify the aircraft positions.

Air Traffic Control Management is associated with the management and operations practices that will create its services delivery to achieve its efficient operations of airspace users such as demand and capacity management, flow control and management.

The Air Traffic Control' Operational-Based Performance

-The FAA has been generated customer-oriented customer-based system performance measures. These measures have been formulated in consultation with the users and indicate the operational outcome desired by the users that reflect the air traffic control performance. The performance outcomes are:

- Increase system safety
- Decrease system delay
- Increase system flexibility
- Increase user access
- Improve service delivery by increasing the availability of critical system
- Increase productivity

(FAA ,1998)

- The EUROCONTROL's European Air Traffic Management System (EATMS) operating concept creates and addresses the service quality plan that define the specific users demand in coordination with customers. The users need flight efficiency and flight punctuality in addition to safety.(EUROCONTROL ,1997) The research study develops the customer surveys(**See Appendix C)** in order to define the operational factors that the airspace users required during the flight . services phases, the customers need :

- Safety
- Reduce delays
- Reduce flight path and flight time
- Flexible flight route, more direct route
- Reduce operating cost (fuel consumption)

4.2 The Results of Customer Surveys

The results of customer surveys or airspace user surveys **(see Appendix C)** come from the questionnaire responses by the pilots or the airspace users selected from airlines, military (large aircraft type and general aviation).

The results of the airspace user survey may be summarized as follows:

The key factors for success of the effectiveness and efficiency of ATC operations from the customers' point of views are as follows:

- The effectiveness of air traffic management system
- The implementation of advanced air traffic control (ATC) technology
- The effectiveness of air traffic control human factor
- The key factors are obstacles for the effectiveness and efficiency of air traffic control operations from the customers' point of view are as follows:
- Ineffective air traffic management system
- The constraints and the shortcomings of current air traffic control technology
- Ineffective air traffic control human factor
- The air traffic demand is increasing continuously

Customer Value Profile's Summery

The customer value profile contains composite set of customer requirements and the key operational success factors of air traffic control services. The profile as defined by the airspace users or customers' point of view conform to the results of customer survey.

The customer value profile can be summarized as follows:

The key operational success factors

The operational success factors may be defined as the factors in which the customers require to achieve the satisfaction during the flight operations period and the air traffic control services providers need to create these factors to the airspace users.

The operational success factors may be illustrated as follows:

1) Quality of Service

- Safety

-Timeliness of services : expeditious

- Flight punctuality

- Flight efficiency : flexible flight routes , more direct routes, minimum flight paths and flight time.

2) The effectiveness of air traffic control technology : availability, reliability and quality of its technology.

3) The effectiveness of air traffic controllers

Customer Requirements

According to the customer requirement for improvement , the improvement needs from the customer's point of views can be summarized as follows:

Air Traffic Management

- The airspace users require Aerothai to arrange the suitable flight route structure.

- The airspace users require Aerothai to maximize its airspace utilization to cope with the increasing traffic demand.

- The airspace users require the company to improve airspace and ATC system capacity.

- The airspace users require Aerothai to improve the effective flow of traffic.

Air Traffic Control Technology

The airspace users require Aerothai to improve the communications, navigation and surveillance system.

Air Traffic Control Human Performance

The airspace users require the company to improve the human performance as follows:

- Problem solving and decision making.

- Communication skill.

- Effective coordination and cooperation with related aviation firms for aviation safety enhancement in a timely manner.
- Situation awareness
- Knowledge and capability of ATC operations
-Ability of English language usage

Reason For Improvement

The Aerothai's ATC services operate for safe, orderly operations of air transportation systems. The company is faced with these critical problems that demand changes. To overcome these problems, it's necessary to improve and optimize its services operations.

The key problems that create the need for change are as follows:

1) Increasing Demand : The company is facing with the increasing traffic demands. With demands become more diversity and complexity. In order to optimise user benefits and cope with the increasing demand, the services delivery must be improveed.

2) Resources Constraints : The company is facing with system constraints while increasing traffic demand. Lack of system capacity to cope with the increasing demand while airports, airspace resources, facilities become more limited and saturated.

3) High Competitiveness among Airlines Business.: The airlines business become more globalized. The airlines try to cut cost and increase profit. These create the pressure from airlines to force Aerothai to reduce or maintain flight charges while improving services and system efficiency.

4) Technology deficiency : The current air traffic control technology has some deficiency. The shortcomings and limitations of current technologies cannot be supported the air traffic control services to cope with the challenge of increasing demand.

From now on, the research study will present the improvement of Aerothai's ATC services by using the benchmarking. The Benchmarking process model used in this research study now will start as follows:

4.4 Planning Phase

4.1.1 Step 1 Determine What to Benchmark

As mentioned in the early phase of Chapter 4 , conclusioning view of air traffic control operations, the key factors that support air traffic control operations and the critical success factors of air traffic control services are listed.

The key success factors used in benchmarking the air traffic control services. are selected in this research as follows :

1 Quality of Service

This factor addresses service performance levels or service value of the air traffic control that is provided to the customers. The quality of service is a critical success factor that the customers or the airspace users need and lead the customers to satisfaction during the service they received. The quality of service indicates the success or failure of its air traffic control services. The quality of service must be selected as the baseline for comparing its service performance against the best-in-class. The benchmarking results will bring service performance improvement needed in achieving the customer satisfaction and requirements.

2 Technological Support Performance

The technological support performance addresses the operations performance of air traffic control technology that supports air traffic control services. The success or failure of air traffic control services depends heavily on the operations of air traffic control technology support. The technology support must be selected as the baseline for comparing of its performance against the world's best. The benchmarking results will bring improvement of air traffic control technology in achieving the improvement of air traffic control services.

3 Human Operations Performance

The human operations performance addresses the key controller's performance in the air traffic control services. The success or failure of air traffic control depends heavily on the controllers performance. Without the controllers, the air traffic control services would not happen.

The human operations must be selected as the baseline for comparing human performance against the world's best. The benchmarking results will bring improvement of human performance through improvement of air traffic control services.

Quality of Service

Four measures are to be developed and set as the baseline for comparing quality of service or service performance with the benchmarked company. The selected measures are the factors that the users need during the flight operations period and provide them satisfaction.

The four measures to be used as the baseline are shown as follows:

Measure 1 Safety level : To measure the operations manner in which affecting service's safety.

Measure 2 Service's Access Rate : To measure the ability of customer can access the system services and obtain the services on their demands.

Measure 3 Timeliness of Services : To measure the services manner,in terms of expeditious ,timely manner, minimize delays, effective flow of traffic.

Measure 4 Flight Efficiency : To measure the services manner in which to provide services delivery to the user's achievement of efficient operations, in terms of fuel saving and time saving.

Technological Support Performance

Measures of technological support performance are to be developed and set as the baseline for measuring the effectiveness of air traffic control technology that support air traffic control operations. Each measure for technological support performance is

based on the operations performance of the main types of air traffic control technology that support air traffic control services. The air traffic control technology are namely, communications system, navigation system and surveillance system.

Three measures are used for comparing the technological support performance as follows :

Measure 1 The effectiveness of communications system

Measure 2 The effectiveness of navigation system.

Measure 3 The effectiveness of surveillance system.

Human Operations Performance

Measures of human operations performance are to be developed and set as the baseline for measuring the controllers performance in air traffic control operations. Some of these measures for human operations performance are based on the controller's cognitive tasks that are critical for air traffic control affecting service's safety and capacity of system services. Other measures for human operation are concerned with the success of failure of air traffic control. The 13 measures used for comparing the controller performance are as follows :

Measure 1 Enthusiasm of service

Measure 2 Responsiveness

Measure 3 Serviceability

Measure 4 Problem solving and decision making in a timely and safe manner

Measure 5 Timeliness of service

Measure 6 Conflict detection and resolution

Measure 7 Situation awareness

Measure 8 Ability to gather and process information

Measure 9 Ability to cooperate with the pilots in a timely and safe manner

Measure10 Ability to control traffic during take off and landing in a satisfactory manner

Measure 11 Ability to control traffic during take off and landing in a satisfactory

manner during traffic peak period

Measure 12 Ability to communicate and operate communications system

Measure 13 Ability to pass the service responsibility to other flight information regions

4.4.2 Step 2 Determine Whom to Benchmark

The research study selects the potential benchmarked company by conducting a literature searches from multiple and extensive sources, brainstorming and consulting with the air traffic control specialists both inside and outside of the companies. For these results, the research study identifies the potential companies to be used as the benchmark as follows :

1. The Federal Aviation Administration (FAA)'s Air Traffic Services (U.S.A.)
2. The EUROCONTROL
3. The National Air Traffic Services Ltd. (NATS) (U.K.)

Introduction to Potential Benchmarked Companies

The Federal Aviation Administration (FAA)

FAA is the element of the U.S. government with primary responsibility for the safety of civil Aviation. FAA was originally designated the Federal Aviation Agency When established by the Federal Aviation Act of 1958. The present name was adopted in 1967 When the FAA become a component of the Department of Transportation. FAA has six line of businesses as follows :

- Air Traffic Services
- Research & Acquisition
- Regulation and Certification
- Airport Infrastructure Development
- Civil Aviation Security
- FAA Administration

FAA's Air Traffic Services (ATS)

The mission of FAA's ATS organization is to ensure safe and efficient operation, maintenance, and use of the air transportation system today and meet tomorrow's challenges to increase system safety, capacity and productivity.

The FAA's air traffic services employ 36,500 employees.

- Control 20,000 aircraft's take off and landing per day.
- Provide 24 hours of air traffic control daily .
- Manage the National Airspace System (NAS) infrastructure by operating and maintaining 38,000 facilities / systems.
- Annually conduct over 11,000 flight inspections nationally and internationally to preserve the safety, quality and reliability of the airspace system.
- Assign and protect more than 5,000 aeronautical radio frequencies used in air traffic control.
- Direct and evaluate the modernization of NAS infrastructure.

The FAA's air traffic services (ATS) consist of five functional are as follows:

- Air Traffic
- Airway Facilities
- Air traffic System Requirements
- System Capacity
- Independent Operational Test and Evaluation
- Aviation System Standards

The FAA's Primary Services

1. Air Route Traffic Control Services (ARTCC)

This service is responsible for 24 centers which control en-route (Area control) traffic for the United States and parts of the Atlantic and Pacific Ocean. The control center is responsible for air traffic control for more than 100,000 square miles of airspace.

2. Terminal Radar Approach Control (TRACON)

There are 185 TRACON's that provide radar separation to arriving and departing flights. TRACON operates in airspace approximately within a 30 miles radius and less than 15,000 feet altitude above the ground.

3. Airport Traffic Control Towers (ATCT)

This service is responsible for control the aircraft during takeoff and landing at the airport. There are over 400 airports operating this services.

4. Traffic Management System

The Air Traffic Control System Command Center (ATCSCC) is located in Herndon, Virginia. The mission of this service is to balance air traffic demand with system capacity. Traffic management specialists plan and regulate the flow of air traffic to minimize delays and congestion while maximizing the overall use of the NAS. This service ensures safe and efficient flow of air traffic within the United states.

5. Aviation Information

The flight service station(FSS) provides more than 75 automated flight service station(AFSS) that serve the information to more than 600,000 pilots about terrain, pre-flight and in-flight weather information, suggested routes, altitude, indications of turbulence, icing and any other information important to the safety of the flight.

6. Navigation Services

The navigation services provide guidance to pilots to determine their location and navigate from point-to-point during flight through an established network of visual and electronic navigation aids.

7. Landing Services

The landing services provide guidance to pilots to determine their position for take off ,landing and airport movement. These services are provided through a network of visual and electronic aids established in the vicinity of airport.

The FAA's Recognition and World Class Program

Free Flight Concept (Flight 2000)

Free Flight is an innovative concept that will improve the efficiency of the National Airspace System. Using supporting procedures and technologies, pilots operating under instrument flight rules(IFR) will be able to select the aircraft's speed and altitude in real time(FAA.1998).

Free Flight is a joint initiative of the global aviation industry and FAA. The FAA working with aviation leaders from around the world developed a free flight action plan (FAA,1998). Free Flight will increase airspace flexibility and accessibility through reduced separation minimums. The aircraft will fly at their optimum altitude, speed and routing. resulting in lower cost for the airspace user(FAA, 1998).

NAS Modernization Program

The NAS Modernization program was developed by FAA and aviation communities to identify the infrastructure improvement through the year 2015.The FAA is modernizing and upgrading with up-to-date equipment and technologies especially the aeronautical communications, navigation, surveillance, automation and decision support tools that

will meet the safety and capacity needs of the 21th century .The NAS modernization will support the Free Flight concept (FAA, 1998).

Source: FAA's Air Traffic Performance Plan 1998-2000 and others literature searches

EUROCONTROL

EUROCONTROL, the European Organization for the safety of Air Navigation, has 26 member states. Its headquarters is based in Haren, Belgium. It was founded in 1996 for overseeing air traffic control in the upper airspace of member states.

The EUROCONTROL's primary objectives are as follows :

1 To operate the Central Air Traffic Flow Management Unit (CFMU) so as to make optimum use of European airspace and to prevent air traffic congestion.

2 To implement short- and medium-term actions to improve the coordination of air traffic control system throughout Europe.

3 To carry out research and development work aimed at increasing air traffic capacity in Europe.

4 To manage the implementation of the European Air Traffic Control Harmonization and Integration Programmed (EATCHIP).

The EUROCONTROL's Services.

1. The Central Flow Management Unit (CFMU)

It is responsible for balancing demand and available airspace capacity, thereby helping reduce congestion in European airspace.

2. The EUROCONTROL Upper Air Traffic Control Center

Located at Maastricht in the Netherlands, this center controls over 900,000 flights a year in the upper airspace of Belgium, Luxembourg, Netherlands and Northern Germany.

3. The EUROCONTROL Experimental Center

Located at Brtigny-Sur-Orge, south of Paris, this center provides support for the design, development and improvement of air traffic control system.

4. The EUROCONTROL Institute of Air Navigation Services.

Located in Luxembourg, this institute provides air traffic services training as well as causes in advanced specialist training.

5. The Central Route Charges Office (CRCO)

Located in Haren, Belgium, this office calculates, bills and collects charges from users of en-route air traffic services and facilities on behalf of 23 states participating in the EUROCONTROL Route Charges System.

The EUROCONTROL employs 2,110 employees in 1996.

The EUROCONTROL's Recognition and World Class Program

EATCHIP Program

The European ATC Harmonization and Integration Program : EATCHIP is aimed at enhancing air traffic management systems of those states belonging to the European Civil Aviation Conference (ECAC) (EUROCONTROL , 1996) This program is designed to meet the overall objectives of ECAC en-route.

Strategy for the 1990 is " to provide increased airspace and control capacity urgently in order to handle traffic expeditiously while maintaining a high level of safety". EATCHIP is coordinated and managed by EUROCONTROL, in partnership with the national air traffic services providers of each of member states.

The European Air Traffic Management System (EATMS) Concept

EUROCONTROL sets up EATMS, air traffic management operational concept that will cope with the European's traffic growth in the future and take Europe into the 21st CENTURY. EATMS is similar to FAA's Free Flight concept that aims at improving service's capacity to meet a challenge of increasing traffic demand as well as

to allow the airspace users to fly at optimum benefits, in terms of flexible flight, more direct routes, efficient flight profiles and EATMS vision as " to allow all airspace users the maximum freedom of movement subjected to the need for safety, cost-effectiveness, environment aspects and national security requirement " [EUROCONTROL, 1996]

Source : EUROCONTROL's Annual Report 1996 and 1997 and others literature searches

The National Air Traffic Services Ltd. (NATS)

The National Air traffic services Ltd. (NATS) is a wholly-owned subsidiary of the Civil Aviation Authorities (CAA) . NATS provides and operates safe efficient and expeditions air traffic services in U.K. and Shanwich airspace. It provides air traffic services for aircraft flying within UK flight information region and over the North Atlantic as well as the Nation's busiest airports such as Heathrow. Gatwick, Stagnated, Birmingham, Cardiff, Manchester, Aberdeen, Glasgow, Edinburgh, Belfast and London city (CAA , 1998)

The NATS's Services

1 **Area Control Services** : Provides area control services at the Scottish and Oceanic Center at Preswick, Manchester Area Control Center. Shanwick Oceanic Center, London Area Control Center, Swanwick Area Control Center.

2 **Airport Services** : Provides air traffic at Heathrow, Gatwick, Stagnated, Aberdeen, Glasgow , Edinburgh, Luton, Farnborough.

3 **Offshore Services** : Provides air traffic services at Aberdeen Airport.

4 **Infrastructure Services** : Provides navigation services to airlines and other users.

Source : CAA's Annual Report 1997,1998 and other literature searches

Select the Potential Company for Use as the Benchmark

The present research study considers three potential benchmarked companies namely EUROCONTROL, FAA and NATS as a candidate list. In order to find the companies with the most potential to be used as the benchmark, the research study searches a wide-variety of information from many sources to evaluate each potential company. The study assigns the weighting scores carefully in selection criteria for EUROCONTROL, FAA and NATS's information and consults with the experts both inside and outside of the company for assigning the scores. Table 4.1 presents the overview of the benchmarked company analysis. Three potential companies are compared in general context of air traffic control services. Table 4.2 describes the measurement scale of the weighting scores for each selection criterion combined in the selection matrix. This table is used in the rating of scores for each potential benchmarked company. Table 4.3 indicates the scores assigned for EUROCONTROL, FAA and NATS for each selection criterion. The summation of total scores is shown in Table 4.4

Table 4.1 Benchmarked Company Analysis

	FAA	NATS	EUROCONTROL
Employees	38000	5300	1960
Traffic holdings / year (millions flights)	40	1.6	0.93
ATC facilities			
Number of area control	24	5	1
Number of approach control	185	7	None
Number of tower control	402	13	None
Number of traffic management system	1	1	1
Service diversity	7	4	5
Area of responsibilities	Upper U.S. airspace and parts of the Atlantic and Pacific ocean	Upper U.K. airspace and over the North Atlantic	Upper airspace of Belgium, Luxembourg Netherlands and Northern Germany

Source : The FAA, NATS, EUROCONTROL's annual reports and other secondary sources.

Table 4.2 The Description of Selection Criteria Matrix

Selection Criteria	Measurement Scale		
	High=5	Medium=3	Low=1
1) Traffic Holding/Area Control(million flights/year)	More than 50% of total traffic-based holding	20-30 % of total traffic-based holding	Less than 10 % of total traffic-based holding
2) Service Diversity	Over Seven	Four or Five	Singular
3) World Class Innovation and Recognition Program for Aviation Communities	The program has received extensive acknowledgment and approval from aviation communities for most part of the world	The program has received extensive acknowledgment and approval from aviation communities for part of the region	There are no world class and recognition program
4) World Class and Good Reputation from Aviation Communities	The company 's reputation is extensively acknowledged and approved from aviation communities for most part of the world	The company's reputation is extensively acknowledged and approved from aviation communities for most part of the world	There is no special reputation from aviation communities

Table 4.3 The Scores for Selection Criteria

Selection Criteria	Scores		
	EUROCONTROL	FAA	NATS
1)Traffic Holding/Area Control(million flights/year)	0.93 M. 31.95 % **Score = 4**	2.91 M. 57 % **Score = 5**	0.32 M. 10.99 % **Score = 2**
2) Service Diversity	Five Services **Score = 4**	Seven Services **Score = 4**	Four Services **Score = 3**
3) World Class Innovation and Recognition Program for Aviation Communities	-EATCHIP Program -EATMS Concept **Score = 5**	-NAS Modernization Program -Free Flight Concept **Score = 5**	None **Score = 1**
4) World Class and Good Reputation from Aviation Communities	-Professional service -Innovative technology, operation concept -Rule and regulation -The world leader in ATC **Score = 5**	-Professional Service -Innovative program and operational concept -The world leader in ATC **Score = 5**	-Professional service -Quality of service -The world leader in ATC **Score = 5**

Description of the Weighting Scores for Selection Criteria

EUROCONTROL

Criterion 1 EUROCONTROL controls total traffic approximately 0.93 million flights/year, the number of area control = 1 , Hence, the total traffic holding/area control= 0.93 million flights/year/center or 31.45% of total traffic-based holding.

The maximum score (5 points) will be assigned for any benchmarked company that control traffic more than 50% of total traffic-based holding.

According to Table 4.2 , the score for EUROCONTROL in this criterion = 4

Criterion 2 EUROCONTROL has five services are Central Flow Management, EUROCONTROL Upper Air Traffic Control Center, EUROCONTROL Experimental Center, Institute of Air Navigation Services and Central Route Charges Office

The maximum score(5 points) will be assigned for any benchmarked company that has service diversity of more than seven services.

According to Table 4.2 , the score for EUROCONTROL in this criterion = 4

Criterion 3 EUROCONTROL has the world class program namely, EATCHIP program and EATMS operation concept. This program aims at improving European's ATC capacity. The program has received extensive approval from aviation communities worldwide.

The maximum score (5 points) will be assigned for any benchmarked company that has the world class's program that is widely accepted and approved for most part of the world.

According to Table 4.2 , the score for EUROCONTROL in this criterion = 5

Criterion 4 EUROCONTROL is the world leader and professional service in ATC service. EUROCONTROl has received extensive acknowledgment from aviation communities worldwide.

The maximum score (5 points) will be assigned for any benchmarked company that has extensively acknowledged and approved from the aviation communities worldwide.

According to the Table 4.2 ,the score for EUROCONTROL in this criterion = 5

FAA

Criterion 1 FAA controls total traffic approximately 40 million flights /year , the number of area control center = 24 , Hence , total traffic holding/area control center =1.66 million flights/year/center or 57% of total traffic-based holding.

The maximum score (5 points) will be assigned for any benchmarked company that control traffic more than 50% of total traffic-based holding

According to Table 4.2 , the score for FAA in this criterion = 5

Criterion 2 FAA has seven services as follows:

- Air Route Traffic Control, Terminal Radar Approach Control, Airport Traffic Control, Traffic Management System and Aviation Information

The maximum score(5 points) will be assigned for any benchmarked company that has service diversity of more than seven services.

According to Table 4.2 , the score for FAA in this criterion = 4

Criterion 3 FAA has the world class and innovative program namely, NAS modernization and Free Flight concept . The program aims at improving ATC capacity to meet the challenge of increasing traffic demand in the year 2000 and providing the user benefits in term of efficient operations. The program has received extensively acknowledgment from aviation communities worldwide.

The maximum score (5 points) will be assigned for any benchmarked company that has a program that is widely accepted and approved from aviation communities worldwide.

According to Table 4.2 , the score for FAA in this criterion = 5

Criterion 4 FAA has received extensive acknowledgment and approval from aviation communities worldwide. FAA is a professional service and the world leader

in ATC service. FAA provides innovative operation concept, rules and regulations as well as state-of-the art technology.

The maximum score (5 points) will be assigned for any benchmarked company that has the outstanding service as viewed by aviation communities worldwide

According to Table 4.2 , the score for FAA in this criterion = 5

NATS

Criterion 1 NATS controls traffic approximately 1.6 million flights / year , the number of area control center = 5 , Hence, the total traffic holding / area control center = 0.32 million flights/year/center or 10.99% of total traffic-based holding.

