National Library
of Canada

Acquisitions and
Bibliographic Services Branch

395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale
du Canada

Direction des acquisitions et
des services bibliographiques

395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file Votre référence

Our file Notre référence

NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Reproduction in full or in part of this microform is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30, and subsequent amendments.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

La reproduction, même partielle, de cette microforme est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30, et ses amendements subséquents.

Canada

Historical Perspective, Assessment and Statistical Analysis of Canadian Commercial Airline Accidents

Beata I. Mielcarek

A Thesis in The Department of
Decision Sciences and
Management Information Systems

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Administration at
Concordia University
Montreal, Quebec, Canada
September 1995

National Library
of Canada

Acquisitions and
Bibliographic Services Branch

395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale
du Canada

Direction des acquisitions et
des services bibliographiques

395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file Votre référence

Our file Notre référence

ISBN 0-612-05115-3

Canada

Name BEATA I. MIEZCAREK

Dissertation Abstracts International is arranged by broad, general subject categories. Please select the one subject which most nearly describes the content of your dissertation. Enter the corresponding four-digit code in the spaces provided.

STATISTICS

SUBJECT TERM

0 4 6 3

SUBJECT CODE

U·M·I

Subject Categories

THE HUMANITIES AND SOCIAL SCIENCES

COMMUNICATIONS AND THE ARTS

Architecture	0729
Art History	0377
Cinema	0900
Dance	0378
Fine Arts	0357
Information Science	0723
Journalism	0391
Library Science	0399
Mass Communications	0708
Music	0413
Speech Communication	0459
Theater	0465

EDUCATION

General	0515
Administration	0514
Adult and Continuing	0516
Agricultural	0517
Art	0273
Bilingual and Multicultural	0282
Business	0688
Community College	0275
Curriculum and Instruction	0727
Early Childhood	0518
Elementary	0524
Finance	0277
Guidance and Counseling	0519
Health	0680
Higher	0745
History of	0520
Home Economics	0278
Industrial	0521
Language and Literature	0279
Mathematics	0280
Music	0522
Philosophy of	0998
Physical	0523
Psychology	0525
Reading	0535
Religious	0527
Sciences	0714
Secondary	0533
Social Sciences	0534
Sociology of	0340
Special	0529
Teacher Training	0530
Technology	0710
Tests and Measurements	0288
Vocational	0747

LANGUAGE, LITERATURE AND LINGUISTICS

Language	
General	0679
Ancient	0289
Linguistics	0290
Modern	0291
Literature	
General	0401
Classical	0294
Comparative	0295
Medieval	0297
Modern	0298
African	0316
American	0591
Asian	0305
Canadian (English)	0352
Canadian (French)	0355
English	0593
Germanic	0311
Latin American	0312
Middle Eastern	0315
Romance	0313
Slavic and East European	0314

PHILOSOPHY, RELIGION AND THEOLOGY

Philosophy	0422
Religion	
General	0318
Biblical Studies	0321
Clergy	0319
History of	0320
Philosophy of	0322
Theology	0469

SOCIAL SCIENCES

American Studies	0323
Anthropology	
Archaeology	0324
Cultural	0326
Physical	0327
Business Administration	
General	0310
Accounting	0272
Banking	0770
Management	0454
Marketing	0338
Canadian Studies	0385
Economics	
General	0501
Agricultural	0503
Commerce-Business	0505
Finance	0508
History	0509
Labor	0510
Theory	0511
Folklore	0358
Geography	0366
Gerontology	0351
History	
General	0578
Ancient	0579
Medieval	0581
Modern	0582
Black	0328
African	0331
Asia, Australia and Oceania	0332
Canadian	0334
European	0335
Latin American	0336
Middle Eastern	0333
United States	0337
History of Science	0585
Law	0398
Political Science	
General	0615
International Law and Relations	0616
Public Administration	0617
Recreation	0814
Social Work	0452
Sociology	
General	0626
Criminology and Penology	0627
Demography	0938
Ethnic and Racial Studies	0631
Individual and Family Studies	0628
Industrial and Labor Relations	0629
Public and Social Welfare	0630
Social Structure and Development	0700
Theory and Methods	0344
Transportation	0709
Urban and Regional Planning	0999
Women's Studies	0453

THE SCIENCES AND ENGINEERING

BIOLOGICAL SCIENCES

Agriculture	
General	0473
Agronomy	0285
Animal Culture and Nutrition	0475
Animal Pathology	0476
Food Science and Technology	0359
Forestry and Wildlife	0478
Plant Culture	0479
Plant Pathology	0480
Plant Physiology	0817
Range Management	0777
Wood Technology	0746
Biology	
General	0306
Anatomy	0287
Biostatistics	0308
Botany	0309
Cell	0379
Ecology	0329
Entomology	0353
Genetics	0369
Limnology	0793
Microbiology	0410
Molecular	0307
Neuroscience	0317
Oceanography	0416
Physiology	0433
Radiation	0821
Veterinary Science	0778
Zoology	0472
Biophysics	
General	0786
Medical	0760