The medium score(3 points) will be assigned for any benchmarked company that control traffic between 20-30% of total traffic-based holding and the minimum score (1 points) will be assigned if those control traffic less than 10% of total traffic-based holding.

According to Table 4.2 , the score for NATS in this criterion = 2

Criterion 2 NATS has four services as follows:

Area Control Service, Airport Service, Off Shore Service and Infrastructure Service

The medium score(3 points) will be assigned for any benchmarked company that has the service diversity between four and five services.

According to Table 4.2 , the score for NATS in this criterion = 3

Criterion 3 NATS has no world class's innovation and recognition program

The minimum score(1 points) will be assigned for any benchmarked company that has no world class program.

According to Table 4.2 , the score for NATS in this criterion = 1

Criterion 4 NATS is a professional service and the world leader in ATC service. NATS has received the outstanding service in term of quality of service as viewed by the airspace users and aviation communities worldwide.

The maximum score(5 points) will be assigned for any benchmarked company that has extensive acknowledgement from aviation communities worldwide in outstanding service.

According to Table 4.2 , the score for NATS in this criterion = 5

Table 4.4 Summation of Total Scores

Selection Criteria	EUROCONTROL	FAA	NATS
1) Traffic Holding/Area Control (million flights/year) (W.F.= 0.1)	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1
2) Service Diversity (W.F.= 0.1)	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1
3) World Class's Recognition and Innovation Program for Aviation Communities (W.F.= 0.4)	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1
4) World Class and Good Reputation from Aviation Communities (W.F.=0.4)	5 4 3 2 1	5 4 3 2 1	5 4 3 2 1
Total	4.80	4.90	2.90

According to Table 4.4, the total scores for EUROCONTROL, FAA and NATS are 4.80, 4.90 and 2.90 respectively. Therefore, The researcher selects " The Federal Aviation Administration (FAA) " for use as the benchmark.

4.4.3 Step 3 Develop Data Collection Methods

The data collection methods employed is as described in chapter 3 and data collection plan can be shown in Appendix B

4.4.4 Step 4 Develop Benchmarking Plan

The benchmarking plan can be shown in Appendix A

4.5 Collecting Phase

4.5.1 Step 5 Internal Data Collection

Service Performance Data

In this phase, the research study conducts the customer satisfaction surveys **(See Appendices D and E)** as tool for collecting the ATC service performance levels. Both Aerothai and FAA's service performance are to be collected simultaneously by asking for the point of view of the airspace users or pilots who receive services from both companies, and able to rate them for differences in services delivery.

The customer satisfaction surveys focus on specific target airlines by focusing on the airlines that use the service from both Aerothai and FAA. The criteria for selecting the qualified users for the customer satisfaction surveys are as follows:

- Selected major airlines (many flight routes, number of flight).
- The major airlines included are: Thai Airways International, NorthWest Airlines,United Airlines, EVA Airlines, Cathey Pacific, Qantas Airways and British Airways .
- All selected airlines have scheduled flights to both U.S. and Thailand.
- The pilots who fly along Thailand routes and U.S. routes are surveyed.
- The pilots who have used the service both Aerothai (Thailand airspace) and FAA (U.S. airspace) are surveyed.
- The number of pilots required depend on the survey period, the number of flights/week for each selected airline and budget.

- The number of flights/week will be completed from the scheduled flights that take off and landing at Bangkok International Airport.

Survey Period = 10 weeks

1 Thai Airways International	7 flight/week , number of pilots	= (7).(10).(3) =210
2 NorthWest Airlines	7	= (7).(10).(3) =210
3 United Airlines	18	= (18).(10).(3) =540
4 EVA Airlines	7	= (7).(10).(3) =210
5 Cathey Pacifie Airlines	7	= (7).(10).(3) =210
6 Qantas Airways	21	= (21).(10).(3) =630
7 British Airways	14	= (14).(10).(3) =420

Total pilots=2430

The number of pilots covered = 6% of total pilots=145.8=145

The number of pilots are 145. selected from

1 Thai Airways International	= 13
2 NorthWest Airlines	= 13
3 United Airlines	= 32
4 EVA Ailines	= 12
5 Cathey Pacific Airlines	= 12
6 Qantas Airways	= 38
7 British Airways	= 25

The Results of Customer Satisfaction Surveys

The number of survey questionnaires were 145, sent directly to the pilots.

The number of returned questionnaires were 64, a 44.13 % returns. All performance data contained in the surveys are summerized in the performance data list in Table 4.5

Table 4.5 Performance Data List

Benchmarking Criteria	Aerothai	FAA
Quality of Service		
1. Safety level	3.59	3.88
2. Access rate	3.43	3.75
3. Timeliness of service	3.45	4.04
4. Flight efficiency	3.21	3.87
Technological Support Performance		
1. Effectiveness of Communications system	2.85	4.36
2. Effectiveness of navigation System	3.52	4.16
3. Effectiveness of surveillance system	3.60	4.35
Human Operations Performance		
1. Enthusiasm of service	3.85	3.85
2. Responsiveness	3.85	3.85
3. Serviceability	3.40	4.12
4. Problem solving and decision making in a timely and safe manner	2.97	4.00

5. Timeliness of service	3.35	3.92
6. Conflict detection and resolution	3.31	4.15
7. Situation awareness	3.30	4.30
8. Ability to gather and process information	3.10	4.12
9. Ability to cooperate with pilot in timely and safe manner	3.36	4.14
10. Ability to control traffic during take off and landing in a satisfactory manner	3.41	3.97
11. Ability to control traffic during take off and landing in a satisfactory manner under traffic peak period	3.00	4.07
12. Ability to communicate and operate communication system	2.98	4.17
13. Ability to pass the service responsibility to other flight information regions	3.63	4.18

The Internal Assessment of Aerothai's Current Operations

The research study conducts the employee surveys **(see Appendices F and G)**, interviews and including secondary searches as methods for assessing Aerothai's air traffic control operations.

For the employee surveys, the survey questionnaires were sent to Aerothai' s controllers. The controllers were selected from Aerorothai's Area Control Center of the total of 240 controllers. A total of the questionnaires of 100 were distributed. 68 of respondents were returned, representing a 68% returns. The results of employee surveys are as follows :

Domain 1 The Obstructions and Shortcomings of Current Air Traffic Control System

1.1) 7.4% of respondents agree that the increasing traffic demand will caused the problem in its services.

1.2) 99.7 % of respondents agree that the current air traffic control technology has its constraints and shortcomings.

1.3) 65.6 % of respondents agree that there lack of the controllers.

1.4) 67.7 % of respondents agree that there is lack of automation an decision support tools

Domain 2 Human Operations in Air Traffic Control

2.1) 99.9% of respondents agree that in the decision making & problem solving, the action of air traffic control instructions depend on the capability of controllers.

2.2) 96.8 %of respondents agree that conflict detection and resolution depend on the capability and skill of controllers.

2.3) 62.9 %of respondents agree that they feel stress during the high workload.

2.4) 90.6 %of respondents agree that they have problems to communicate with the pilots due to the shortcomings of communications system.

2.5) 81.2 %of respondents agree that they don't use the automation and decision support tool to support and assist their tasks.

2.6) 93.7 % of respondents agree that they never participated in the assessment of equipments and systems used for air traffic control.

2.7) 100 % of respondents agree that they never participated in the design of equipment, system used for air traffic control.

2.8) 92 % of respondents agree that the automation does't assist and support the air traffic control at terminal control in current environment.

2.9) 80 % of respondents agree that automation is necessary for supporting air traffic control operations.

2.10) 76 % of respondents consider that the implementation of automation will change the controller's tasks, work environment, procedures and make it difficult to operate.

2.11) 96 % of respondents consider that the current communications system have its constraints.

2.12) 76 % of respondents concede that they make an errors from using of equipment or system for air traffic control once in a while.

2.13) 76.9 %of respondents consider that the traffic peak period is the problem of air traffic control.

2.14) 84.2 %of respondents agree that they feel stress during the high workload.

2.15) 59.9 %of respondents agree that service's delays is the problem of air traffic control.

2.16) 77.3 %of respondents agree that lack of automation support the problem solving and decision making

2.17) 62.5 % of respondents agree that they may make an errors for decision making and problem solving during the high workloads.

2.18) 78.1 % of respondents agree that they may make an error in the perception of information from multiple sources under time constraints.

2.19) 62.5 % of respondents agree that they have less productivity during high workloads.

2.20) 62.4 % of respondents agree that the high controller's workloads can seriously affect controller's cognitive tasks such as memory, traffic prediction, action selection and action implementation.

2.21) 90.2 %of respondents agree that they have communications problems with pilots.

2.22) 90.1 % of respondents agree that they have to repeat ATC instructions to pilots several times because of the language difficulties.

Domain 3 Air Traffic Control Technology

3.1)100 % of respondents consider that the existing communications system have many shortcomings and constraints, the quality of voice was poor and the range of its communications was limited.

3.2) 74.9 % respondents consider that the current radar system can cover all the area of services both area control and approach control.

3.3) 81.2 % of respondents don't consider that the current radar system can cover the oceanic airspace.

3.4) 68.2 % of respondents consider that the current radar system is high effective.

3.5) 62.4 % of respondents don't consider that the en-route navigation system can cover all areas of services.

3.6) 96.7 % of respondents consider that the navigation aids for landing can be facilitated at major airports only.

3.7) 93.4 % of respondents consider that the current navigation system is highly effective.

Domain 4 Air Traffic Management

4.1) 90.3 % of respondents agree that the automation and decision support tool has had little role to support and assist air traffic management.

4.2) 89.9 % of respondents consider that the traffic flow control and management is not applied and utilized for air traffic control..

4.3) 68.7 % of respondents consider that lack of effective coordination between area control and approach control can cause delays.

4.4) 71.4 % of respondents consider that lack of automation supporting air traffic management can cause delays.

4.5) 53.2 % of respondents consider that lack of system capacity to cope with traffic demand can cause delays.

4.6) 59 % of respondents consider that the current air traffic control in type of fixed route structure can not be utilized the optimum users benefit in terms of rule saving, and time saving.

The controllers give comments on existing problems of air traffic management areas as follows:

4.6.1) 80.4 % of respondents comment on the increasing traffic demand.

4.6.2) 81.8 % of respondents comment on the airspace and flight routes constraints.

4.6.3) 83.8 % of respondents comment on high controller's workloads.

4.6.4) 65.6 % of respondents comment on that lack of automation support and assist air traffic management.

Analysis and Disccusion

After completing the employee surveys **(see Appendices F and G)** , interviews and literature searches, the Aerothai's internal operations of current air traffic control services are listed that can be divided into three main areas as follows:

1) Air Traffic Management
2) Air Traffic Control Human Operations
3) Air Traffic Control Technology

Aerothai's Air Traffic Management

Air Traffic Control Process

The current air traffic control process in Aerothai's environment can be divided into three phases of services as follows : (See Fig 4.3)

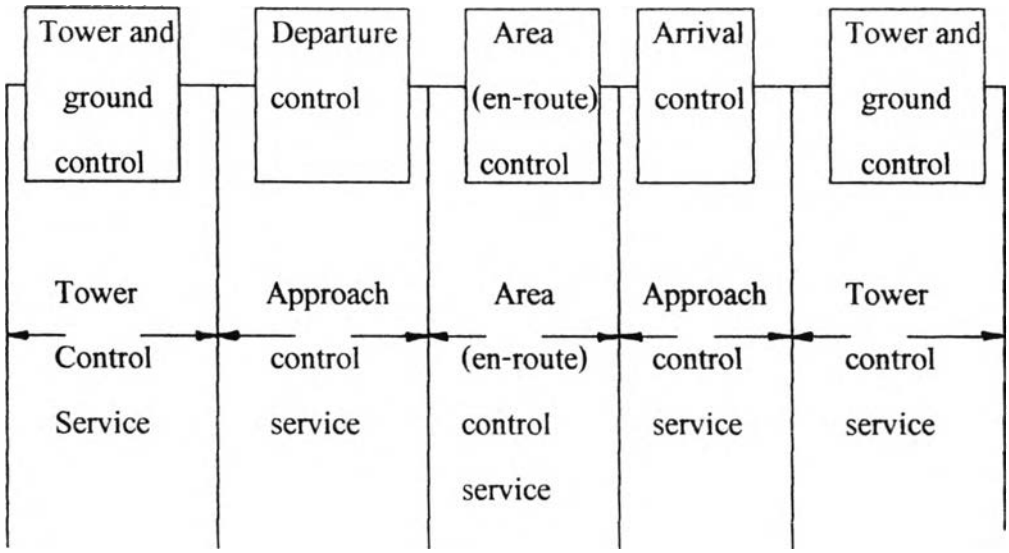


Figure 4.3 Phases of Air Traffic Control Services

Adapted from FAA (1998)

1) Tower Control Phase : Responsible for controlling the aircraft during takeoff and landing including controlling the ground traffic at the airport.

2) Approach Control Phase : To control the departing aircraft from the airport by tower control to area control and the arriving aircraft from area control to tower control on a final approach for landing of the airport. In the approach control phase, the controllers use the radar for safe separation between the aircraft..

3) Area Control Phase : To control the aircraft fly across the country In this phase, the controllers use radar for safe separation between the aircraft. If the radar dose not cover certain area. The controller will use non-radar procedure to guide the pilots for safe separation.

In the current environment, Aerothai's air traffic control operations operate as " A fixed route structure". Manual and procedures-based was controlled by controllers, and the controllers use procedural restrictions to ensure safe separation for the aircraft. In Aerothai's air traffic control process for " fixed route structure" , the pilots set up a flight plan that contains flight destination, routes of flight, time of departure, flight profiles (speed, altitudes, climb and decent) . This plan requires the aircraft to fly along specific route . Any deviations from the designated route must be

pre-approved by the controllers (FAA, 1998). In the fixed route structure environment, the controllers use the procedural restrictions as a tool for reducing the potential conflict between the aircraft, ensure separation, safety of flight and prevent unauthorized entry into special use airspace. (FAA,1998)

- The Aerothai does not use the automation and decision support tool for carrying out the air traffic management.
- The Aerothai does not implement air traffic management system for supporting air traffic control operations. (air traffic management system is used in FAA for balancing and managing system capacity with demand (Mavor et al.,1998)

The Current Problems of Air Traffic Management

1) From the Aerothai's controllers's viewpoint, the current problems of air traffic management are as follows :
   -The increasing traffic demand.
   - Airspace resources are constrainted and limited flight routes
   - Lack of automation support traffic management
   - Fixed route structure are constrained to the pilots to fly at optimum flight routes in order to reduce flight path and flight time.
   - Lack of service's capacity when traffic demand is dramatically increased, high traffic loads and high controller's workloads.
2) The flight route is inflexible where the flight efficiency is not achieved. The inflexible flight routes are difficult for the pilots to operate in an efficient manner through the solution of airspace congestion problems.
3) The fixed route structure was constrained by the procedural restrictions by mean of which the airspace users cannot fly at optimum flight paths and select their intended flight routes as required due to the procedural restrictions (FAA,1998). The use of procedural restrictions will result in increased fuel use, increase flight times, loss of flexibility and reduced traffic flow (Nolan,1994)
4) Congestion problems and delays.

Aerothai's Human Operations

After completing the internal assessment of ATC operations, in terms of human factor, the key issues associated with human operations may be listed as follows:

- The various tasks of Aerothai's controllers such as decision making & problem solving, action selection and action implementation depend heavily on the skills and capabilities of each individual controller.
- Conflict detection and resolution rely on the capabilities of each controller.
- High controller's workloads under time constraints may cause human stress.
- Some controllers have serious problems to communicate with pilots due to the shortcoming and constraints of communications system.
- The controllers do not use the automation and decision support tools to assist them to carry out the controller's tasks under current environment.
- The controllers do not participate in the design and evaluation of air traffic control system.
- Not many controllers used to test, assess and evaluate the effect of equipment and system on their performance.
- The controllers do not use the automation and decision support tools to assist them in terminal control services under current environment.
- The controllers consider that the automation and decision support tools can assist them to carry out their tasks effectively.
- The controllers consider that the communications system have many constraints and shortcomings that prevent them from communicating with the pilots effectively.
- Some of the controllers make mistakes in the use of equipments, systems for air traffic control services.
- Some of controllers have some communications problems with pilots.
- High workloads under time constraints cause serious problems to controllers.

- High workloads may cause human stress and low productivity compared with normal workload.
- High traffic loads during take off and landing period will cause service's delays.
- High work loads under time constraints will create service problems for controllers. They may be confused and make errors for such tasks as follows:
  - Decision making and problem solving.
  - Information gathering.
  - Cooperate in decision making with pilot.
  - Lack of situation awareness.
  - Action selection and action implementation.
- High controllers' workload will degrade human performance and induce human errors.
- High controller's workloads will cause delays and lack of services ability to accommodate traffic demand
- Some of the controllers have problems in communicating with pilots, in terms of language's ability
- Some of the controllers repeat ATC instructions to pilots many times because of the communications problems.
- Most of the air traffic control tasks done by Aerothai's controllers today depend on human - manual - based control. The tasks in air traffic control process done by controllers rely heavily on the cognitive ability of each controller. The abilities and limitations of controllers impact on the success and failure of its services.
- Automation and decision support tool has little role in assisting and supporting Aerothai's air traffic control services in current environment.
- Human factor in air traffic control in Aerothai's environment has little role in the design and evaluation of air traffic control system.

The Current Problems of Human Operations

After assessing the internal operations of Aerothai in, terms of human operations, the key problems can be represented as follow:

- Language difficulty and Communications skill
- Controller's cognitive constraints (situation awareness, conflict detection & resolution, information gathering and processing, problem solving and decision making)
- Pilot-Controller interface
- Controller's error (stress, fatigue, vigilance, workloads)
- Training and selection constraints to support the rapid change of human operations

The Current Problems of Air Traffic Controller Technology

After assessing the internal operations of Aerothai's air traffic controller technology, the key problems can be represented as follows :

The shortcomings and constraints of current ground-based technology such as

- Non-availability of current communications system that not coverage to all area of service operations.
- Low reliable of current communications system.
- The voice of communications system was poor
- Non-availability of navigation and surveillance system.

Table 4.6 presents the overview of Aerothai's current practices.

Table 4.6 Profile Summary of Internal Data Collection

Key factors of ATC	Current Practices
Air Traffic Management	- Manual-based control - A few role of automation and decision support tool to carried out in air traffic control operations - Air traffic control as a fixed-route structure - Inflexible flight route - Traffic Control as a tactical operations
Air Traffic Control Technology	- Communication, navigation and surveillance system are main technology for supporting air traffic control operation - Less functional -Technology research and acquisition is a new challenge
Air Traffic Control Human factor	- Manual-based control - Automation and decision support tool has a few role for supporting controllers - Non-human factor-based research

4.5.2 Step 6 External Data Collection

FAA's Service Performance Data

The research study conducts the customer satisfaction surveys **(see Appendices D and E)** as a tool for collecting the FAA's service performance data as discussed earlier in step 5 internal data collection

FAA's Internal Operations

The research study conducts the benchmarking questionnaire **(see Appendix H)** and literature searches from secondary sources as a method for assessing the FAA's internal operations of air traffic control services.

Analysis and Discussion

After completing the analysis of the benchmarking questionnaire and further secondary research from the FAA, the FAA's internal operations of the air traffic control services will be listed, and the key practices for improvement of the air traffic control operations will be defined.

FAA Technologies and Systems

FAA aims at improving the air traffic control services, in terms of service's safety, capacity and efficiency and meet the challenge of increasing traffic demand as well as the diversity and flexibility of their services. FAA focuses on the importance of air traffic control technology as part of the success of system services in providing safe, capacity and efficiency of the air transportation system.

FAA develops, improves and modernizes its air traffic control technology and system continuously with up-to-date, modern and advanced technology. The key contribution for the FAA's technology improvement efforts are research & acquisition, technology modernization, joint research with aviation communities and expert firms, communicating with customer and employee involvement in research & acquisition.

Research & Acquisition (Continuous Technology Improvement)

The FAA's research and acquisition is responsible for modernizing and acquiring modern and advanced technologies to improve safety, capacity and efficiency of system services through common benefits of airspace users.

FAA's research & acquisition associated with the improvement of air traffic control technology and system can be divided into two main areas as follows :

1) Air Traffic System Development : Responsible for acquiring, modernizing and improving air traffic control's automations. Various automations and systems were deployed in many sites and some are being developed. The automation has been delivered to improve the air traffic control services.

2) Communications, Navigation and Surveillance System : Responsible for acquiring, modernizing and improving air traffic control technology used in U.S. National Airspace System. Many items have been delivered and some are in developing and evaluating phase. FAA develops various CNS technologies as follows:

Communications System

Voice Switching / Recording : Such as Terminal Voice Switch Replacement (TVSR), Enhanced Terminal Voice Switch (ETVS),Digital Voice Recorder System (DVRS).

Voice and Data Communications : Such as Radio Frequency Interface (RFI) Elimination, Communication Facilities Enhancement (CFE), Back Up Emergency Communication (BUEC), Next Generation Air/Ground Communication, Next Generation Very High Frequency (VHF) Air/Ground Communication System.

Aeronautical Data Link : Such as Aeronautical Data Link System (ADLS), Situation Awareness for Safety (SAS).

Navigation System : Global Positioning System. (Local Area and Wide Area Augmentation System)

Surveillance System : Such as Airport Surveillance Radar (ASR-9 &11), Air Route Surveillance Radar (ARSR-S) , Airport Surface Detection Equipment (ASED-3), Terminal Doppler Weather Radar (TDWR).

Aircraft / Avionics system : Traffic Alert and Collision Avoidance system (TCAS) , Aeronautical Datalink (ADLS).

Technology modernization (Continuous technology improvement)

FAA upgrades and improves the U.S. National Airspace System with modern and advanced technology, equipments and systems that will meet the challenging needs through achieve safety, capacity and efficiency. FAA has upgraded and developed air traffic control technology such as communications, surveillance and navigation as well as integrated automation and decision support tool for supporting and assisting controllers.

Communicating with Customers

FAA communicates with the airspace users, understand their needs both current and future. FAA uses and integrates the voice of customers into the acquisition process by allowing the FAA to develop, validate and implement advanced technology to meet user requirements.

Joint Research with Aviation Communities and Industry

FAA joins in research effort in technology with aviation communities to achieve common benefits of technology improvement.

Employee Involvement in Technology Research and Acquisition

FAA focuses on the FAA's employee in the research and acquisition of new system and technology. This will bring the well-trained people, employee's effort and individual's capability tol help and support FAA in improving its technology for the long term benefits.

FAA's Automation

FAA is facing increasing traffic demand that drives towards to automated air traffic control system. The current practices, procedures and equipments cannot be adapted to cope with a lot of traffic and continuously increased traffic. The FAA considers that the increased traffic is the factor that drives the automation needed and the increasing tendency of air traffic control providers to serve rather than to control the aviation communities in its use of airspace resources. Automation is seen as one of the ways in which service providers can meet the needs of airspace customers both now and in the future (Mavor et al.,1998) .

FAA establishes plan for implementation of automation call " Automation strategic plan (Mavor et al., 1998) . Accoding to the plan, the goals of automation are to improve system safety and efficiency.

Details of the improvement of system safety are as follows :

- Reduce human error, better human-computer interfaces
- Improve data communications (Datalink)
- Improve surveillance
- Improve reliability of equipment
- Prevent system overload

Details of the improvement of system efficiency are as follows:

- Reduce delay
- Improved workforce efficiency
- Provide fuel-efficient profiles
- Accommodate user-preferred trajectories

FAA implements various types of automation and decision support tools in all phases of services : area control, approach and tower control service and introduces it over time.

Various types of automations and decision support tools that are implemented in the U.S. airspace system are as follows :

Tower Control Phase

- Airport Surface Detection Equipment (ASDE)
- Runway Visual Range System (RVRS)
- Airport Movement Area Safety System (AMASS)
- Terminal Doppler Weather Radar (TDWR)
- Departure Sequencing Program (DSP)

Approach Control Phase

- Automate Radar Terminal System (ARTS)
- Conflict Alert (CA)
- Minimum Safe Altitude Warning (MSAW)

- Voice Switching Control System (VSCS)
- Descent Advisor (DA)
- Traffic Management Advisory (TMA)
- Final Approach Spacing Tool (FAST)
- User Request Evaluation Tool (URET)
- Departure Sequencing Program (DSP)

Area Control Phase

- Radar Data Processing (RDP)
- Flight Data Processing (FDP)
- Conflict Alert (CA)
- Minimum Safe Altitude Warning (WSAW)
- Host Computer Upgrade (HOST)
- Center-Tracon Automation System (CTAS)
- En-route Metering System (ERM)

Some key automations in FAA can be explained in more specific terms as follows :

Automated En-Route Air Traffic Control (AERA)

FAA established this system in 1998. AERA is an automation system that supports and assists the FAA's air traffic control system . This automation system provides benefits to FAA as follows:

- Improve service's safety by means of which human errors are reduced and support the controllers in predicting flight conflict (resolve the conflict)
- Improve service's capacity due to the ability to accommodate more traffic
- Improve service's efficiency to user need by providing pilot preferred routes of flight .

Conflict Resolution Advisory

This tool provides automated assistance to en-route radar controllers when resolving potential conflict between two aircraft (Nolan ,1994)

Conflict Alert

This tool assists controller in identifying potential conflict alert between the aircraft. (Nolan ,1994).

Conflict Detection

This tool assists controllers in estimating the future aircraft position in order to eliminate and avoid the conflict between the aircraft. (Mavor et al.,1998)

Enhanced Traffic Management System (ETMS)

This automation supports FAA's controllers and traffic management to manage the flow of traffic, minimize the congestion problems both at the airports and in the airspace including delays as well as maximize the use of existing system capacity. The ETMS provides numerous benefits to FAA, in terms of improved safety , capacity and maximize efficiency. The ETMS contains **the monitor and alert function** to provide the automated display alert when the demand exceeds system capacity and its contain **aircraft situation display (ASD)** that assists the controllers to monitor all aircraft's positions in the area control airspace in order to help the controllers to manage and control the flow of traffic.(ICAO,1984)

Air Traffic Control Performance

The FAA has developed and addressed several key practices and programs for improving air traffic control services performance. The analysis of benchmarking questionnaires and the sources of secondary research can be defined, in terms of various practices and programs associated with the improvement of key primary operational performance of services operations that can be demonstrated as follows:

Improve Service's Safety

1) FAA focuses on human factor in air traffic control operations that contribute to aviation safety. FAA emphasises human factor performance by creating the way to improve human performance and reduce human errors. FAA develops various human

factor's activities concerned with the optimization of service's safety. Human factor research in FAA demonstrates a multidisciplinary human factor efforts. Human factor's capabilities and limitations as well as human performance and human degradation-based information will be gathered and analyzed and applied to the design of equipment and system, training and personnel selection in order to enhance human performance and reduce human constraints.

2) FAA collaborates with aviation communities to enhance aviation safety. The aviation safety information will be gathered and analyzed in such a manner that the aviation safety will be improved. FAA gives the safety policy, provides training needs and develops analytical tools, resources associated with safety improvement. The safety risk assessment and management is conducted in FAA to strengthen operational safety.

3) FAA has introduced automation and decision support tool since 1980. Automation has been implemented at all phases of U.S. airspace system. FAA sets up automation plan to guide the implementation of automation aimed at improving system safety.

4) FAA has improved, upgraded and modernized its current air traffic control technology with modern and advanced technology to meet the challenge of increasing service's safety to cope with the increasing traffic demand.

Improve Service's Capacity and Efficiency

1) FAA sets up air traffic management system as a central flow control and management unit located in Virginia. FAA establishes the system so as to balance capacity with traffic demand and management of traffic throughout the air traffic control system. The main benefits of traffic management system are to improve airspace utilization, effective flow of traffic, reduce congestion and delays.

2) FAA develops National Route Program (NRP) . This program provides the preferred flight routes to users with flexible and cost-effective flight routes. This program allows the users who fly above 20,000 feet to select their own routes or preferred routes. This program will remove the procedural restrictions and constraints to the user. FAA estimates that the National Route Program saved the customer's cost by 40 million U.S. dollars in 1994 Since the pilot can fly more optimum routes (FAA, 1998)

3) FAA implements automation and decision support tool in all phases of services. FAA establishes the plan for implementation called " automation strategic plan in 1994 (Mavor et al., 1998) . The major goals for automation are to improve service's safety and increase service's efficiency.

FAA's Human Operations

FAA concentrates on the human factor in ATC as the key success of Aviation's safety and the efficiency of air transportation system. They consider that the human performance and human errors can be contributed to accidents and incidents in aviation.

The FAA establishes the National plan for Aviation human factor : a human factor research. The plan contains various comprehensive programs of human factor research in various research areas. The plan aims at improving human performance and alleviating human performance problems in air traffic control service. and reducing human errors.

The National plan for human factor research is supported and carried out by the FAA office of Aviation Medicine's Civil Aeromedical Institule (CAMI) carried out under the Human Factors and Aviation Medicine component of the FAA research Engineering and Development Program (RE& D) (FAA, 1995)

The human factor research focuses on the information of human factor that cause accidents, human errors and degradation of human performance. The research based-information on human factor was accumulated and acquired so as to apply this to the benefits of equipment design, procedures, selection and training that will lead to the improvement of human operations.

1) Human - Centered Automation

This research focuses on the impact of automation and advanced technology on human performance. The research aims at reducing and eliminating human errors from the system.

The research plan will emphasise human capabilities and their limitations in the design of air traffic control system to help in eliminating human errors in human-system interaction and gain the knowledge of human factor to design system, equipment for ease to use and reduce human errors from system implementation.

2) Selection & Training

FAA focuses on selection and training will enhance and strengthen human performance. Various training programs will enhance human performance and the selection programs are created to ensure that FAA will choose the right people to perform the work well. FAA conducts the research in training & selection. The human information-based on training and selection will gather and analyze in order to subsequently evaluated the human operational performance of individual to determine additional training and selection needed for controllers. FAA develops methods, tools, techniques and reference information to improve training and selection.

3) Human Performance Assessment

FAA develops models. tools and baselines for assessing human performance and measuring the effect of change on human performance, human skill from implementation of automation , equipment , procedure and training .

FAA conducts the research on human performance assessment in order to

- Measure human performance from using automation, system, equipment, method, training and define the factors that affect human performance.
- Explore operational errors
- Identify the needs or further changes in order to enhance human performance and reduce operation errors
- Ensure that new procedures, automation, equipment, training will enhance human performance.

4) Information Management and Display

FAA conducts research on information management and display. The research emphasises on the improvement of information transfer by reducing the errors of the information transfer process from pilot-controllers, controller-controller pilot-airline operations. The information transfer is associated with communication and coorperate

decision making. FAA develops tools, equipment and system to enhance the information transfer process and reduce errors from the process.

Table 4.7 presents the overview of FAA's current practices.

Table 4.7 Profile Summary of External Data Collection

Key Factors of ATC	Current Practices
Air Traffic Management	-Fixed-route structure and user-preferred flight routes - Flexible and dynamic routing - Tactical and strategic traffic control - Traffic flow control and management - Capacity and demand management -Widely-used automation and decision support tool in air traffic control operations
Air Traffic Control Technology	- Communication, navigation and surveillance systems are main technology for supporting its services -Multifunctional and state-of the art technology -Research and acquisition can be effectively utilized for technology improvement and development
Air traffic control Human Factor	-Manual-based control -Automation and decision support tool are widely-used for supporting controllers -Human factor research can be effectively utilized and deployed in human activities

4.6 Analyzing Phase

4.6.1 Step 7 Compare Performance and Determine Gap.

In this step, the service performance data from collecting phase(**see Step 5 Internal Data Collection, Step 6 External Data Collection , Appendices D and E)** for both Aerothai and FAA will be listed and compared. The research study employs various gap analysis tools for demonstrating and determining the performance gap that exists between Aerothai and FAA. The gap analysis tools used in this step are as follows:

-Table of performance comparison (see Table 4.8, 4.9, 4.10 and 4.11)

-Z-chart (see Fig 4.4, 4.5 and 4.6)

-Bar chart (see Fig 4.7)

-Radar chart (see Fig 4.9 and 4.10)

-Performance profile chart (see Fig 4.8)

From now on, the research study will calculate the performance gap that exists between Aerothai and FAA

Finnigan (1996) states that **Gap = Internal Measurement – Benchmark**

In this research study, internal measurement is refer to the performance data for all Aerothai's measures of benchmarking factors and benchmark is refer to the performance data for all FAA's measures of benchmarking factors.

According to Table 4.8, the performance gap for the quality of service : safety level

Gap= 3.59-3.88= -0.29

Table 4.8 Table of Performance Comparison

Benchmarking Factors	Aerothai	FAA	Gap
1. Quality of Service			
1) Safety level	3.59	3.88	-0.29
2) Service's access rate	3.43	3.75	-0.32
3) Timeliness of service	3.45	4.04	-0.59
4) Flight efficiency	3.21	3.87	-0.66

2. Technological Support Performance			
1) Effectiveness of communications system	2.85	4.36	-1.51
2) Effectiveness of navigation system	3.52	4.16	-0.64
3) Effectiveness of surveillance system	3.60	4.35	-0.75
3. Human Operations Performance			
1) Enthusiasm of service	3.85	3.85	0
2) Responsiveness	3.85	3.85	0
3) Serviceability	3.40	4.12	-0.72
4) Problem solving and decision making in a timely and safe manner	2.97	4.00	-1.03
5) Timeliness of service	3.35	3.92	-0.57
6) Conflict detection and resolution	3.31	4.15	-0.84
7) Situation awareness	3.30	4.30	-1.00
8) Ability to gather and process information	3.10	4.12	-1.02
9) Ability to cooperate with pilot in timely and safe manner	3.36	4.14	-0.78
10) Ability to control traffic during take off and landing in a satisfactory manner	3.41	3.97	-0.56
11) Ability to control traffic during take off and landing in a satisfactory manner under traffic peak period	3.00	4.07	-1.07
12) Ability to communicate and operate communications system	2.98	4.17	-1.19
13) Ability to pass the service responsibility to other flight information regions	3.63	4.18	-0.55

Table 4.9 Quality of Service Comparison

Quality of Service	Aerothai	FAA	Gap
1) Safety level	3.59	3.88	-0.29
2) Service's access rate	3.43	3.75	-0.32
3) Timeliness of service	3.45	4.04	-0.59
4) Flight efficiency	3.21	3.87	-0.66
Total	3.42	3.88	-0.46

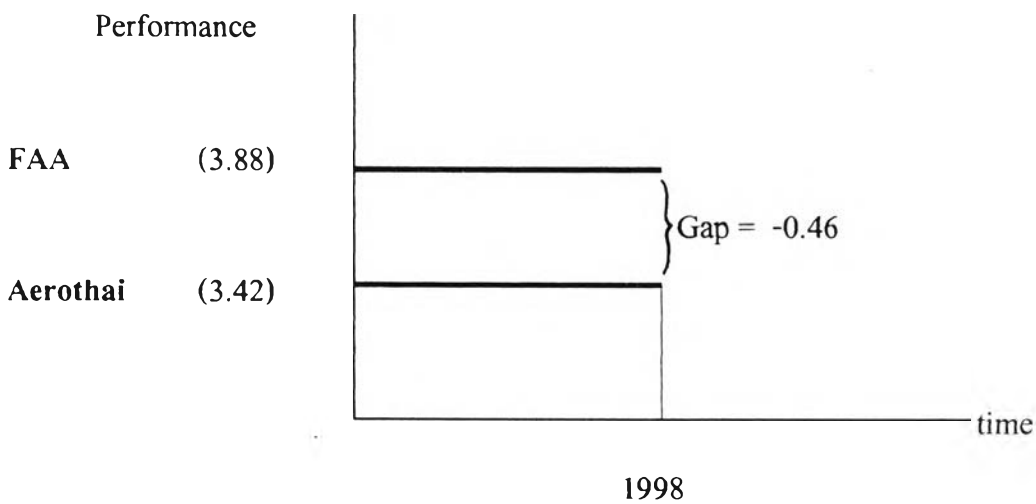


Fig 4.4 The Analysis of Quality of Service Gap

The quality of service performance of Aerothai = 3.42

The quality of service performance of FAA = 3.88

The current performance gap = 3.42 -3.88 = -0.46

Table 4.10 Technological Support Performance Comparison

Technological Support Performance	Aerothai	FAA	Gap
1) Effectiveness of communications system	2.85	4.36	-1.51
2) Effectiveness of navigation system	3.52	4.16	-0.64
3) Effectiveness of surveillance system	3.60	4.35	-0.75
Total	3.32	4.29	-0.97

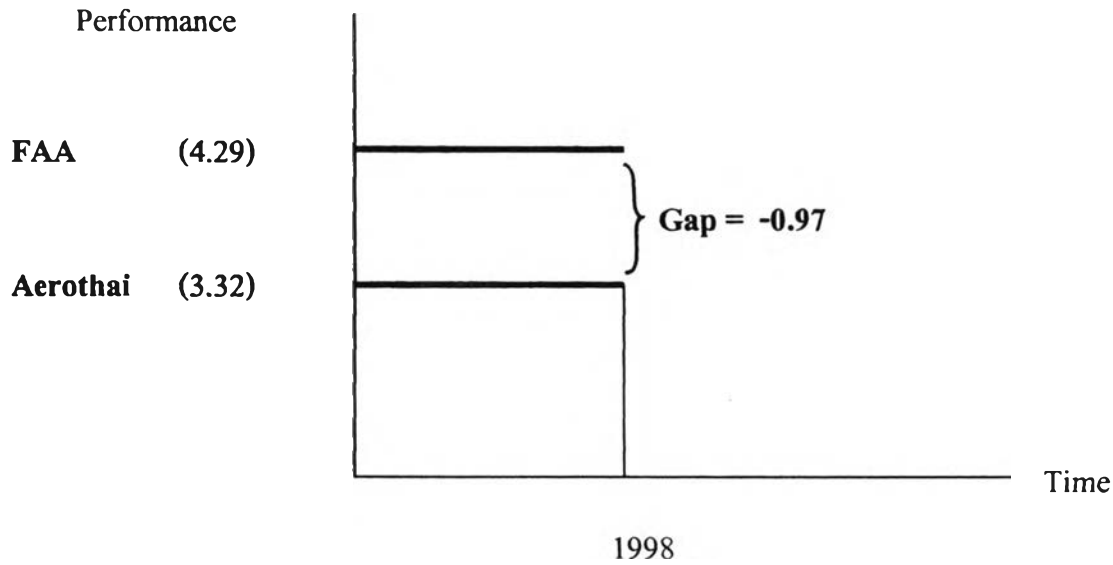


Fig 4.5 The Analysis of Technological Support Performance Gap

The technological support performance of Aerothai = 3.32

The technological support performance of FAA = 4.29

The current performance gap = 3.32-4.29 = -0.97

Table 4.11 Human Operations Performance Comparison

Human Operations	Aerothai	FAA	Gap
1) Enthusiasm of service	3.85	3.85	0
2) Responsiveness	3.85	3.85	0
3) Serviceability	3.40	4.12	-0.72
4) Problem solving and decision making in a timely and safe manner	2.97	4.00	-1.03
5) Timeliness of service	3.35	3.92	-0.57
6) Conflict detection and resolution	3.31	4.15	-0.84
7) Situation awareness	3.30	4.30	-1.00
8) Ability to gather and process information	3.10	4.12	-1.02
9) Ability to cooperate with pilot in timely and safe manner	3.36	4.14	-0.78
10) Ability to control traffic during take off and landing in a satisfactory manner	3.41	3.97	-0.56
11) Ability to control traffic during take off and landing in a satisfactory manner under traffic peak period	3.00	4.07	-1.07
12) Ability to communicate and operate communications system	2.98	4.17	-1.19
13) Ability to pass the service responsibility to other flight information regions	3.63	4.18	-0.55
Total	3.34	4.06	-0.72