EARTH SCIENCES

Biogeochemistry	0425
Geochemistry	0996
Geodesy	0370
Geology	0372
Geophysics	0373
Hydrology	0388
Mineralogy	0411
Paleobotany	0345
Paleoecology	0426
Paleontology	0418
Paleozoology	0985
Palynology	0427
Physical Geography	0368
Physical Oceanography	0415

HEALTH AND ENVIRONMENTAL SCIENCES

Environmental Sciences	0768
Health Sciences	
General	0566
Audiology	0300
Chemotherapy	0992
Dentistry	0567
Education	0350
Hospital Management	0769
Human Development	0758
Immunology	0982
Medicine and Surgery	0564
Mental Health	0347
Nursing	0569
Nutrition	0570
Obstetrics and Gynecology	0380
Occupational Health and Therapy	0354
Ophthalmology	0381
Pathology	0571
Pharmacology	0419
Pharmacy	0572
Physical Therapy	0382
Public Health	0573
Radiology	0574
Recreation	0575
Speech Pathology	0460
Toxicology	0383
Home Economics	0386

PHYSICAL SCIENCES

Pure Sciences

Chemistry	
General	0485
Agricultural	0749
Analytical	0486
Biochemistry	0487
Inorganic	0488
Nuclear	0738
Organic	0490
Pharmaceutical	0491
Physical	0494
Polymer	0495
Radiation	0754
Mathematics	0405
Physics	
General	0605
Acoustics	0986
Astronomy and Astrophysics	0606
Atmospheric Science	0608
Atomic	0748
Electronics and Electricity	0607
Elementary Particles and High Energy	0798
Fluid and Plasma	0759
Molecular	0609
Nuclear	0610
Optics	0752
Radiation	0756
Solid State	0611
Statistics	0463

Applied Sciences

Applied Mechanics	0346
Computer Science	0984
Engineering	
General	0537
Aerospace	0538
Agricultural	0539
Automotive	0540
Biomedical	0541
Chemical	0542
Civil	0543
Electronics and Electrical	0544
Heat and Thermodynamics	0348
Hydraulic	0545
Industrial	0546
Marine	0547
Materials Science	0794
Mechanical	0548
Metallurgy	0743
Mining	0551
Nuclear	0552
Packaging	0549
Petroleum	0765
Sanitary and Municipal	0554
System Science	0790
Geotechnology	0428
Operations Research	0796
Plastics Technology	0795
Textile Technology	0994

PSYCHOLOGY

General	0621
Behavioral	0384
Clinical	0622
Developmental	0620
Experimental	0623
Industrial	0624
Personality	0625
Physiological	0989
Psychobiology	0349
Psychometrics	0632
Social	0451

CONCORDIA UNIVERSITY

Division of Graduate Studies

This is to certify that the thesis prepared

By: Beata I. Mielcarek

Entitled: Historical Perspective, Assessment and Statistical Analysis
of Canadian Commercial Airline Accidents

and submitted in partial fulfillment of the requirements for the degree of

Master of Science in Administration (Statistics)

complies with the regulations of this University and meets the accepted standards with respect to originality and quality.

Signed by the final examining committee:

______________________________ Chair
______________________________ Examiner
______________________________ Examiner
______________________________ Examiner
______________________________ Thesis Supervisor

Approved by ______________________________
Chair of the Department or Graduate Program Director

__________ 19 _____ ____________________
Dean of Faculty

ABSTRACT

Historical Perspective, Assessment and Statistical Analysis of Canadian Commercial Airline Accidents

B. I. Mielcarek

The goal of this paper is to study the safety record of the Canadian commercial aviation industry, using accident data for the period from 1976 to 1993. An overview of the Canadian aviation history is provided in order to present the technological and economic aspects influencing the successful developments in the field of flight, as well as the specific elements affecting its safety record. General concepts of measuring air travel safety are also defined. An assessment of the risk of flying is made using accidents, fatalities and injuries rates over time. In addition, raw accident data is presented, thus providing a better understanding of the circumstances influencing air travel safety. Subsequent factor analysis explores and confirms the generally assumed dominant factors causing air disasters. Finally, a regression model developed to predict the yearly rate of total and fatal aviation accidents is presented. In addition, the effect of economic deregulation on aviation safety in Canada is assessed as well. Throughout the study, the use of variables directly related to flight operations, as opposed to the generally proposed economic indicators, is emphasized. In addition to providing an overall understanding of the air travel environment and the related risks, the analysis presented in this paper shows that the confirmed factors greatly contribute to predicting yearly accident rates.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Many of the research efforts concerning aviation safety, so far, have centered on economic determinants as the dominant sources of safety problems. Factors such as profit margins, debt-equity ratios and company cash flows were studied in order to explain the elements influencing safety levels in the aviation industry. This paper, proposes a new approach, that of looking at the immediate factors governing the airline community, and especially the people flying and being flown in an aircraft. The primary objective, then, is to evaluate the variables directly related to flight.

The first chapter of this research project presents a historical review of the forces that shaped Canada's aviation industry. Individuals' determination and government regulations of the ever expanding air travel market have both promoted technological advancement, and increased awareness and promotion of safety issues.

The second chapter describes specific factors affecting air travel. Accident and incident definitions are provided, as well as various methods of measuring safety.

Chapter three reviews and evaluates the economic trends and performance of the aviation industry and their influence on the increased public confidence in this now widely accepted mode of transport.

The following chapter assesses air travel safety based on airline accidents, fatalities and injuries rates over the past 20 years. Elements contributing to the highest occurrence of these tragic events are also emphasized.

The next two chapters provide a more systematic approach to evaluating safety. First, factor analysis (chapter 5) is used in order to confirm the generally assumed four principal causes of aircraft accidents: natural and operational environments, machine failure and human errors. Next, regression analysis (chapter 6) is used to develop a model forecasting the total and fatal number of accidents. In addition, the effect of economic deregulation in 1988 in Canada is assessed.

The last chapter gives an overall perspective on the world-wide air travel safety as a point of reference to the Canadian record discussed in the preceding sections. Issues of pressing safety importance are also discussed to focus attention on challenges still lying ahead.

CHAPTER I

HISTORY OF AVIATION REGULATION IN CANADA

THE EARLY DAYS

The quest to master the art of flying took almost twenty four centuries, with the original thought of humans flying dating back to at least the days of Aristotle, 4-th century BC. A great number of challenges have been overcome from the initial attempts to imitate birds, based on the unsupported theory that they flapped their wings downwards and backwards, pressing up and along against the air which lay behind. A number of great theoreticians contributed to the understanding of the theory of flight. First, Archimedes (287 to 212 BC) should be credited with having been the first to understand that when an object is immersed in a fluid, its apparent weight is reduced by an amount equal to the weight of the fluid which it displaced. Second, Leonardo da Vinci's (1452-1519) ideas about bird flight were more sophisticated than those of most of his contemporary theoreticians, based on the careful observations of a man blessed with the eye of a great painter, and his meticulous analysis worthy of a professional engineer, and resulted in some very sensitive investigation of the potentiality of gliding flight. Then, Daniel Bernoulli (1700-1782) advanced the theorem of aerodynamic lift: the sum of velocities over the top of the airfoil is greater than that over the bottom. And finally, Sir George Cayley (1773-1859) was dubbed the Father of Aerial Navigation, credited with the first successful insight into the separation of lift and thrust in connection with the heavier-than-air flight. He designed a man-carrying aeroplane, equipped with rigid wings and flappers for propulsion, as opposed to the sketches trying to combine both lift and thrust in one unified system. The imagination, genius and perseverance of these and many other great minds allowed us to comprehend aeronautics and to experience what man has always desired: defy the laws of gravity and fly !

In Canada, the first official record of flight can be traced back to two articles in the Montreal Daily Witness, on May 14 and June 18, 1879. They provide a full description of the design and construction of the original flying machine (Wilson, 1948). The invention of Mr. Charles Page of Montreal, built with the support of Mr. Richard W. Cowan, a retired merchant of the city, was a dirigible, cigar-shaped balloon, called the Canadian. The trial flight was made on June 21, 1879 from the Shamrock

Lacrosse grounds in Westmount. Although the 45 mile trip was uneventful, the crew learned the perils of landing in the dark (at St. Jude, nine miles from St. Hyacinthe). Albeit not a major event in itself, compared to other European and American air travel endeavors, the recording of the flight marked the beginning of what became a long and impressive list of Canadian aviation achievements.

The dawn of the twentieth century brought about more experiments in the attempts to fly, and the father of aeronautical research in Canada, Mr. Wallace Rupert Turnbull. In 1902, he constructed the first Canadian wind tunnel at Rothesay, N.B., and by 1907 published the first Canadian aeronautical research paper in Physical Review entitled "Researches on the Forms and Stability of Aeroplanes". Turnbull's efforts culminated in his greatest invention, the controllable pitch propeller (Wilson, 1948).

To the above mentioned names Mr. John A. Douglas McCurdy and F. W. "Casey" Baldwin should also be added. The two engineering graduates of Toronto University, greatly contributed to the work of Dr. Alexander Graham Bell at the Aerial Experiment Association (AEA). Established in Halifax, September 30, 1907, the main objective of the Association was "to create a practical aerodrome or flying machine driven through the air by its own power and carrying a man". This was further explained by Bell, as a "co-operative scientific association, not for gain but for the love of the art and doing what we can to help one another" (Fuller, 1983). The best designs of their heavier-than-air flying machines and aircraft engines lead to some of the history making flights in Canadian aviation.

First, on December 6, 1907, a large tetrahedral kite named "Cygnet", built and designed by Dr. Bell, was successfully flown with Lieutenant Thomas Selfridge, of the US Army, as a passenger. The motor, powered by a steam tug, took off the surface of the Bras d'Or Lake, rose to a height of 170 feet and made one of the first few recorded flights carrying a passenger aboard a heavier-than-air aircraft in Canada. Subsequent aircraft, designed and built by the Association, showed significant advances in safety over the contemporary models and flew more than 200 successful flights that winter and later held many records. Unfortunately, the AEA experienced a major setback on September 17, 1908, when Selfridge was killed at Fort Myer, Virginia, on one of the Orville Wright demonstration flights. Thus, he became the world's first aviation passenger fatality (Fuller, 1983).