The Human operations performance of Aerothai = 3.34

The Human operations performance of FAA = 4.06

The current performance gap = 3.34-4.06 = -0.72

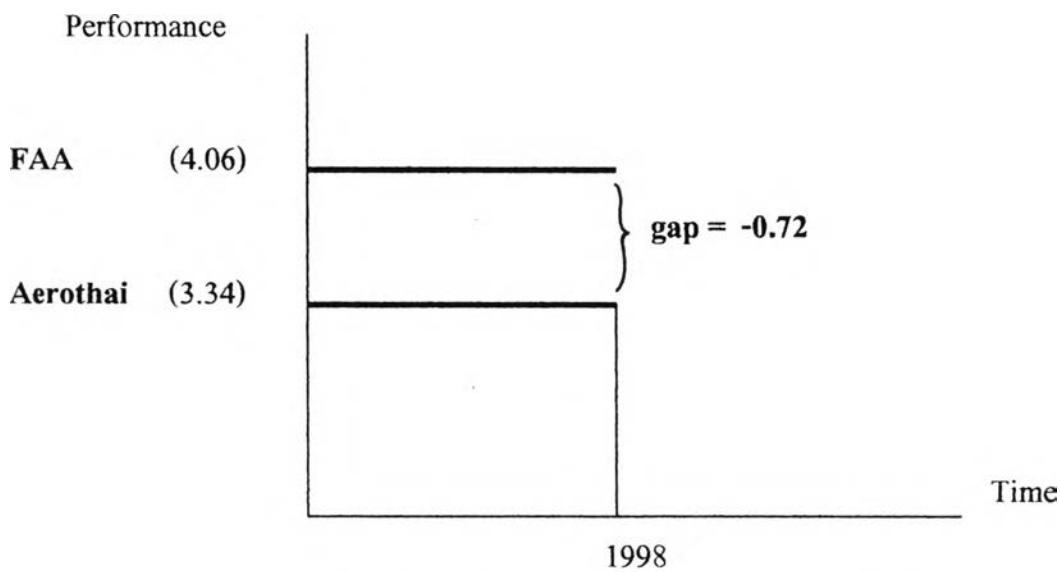


Fig 4.6 The Analysis of Human Operations Performance Gap

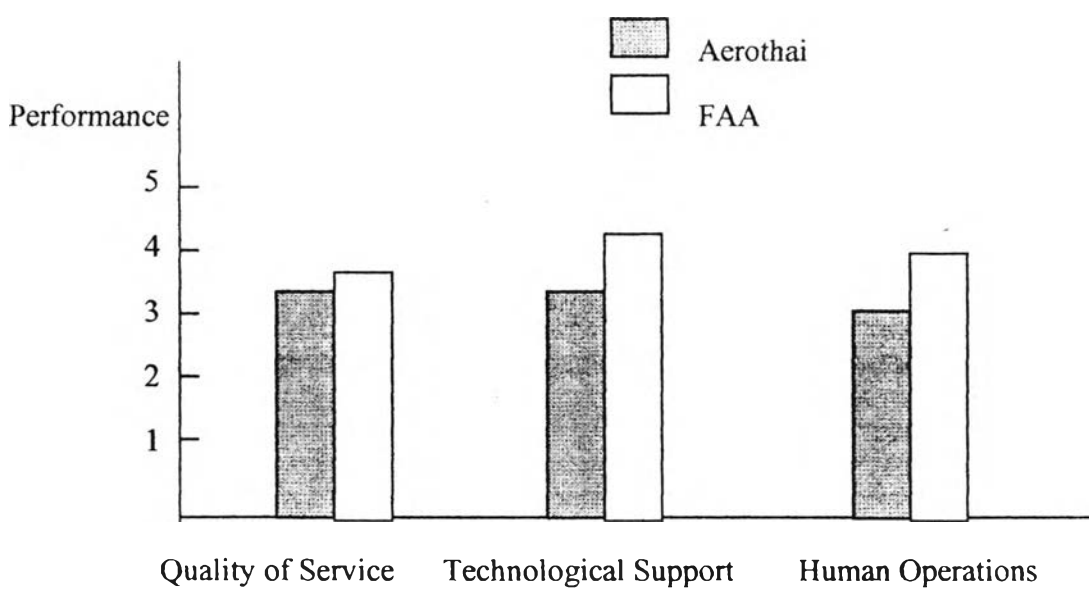


Figure 4.7 Performance Gap Bar-Chart

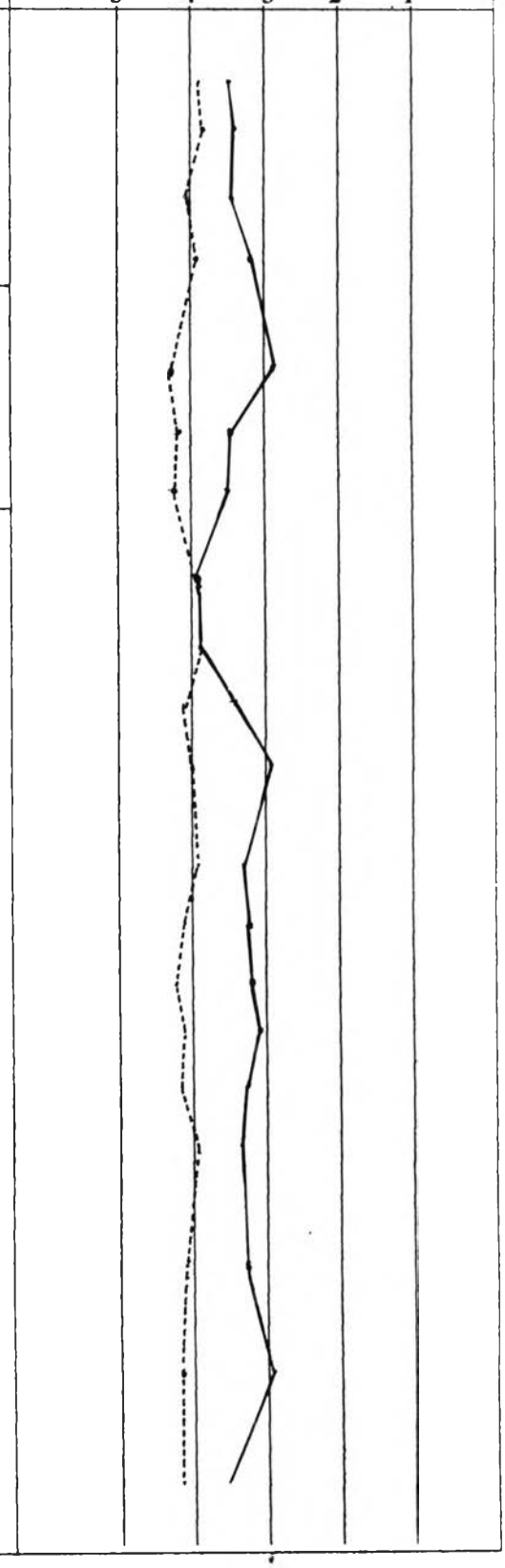
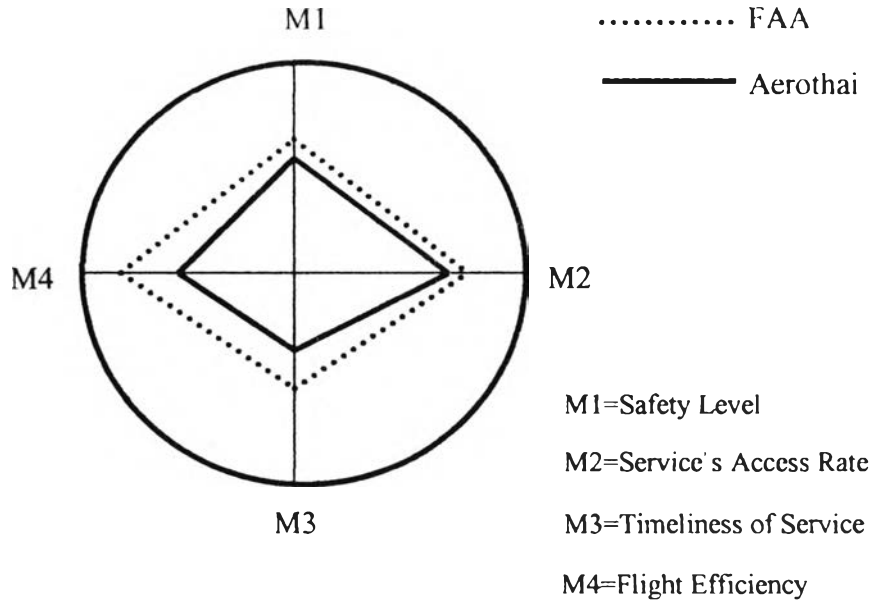
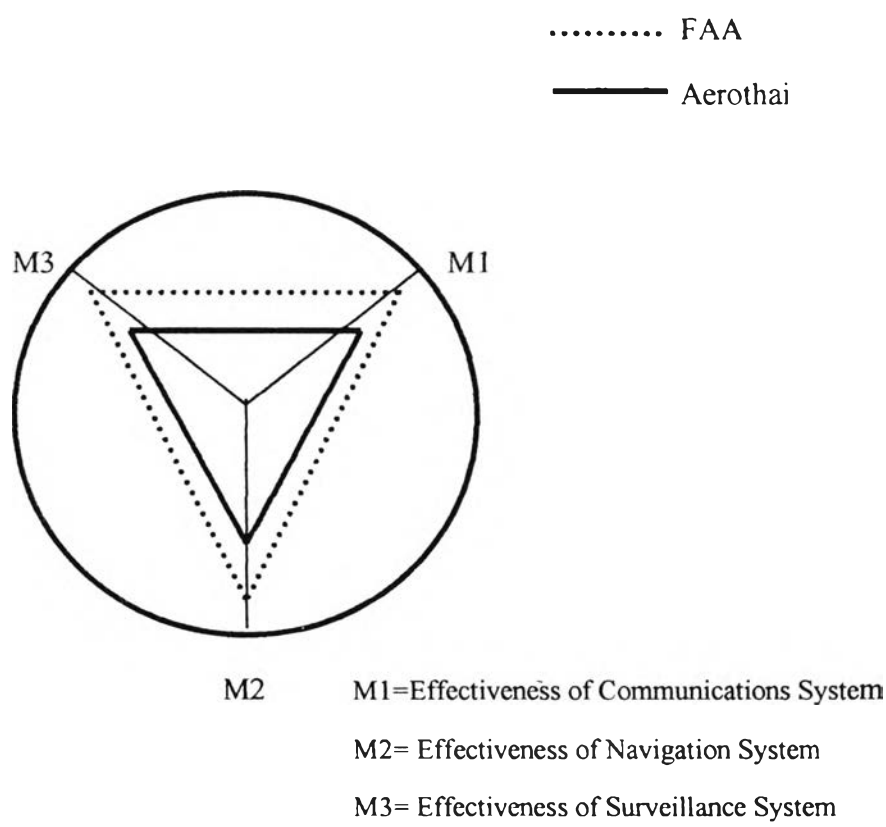
Benchmarking Factors	Performance Level
Quality of Service 1) Safety level 2) Service's access rate 3) Timeliness of service 4) Flight efficiency	
Technological Support Performance 1) Effectiveness of communications system 2) Effectiveness of navigation system 3) Effectiveness of surveillance system	
Human Operations Performance 1) Enthusiasm of service 2)Responsiveness 3)Serviceability 4)Problem solving and decision making in a timely and safe manner 5)Timeliness of service 6)Conflict detection and resolution 7)Situation awareness 8)Ability to gather and process information 9)Ability to cooperate with pilot in a timely and safe manner 10)Ability to control traffic during take off and landing in a satisfactory manner 11)Ability to control traffic during take off and landing in a satisfactory manner under traffic peak period 12)Ability to communicate and operate communications system 13)Ability to pass the services responsibility to other flight information regions	

Figure 4.8 Performance Profile Chart _____ Aerothai

---------- FAA

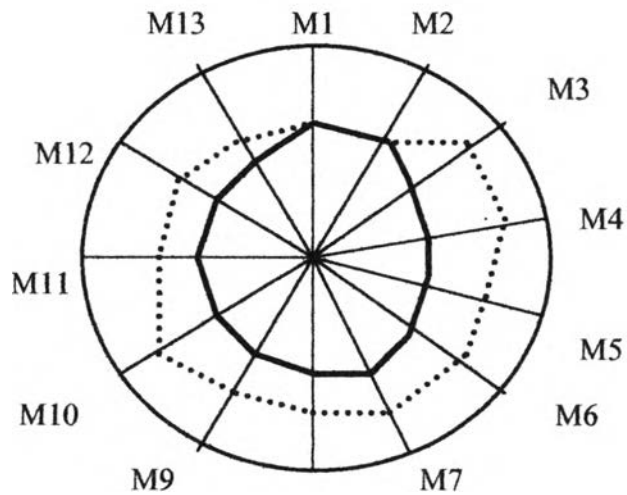


Quality of Service



Technological Support

Fig 4.9 Performance Gap Radar Chart



M1=Enthusiasm of service

M2=Responsiveness

M3=Serviceability

M4=Problem solving and decision making in a timely and safe manner

M5=Timeliness of service

M6=Conflict detection and resolution

M7=Situation awareness

M8=Ability to gather and process

M9=Ability to cooperate with pilots in a timely and safe manner

M10=Ability to control traffic during take off and landing in a satisfactory manner

M 11=Ability to control traffic during take off and landing in a satisfactory manner under traffic peak period

M 12= Ability to communicate and operate communication system

M 13=Ability to pass the service responsibility to other flight information regions

Fig 4.10 Performance Gap Radar Chart (continued)

Analysis and Discussion

Quality of Service

Table 4.12 Quality of Service Gap

Benchmarking Factors	Aerothai	FAA	Gap
Quality of Service			
1) Safety level	3.59	3.88	-0.29
2) Service's access rate	3.43	3.75	-0.32
3) Timeliness of service	3.45	4.04	-0.59
4) Flight efficiency	3.21	3.87	-0.66
Total	3.42	3.88	-0.46

According to Table 4.12

For Aerothai, the four measures of quality of service were addressed: safety level, service's access rate, timeliness of service, and flight efficiency. The performance rating for each measure is 3.59, 3.43, 3.45, and 3.21 respectively. Total performance rating = 3.42 . **For FAA**, The performance rating for each measure is 3.88, 3.75, 4.04, and 3.87 respectively. The total performance rating = 3.88 . All performance gap for each measures indicate negative gap meaning that FAA's performance is superior to Aerothai's performance for all measures. Aerothai should therefore,improve its performance levels for all measures. The best practices that facilitate and drive superior performance for all measures must be learned from the benchmarking analysis.

Table 4.13 indicates the areas that need improvement of quality of service.

Table 4.13 The Areas that Need Improvement of Quality of Service

Benchmarking Factors	Gap	Improvement Needed	Root-Cause Analyze
1) Safely level	Negative	Strongly Needed	Analyze
2) Service's access rate	Negative	Needed	Analyze
3) Timeliness of service	Negative	Strongly Needed	Analyze
4) Flight efficiency	Negative	Strongly Needed	Analyze

Technological Support Performance

Table 4.14 Technological Support Performance Gap

Benchmarking Factors	Aerothai	FAA	Gap
1) Effectiveness of communications system	2.85	4.36	-1.51
2) Effectiveness of surveillance system	3.52	4.16	-0.64
3) Effectiveness of navigation system	3.60	4.35	-0.75
Total	3.32	4.29	-0.97

According to Table 4.14, **for Aerothai,** three measures of technological support performance were addressed: effectiveness of communications, navigation and surveillance system. The performance rating are 2.85, 3.52 and 3.60 respectively

The total performance rating = 3.32

For FAA, the performance rating are 4.36, 4.16 and 4.35 respectively

Total performance rating = 4.29

FAA's performance are superior to Aerothai's performance for all measures of technological support.

All performance gap for each measure indicate negative gap. The largest difference in gap is effectiveness of communications system. Aerothai's performance is less than FAA's performance for all measures of technological support. Aerothai should therefore improve its performance level for all measures, especially communications system.

Table 4.15 indicates the areas that need improvement of technological support.

Table 4.15 The Areas that Need Improvement of Technological Support

Benchmarking Criteria	Gap	Improvement Needed	Root-Cause Analyze
1) Effectiveness of communications system	Negative	Strongly Needed	Analyze
2) Effectiveness of Navigation system	Negative	Needed	Analyze
3) Effectiveness of surveillance system	Negative	Needed	Analyze

Human Operations Performance

Table 4.16 Human Operations Performance Gap

Benchmarking Factors	Aerothai	FAA	Gap
1) Enthusiasm of service	3.85	3.85	0
2) Responsiveness	3.85	3.85	0
3) Serviceability	3.40	4.12	-0.72
4) Problem solving and decision making in a timely and safe manner	2.97	4.00	-1.03
5) Timeliness of service	3.35	3.92	-0.57
6) Conflict detection and resolution	3.31	4.15	-0.84
7) Situation awareness	3.30	4.30	-1.00
8) Ability to gather and process information	3.10	4.12	-1.02
9) Ability to cooperate with pilot in a timely and safe manner	3.36	4.14	-0.78
10) Ability to control traffic during take off and landing in a satisfactory manner	3.41	3.97	-0.56
11) Ability to control traffic during take off and landing in a satisfactory manner under peak traffic period	3.00	4.07	-1.07
12) Ability to communicate and operate communications system	2.98	4.17	-1.19
13) Ability to pass the services responsibility to other flight information regions	3.63	4.18	-0.55
Total	3.34	4.06	-0.72

Human Operation Performance

According to Table 4.16, 13 measures were addressed to measure human operations performance

For Aerothai, the performance ratings for 13 measures are 3.85, 3.85, 3.40, 2.97, 3.35, 3.31, 3.30,3.10, 3.36, 3.41, 3.00, 2.98, and 3.63 respectively.
Total performance rating = 3.34

For FAA, the performance ratings are 3.85, 3.85, 4.12, 4.00, 3.92, 4.15 , 4.30, 4.12, 4.14,3.97,4.07,4.17 and 4.18 respectively. Total performance rating = 4.06. FAA's performance are superior to Aerothai's performance for all measures of human operations except responsiveness and enthusiasm of service. Performance gap for each measure of human operations indicates negative gap.

There are six measures for human operations that represent clear differences in gap. These measures are as follows :

- Problem solving and decision making in a timely and safe manner
- Conflict detection and resolution
- Ability to gather and process information
- Ability to cooperate with pilots in timely and safe manner
- Ability to communicate and operate communications system
- Situation awareness
- Ability to control traffic during landing and take off under traffic peak period in a satisfactory manner

All these measures are the first consideration that Aerothai must concentrate and improve for controller operations.

Table 4.17 indicates the areas that need improvement of human operations

Table 4.17 The Areas that Need Improvement of Human Operations

Benchmarking Factors	Gap	Improvement Needed	Root-Cause Analyze
1) Enthusiasm of service	Parity	No	No
2) Responsiveness	Parity	No	No
3) Service ability	Negative	Needed	Analyze
4) Problem solving and decision marking in a timely and safe manner	Negative	Strongly Needed	Analyze
5) Timeliness of service	Negative	Needed	Analyze
6) Conflict detection and resolution	Negative	Strongly Needed	Analyze
7) Situation awareness	Negative	Strongly Needed	Analyze
8) Ability to gather and process information	Negative	Strongly Needed	Analyze
9) Ability to cooprate with pilot in a timely and safe manner	Negative	Needed	Analyze
10) Ability to control traffic during take off and landing in a satisfactory manner	Negative	Needed	Analyze
11) Ability to control traffic during take off and landing in a satisfactory manner under traffic	Negative	Strongly Needed	Analyze

manner under traffic peak period			
12)Ability to communicate and operate communications system	Negative	Strongly Needed	Analyze
13) Ability to pass the service responsibility to other flight information regions	Negative	Needed	Analyze

4.6.2 Step 8 Determine the Root Cause of Gap

This step is concerned with the answer to the question : " how the differences in performance that exists between Aerothai and FAA can be determined". The research study employs cause & effect diagram and the comparatives analyses of the practices approach to determine its differences in both performance and practices. The information which is based on internal operations of Aerothai and the benchmarked company as FAA's information **(See Step 5 Internal Data Collection and Step 6 External Data Collection)** and the analysis of the key strengths and weakness of both Aerothai and FAA during the internal and external data collection period, can provide insight and key benefits to determine and investigate the root-cause analysis of gap in order to identify the differences both performance and practices.

Figs 4.11 , 4.12 , 4.13 represent the root-cause analysis of Aerothai' s current operations that are based on the information-based on internal assessment and the performance-based outcome on safety , timeliness of services and flight efficiency rated by the customer point of view,(both Aerothai's and FAA's customer).

Figs 4.14 , 4.15 ,4.16 represent the root-cause analysis of FAA's current operations that are based on the information-based on the benchmarking questionnaires , secondary sources and the performance-based outcome on safety , timeliness of service and flight efficiency rated by the customer point of view,(both Aerothai's and FAA's customer) .

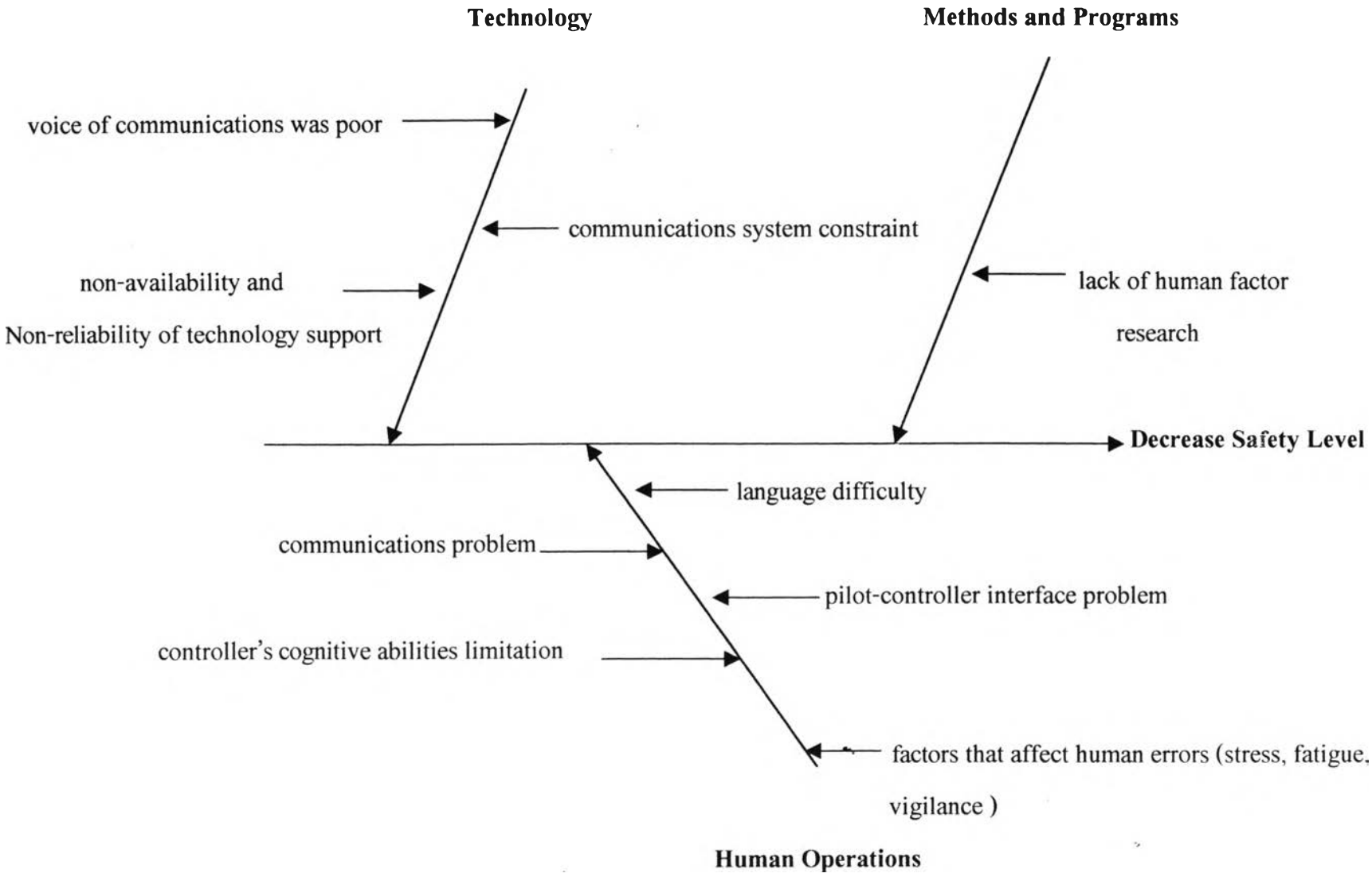


Fig 4.11 Root-Cause Analysis of Safe Operations (Current Practices)

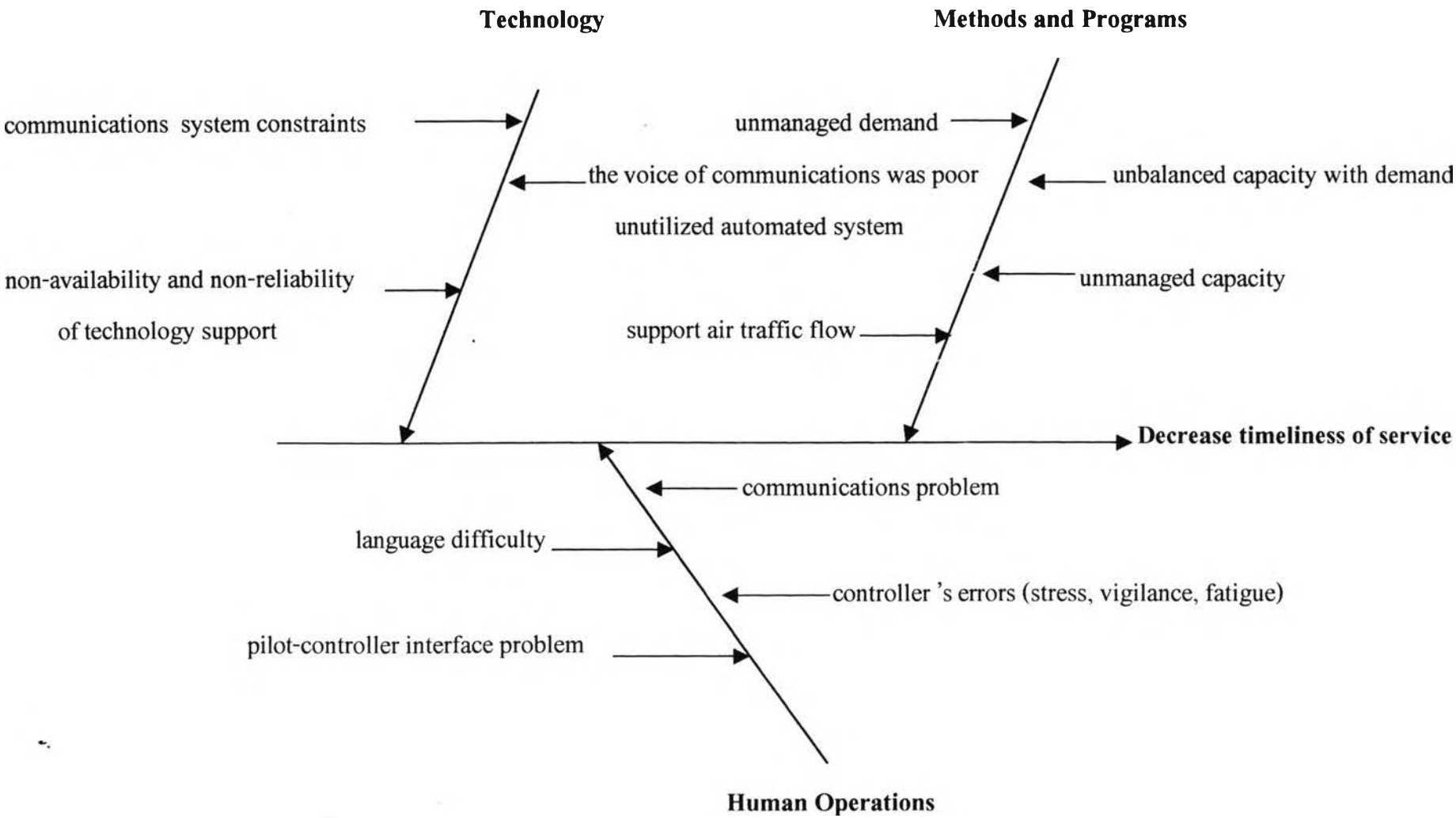


Fig 4.12 Root-Cause Analysis of Timeliness of Service (Current Practices)