Then, in November 1908, after extending its year-long mandate for an additional six months, and multiple trials in building and flying gliders equipped with a motor, McCurdy's "Silver Dart" was completed and assembled at the Bell headquarters and laboratory in Baddeck, N.S., for trials on the ice. The plane had a 49-foot wing span, weighed 800 pounds fully loaded, and was powered by 35 horse power Curtiss engine. On February 23, 1909, Dr. Bell was able to capture the momentous flight as follows, in his cable to London Times:

> "First flight of a flying machine in Canada occurred here today when Mr. Douglas McCurdy, native of Baddeck, Nova Scotia, flew a distance of about one-half mile at an elevation of about thirty feet above the ice on Baddeck Bay in an aerodrome of his own design, named the "Silver Dart"" (Wilson, 1948).

Later he also wrote:

> "This may seem to be a small matter at the present moment; but when flying machines have become common, and Aerial Locomotion a well-organized and established mode of transit, the origin of the art in Canada will become a matter of great historical interest, and people will look back to the flight made on February 23, 1909, as the first flight machine in the Dominion of Canada" (Fuller, 1983).

The importance of this and other flights sponsored by the AEA was most significant because of several new features of this advanced aircraft, compared to those previously flown. Incorporating a three wheel undercarriage, tapered wings, and the use of aileron control increased the flight safety by providing more stability to the aircraft and more control to the crew.

Those were just a few of the Canadian firsts. It marked an end of an era when all that was needed was a dream, and the will and persistence to realize it. From now on, a more structured approach to aeronautical research would be taken, mostly supervised and regulated by government sponsored authorities. Consequently, the following years would see the aviation activities expand from research and design, to adventurous overseas flights, and even mail delivery. At every step along the way, engineers and pilots encountered new challenges, pushing their quest for better and safer machines and flight performance even further.

THE FIRST WORLD WAR AND ARMISTICE

The outbreak of World War I initiated the efforts to provide standard training to pilots and mechanics specially recruited to help the fight overseas. First used solely in observation missions, the role of airmen quickly grew to fighting in the air with revolvers and shot guns. Later aircraft were armed with machine guns. As the power and speed of planes increased, bombing was added (Wilson, 1948). To meet this growing demand of skilled pilots, the Curtiss Flying School in Toronto was established in the spring of 1915. It commenced operation on May 10 from Toronto Island airport, using Curtiss flying boats. On July 11, 1915, the first pilots were licensed in Canada. A. Strachan Ince and F. Homer Smith passed their tests at Curtiss Aviation School and were granted certificates no. 1519 and 1520 by the Royal Aero Club of the United Kingdom (Milberry, 1979).

With facilities such as the one at Toronto Island and later organized training camps of the Royal Flying Corpses (established in December, 1916) in Borden, Long Branch, Leaside, Armour Heights, Mohawk and Beamsville, as well as the ground school at Toronto University, Canadians made remarkable efforts during the war* . Their talents and exploits in air warfare were recognized immediately by the British, under whose direction they flew. Recruitment of thousands of Canadian youngsters, clamoring for an opportunity to do their part in the air, increased substantially, whereas it almost reached its limit in Great Britain (Wilson, 1948).

After the armistice of 1918, Canada was in an excellent position to deal with aviation issues intelligently. Although there was little recognition on the part of the general public of the importance of flight during peace time, its role would become even greater than in war. The halted progress of research, during the international conflict, eagerly sought the outlets for aviation. To remedy the situation, preliminary efforts were already made in the fall of 1915 by Dr. Charles Camsell, Deputy Minister of Mines and Resources, to obtain flying boats for use in northern Canada to ease the burden and increase

---

* By 1940, Canada became a center for air training by setting up the Empire Air Training Scheme.

the efficiency of scientific expeditions. Later, Canadian pilots returning home from overseas were demanding that their opportunities for flying be continued and extended. Many made personal businesses of barnstorming: this meant a lot of dollar-a-minute joy riding, and dropping in at fairs and exhibitions to hustle rides among the crowds (Fuller, 1983). With the surplus of aircraft and war disposal stock coming on the market and available at low prices, it became increasingly necessary to control flying in Canada. The government's awareness of the potential of air transport and the safety problems that were likely to arise prompted the authorities to act.

The first step taken by the Canadian government to determine the principles underlying the regulation of civil aviation at home and abroad was to participate in the Peace Conference of 1919 and in drafting the International Convention for Air Navigation. The Convention resolved a number of issues of a technical nature such as the registration of aircraft and airworthiness, and established the International Commission for Air Navigation (CINA), whose major responsibility was to collect and disseminate information bearing upon air navigation and to make recommendations for amending the Convention (Milberry, 1979). It did not however deal with the economic aspects of regulation, such as exchange of routes, frequency, capacity, and fares. Those issues, as well as safety related topics, would receive adequate attention only much later. The Convention was ratified by twenty-six countries and served as a 'first constitution' for international aviation among signatory States.

The next step increased safety by bringing order and rationale to the national commercial flying ventures. For that purpose, the government introduced the Air Board Act in Ottawa, and received Royal Assent on July 6, 1919. Passing of the act established the Board of Aeronautics with broad powers of control over all forms of aeronautics throughout the country (Wilson, 1948). Its primary mandate was to name the air routes, license pilots, register aircraft, and investigate accidents; all the issues yet unresolved at the international level. Most attention however was given to the air transportation in the outlying districts of Canada; in forest patrol and exploration, in aerial surveys, and scientific and industrial research. General flight and safety regulations were still greatly ignored and received little attention.

NATIONAL DEFENSE AND TRANSPORT CANADA

On January 1, 1923, the Air Board ceased to exist with the proclamation bringing into effect the Act creating the Department of National Defense (Wilson, 1948). The control of civil aviation fell then under the responsibility of the Branch of Secretary of the Royal Canadian Air Force. On April 1, 1924, 68 officers and 307 airmen formed the RCAF whose mandate included mapping, locating hunting smugglers and illegal immigrants and carrying mail. Their task also included the transport of injured persons; the beginning of Medevac. However, because the work had increased so greatly that the duties of Air Regulation and licensing of civil aircraft and aviation personnel could no longer be performed without a permanent organization and staff specially trained for the work, the Civil Aviation Branch replaced the Secretary's Branch (1927). Further subdivision of the branch into separate Air Regulations and Airways Division became necessary when, in 1928, construction of trans-Canada airways was decided. The first dealt with the inspection and licensing of aircraft, the examination of pilots and air engineers and the supervision of the air regulations in general. The second was charged with airway and airport surveys, the location and construction of aids to navigation on the airways, including intermediate aerodromes and lighting, the co-ordination of the radio and meteorological services, and the licensing of airports and seaplane bases (Wilson, 1948). From then on, the enormity of the project of building a coast to coast "air highway" insured the proper monitoring and constant improvement of Canadian aviation industry and the laws that governed it.

The entire RCAF underwent many changes and subdivisions to deal with the standardization of Canadian air transport, until finally in 1936 the Department of Transport (now Transport Canada) was formed. From then on, all services in Canada having jurisdiction over transportation and communications would be brought under one Minister of the Crown. This was possible through the Department of Transport Act (1936) - providing the organizational guidelines for the administration of all aspects of civil aeronautics, the Trans-Canada Air Lines Act (1937) - creating a national medium for the operation of national main line air transport services and international main line connections to other countries, and the Transport Act (1938) - establishing, through the Board of Transport Commissioners, an independent judicial organization to deal with air route licensing, including the judgment on necessity and convenience, tariffs and other related matters, leaving regulation of the technical and safety factors to the Air Services Branch. As stated in Transport Canada's yearly expenditure plans: "Federal responsibilities for transportation originated from the jurisdiction outlined in the British North American Act. These responsibilities have evolved to include coordination and regulation to ensure safety and efficiency in aeronautics, navigation, shipping facilities, ferries, airways and canals connecting provinces or connecting a province with any foreign country..." (TC, 1993). Today, the goal of Transport Canada is to attend to the development and operation of a safe and efficient national transportation system that contributes to the achievement of government objectives, and to operate specific elements of this system. Credit for the above initiatives should be given to the then Minister of Transport, and later the Minister of Munitions and Supplies, Mr. C.D. Howe (Wilson, 1948). Under his able and energetic direction regulations were introduced and passed through Parliament in Ottawa just in time to deal with the increasing interest in air travel. Consequently, the civil and military functions became separate, even though still totally under the control of the federal government, and stability in the organization of the air services of the nation was finally achieved.

With increasing demand for air transportation in the 1930's and early 40's, a number of new airlines began operation, catering to the need for domestic and international scheduled air services. In 1937 a national carrier was established. The Trans-Canada Air Lines (TCA, later renamed Air Canada), a wholly-owned subsidiary of the Canadian National Railway (CNR), would soon become Canada's major airline flying coast to coast (Milberry, 1979). In order to help and monitor the business side of its airline industry, the government set up an independent regulatory body, the Air Transport Board in 1944. Its role was to regulate the economic aspects of commercial aviation. Special legislation empowered the Board to allocate routes to companies already in the field and to prevent cut-throat competition from newly-formed carriers. It also had the authority to investigate complaints on routes and tariffs charged by airlines (Aviation in Canada, 1986, 1993). In addition, safety inspections were required in order to warrant an operating certificate. Thus, for the first time, airlines needed a license to operate a route or to operate from a base. This type of tight operations and safety level control would prevail until the mid 1980's and the advent of deregulation.