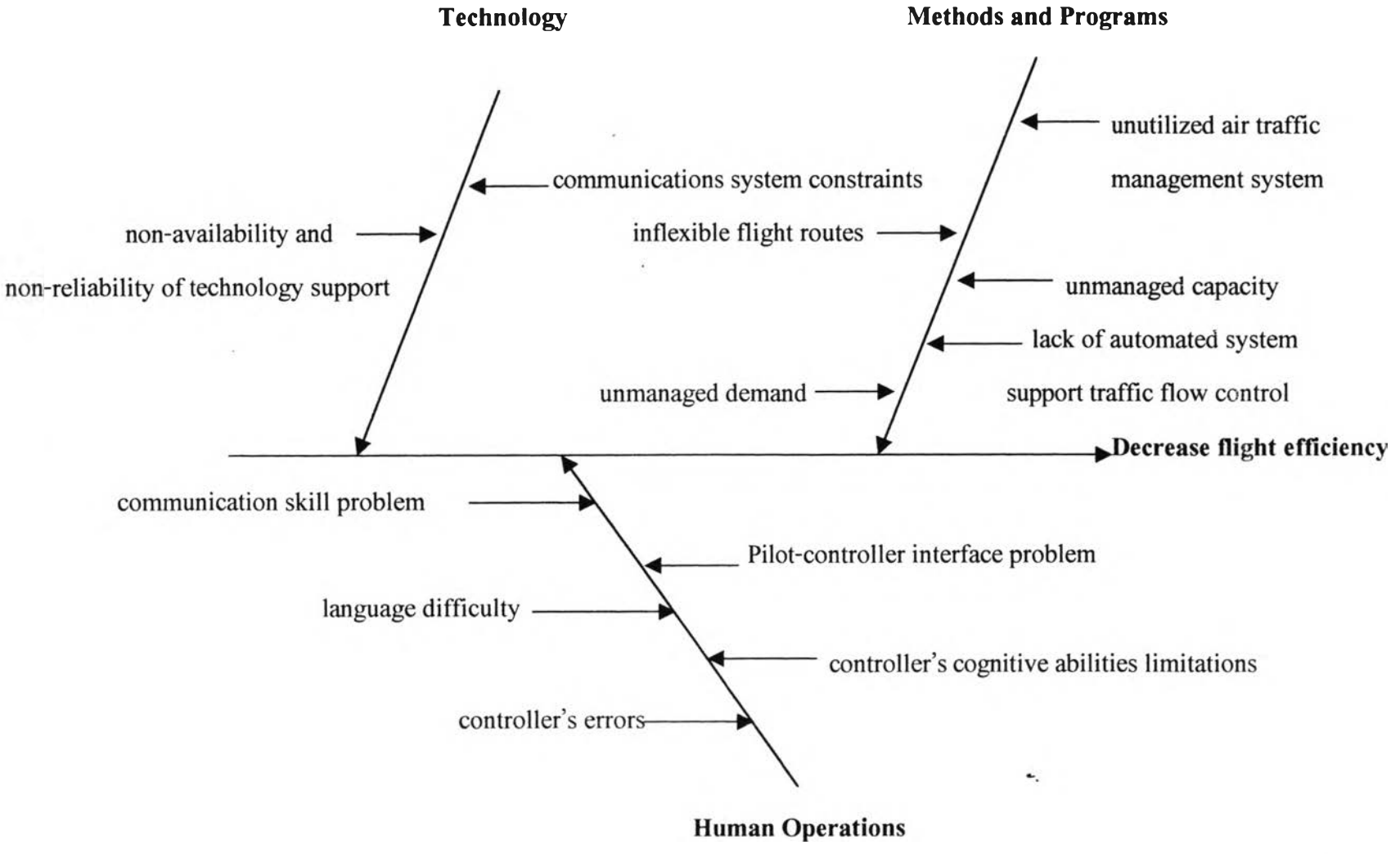


Fig 4.13 Root-Cause Analysis of Flight Efficiency (Current Practices)

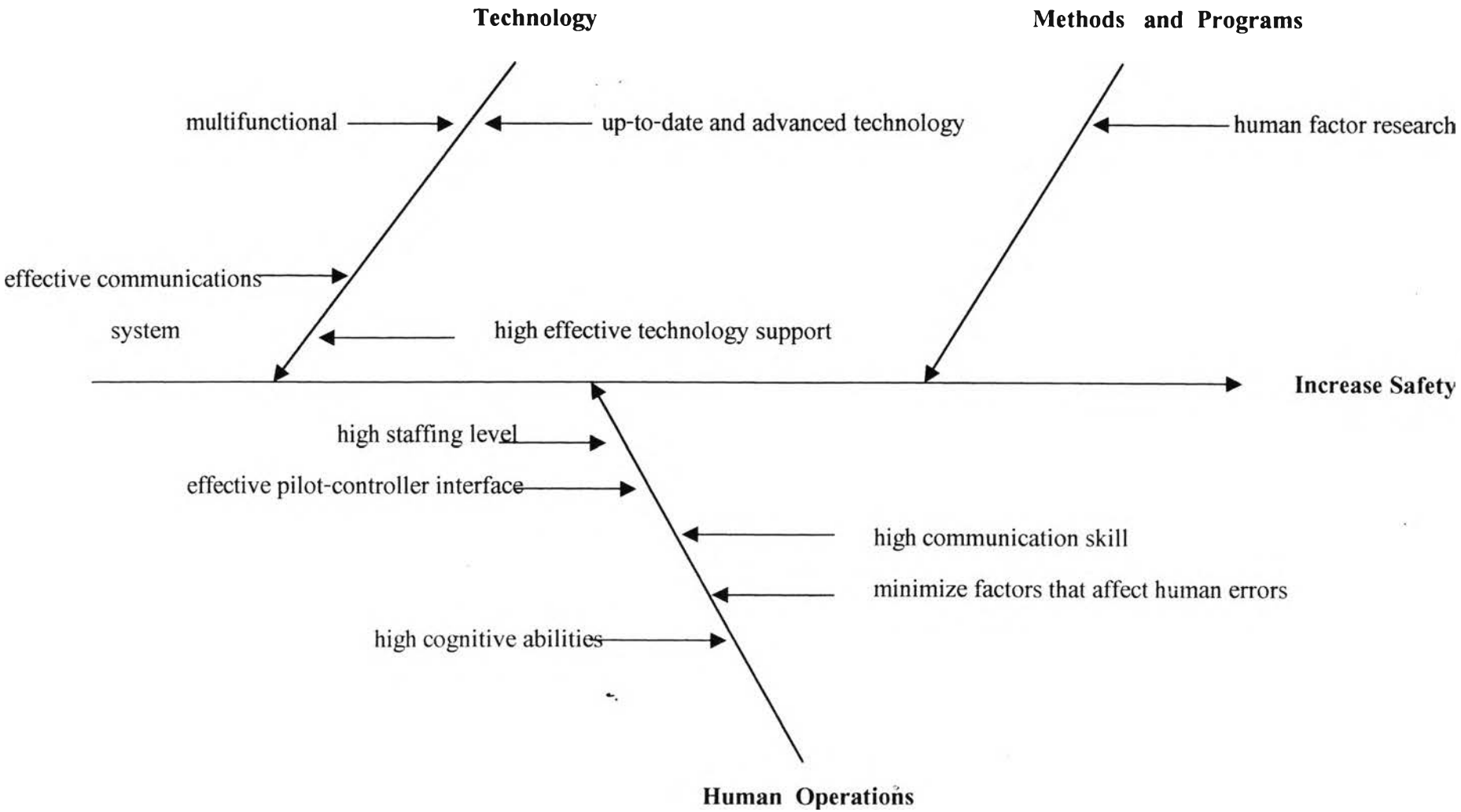


Fig 4.14 Root-Cause Analysis of Safe Operations (Best Practices)

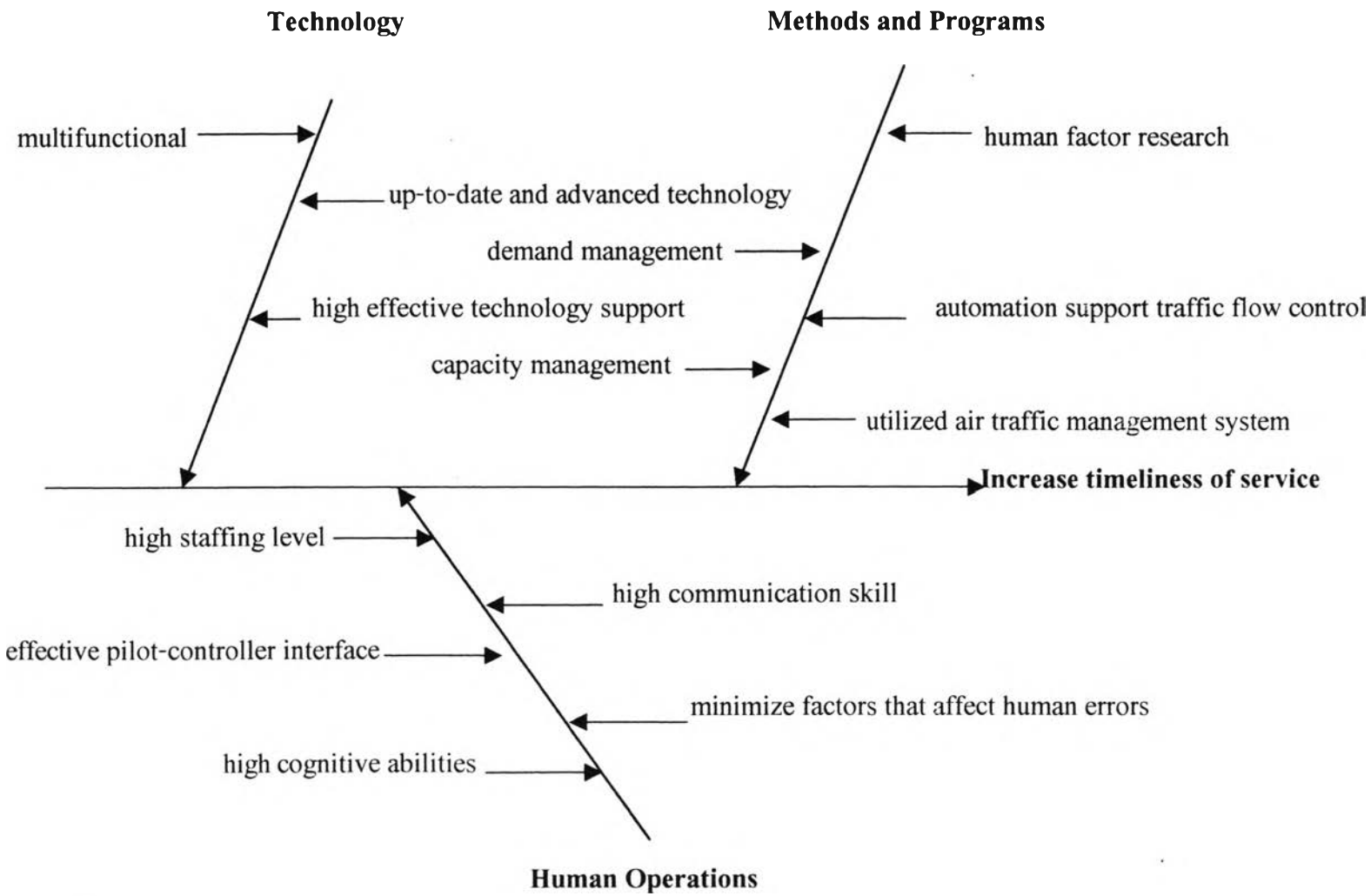


Fig 4.15 Root-Cause Analysis of Timeliness of Service (Best Practices)

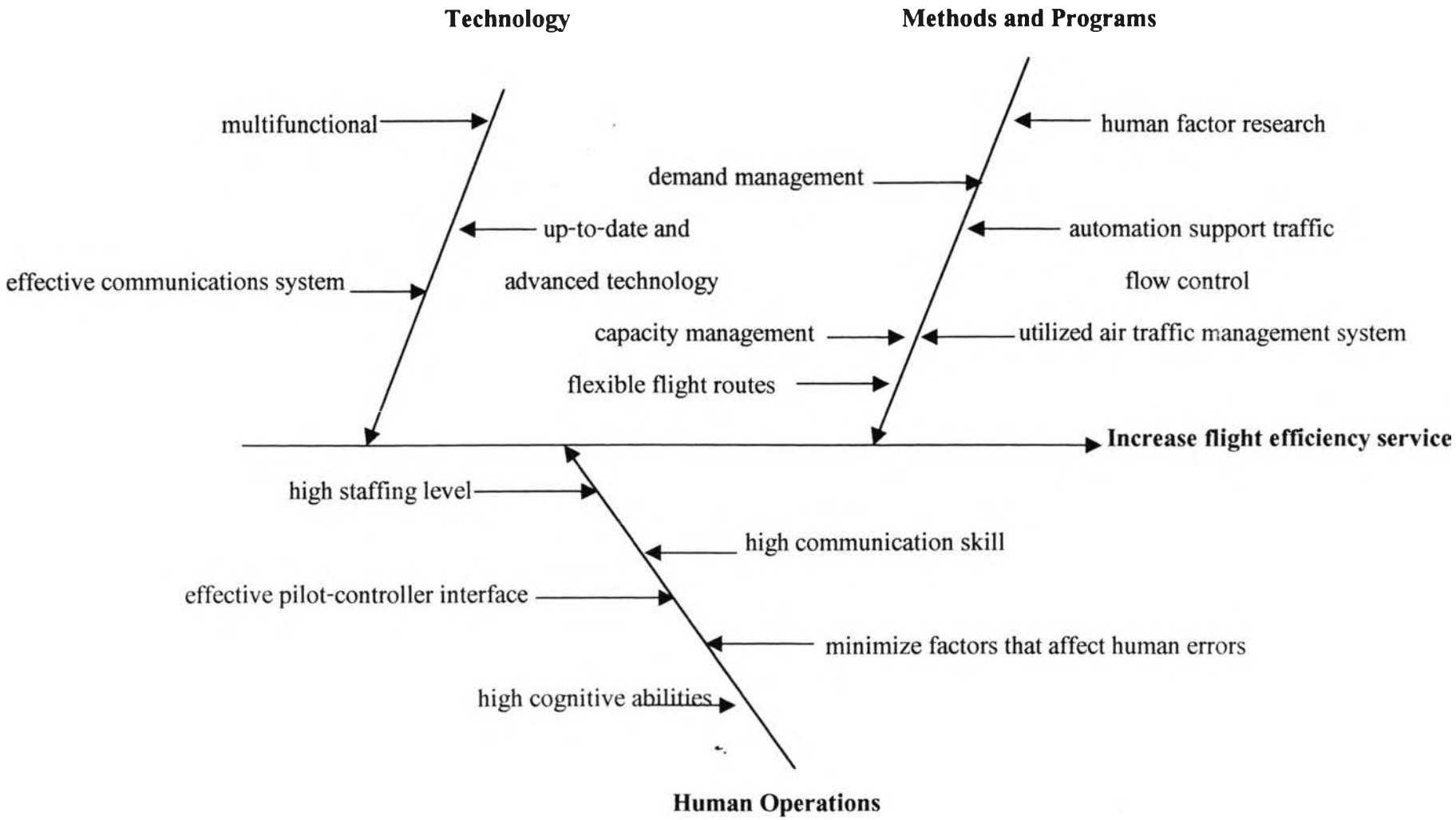


Fig 4.16 Root-Cause Analysis of Flight Efficiency (Best Practices)

Table 4.18 Comparative Analyses of the Practices to Safe Operations

Aerothai	FAA
A few role in human factor research	Human factor research
Safety management system	Safety management system
High level of automation -Flight data processing (FDP) -Radar data processing (RDP)	Automations are widely-used in all Phases of services

Analysis of Practices to Practices Comparison to Safe Operations

Referring to Table 4.18,

-Human factor research provides key benefits to enhance controller performance. The research findings deploys and utilizes a broad areas of human factor activities such as training , selection, human performance assessment, human-system interface and research-based on shift work. These human activities support controller and enhance controller performance to improve safety operations.

-Automations are widely-used in FAA for supporting controller performance and reducing controller's workloads.

Table 4.19 Comparative Analyses of the Practices to Timeliness of Service

Aerothai	FAA
Some high level of automation -Radar data processing (RDP) -Flight data processing (FDP)	Automations are widely-used in all phases of services to support traffic flow control and management
Few role in human factor research	Human factor research
Unutilized air traffic management System -Tactical traffic control	Utilized air traffic management system -Capacity and demand management -Strategic and tactical management

Analysis of Practices to Practices Comparison to Timeliness of Service

Referring to Table 4.19,

-Air traffic management system practice operates as a central flow management to balance system capacity with traffic demand for solving congestion problems both airspace and airport including reducing delays.

-Automated system and automation can be enhanced system capacity to cope with the traffic demand by accommodating more traffic and supporting traffic flow activities.

-Human factor research can be deployed a broad area of human factor activities to utilized controller performance. High controller performance can increase service's capacity.

Table 4.20 Comparative Analyses of the Practices to Flight Efficiency

Aerothai	FAA
- Fixed-route structure -Inflexible flight routes	-Fixed-route structure -User-preferred flight route program 1 Flexible flight routes 2 Cost-effective route
-Unutilized air traffic management -System -Tactical traffic management	Utilized air traffic management system -Capacity and demand management -Strategic and tactical traffic control
Few roles, if any	Automation support traffic flow control and management
Few role in human factor research	Human factor research

Analysis of Practices to Practices Comparison to Flight Efficiency

Referring to Table 4.20,

-Fixed route structure represents constraints for pilots to fly at optimum flight benefits, in terms of economic fuel route and flight time saving. In turn, the user-preferred routes

program can provide the optimum user benefits, in terms of flight efficiency. It provides the cost-effective routes and flexible flight routes to user needs.

-Air traffic management system operates as a central flow management to manage and balance capacity with traffic demand in reducing congestion problems and delays.

Table 4.21 Comparative Analyses of the Practices to Human Operations

Aerothai	FAA
-Implement existing training Training tools as simulation	-Training-based research -Deploy and utilize new training program and integrate into current training environment -Training tools as simulation, computer-based training, team training ,crew resource management and others technology-based training
-Implement existing selection	-Selection-based research -Deploy and utilize new selection program and integrate into current selection environment
-Performance assessment tools such as performance check lists, job performance measurement	-Human performance assessment -Assessment tools such as cognitive task analysis, performance check list, job-performance measurement -human performance assessment-based research
-Few roles, if any	-Human factor research

Analysis of Practices to Practices Comparison to Human Operations

Referring to Table 4.21,

-FAA conducts human factor research-based on selection, training, shift work, human-system interface and human performance assessment. The results of research findings utilize the improvement and development of training, selection, shift work management.

-FAA provides simulation-based training, computer-based training and others technology-based training tools aim at improving controller's cognitive abilities, skill and knowledge.

-The human performance assessment tools can be used as a tool for measuring controller performance and cognitive abilities when performance change and degrade, the assessment tools can be used as a criteria for further training and selection.

-The crew resource management and team training are training tools for improving controller's communication skill among team operations.

Table 4.22 Comparative Analyses of the Practices to Technological Support

Aerothai	FAA
-Some advanced technology is deploying	-Multifunctional -State-of the art technology
-Technology research and acquisition is a new challenge	-Technology research and acquisition is a major role for continuous technology development
-Some projects that joint research effort with industry	-Joint research effort with industry and aviation communities
-Few roles, if any	-Integrate technology development team -Team-focused

The Analysis of Practices to Practices Comparison for Technological Support

Referring to Table 4.22,

-Technology research & acquisition demonstrates the best business practices for optimizing technology development and improvement. Up-to-date and advanced technology support are the key benefits of technology research and acquisition.

-To join research effort with industry and aviation leaders in technology support that will provide the technology improvement in long term benefits for both ATC organizations and airspace users to cope with a challenge of increasing traffic demand.

Analysis and Discussion

According to the performance gap, the differences in gap are defined by root cause analysis.

There are many differences in its performance as follows:

Safe Operations

1 Difference in technology support : Capability, effectiveness

2 Difference in human operations : Cognitive abilities, staffing levels

3 Difference in practices and program support : Human factor research.

Capacity and Efficiency

1 Difference in Technology support : Capability, effectiveness

2 Difference in Human operations : Cognitive abilities, staffing level

3 Difference in practices and program supports : Automations and decision support tools, air traffic management system, Human factor research, user-preferred flight route Program.

FAA utilizes the key practices and programs to support and improve quality of service as follows:

-Automation and decision support tool can enhance services's safety and efficiency

-Air traffic management system and user-preferred flight routes program can enhance service's capacity and efficiency.

-Human factor research can be deployed broad areas of human factor activities utilized which aims at improving controller performance.

Human Operations

1 Difference in staffing level and cognitive capabilities

2 Difference in key practices

FAA utilizes the key practices and program that support and enhance human

FAA utilizes the key practices and program that support and enhance human performance

Human factor research can be utilized broad area of human factor activities deployed that will support and enhance human performance. The key main benefits of human factor research findings are as follows:

-Training improvement and development.

-Selection improvement and development.

Technology Support: Difference in capability and effectiveness

FAA obtains the utilization of technology research & acquisition to deploy and acquire up-to-date, state of the-art technology to replace existing technology. The continuous technology improvement can be effectively utilized.