INTERNATIONAL ORGANIZATIONS

In the mean time, a somewhat similar mandate was attributed to a world wide organization, the International Air Traffic Association (IATA, now International Air Transportation Association), a newly established body formed on August 28, 1919 in the Hague. The association was formed "with a view to cooperate to mutual advantages, in preparing and organizing international aerial traffic" (Brancker, 1977). The original role of IATA, as defined by its first six members (all European airlines), was to establish standards with respect to the procedures and forms used for handling traffic and to make air travel more convenient and more acceptable to the customers. By 1933, IATA adopted standards for airline tickets and waybills, and an interline reservations code. It defined the ways of providing weather reports, radio communications and specified the rights and responsibilities of passengers, airline operators, or shippers in an event of loss, injury or death. IATA also defined the rules governing liabilities between airlines involving damage to aircraft on the ground or in the air, and damage to third parties on the ground. Other than traffic and commercial issues, the association was also concerned with the standardization of the technical field: "Safety in flight ... and economy in operating cost ... are two goals towards which the airlines must constantly strive. Safety and economy are unfortunately very often opposed, but standardization irreproachably conceived and widely carried out, offers a straight way to both these essential aims at the same time" (Brancker, 1977). Still today, IATA emphasizes the need to deliver better customer service and reduce costs. It also acts as a link between governments and airlines. It provides collective views of the airlines to official organizations, but it can not, and does not take action which might appear to interfere in the relationship between a government and its own national carriers. The Association is still involved, more then ever, in matters connected with the movement of both passengers and cargo. Its conciliatory role between airlines, as well as its authority on setting rates on scheduled flights, makes the international air travel more fair and convenient for its customers and operators. More importantly, its continuous participation in world safety conferences and direct contact with flight crews, ensures incessant efforts to make those flights safer as well.

While IATA was mostly involved with commercial and economic issues, another international authority, formed in 1944, was primarily concerned with the safety of air travel. The International Civil

Aviation Organization (ICAO) was established at the Chicago Convention and provided for the recognition of five "freedoms of the air". These allow the participating nations the right to fly over the territory of a foreign nation for non-traffic purposes (first two freedoms), enabled a state to drop off and pick-up passengers in a foreign state (third and fourth freedoms), and permits a state to carry passengers and cargo between two foreign states (fifth freedom). In addition, a number of bilateral agreements were put forward for countries unwilling to endorse all the freedoms (Aviation in Canada, 1986, 1993). Most importantly however, ICAO's Accident Investigation Division was created to monitor and promote the safety practices of its members, as defined in Annex 13 to the Chicago Convention (Aircraft Accident Investigation). Concerned with the safety aspect of operations, it relies on the basic principle of one state (the state of registry) being able to participate in the investigation conducted by another state (the state of occurrence). Its objective is to cooperate in the search for accident causes, publication and promotion of resulting recommendations, and introduce and promote new safety standards. ICAO's mandate spans across all facets of aviation safety-related fields, from personnel licensing, rules of the air and air traffic services to aeronautical charts, transport of dangerous goods, operation and airworthiness of aircraft, as well as search and rescue standardization.

The specification of all the ICAO annexes fall into two groups: the 'standards' and the 'recommended practices'. The former are considered by the council of ICAO to be *necessary* to help bring about the regularity and safety of air transport, while the latter are considered merely to be *desirable*. Any signatory of the Convention is required to register a formal difference with the secretariat if its own laws prevent it from adhering to a 'standard', whereas failure to implement a 'recommended practice', only asks that the secretariat be notified (Tench, 1985).

Today, in its quest for safety, ICAO establishes specific rules of dealing with accident investigation, its reporting, and distribution to all concerned, in order to ensure the same errors are avoided by others. It also publishes magazines and manuals, conducts research and establishes new regulations, all with the participation and approval of its member states in the pursuit of international air travel safety.

For the better half of this century the development of international air law and regulations has been sporadic and often difficult, due to the need for acceptance by many contracting states - each with differing national agenda. Similarly, Canadian interests were not regularly served by its own leaders.

NATIONAL TRANSPORTATION ACT AND FREEDOM TO MOVE

It wasn't until 1967 that the Canadian government began a complete review and overhaul of its transportation policies. The National Transportation Act (1967) was a comprehensive program aimed at regrouping individual transport sectors into a single multi-modal unit where separate policies would be looked at from a global perspective. The result was the creation of a single regulatory body, the Canadian Transport Commission (CTC), with commissioners representing each mode. Consequently, the regulation of economic issues of commercial aviation, which until now fell under the Air Transport Board, was delegated to the Air Transport Committee (ATC). Once again, the control of route allocations and competition between domestic carriers, with the emphasis on protecting the national airline, continued to be exercised by the federal government (Aviation in Canada, SC, 1986 and 1993). However, tremendous growth in demand for air travel, technological development of the jet engine, as well as increased safety of air transport, presented new challenges to the policy of regulated competition over the following two decades.