4.6.3 Step 9 Project Performance in the Future

In order to enhance service performance to meet the customer satisfaction and enhance service delivery, the projected performance requirement(see Table 4.23, Fig 4.17 and Fig 4.18) must be set as the target levels(no differences in performance gap with FAA) for performance improvement needed. By consulting with the Aerothai's experts ,the target levels will be set at 5 years **(see Step 13 set Target Levels and Performance Goals)**. To achieve the target, the action plans **(see Step 14 Develop Action Plans)** are to be developed so as to meet the target levels at 5 years in timescale. Aerothai and FAA's performance levels at current state were collected from the customer satisfaction surveys **(see Appendices D and E).**

Table 4.23 Projected Performance Required

Benchmarking Factors	**Current Performance**	**Current Gap**	**Competitive Performance Required**
Quality of Service			
1) Safety level	3.59	-0.29	3.88
2) Service's access rate	3.43	-0.32	3.75
3) Timeliness of service	3.45	-0.59	4.04
4) Flight efficiency	3.21	-0.66	3.87
Technological Support Performance			
1) Effectiveness of communications system	2.85	-1.51	4.36
2) Effectiveness of navigation system	3.52	-0.64	4.16
3) Effectiveness of surveillance system	3.60	-0.75	4.35
Human Operations Performance			
1) Enthusiasm of service	3.85	0	No
2) Responsiveness	3.85	0	No
3) Serviceability	3.40	-0.72	4.12
4) Problem solving and decision making in a timely and safe manner	2.97	-1.03	4.00
5) Timeliness of service	3.35	-0.57	3.92

6) Conflict detection and resolution	3.31	-0.84	4.15
7) Situation awareness	3.30	-1.00	4.30
8) Ability to gather and process information	3.10	-1.02	4.12
9)Ability to cooperate with pilots in timely and safe manner	3.36	-0.78	4.14
10) Ability to control traffic during take off and landing in a satisfactory manner	3.41	-0.56	3.97
11) Ability to control traffic during take off and landing in a satisfactory manner under traffic peak period	3.00	-1.07	4.07
12) Ability to communicate and operate communications system	2.98	-1.19	4.17
13) Ability to pass the service responsibility to other flight information regions	3.63	-0.55	4.18

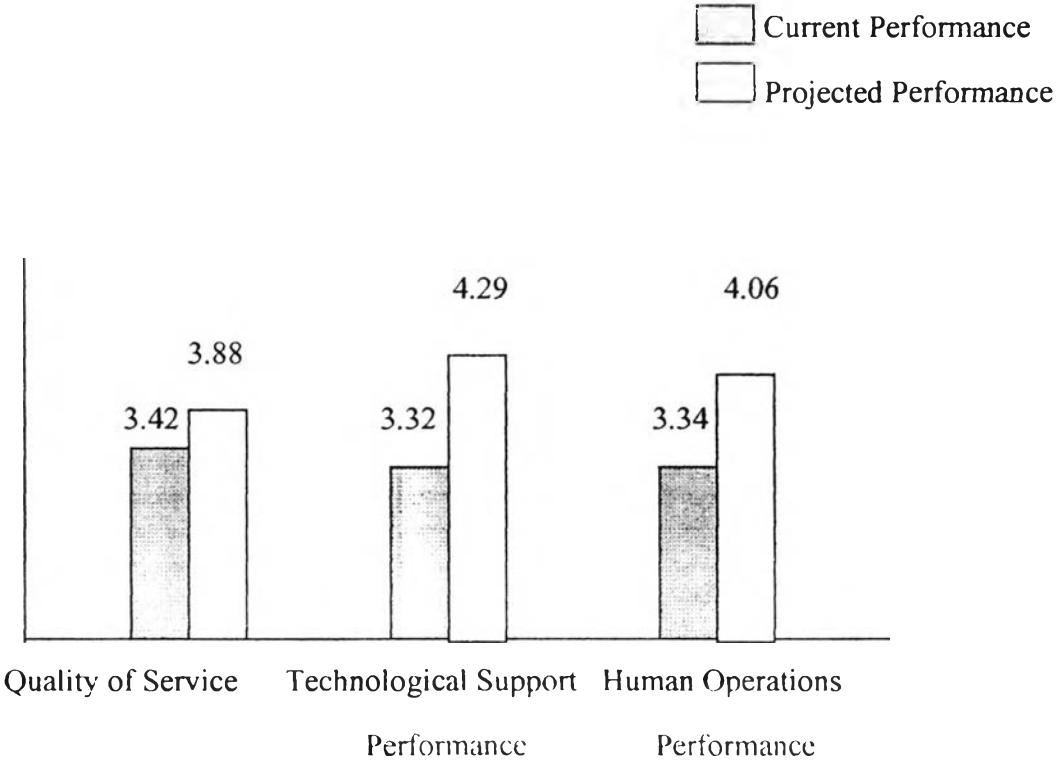


Figure 4.17 Projected Performance Bar-Chart

Benchmarking Factors	Performance Level
Quality of Service	
1) Safety level	
2) Service's access rate	
3) Timeliness of service	
4) Flight efficiency	
Technological Support Performance	
1) Effectiveness of communications system	
2) Effectiveness of navigation system	
3) Effectiveness of surveillance system	
Human Operation Performance	
1) Enthusiasm of service	
2) Responsiveness	
3) Serviceability	
4) Problem solving and decision making in a timely and safe manner	
5) Timeliness of service	
6) Conflict detection and resolution	
7) Situation awareness	
8) Ability to gather and process information	
9) Ability to cooperate with pilot in timely and safe manner	
10) Ability to control traffic during take off and landing in a satisfactory manner	
11) Ability to control traffic during take off and landing in a satisfactory manner under traffic peak period	
12) Ability to communicate and operate communications system	
13) Ability to pass the services responsibility to other flight information regions	

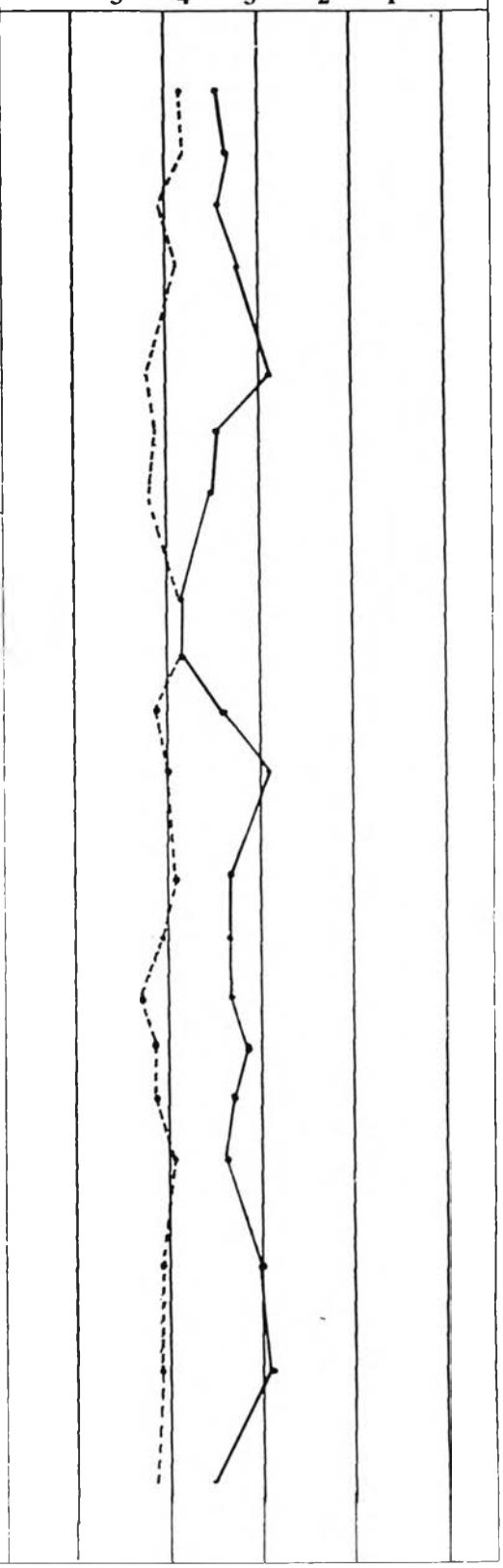


Figure 4.18 Competitive Profile Chart

_____Current Performance

-------Projected Performance

Analysis and Discussion

The Aerothai's ATC performance levels obtained from the customer satisfaction surveys **(see Appendices D and E)** in 1998 will be set at parity levels (no differences in performance gap with FAA) for achievement of projected performance requirement at 5 years **(see Step 9 Project Performance in the Future)** in all benchmarking factors as follows:

1 Quality of Service

2 Technological Support

3 Human Operations

The action plans **(See Step 14 Develop Action Plans)** are to be developed so as to enhance its performance to meet the target levels at 5 years.

Quality of Service

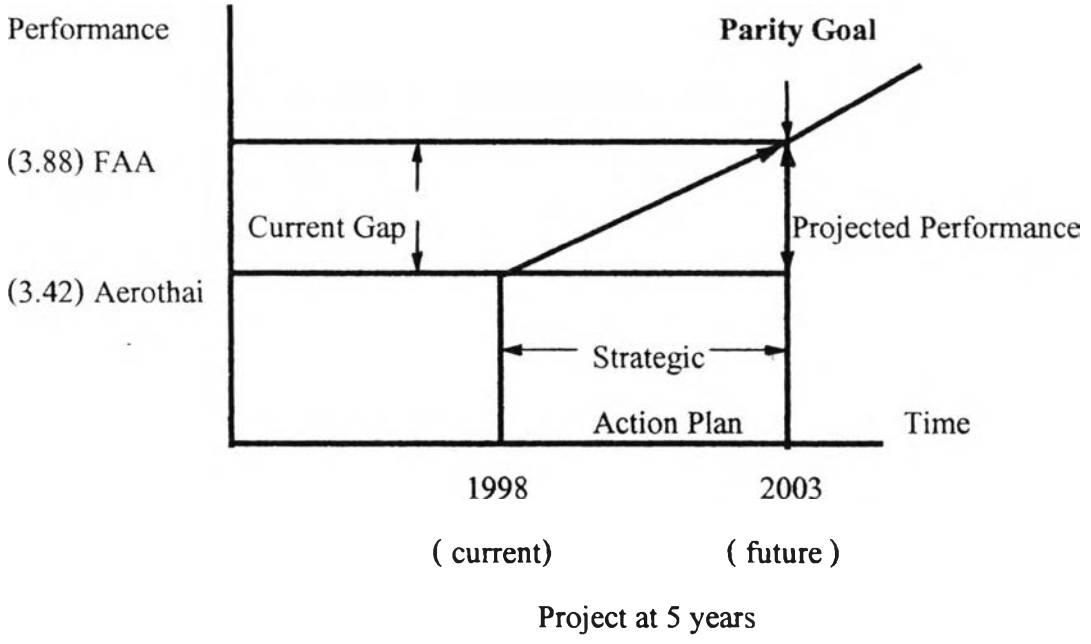


Fig 4.19 Projected Performance for Quality of Service

According to Fig 4.19, the Quality of Service performance of Aerothai = 3.42, assuming the FAA's performance rate remains at current levels . To achieve parity goal at 5 years **(see Step 13 Set Target Levels and Performance Goals)** , the projected performance required to achieve parity goal = 3.88-3.42= 0.46

If the FAA's performance rate increases over time. To achieve parity goal, or closing the gap,the improvement rate of Aerothai must be faster than the improvement rate of FAA.

To achieve the projected performance required,the action plans must be established **(see Step 14 Develop Action Plans).** The plans will operate at 5 years in project timescale.

Technological Support Performance

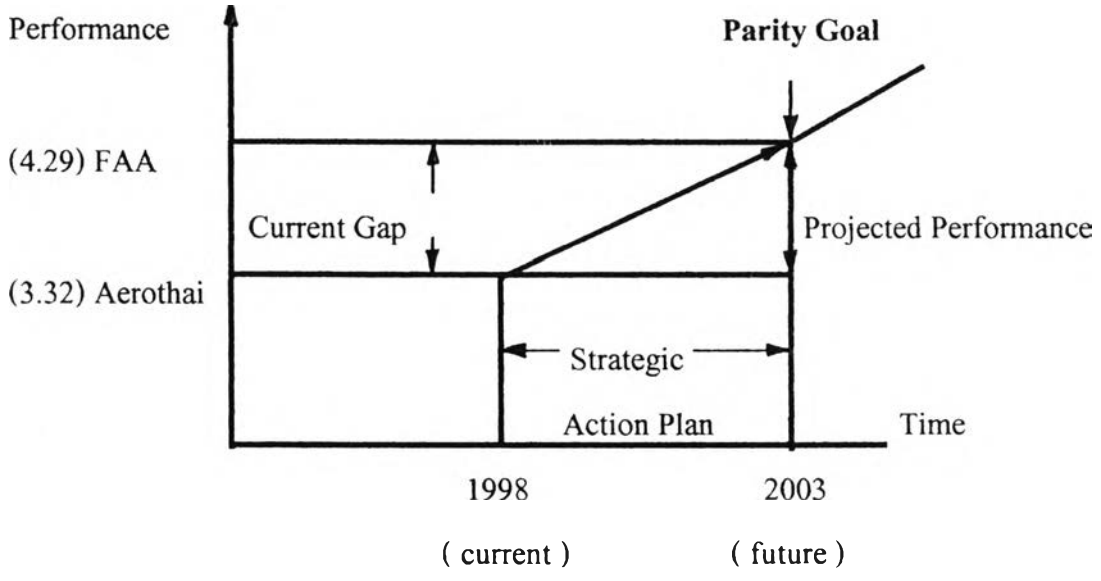


Fig 4.20 Projected Performance for Technological Support

According to Fig 4.20, the technological support performance of Aerothai = 3.32, assuming the FAA's performance rate remains at current levels . To achieve parity goal at 5 years **(see Step 13 Set Target Levels and Performance Goals),** the projected performance required to achieve parity goal = 4.29-3.32 = 0.97

If the FAA's performance rate increases over time. To achieve parity goal, or closing the gap, the improvement rate of Aerothai must be faster than the improvement rate of FAA.

To achieve the projected performance required, the action plans must be established(**see Step 14 Develop Action Plans).** The action plans will operate at 5 years in project timescale.

Human Operations Performance

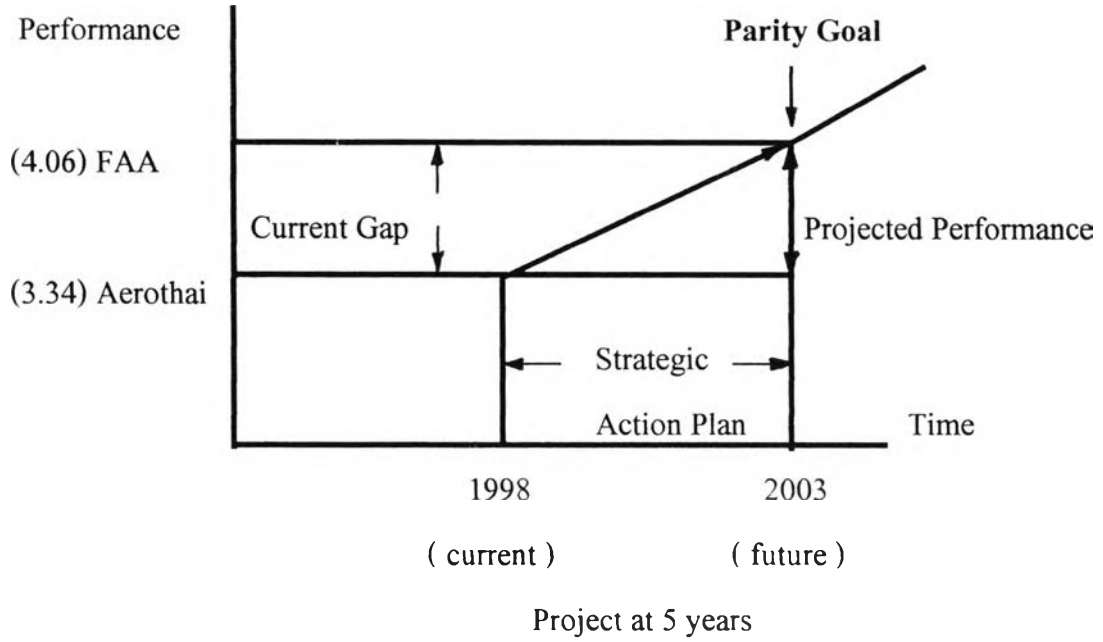


Fig 4.21 Projected Performance for Human Operations

According to Fig 4.21, the Human operations performance of Aerothai = 3.34, assuming the FAA's performance rate remains at current levels . To achieve parity goal at 5 years(**see Step 13 Set Target Levels and Performance Goals),** the projected performance required to achieve parity goal = 4.06-3.34 = 0.72

If the FAA's performance rate increases over time. To achieve parity goal, or closing the gap, the improvement rate of Aerothai must be faster than the improvement rate of FAA.

To achieve the projected performance required, the action plans must be established **(see Step 14 Develop Action Plans).** The action plans will operate at 5 years in project timescale.

4.6.4 Step 10 Determine Key Findings and Lessons Learned

In this step, the examination of the differences in both performance and practices by root-cause analysis of gap **(See Step 8 Determine the Root Cause of Gap)** will explore the key findings and determine the best practices found.

The research study explores the weak points that need improvement and search for the best practices in order to enhance and improve its weak point as shown below in Tables 4.24, 4.25, 4.26, 4.27 and 4.28

Table 4.24 The Best Practices for Safe Operations

Weak Points	Best Practices Found
-Language difficulty -Communication problem	-English language training course -Crew resource management program
-Pilot-controller interface problem	-Crew resource management program
Cognitive abilities limitations -Situation awareness -Conflict detection & resolution -Information processing & gathering -Decision making & problem Solving	-Simulation-based training -Computer-based training (CBT) -Human performance assessment tool -Human factor research
Controller's error -Stress, vigilance, fatigue	-Shift work logic -Shift work management -Work-rest schedules management -Research-based on shift work
-Communications system constraints -The voice of communications system was poor	-Satellite and digital-based communications -Multifunctional technology -Research & acquisition

Table 4.25 The Best Practices for Timeliness of Service

Weak Points	Best Practices Found
-Unbalanced traffic demand with capacity -Unexpected demand exceed capacity -Congestion problems	Air traffic management system -Demand management -Capacity management -Automated system
-Language difficulty -Communication problem	-English language training course -Crew resource management
-Pilot-controller interface problem	-Crew resource management
Controller's cognitive abilities limitations	-Simulation-based training -Computer-based training -Human performance assessment tool -Human factor research
Controller's error -Stress, vigilance, fatigue	-Shift work logic -Shift work management -Work-rest schedules management
-Communications system constraints -The voice of communications system was poor	Satellite and digital-based communications system -Multifunctional technology -Research & acquisition

Table 4.26 The Best Practices for Flight Efficiency

Weak Points	Best practices Found
-Inflexible flight routes	-User-preferred flight routes program -Flexible flight routes
-Unbalanced traffic demand with capacity -Congestion problem	Air traffic management system -Demand management -Capacity management
-Language difficulty -Communication problem	-English language training course -Crew resource management
-Pilot-controller interface problem	-Crew resource management -Team training
Controller's cognitive abilities limitations	-Simulation-based training -Computer-based training -Human performance assessment tool -Human factor research
Controller's error -Stress, vigilance, fatigue	-Shift work logic -Shift work management -Work-rest schedules management
-Communications system constraints -The voice of communication system was poor	-Satellite and digital-based communications -Multifunction technology -Research & acquisition

Table 4.27 The Best Practices for Human Operations

Weak Points	Best Practices Found
-Language difficulty -Communication problem	-English language training program -Crew resource management program
-Pilot-controller interface problem	-Crew resource management -Team training
Cognitive abilities limitations -Situation awareness -Conflict detection and resolution -Information processing and gathering -Decision making and problem solving	-Simulation-based training -Computer-based training (CBT) -Human performance assessment -Human factor research
Controller's errors -Stress -Vigilance -Fatigue	-Shift work management -Work-rest management -Research-based on shift work
-Communications system constraints -The voice of communications was poor -Non-availability and non- reliability of other current technology support	-Satellite and digital-based communications system -Multifunctional technology -Research & acquisition
-Existing training program -Training constraints can not support the change of human operation's environment	-Human factor research-based on training -Continuous development and improvement of training
-Existing selection program -Selection constraints can not support the change of human operation's environment	-Human factor research-based on selection -Continuous development and improvement of selection

Table 4.28 The Best Practices for Technological Support

Weak Points	Best Practices Found
-Communications system constraints -The voice of communications system was poor -Non-availability and non-reliability of communications system	-Satellite and digital-based communications system -Multifunction communications system -Research and acquisition
-Non-availability and non-reliability of other technology support control; navigation system and surveillance system	-Satellite and digital-based technology support -Multifunctional technology -Research and acquisition

Analysis and Discussion

Safe Operations

1 The human factor research in FAA demonstrates the best practices for optimizing controller performance to improve safety in its operations. The results of research findings can be deployed and utilized a broad area of human factor activities.

2 The effective training tools such as simulation-based training, computer-based training aim at improving controller's cognitive abilities, skill and knowledge.

3 The controller skill among team operations such as pilot-controller, controller-controller is a critical task that impacts on safety. Crew resource management and team training are powerful training tools that improve communication skills among team operations.

4 Human factor in air traffic control services is the most important role that leads to accidents in aviation system. In order to increase service's safety, human operation's

role in services operations must be optimized. Human performance must be enhanced and human errors must be eliminated.

5 Automation and decision support tool extensively implemented in all phases of control services in FAA to improve human performance, support controller's tasks and reduce human errors in order to enhance service's safety.

6 The air traffic control technology is one of the key primary factors that support services operations. Air traffic control technology can affect service's safety. The technology must be continuously improved and upgraded in order to reduce the shortcomings and limitations of current technology and ensure that the effective technology support will maintain and the service's safety will increase.

Timeliness of Service and Flight Efficiency

1. The implementation of air traffic management system in U.S.A. airspace is showing a real practical benefits of the utilization of service's capacity to meet the changing needs of traffic demand. Air traffic management system manages and balances existing service's capacity with traffic demand, manage effective flow of traffic and reduce congestion problem both airport and airspace as well as delays will be eliminated.

2. In order to meet user needs, in terms of flight efficient operations, the flexibility of flight, more direct routes and user-preferred flight routes must be provided. The user-preferred flight routes program in FAA indicates the best practices to provide services delivery to user's efficient operations achievement. These results can be saved the user's flight paths and time.

3. The implementation of various automations and decision support tools in all phases of services in U.S. airspace system show the best practices and real benefits improvement for achieving not only service's safety but also service's capacity. It provides numerous benefits improvement to service providers such as accommodating more traffic, improving service's productivity and human performance.

4. Air traffic control services in Aerothai's environment lack automation and decision support tools that support and assist air traffic control operations such as the management of traffic flow. The service's capacity is constrained by the controller's capabilities and limitations, high controller's workloads and high traffic loads.

5. The human operations in air traffic control services affect not only service's safety but also service's capacity. The high level of human performance can enhance service's capacity.

6.The current air traffic control technology is faced with many problems, the shortcomings and limitations of current technology cannot cope with the increasing traffic demand for both current and future needs. In order to meet traffic demand and improve service's capacity, the air traffic control technology support, in terms of communications, navigation and surveillance system must be upgraded and improved.

Air Traffic Control Technology

1. Air traffic control technology is a part of the success of air traffic control services of safety, capacity and efficient operations for both current and future challenge needs. In order to meet the customers and aviation communities benefits through system services improvement. the air traffic control technology must be continuously improved, upgraded and modernized over time. The shortcomings and constraints of its current technology, that are the major problems for safe, capacity and efficient operations of air traffic control services, must be eliminated.

2. Research and acquisition in technology is vital for air traffic services organizations in developing, acquiring and join research efforts for the modernizing new and advanced technology to improve system services.

3. In order to obtain the optimum user benefits, it is necessary to understand customer's needs, integrate customer information into and let the customer participate in the technology acquisition process to ensure that the acquiring new technology not only improves system services but also meets the customer needs.

4 Collaborate and communicating with aviation communities to develop, modernize and verify technology improvement.

The current air traffic control technology is a ground-based technology that is faced with many shortcomings and limitations of its technology. These problems mean that the current technology cannot cope with the increasing traffic demand for both current and future needs. The modernization of air traffic control technology at FAA demonstrates the technology improvement needed in order to eliminate the limitations of current technology by replacing new and advanced technology. The technology modernization aims at improving safety and capacity of system services by minimizing current technology's limitations.