By 1984, the planning and implementation of civil aviation demanded yet another adjustment. This time though, even the matter of government control of the industry came under scrutiny. Until now, the federal government was the only institution in a position to provide the level of support and supervision required. The capital needed to cover the high cost of airport building and maintenance, the protection of sovereignty and the need to control potentially destructive levels of competition was becoming scarce. Changing circumstances in the Canadian economy called for a new approach to solving the economic growth, innovation and competitiveness issues. A proposal for economic regulatory reform entitled "Freedom to move" was published by the Minister of Transport, Don Mazankowski, in July of 1985. It described the inability of the present authorities to effectively keep pace with the changing economy and the transport system itself (Aviation in Canada, 1986, 1993). To deal with these problems, it recommended an economic deregulation of the air industry (similar to what the Americans did in 1978). The National Transportation Act put these recommendations into effect in 1987, by creating the National Transportation Agency (NTA) which assumed responsibility for the federal regulation of Canadian transportation on January 1, 1988, thus replacing the CTC. As stated in its annual report of 1992 "the ultimate goal of all NTA activities is to support the implementation of the national transportation policy through the economic regulation of carriers and modes of transportation that came under federal jurisdiction" (NTA, 1993). This can be achieved through the present transport legislation which is based on the premise that less government interference encourages innovation and enterprise. And since transport is now oriented towards a more competitive marketplace, economic regulation has been reduced and is geared to problem-solving services and protecting the public interest. Also, some of the financial burden on the federal government has been levied by privatizing airports through local airport authorities. Out of 1,255 licensed airports in Canada, 122 were operated by Transport Canada in 1991, and only 105 in 1993 (TC, 1993).

The six branches of NTA provide services in issues ranging from dispute resolution about rates and services between carriers and shippers/travelers, regulation of international air tariffs and transportation facilities, licensing of Canadian and foreign air carriers, monitoring of the economic impact of regulatory reform, as well as participation in international air agreements (NTA, 1993). The most important difference between the old and the new rules is the significantly reduced requirements for market entry. Carriers need only to prove that they are Canadian-controlled and fit, willing and able to provide air service in order to gain market entry, especially in the southern regions of the country. Also, public convenience and necessity criteria still apply, but it became the existing carriers' responsibility to prove that a license to a new carrier should not be granted. In addition, the government no longer requires the submission of fares for its approval, but the terms and conditions of any fare have to be readily available to the customer. Basically, the role changed from protecting the air carrier and in particular the national flag carrier, to protecting the traveler.

This protection from higher costs however, may later come at the expense of safety. It has been suggested that lower profit margins, caused by ardent competition, diminish the available capital otherwise invested in safety. Deregulation of financial competition may impede later efforts to keep the high level of aviation security, with safety still firmly regulated.

In addition, other organizations came to life in the government's search for better traffic control services and aviation regulation. A reorganization of Transport Canada in 1986 prompted the establishment of two groups: the Aviation Group - put in charge of maintaining all air traffic control services and aviation regulation, such as licensing and certification, legislation and enforcement, aviation medicine, and international technical liaison to ICAO, IATA, etc. The Airports Authority Group assumed the responsibility of managing Canada's airport system by maintaining Transport Canada's owned and operated airports (as of March, 1993 - 8 major international airports and 97 national, regional and local airports), that is, it supervises airport concessions and security, delegates airport construction, engineering, building and maintenance of runways, as well as overall marketing activities (Aviation in Canada, 1986, 1993).

INQUIRY ON AVIATION SAFETY

Only recently the government established a separate non-partisan entity dealing with aviation safety issues. The creation of the Canadian Aviation Safety Board (CASB) in 1984 was a significant step, because for the first time aviation safety was under the jurisdiction of a board which was totally independent from the Minister responsible for aviation. Until then, accidents/incidents investigation and research into safety issues fell under the authority of different establishments. The recommendation to set up such an organization came from the Commission of Inquiry on Aviation Safety (the Dubin Commission, 1981) as the following quote indicates: "The analysis of the aviation safety system must be that of an independent tribunal. The function of the tribunal should be much more than the investigation and reporting of accidents and incidents, as important as that function is. The tribunal's sole concern must be that of aviation safety." (Dubin, 1981) Thus, CASB operated independently of any government department and reported directly to Parliament.

The need for an independent body to investigate aviation accidents had been considered earlier in other countries. Conflicts of interest reappeared whenever a sensational aviation accident brought an investigation into the public eye. The dilemma had been identified some forty-five years earlier in the United States, after five people, including Senator Bronson M. Cutting of New Mexico, died in the crash of a Transcontinental and Western Air DC-2 near Kirksvilles, Missouri (Filotas, 1991). The Bureau of Air Commerce (BAC), which investigated aviation accidents at the time, attributed the cause to the airline and not the Department of Commerce (the BAC's employer) navigation aids. The findings outraged the airline and Cutting's senatorial colleagues, aware of the Roosevelt administration's budget and its slashed funding for navigation aids which could have been a factor in the accident. Consequently, the US Senate launched its own investigation of the crash, calling into question the previous investigation's findings, as well as the policy behind it. The Senate probe found more fault with the government than with the airline, claiming that the accident could have been prevented if the government lived up to its responsibility in providing aids to air navigation. As a result, an Air Safety Board (ASB) was set up in 1935. Its role was to investigate accidents, determine probable cause and recommend prevention measures, independently of the new Civil Aeronautics Authority. Later, the ASB was replaced by the National Transportation Safety Board (NTSB) which still exists today (Filotas, 1991).