Human Operations

1. Language difficulty, communications problem and pilot-controller interface are the critical problems for human operation. Team training, crew resource management are the practices that enhance communication skill and improve pilot-controller interface.
2. Simulation-based training and computer-based training are effective tools for improving controller's cognitive abilities including skills and knowledge.
3. Some factors such as stress, vigilance and fatigue cause human errors and degrade human performance. The shift work management, work-rest schedule management are the practices that overcome these problems.
4. FAA focuses on human factor, which is part of its success in aviation system. Human errors can lead to accidents and incidents of aviation system. Human factor research at FAA focuses on human factor standpoint aims at alleviating human errors and increasing human performance. The human performance-based research information related to human errors, human degradation, accidents will be gathered and analyzed. This information is then used to training and selection, human-automation interface design, human performance assessment.

5. The implementation of various automations and decision support tools in FAA demonstrates a good example of providing for realistic benefits improvement for controller's tasks such as managing, supporting cognitive tasks, increasing human performance and reducing human errors .
6. Aerothai lacks human factor-based research support in deploying and utilizing human factor activities. Controllers have little role in areas of human factor research. Aerothai lacks training & selection-based research to identify additional and suitable training & selection needed for controllers and human performance assessment for measuring performance outcome and performance change. The lack of human factor-based research mean that potentially useful information can not be utilized. The innovative best practices for human performance improvement cannot be developed.
7. Automations and decision support tools have little role for supporting controller's tasks in Aerothai's current environment. The air traffic control operations depend heavily upon the cognitive abilities of each controllers. The abilities and limitations of each controllers have an impact on safety, capacity and efficient operations.
8. In order to maintain high staffing levels, the training & selection programs should provide and support at all levels. FAA addresses training & selection-based research to continuously developed training program for enhancing controller performance. The selection criteria. methods and programs will select the right personnel to perform the right tasks.
9. FAA addresses human performance assessment to measure and evaluate human performance change on automation, equipment, procedures, training and selection to ensure that new automation, equipment, procedures and training can enhance human performance and human errors can be detected and eliminated.

4.7 Improving Phase

4.7.1 Step 11 Adopt and Modify Best Practices

The results of benchmarking study explores the key findings and best practices found. **(See Step 10 Determine the Key Finding and Lessons Learned)** The application and adoption of key best practices can be established as the opportunities for improvement.

The benchmarking results will bring the approach to develop, adopt and modify best practices found and key findings into Aerothai's environment and set as the opportunities for Aerothai's performance improvement.

Tables 4.29, 4.30, 4.31, 4.32 and 4.33 present the opportunities for improvement as follows:

Table 4.29 The Opportunities for Improvement of Safe Operations

Weak Points	Improvement Needed (Benchmarked)	New Changes
-Language difficulty -Communication problem	-Improve controller's communication skill and reduce language difficulty	-English language training course -Crew resource management
-Pilot-controller interface problem	-Eliminate pilot-controller interface problem	-Crew resource management -Team training -Human factor research
-Controller's cognitive abilities limitations	-Enhance controller's cognitive abilities	-Simulation-based training -Computer-based training -Human performance assessment tool -Human factor research

-Controller's error Stress, vigilance, fatigue	-Reduce controller's error -Eliminate the factors that cause human error and degrade performance	-Shift work management -Work-rest schedules management
-Communications system constraints -The voice of communications system was poor	-Improve and upgrade current communications system	-Satellite and digital-based communications system -Research & acquisition

Table 4.30 The Opportunities for Improvement of Timeliness of Service

Weak Points	Improvement Needed (Benchmarked)	New Changes
-Unbalanced traffic demand with capacity -Unexpected demand exceed capacity -Congestion problem	-Balance traffic demand with capacity	Air traffic management -Demand management -Capacity management
-Language difficulty -Communications problem	-Improve controller controller's communication skill and reduce language difficulty	-English language training -Crew resource management
-Pilot-controller interface problem	-Eliminate pilot-controller interface problem	-Crew resource management -Team training -Human factor research
-Controller's cognitive	-Reduce controller	-Simulation-based training

abilities limitations	controller's error -Eliminate the factors that cause human error and degrade performance	-Computer-based training -Human performance assessment -Human factor research
Controller's error -Stress, vigilance, fatigue	-Enhance controller's cognitive abilities	-Shift work management -Work-rest schedules management -Research-based on shift work
-Communications system constraints -The voice of communications system was poor	-Improve and upgrade current communications system	-Satellite and digital-based communications system -Research & acquisition

Table 4.31 The Opportunities for Improvement of Flight Efficiency

Weak Points	Improvement Needed (Benchmarked)	New Changes
-Inflexible flight routes	-Flexible flight routes -Dynamic routings	-User-preferred flight routes program
-Unbalanced traffic demand with capacity -Unexpected demand exceed capacity -Congestion problem	-Balance traffic demand with capacity	Air traffic management system -Capacity management -Demand management
-Language difficulty -Communications problem	-Improve controller's communications skill and reduce language difficulty	-English language training course -Crew resource management

-Pilot-controller interface problem	-Eliminate pilot-controller interface problem	-Crew resource management -Team training -Human factor research
-Controller's cognitive abilities limitations	-Enhance controller's cognitive abilities	-Simulator-based training -Computer-based training -human performance assessment -Human factor research
-Controller's error -Stress, vigilance, fatigue	-Reduce controller's error -Eliminate the factors that cause human error and degrade performance	-Shift work management -Work-rest schedules management -Research-based on shift work
-Communications system constraints -The voice of communications system was poor	-Improve and upgrade current communications system	-Satellite and digital-based communications system -Multifunctional technology -Research & acquisition

Table 4.32 The Opportunities for Improvement of Human Operations

Weak Points	Improvement Needed (Benchmarked)	New Changes
-Language difficulty -Communication problem	-Improve controller's communication skill and reduce language difficulty	-English language training -Crew resource management -Human factor research
-Pilot-Controller interface problem	-Eliminate Pilot-Controller interface problem	-Crew resource management -Team training -Human factor research
-Controller's cognitive abilities constraints	-Enhance controller's cognitive abilities, knowledge and skill	-Simulation-based training -Computer-based training -Human performance assessment tools -human factor research
-Controller's error vigilance, stress, fatigue	-Reduce controller's error -Eliminate the factors that cause error and degrade performance	-Shift work management Work-rest schedules management -Research-based on shift work
-Existing training -Training constraints while human environment changes	-Improve training program	-Training-based research -Acquiring and developing training program
-Existing selection -Selection constraints while human environment changes	-Improve selection methods , programs	-Selection-based research on selection -Acquiring and developing selection program

Table 4.33 The Opportunities for Improvement of Technological Support

Weak Points	Improvement Needed (Benchmarked)	New Changes
-Current communications system constraints -The quality of voice of communications system was poor. -Unreliability and unavailability of communications system.	-Improve, upgrade and modernize communications system -High effective communications system	-Satellite and digital-based communications system -Multifunctional -Research and acquisition
-Unreliability and unavailability of current technology support.	-Improve, upgrade and modernize current others technology support	-Satellite-based technology support -Research and acquisition

Analysis and Discussion

The research study sets the opportunities for improvement that can be divided into three domains as follows :

1 Quality of Service

2 Air traffic Control Technology

3 Air traffic Control Human Operations

Domain1 Quality of Service

Safety Level

1.The controller's communication skill should be improved and the language difficulty must be eliminated. Aerothai should develop and provide English training course

for all staffs. The English training tool should be provided as a self-training tool in addition to classroom facilities.

2. The pilot-controller interface problem must be eliminated. The communication skill among team operations such as pilot-controller including controller-controller should be improved. Aerothai should develop and provide the crew resource management and team training program to solve these problem.

3.The controller's cognitive abilities limitations in current environment must be eliminated. Aerothai should improve the controller's cognitive skill. These cognitive skills are as follows:

-Situation awareness

-Conflict detection and resolution

-Information processing and gathering

-Problem solving and decision making

Including knowledge and skills

To achieve these improvement,

- Aerothai should provide training tools such as simulation-based training, computer-based training for all staffs at all operational levels. These tools should be both field training and self-training tool.

- Aerothai should develop human performance assessment tools, models and methods to measure the controller performance and cognitive abilities to ensure that the controller's cognitive abilities and skill and knowledge can maintain at maximum levels. If there is any performance degradation and deviation, human performance assessment can be used as criteria for training or selection to effect change. The assessment tools are controller performance measurement, performance checklist, cognitive task analysis and job-task analysis.

4. Aerothai should focus on the factors that cause controller error and degrade performance. Some factors such as stress, fatigue, vigilance, sleep-loss that impact on controller must be eliminated. Aerothai should focus on the shift work , work-rest schedules that impact on these factors. To solve these problem,

- Aerothai should conduct research-based on shift work, work-rest schedules with the experts to develop the shift work management practices to the best solutions in long term benefit.

5. Aerothai should focus on human factor in air traffic control services operations. Human operations can contribute to the success or failure of its services. Human errors and degradation can cause accidents and incidents in aviation system. The human operations should be considered as the first priority for improvement. The optimization of human performance and minimization of human errors should be met. A broad area of human factor activities should be occurred in Aerothai's environment. The human factor research should be supported at all human factor activities in Aerothai. The research findings should be employed to benefits of human performance improvement.

6. Aerothai should focus on air traffic control technology in service operations. The technology support in its operations must be continuously improved, upgraded with up-to-date and advanced technology in order to minimize the shortcomings and constraints of its current technology that affect safe operations. In order to meet the challenge of increasing service's safety, all the activities concerned with the technology improvement must be employed.

- The research and technology acquisitions in Aerothai should support technology improvement and development. The research findings should be effectively utilized and a realistic technology improvement deployed.

- Collaborating and coordinating with industry and aviation communities in joint research efforts should be encouraged in order to achieve common benefits.

- All Aerothai's employee should be involved in technology acquisition process.

Service's Capacity and Efficiency

The service's capacity and efficiency will include the key primary operational success factors of the air traffic control operations areas follows :

Service's access rate : The ability of users to access the system services and obtain the services on their demands.

Timeliness of services : Expeditious, timely manner, minimize delays, effective flow of traffic.

Flight efficiency : The services manner in which to provide services delivery to user's achievement of efficient operations in terms of fuel saving, time saving.

The opportunities for improvement of service's capacity and efficiency are as follows:

1. Aerothai should establish the air traffic management system as a center for management of air traffic flow throughout Thailand airspace and its territory. The air traffic management system that should be set up to accomplish the objectives consists of the following:

-Manage and balance service's capacity with traffic demand.

-Predict traffic situation in advance both airspace and airport and reduce the barriers for the flow of traffic pass through the nations in South-East Asia region in sharing airspace value.

- Improve airspace utilization.

- Improve effective flow of traffic, reduce delays both airspace and airport.

2. Aerothai should establish Thailand as a central flow management unit connect to each flow management unit and major airport in each countries to manage flow of traffic throughout South-East Asia region.

3. Aerothai should coordinate and cooperate with the air traffic service organizations among South-East Asia region to join conceptual agreement to achieve common of benefits in this region.

4. Aerothai should develop user-preferred flight routes in order to provide services delivery to accomplish the optimum user benefits in terms of flight efficiency. The user-preferred flight routes should optimize the flight efficiency, in terms of flexible flight routes, more direct routes and fuel efficient routes. Aerothai should reserve the available flight routes and address its flight routes to published user-preferred flight routes. This is allow the pilot to fly as required by pilot's intentions to achieve the optimum flight profiles and efficient flight routes.

5. Aerothai should redesign the specific airspace support for the published user-preferred flight routes.

6. Aerothai should appropriately use automation and decision support tools to support and assist the traffic flow management and flow control. The automated system should be facilitated at Bangkok International Airport and Area Control Center where traffic demand exceed or will exceed system capacity. Aerothai should develop automation plan to guide and support the implementation of automation. The plan should cover guidelines, training, selection, human-automation interface design, automated-performance assessment and research support human-automation interface to ensure that a new challenge of automation will be matched with the human's capabilities and limitations.

7. Aerothai should focus on human factor in air traffic control services. The human factor is a part of the service's success that is not contributed to only service's safety but also service's capacity. The improvement of human performance can improve system service performance in terms of safety ,capacity and efficiency. All the human factor activities associated with the improvement of human performance affecting service's capacity should be created in Aerothai's environment. Aerothai should focus on the main human factor issues as follows :

-The human factor research should support all human factor activities in Aerothai. The research findings should be utilized and deployed human performance improvement. A broad area of human factor research should be conducted such as training & selection, and human-automation interface. To support human factor-based research, the human performance based information should be gathered and analyzed.

Domain 2 Technological Support

Aerothai should conduct as follows:

1. Aerothai should improve, upgrade and modernize existing ground-based air traffic control technology in terms of communications, navigation and surveillance system that have many constraints and shortcomings and cannot cope with the increasing traffic

demand. The replacement of existing ground-based technology with satellite-based technology should be conducted.

2. Aerothai should continuously improved its air traffic control technology with up-to-date and advanced technology. The acquiring of new technology should be developed for replacing its existing technology. The technology research & acquisition should be made and effectively utilized its technology support developed. The research & acquisition should cover a broad area of communications, navigation and surveillance system.

3. Aerothai should conduct joint research efforts with aviation communities and industry in acquiring technology in order to gain the maximum benefits to its research & acquisition.

4. Aerothai should set up the integrated product development team. Such a team should be created by involving well-trained, capable engineers, technicians and other technical professionals for the development, research and acquisition of technology.

Domain 3 Human Operations

The opportunities exist for improvement of human operations in air traffic control. The Aerothai should conduct as follows:

1 The controller's communication skill should be improved and language difficulty must be eliminated. Aerothai should provide the English language training course for required staffs. The training tool should provide both self-training tool and class room facilities.

2 Aerothai should develop and provide the crew resource management program and team training to support and improve communication skill among team operations such as pilot-controller and controller-controller as well as reduce pilot-controller interface problem.

3 Aerothai should focus on the controller's cognitive abilities. The limitations of these abilities must be eliminated. The cognitive abilities should be focused are as follow:

-Situation awareness.

-Conflict detection and resolution.

-Information gathering and processing.

-Problem solving and decision.

-Controller's skills and knowledge.

In order to solve these problems

- Aerothai should provide simulation-based training, computer-based training and others technology-based training tool for all staffs at all operation levels. These training tools should provide both field training and self-training tool.

-Aerothai should develop the human performance assessment tools, methods and models to continuously measured controller's performance and cognitive abilities to ensure that all controller's cognitive abilities, skills and knowledge can maintain at maximum level. If performance deviation and degradation, the assessment tool can be used as criteria for further training and selection. The assessment tools should be provided as cognitive task

analysis, job-task analysis, performance checklist and controller performance-measurement.

4 Aerothai should focus on the factors that cause controller error such as stress, vigilance, fatigue, sleep-loss that must be eliminated. Aerothai should focus on shift work and work-rest schedules that impact on controller's stress, vigilance and fatigue.

- Aerothai should conduct research-based on shift work with the experts in order to develop shift work management practices through achieve optimum solution in long term benefit.

5 In order to optimize and enhance controller performance in all staffing and operational levels, Aerothai should provide training cover area of its operations. The human performance-based on training will be gathered and analyzed to subsequently evaluated additional training. The improvement and development of training program should be conducted.

6 Due to the cognitive capabilities of controllers concerned with the safety operations of its services and ensure that the controllers can improve at existing performance levels. Aerothai must select the appropriate personnel to perform tasks at difference levels and operational units. The improvement and development of criteria. methods and selection programs must be facilitated and utilized controller's selection.

7 Aerothai should conduct human factor research. A broad area of human factor research should be addressed. Aerothai should set up the human factor research & development to guide, support and facilitate a broad area of human factor research.

The research area should be as follows:

-Training and selection

-Human performance assessment, human-system interface

The research findings will be deployed and all human factor activities utilized in Aerothai's environment.

4.7.2 Step 12 Communicate Findings and Gain Acceptance

The results of benchmarking study addresses new practices and new changes for Aerothai's environment. To ensure that all new practices can accomplish its realistic improvement and be important to its services operations, the study will verify its best practices by allowing the controllers or system operators to verify the practices.

The research study develops its verification form, copies of which are sent directly to Aerothai's controllers to rate its important of best practices and give the comment. The number of participating controllers is 100 selected from Aerothai's Area Control Center. Sixty-two retured forms are received.

The results of the verification of best practices as shown in Table 4.34 based on the majority of the results of controllers' point of view.

Table 4.34 The Results of Verification of Best Practices

List of Best Practices	Importance to ATC Operations	Necessary for Current Environment
1) Integrate automation and decision support tool into current operations to support its services	Medium	Necessary
2) Establish air traffic management system where capacity and management can be facilitated	Medium	Necessary
3) Develop and modernize its existing technologies with state-of-the art technologies	High	Necessary

4) Establish user-preferred flight route program where flexible flight route, cost-effective routes can be provided	Medium	Necessary
5) Conduct human factor-based research	High	Necessary
6) Conduct human performance assessment	High	Necessary
7) Design and evaluation of selection	High	Necessary
8) Design and evaluation of training	High	Necessary
9) Controllers are to participate in the design and evaluation of selection	High	Necessary
10) Controllers are to participate in the design and evaluation of training	High	Necessary
11) Controllers are to participate in the assessment of performance on the use of air traffic control system, equipment, training & selection	High	Necessary

Analysis and Discussion

The research communicates the benchmarking results by verifying the best practices that gain from the results of the benchmarking study. The research study allow Aerothai's controllers to give the comments on the best practices. The results of the verification of the best practices are based on the majority outcome of the survey. According to the surveys, the Aerothai's controllers consider that some practices are very important to air traffic control operations in current environment. Other practices are important. The Aerothai's controllers suggest that all new practices are necessary to air traffic control services in current environment.

4.7.3 Step 13 Set Target Levels and Performance Goals

The performance goals will be set up as the target levels for achieving the performance requirements to meet the customer satisfaction.

The research study focuses on two performance goals: parity goal and leadership goal as follows:

The parity goal: Where no differences in performance levels between Aerothai and FAA.

The leadership goal: Where the Aerothai's performance levels is superior to FAA's performance level.

First, Aerothai must enhance its performance levels to attain the parity level before accomplishing its leadership goal.

The performance goals will be set at parity level where the performance gap is zero or no differences in performance levels between Aerothai and FAA. To achieve the performance goals, the action plans **(see Step 14 Develop Action Plans)** will be developed.

Quality of Service (see Table 4.35 and Fig 4.22)

Table 4.35 The Performance Goal of Quality of Service

	Aerothai Performance	FAA Performance	Parity Goal
1) Safety level	3.59	3.88	3.88
2) Service access rate	3.43	3.75	3.75
3)Timeliness of services	3.45	4.04	4.04
4) Flight efficiency	3.21	3.87	3.87
Total	3.42	3.88	3.88

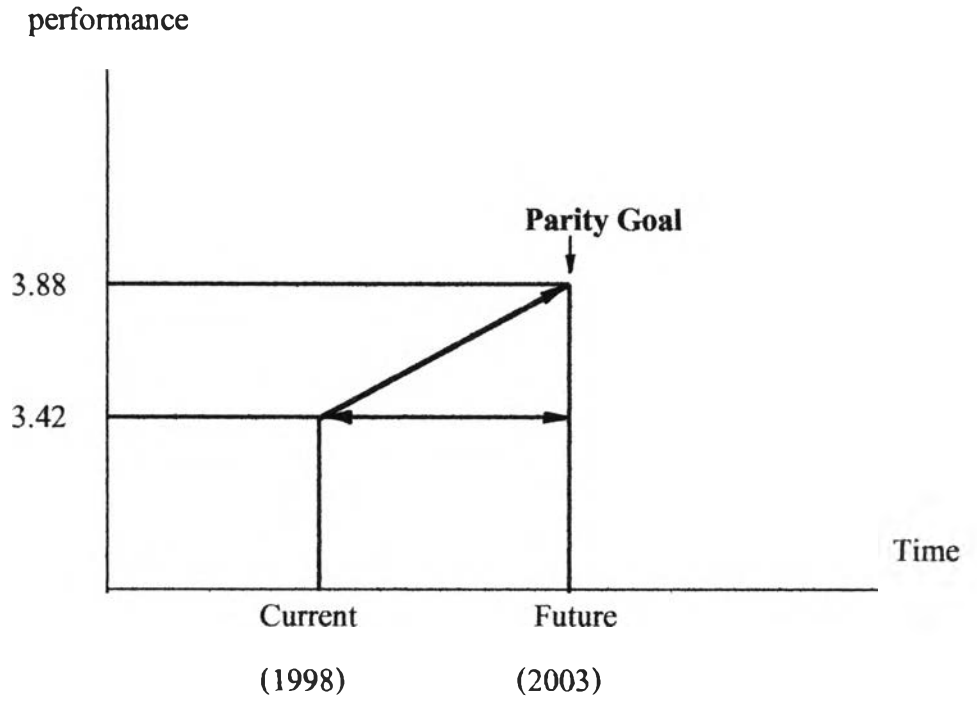


Fig 4.22 The Performance Goal of Quality of Service

Technological Support (see Table 4.36 and Fig 4.22)

Table 4.36 The Performance Goal of Technological Support

	Aerothai Performance	FAA Performance	Parity Goal
1) Effectiveness of communications system	2.85	4.36	4.36
2) Effectiveness of navigation system	3.52	4.16	4.16
3) Effectiveness of surveillance system	3.60	4.35	4.35
Total	3.32	4.29	4.29

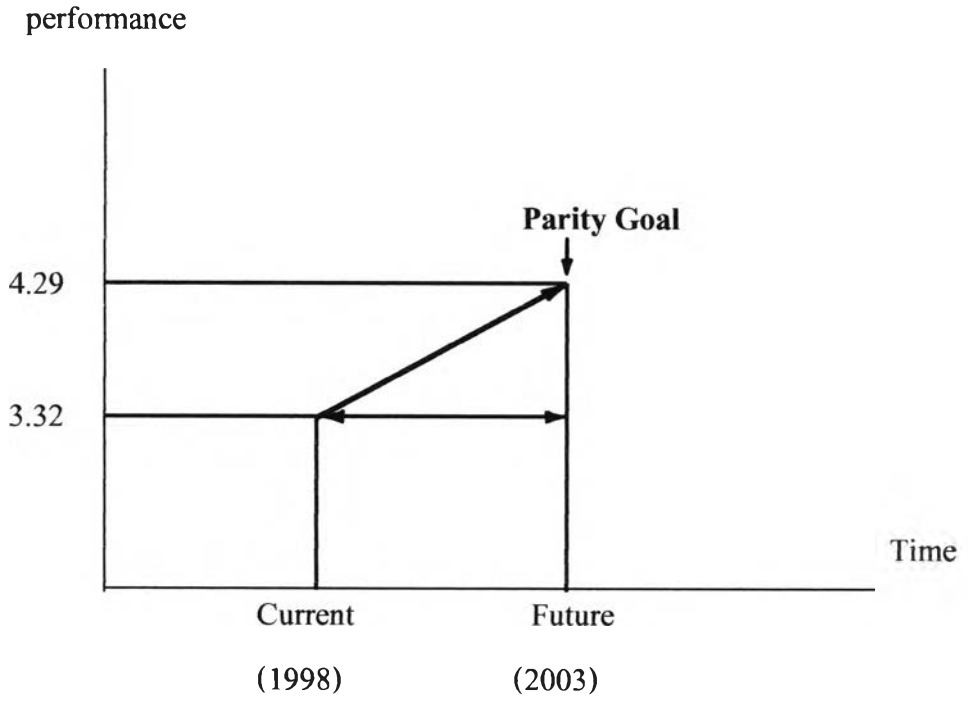


Fig 4.23 The Performance Goal of Technological Support

Human Operations Performance (see Table 4.37 and Fig 4.23)

Table 4.37 The Performance Goal of Human Operations

	Aerothai Performance	FAA Performance	Parity Goal
1) Enthusiasm of service	3.85	3.85	none
2) Responsiveness	3.85	3.85	none
3) Serviceability	3.40	4.12	4.12
4) Problem solving and decision making in a timely and safe manner	2.97	4.00	4.00
5)Timeliness of service	3.35	3.92	3.92
6) Conflict detection and resolution	3.31	4.15	4.15

	Aerothai Performance	FAA Performance	Parity Goal
7) Situation awareness	3.30	4.30	4.30
8)Ability to gather and process Information	3.10	4.12	4.12
9)Ability to cooperate with pilot in timely and safe manner	3.36	4.14	4.14
10) Ability to control traffic during take off and landing in a satisfactory manner	3.41	3.97	3.97
11) Ability to control traffic during take off and landing in a satisfactory manner under traffic peak period	3.00	4.07	4.07
12)Ability to communicate and operate communications system	2.98	4.17	4.17
13)Ability to pass the service responsibility to other flight information regions	3.63	4.18	4.18
Total	3.34	4.06	4.06

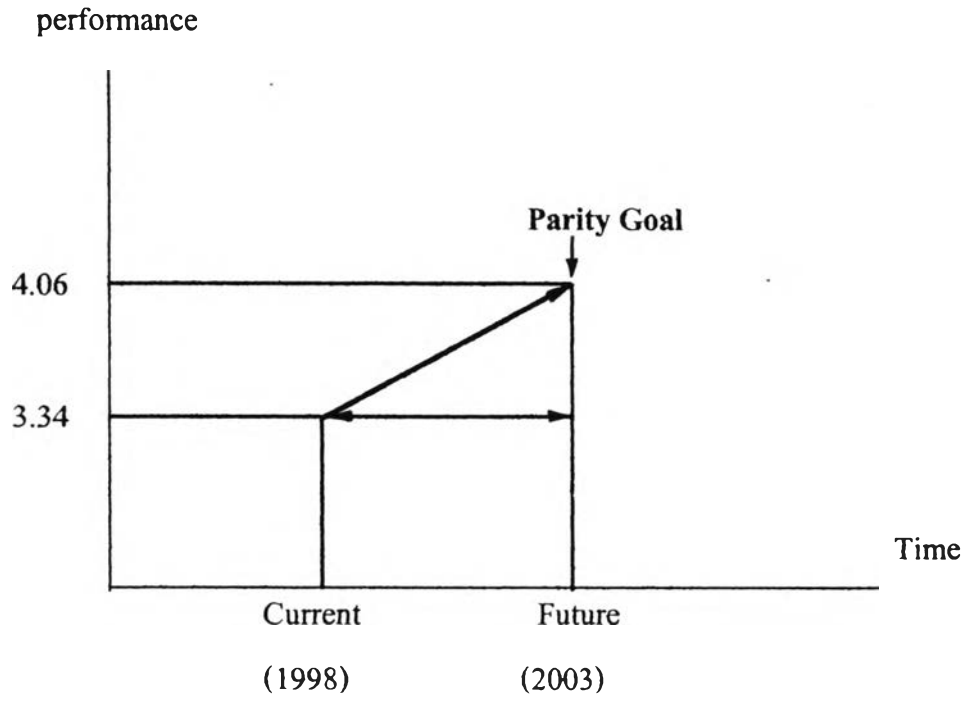


Fig 4.24 The Performance Goal of Human Operations

Analysis and Discussion

All benchmarking factors: quality of service, technological support and human operations will be set the target levels or performance goals at parity level within 5 years . Aerothai must improve its performance to reach its parity or enhance its performance to be equal to FAA performance. If FAA performance improvement rate increases over time, to reach its parity goal ,the Aerothai's performance improvement rate must be faster than FAA's rate.

When Aerothai accomplishes the parity goal, Aerothai can meet and attain the leadership goal in the future by means of which the action plans **(see Step 14 Develop Action Plans)** can effectively be implemented within the timescale. The continuous improvement plan must be conducted and the empowerment and encouragement must be created.

4.7.4 Step 14 Develop Action Plans

The action plans are to be developed and established in order to set specific actions to reduce existing performance gap **(see Step 7 Compare Performance and Determine Gap)** and enhance its service performance to meet and achieve the performance goals **(see Step 13 Set Target Levels and Performance Goals).**

The action plans are based on the results of benchmarking study : key findings and best practices found **(see Step 10 Determine Key Findings and Lessons Learned)** including the adoption and modification of best practices **(see Step 11 Adopt and Modify Best Practices).** The research study develops the action plans in a final step aims at improving Aerothai's air traffic control service performance that can be divided into two main topics as follows:

1 The Air Traffic Control Performance Plan

2 The Air Traffic Control Operations Plan

Quality of Service

1 Safety Level

1.1 Results of the Research Study

The research study indicates that language difficulty, communications problem and pilot-controller interface problem are the critical problems that affect safe operations. The research study found that the implementation of English language training course , team training and crew resource management program are the best practices to reduce language difficulty, improve communications skill and enhance pilot-controller interface.

Goal : To enhance controller's communication skill, language abilities and enhance pilot-controller interface.

Objectives

1 Implement English language training course to enhance controller's communications skill and language abilities.

2 Implement crew resource management program and team training to enhance pilot-controller interface and communication skill.

Action Plans

1 Develop and implement English training course and training tools for all qualified staffs in the beginning of the year 2000.

2 Develop and implement crew resource management program in the beginning of the year 2000.

3 Develop and implement team training program in the beginning of the year 2000.

1.2 Results of the Research Study

The research study indicates that the controller's cognitive abilities limitations including knowledge and skill are the critical problems that affect heavily on safe operations that need to improve. The cognitive abilities are as follows: situation awareness, conflict detection & resolution, information gathering & processing, problem solving & decision making. The research study found that the key best practices can improve the cognitive abilities are as follows :

-Training Tools : Simulation-based training , computer-based training

-Human performance assessment-cognitive task analysis

-Human factor research

Goal : To enhance controller's cognitive abilities , knowledge and skills.

Objectives

1 Implement simulation-based training and computer-based training to enhance controller's cognitive abilities.

2 Implement performance assessment tool as a performance monitoring to enhance controller's performance.

3 Conduct human factor research to enhance controller's performance in long term benefits.

Action Plans

1 Develop and implement simulation and computer-based training as a self-training tools for all members of staffs by the year 2000.

2 Develop human performance assessment models, methods and procedures by the year 2000.

3 Develop human factor research plan in the beginning of the year 2000. Implement and follow up the plan in mid of the year 2000.

1.3 Results of the Research Study

The research study indicates that there are some factors that cause human error and degrade controller's performance. These factors seriously affect safe operations. The research study explores the best practices found that can minimize some factors as stress, vigilance and fatigue. The best practices are : shift work logic and shift work management.

Goal : To eliminate the factors that affect human error and degrade controller's performance.

Objectives

1 Implement shift work logic, shift work management practices and work-rest schedules practices to eliminate unexpected factors that cause human error and degrade controller's performance.

2 Conduct research, based on shift work for the long term benefit.

Action Plans

1 Implement the shift work logic in the beginning of the year 2000.

2 Conduct further research, based on shift work, work-rest schedules in the beginning of the year 2000.

1.4 Results of the Research Study

The current communications system was a constraining factor, and the voice of communications system was poor. The research study found that the satellite and digital-based communications system can reduce the shortcomings and limitations of present communications system. The research & acquisition in technology provides state-of-the art , modern technology and long term continuous technology development and improvement.

Goal : To improve and maintain highest effectiveness of the air traffic control

technology support highest service's safety, capacity and efficiency.

Objectives

1 Implement satellite and digital-based communications system support to enhance the effectiveness of communications system.

2 Conduct technology research & acquisition to continuously improved technology and gain the results of research findings to deploy and utilize up-to-date and advanced technology.

3 Joint research & acquisition to share conceptual agreement and research efforts with aviation communities and industry.

4 Set up integrated product development team in order to allow the employee involvement and gain a well-trained workforce as well as individual's capabilities in technology research and acquisition.

Action Plans

1 Replace current ground-based communications system with satellite and digital-based communications system for al phases of services within the year 2000.

2 Cooperate and coordinate plan of agreement with customers , aircraft manufacture and aviation communities in technology transition plan from current system to new system in the beginning of the year 2000.

3 Establish technology research & acquisition in the beginning of the year 2000.

4 Develop integrated product development team in the beginning of the year 2000.

5 Cooperate and coordinate plan of agreement with industry in technology research and acquisition by the year 2000.

2 Timeliness of Service

2.1 Results of the Research Study

The key main problems of current air traffic control are as follows :

-Unexpected traffic demand exceed capacity.

-Unbalanced traffic demand with capacity will cause congestion problems both in the airspace and in the airports including increasing delays. The research study found that the implementation of air traffic management system is the best practices in managing system capacity with demand, improving flow of traffic and reducing congestion problems.

Goal : To operate its services with expeditious, timely manner, eliminate delays to user needs.

Objectives

1 Set up the air traffic management system to manage and balance system capacity with traffic demand , improve flow of traffic and reduce congest problem.

Action Plans

1 Set up the air traffic management system by the end of the year 2000.

2 Cooperate and coordinate plan of agreement among air traffic services organization in the region in set up air traffic management system in the beginning of the year 2000.

2.2 Results of the Research Study

The study found that the implementation of automation and automated system can support and provide numerous benefits to air traffic control operations. The automation can increase system capacity by accommodating more traffic.

Goal: To operate its services with expeditious, timely manner, eliminate delays to user needs.

Objectives

Integrate automation and automated system to support air traffic control operations.

Action Plans

1 Integrate automation and automate system in all phase of services by the year 2002.

2 Establish automation and automated system plan by the year 2000.

2.3 Results of research study

The research study indicates that language difficulty, communications problem and pilot-controller interface problem are the critical problem that affect timeliness of service of controller operations. The research study found that the implementation of English language training course , team training and crew resource management program are the best practices that reduce language difficulty, improve communications skill and enhance pilot-controller interface.

Goal : To enhance controller's communication skill, language abilities and enhance pilot-controller interface.

Objectives

1 Implement English language training course to enhance controller's communications skill and language abilities.

2 Implement crew resource management program and team training to enhance pilot-controller interface and communication skill.

Action Plans

1 Develop and implement English training course and training tools for all qualified staffs in the beginning of the year 2000.

2 Develop and implement crew resource management program in the beginning of the year 2000.

3 Develop and implement team training program in the beginning of the year 2000.

2.4 Result of the Research Study

The research study indicates that the controller's cognitive abilities limitations including knowledge and skills are the critical problems that affect timeliness of service of controller operations that need to improve. The cognitive abilities are: situation awareness, conflict detection & resolution, information gathering & processing, problem solving & decision making. The research study found that the key best practices that can improve the cognitive abilities are as follows :

-Training Tools : Simulation-based Training , computer-based training

-Human performance assessment-cognitive task analysis

-Human factor research

Goal : To enhance controller's cognitive abilities , knowledge and skill.

Objectives

1 Implement simulation-based training and computer-based training to enhance controller's cognitive abilities.

2 Implement performance assessment tool as a performance monitoring to enhance controller's performance.

3 Conduct human factor research to enhance controller's performance in long term benefits.

Action Plans

1 Develop and implement simulation and computer-based training as a self-training tools for all staffs by the year 2000.

2 Develop human performance assessment models, methods and procedures by the year 2000.

3 Develop human factor research plan in the beginning of the year 2000. Implement and follow up the plan in mid 2000.

2.5 Results of the Research Study

The research study indicates that there are some factors that cause human error and degrade controller's performance. The research study explores the best practices found that can be minimized some factors such as stress, vigilance and fatigue. The best practices are : shift work logic and shift work management.

Goal : To eliminate the factors that affect human error and degrade controller's performance.

Objectives

1 Implement shift work logic, shift work management practices and work-rest schedules practices to eliminate unexpected factors that cause human error and degrade controller's performance.

2 Conduct research,based on shift work for long term benefit.

Action Plans

1 Implement the shift work logic in the beginning of the year 2000.

2 Conduct further research,based on shift work, work-rest schedules in the beginning of the year 2000.

2.6 Results of the Research Study

The current communications system was a constraining factors, and the voice of communications system was poor. The research study found that the satellite and digital-based communications system can be reduced the shortcomings and limitations of present communications system. The research & acquisition in technology provides state-of-the art , modern technology and long term continuous technology development and improvement.

Goal : To improve and maintain highest effectiveness of the air traffic control technology support highest service's safety, capacity and efficiency.

Objectives

1 Implement satellite and digital-based communications system support to enhance the effectiveness of communications system.

2 Conduct technology research & acquisition to continuously improved technology and gain the results of research findings to deploy and utilize up-to-date and advanced technology.

3 Joint research & acquisition to share conceptual agreement and research efforts phases of services with aviation communities and industry.

4 Set up integrated product development team in order to let the employee involve and gain a well-trained as well as individual's capabilities in technology research and acquisition.

Action Plans

1 Replace current ground-based communications system with satellite and digital-based communications system for all phases of services by the year 2000.

2 Cooperate and coordinate plan of agreement with customers , aircraft manufactures

aviation communities in technology transition plan from current system to new system n the beginning of the year 2000.

3 Establish technology research & acquisition in the beginning of the year 2000

4 Develop integrated product development team in the beginning of the year 2000.

5 Cooperate and coordinate plan of agreement with industry in technology research & acquisition by the year 2000.

3 Flight Efficiency

3.1 Results of the Research Study

The research study found that the user-preferred flight routes program demonstrate the best practices for achieving the flight efficiency. It provides flexible flight routes ,more direct routes that allow the pilot can fly at optimum flight profile and the users can save flight time and fuel loss.

Goal: To create service delivery that allow the pilots to operate as an efficiency manner through achieve the economic performance of user needs.

Objective

1 Implement user-preferred flight routes program to provide the cost-effective routes to user need.

Action Plans

1 Develop user-preferred flight routes program within the year of 2000 and implement by the year 2002.

2 Redesign a specific airspace where the user-preferred flight routes can be made by the year 2000.

3 Cooperate and coordinate plan of agreement with the aviation communities in the region in set up the program by the year 2001.

3.2 Results of Research Study

The research study found that the implementation of the air traffic management system is the best practices to manage capacity with demand and reduce congestion problem both airspace and airports.

Goal : To operate its services with expeditious, timely manner, eliminate delays through user needs.

Objective

1 Set up air traffic management system to balance system capacity with traffic demand, improve flow of traffic and reduce congestion problem.

Action Plans

1 Set up air traffic management system by the end of the year 2000.

2 Cooperate and coordinate plan of agreement with air traffic organizations in the region in set up air traffic management system in the beginning of the year 2000

3.3 Results of the Research Study

The research study indicates that language difficulty, communications problem and pilot-controller interface problem are the critical problem that affect controller operations . The research study found that the implementation of English language training course , team training and crew resource management program are the best practices to reduce language difficulty, improve communication skill and enhance pilot-controller interface.

Goal : To enhance controller's communication skill, language abilities and enhance pilot-controller interface.

Objectives

1 Implement English language training course to enhance controller's communication skill and language abilities.

2 Implement crew resource management program and team training to enhance pilot-controller interface and communication skill.

Action Plans

1 Develop and implement English training course and training tools for all qualified staffs in the beginning of the year 2000.

2 Develop and implement crew resource management program in the beginning of the year 2000.

3 Develop and implement team training program in the beginning of the year 2000.

3.4 Results of the Research Study

The research study indicates that the controller's cognitive abilities limitations including knowledge and skills are the critical problems that affect heavily on controller operations that need to improve. The cognitive abilities are situation awareness, conflict detection & resolution, information gathering & processing and problem solving & decision making. The research study found that the key best practices can improve the cognitive abilities are as follows :

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-Human Performance assessment-cognitive task analysis

-Human Factor Research

Goal : To enhance controller's cognitive abilities , knowledge and skills.

Objectives

1 Implement simulation-based training and computer-based training to enhance controller's cognitive abilities.

2 Implement performance assessment tool as a performance monitoring to enhance controller's performance.

3 Conduct human factor research to enhance controller's performance in long term benefits.

Action Plans

1 Develop and implement simulation and computer-based training as a self-training tools for all staffs by the year 2000.

2 Develop human performance assessment models, methods and procedures by the year 2000.

3 Develop human factor research plan in the beginning of the year 2000. Implement and follow up the plan in mid 2000.

3.5 Results of the Research Study

The research study indicates that there are some factors that cause human error and degrade controller's performance. These factors seriously affect controller operations. The research study explores the best practices found that can minimize some factors as stress, vigilance and fatigue. The best practices are shift work logic, shift work management and work-rest schedules management.

Goal : To eliminate the factors that affect human error and degrade controller's performance.

Objectives

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controller's performance.

2 Conduct research,based on shift work for long term benefit.

Action Plans

1 Implement the shift work logic in the beginning of the year 2000.

2 Conduct further research,based on shift work, work-rest schedules in the beginning of the year 2000.

3.6 Results of the Research Study

The current communications system was a constrainning factors, and the voice of communications system was poor. The research study found that the satellite and digital-based communications system can reduce the shortcomings and limitations of present communications system. The research & acquisition in technology provides state-of-the art, modern technology and long term continuous technology development and improvement.

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Objectives

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Action Plans

1 Replace current ground-based communications system with satellite and digital-based communications system for all phases of services by the year 2000.

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3 Establish technology research & acquisition in the beginning of the year 2000.

4 Develop integrated product development team in the beginning of the year 2000.

5 Cooperate and coordinate plan of agreement with industry in technology research & acquisition by the year 2000.

4 Technological Support

Results of the Research Study

The current communications system was a constraining factors, and the voice of communications system was poor. The research study found that the satellite and digital-based communications system can reduce the shortcomings and limitations of present communications system. The research & acquisition in technology provides state-of-the art . modern technology and long term continuous technology development and improvement.

Goal : To improve and maintain highest effectiveness of the air traffic control technology support highest service's safety, capacity and efficiency.

Objectives

1 Implement satellite and digital-based communications system support to enhance the effectiveness of communications system.

2 Conduct technology research & acquisition to continuously improved technology and gain the results of research findings to deploy and utilize up-to-date and advance technology.

3 Joint research & acquisition to share conceptual agreement and research efforts phases of services with aviation communities and industry.

4 Set up integrated product development team in order to let the employee involve and gain a well-trained workforce as well as individual's capabilities in technology research & acquisition.

Action Plans

1 Replace current ground-based communications system with satellite and digital-based communications system for all phases of services in the beginning of the year 2000.

2 Cooperate and coordinate plan of agreement with customers , aircraft manufactures and aviation communities in technology transition plan from current system to new system in the beginning of the year 2000.

3 Establish technology research & acquisition in the beginning of the year 2000.

4 Develop integrated product development team in the beginning of the year 2000.

5 Cooperate and coordinate plan of agreement between industry in technology research & acquisition by the year 2000.

5 Human Operations

5.1 Results of the Research Study

The research study indicates that language difficulty, communications problem and pilot-controller interface problem are the critical problems that affect safe operations. The research study found that the implementation of English language training course , team training and crew resource management program are the best practices to reduce language difficulty, improve communications skill and enhance pilot-controller interface.

Goal : To enhance controller's communication skill, language abilities and enhance pilot-controller interface.

Objectives

1 Implement English language training course to enhance controller's communications skill and language abilities.

2 Implement crew resource management program and team training to enhance pilot-controller interface and communication skill.

Action Plans

1 Develop and implement English training course and training tools for all qualified staffs in the beginning of the year 2000.

2 Develop and implement crew resource management program in the beginning of the year 2000.

Develop and implement team training program in the beginning of the year 2000.

5.2 Results of the Research Study

The research study indicates that the controller's cognitive abilities limitations including knowledge and skill are the critical problems that affect heavily on safe operations that need to improve. The cognitive abilities are situation awareness, conflict detection & resolution, information gathering & processing and problem solving & decision making. The research study found that the key best practices can improve the cognitive abilities are as follows :

-Training Tools : Simulation-based training , computer-based training

-Human performance assessment-cognitive task analysis

-Human factor research

Goal : To enhance controller's cognitive abilities , knowledge and skill.

Objectives

1 Implement simulation-based training and computer-based training to enhance controller's cognitive abilities.

2 Implement performance assessment tool as a performance monitoring to enhance controller's performance.

3 Conduct human factor research to enhance controller's performance in long term benefits.

Action Plans

1 Develop and implement simulation-based training and computer-based training as a self-training tools for all member of staffs by the year 2000.

2 Develop human performance assessment models, methods and procedures by the year 2000.

3 Develop human factor research plan in the beginning of the year 2000. Implement and follow up the plan in mid 2000.

5.3 Results of the Research Study

The research study indicates that there are some factors that cause human error and degrade controller's performance. These factors seriously affect safe operations. The research study explores the best practices found that can minimize some factors such as stress, vigilance and fatigue. The best practices are shift work logic, shift work management and work-rest schedules management.

Goal : To eliminate the factors that affect human error and degrade controller's performance.

Objectives

1 Implement shift work logic, shift work management practices and work-rest schedules practices to eliminate unexpected factors that cause human error and degrade controller's performance.

2 Conduct research,based on shift work for long term benefit.

Action Plans

1 Implement the shift work logic in the beginning of the year 2000.

2 Conduct further research,based on shift work, work-rest schedules in the beginning of the year 2000.

5.4 Results of the Research Study

The research study indicates that the human factor research provide various benefits to deploy and utilize human factor activities to support and enhance controller's performance.

Objectives

1 Selection & Training : Develops and provides various effective training programs to support and enhance controller's performance, skill and capability of Aerothai's controllers in all staffing levels.

2 Human performance assessment : Develops tools, methods and procedures to identify the performance, how well Aerothai's controllers perform the tasks to ensure that new automation, equipment, procedures , training and selection can enhance human performance and human errors can detect and reduce.

3 Human-system interface : Focus on human-system perspective by increasing the role of Aerothai's controlles in the design and evaluation of automation to ensure that the implementation of automation can match with the controllers' capabilities and limitations.

Action Plans

1 Develop human factor research plan in the beginning of the year 2000. Implement and follow up the plan in mid 2000.

2 Develop methods and guidelines for the research of selection and training in the beginning of year 2000.

3 Develop human performance-based assessment methods, standards and procedures for the benefits of controller selection and training in the beginning of the year 2000.

4 Develop training program for the full use of advanced automation system by the year 2000.

6. Develop human performance assessment methods, models for human-automation interface in the beginning of the year 2000.

7. Develop human performance-based information for improved controller selection and training by the year 2000.