Since the Canadian air transport system is modeled closely on the American example, the value of an independent accident investigation agency was apparent to the Canadian government well before the Dubin Commission started its research. On November 29, 1963, a DC-8 of Trans-Canada Airlines, crashed near Ste-Therese, Quebec, killing 118 people. The precise cause of the accident was never found, but the investigation emphasized jurisdictional disputes and conflict of interest. The salvage of the wreckage necessitated the removal of great amounts of earth and screening of its contents. The cost of heavy equipment and up to 1,500 workers was assumed by the airline. This gave some senior TCA officials the impression that it was their investigation, causing confusion between the airline and the Transport Department. The conflict prompted the government to commission a study to determine how this could be avoided in the future. The NTSB, then being formed in the United States, suggested a possibility of a similar agency in Canada.

Then, on July 5, 1970, another Air Canada DC-8 crashed on its way from Montreal to Los Angeles. The subsequent investigation revealed that the accident was caused by a mechanical malfunction. It could have been easily avoided only if the plane was equipped with a more sophisticated and easily available safety device. However, the American FAA* which authorized the manufacture of the plane, didn't require the device, and the Canadian Transport Department was not in the habit of questioning American airworthiness decisions. Later, in order to forestall another controversy, Minister of Transport, Mr. Don Jamieson, ordered a judicial inquiry. The Exchequer Court of Canada, found that the Captain of the DC-8 did not follow the manual (pilot error was the cause as indicated in the Transport Department's report), but also the flight manuals contained inaccuracies and misinformation, which the Transport Department had accepted and approved. The court recommended that the department review its procedures in approving the design of aircraft imported to Canada, and do a better job of monitoring flight procedures. Once again the report rekindled interest in the idea of an independent board and yet another study was commissioned to a retired Judge Advocate Brigadier-General Harold A. McLearn. In 1973 McLearn recommended the creation of an independent board along the lines of the NTSB, to effectively eliminate or at least reduce the existing risks of conflict of interest. But once again the commotion soon had died down, and the idea was abandoned. On a few other occasions the issue of an independent agency came up but it was not until 1981 that concrete efforts were made to finally implement the concept.

As the goal of implementing a global multi-modal transportation policy suggested in 1967, soon the safety issues of all modes of transport became integrated. This move was prompted by the proclamation of the Canadian Transportation Accident Investigation and Safety Act (1990), and creation of the Transportation Safety Board (Aviation in Canada, 1986, 1993). The mandate of the TSB today is to advance safety in all modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their cause and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and

---

* FAA: Federal Aviation Administration.

- conducting special studies and special investigations on transportation safety matters (TSB, 1992, 1993).

Consequently, the primary objective is to promote safety and not to assign fault or determine civil or criminal liability. Also, as further described in its annual report (1992):" To enable the public to have confidence in the transportation accident investigation process, it is important that the investigation agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments" (TSB, 1992). For now, this seems to work in Canada as well as in other countries. If only we could do more about the accidents.

The preceding historical overview described Canada's early days of flight, its involvement in the war efforts, the continuous development and improvement of the aviation industry and its regulation.* This particular mode of transportation is unique in its explosive innovation and growth, as well as quick public acceptance of it as a regular means of traveling over great distances. In spite of the economic downturn over the last few years, carriers accommodate a growing number of passengers. The number of hours flown nearly quadrupled since the 1960's. At the same time, the number of fatal accidents during this same time period, for all of commercial aviation, declined by almost one-half.

However, despite these very impressive statistics, public opinion can be greatly influenced as to the excellent safety record by reports of just one accident. That's mostly due to the number of fatalities involved at one crash site; with capacity of over 400 passengers on board (Boeing 747), the resulting losses can be horrifying. In this respect, air travel can be very unforgiving.

The following chapter, defines exactly what constitutes an accident and incident, and the factors influencing their occurrence. In terms of aviation activity, Canada ranks within the top ten states with the most number of registered aircraft and hours flown (ICAO, Annual Report, 1992). The increasing importance of flying and of Canadian carriers as travel options necessitates a detailed safety assessment of the accident causes in order to ensure a continuous downward trend of catastrophes in the air.

---

* For a listing of the mentioned and other aviation organizations in Canada refer to Appendix A.

CHAPTER II

FACTORS AFFECTING AIR TRAVEL AND MEASUREMENT OF SAFETY

The introduction of new technologies (such as the radar, the jet engine in the early 1950's, CAATS, MLS, and RAMP* projects in the mid 1980's), review of air regulations (including National Transportation Acts of 1967 and 1987), as well as the overall impact of economic environment of the country and the world have had a significant impact on the safety of air passengers and aviation operators. This study looks at the entire safety record of the Canadian commercial airline industry and classifies and analyzes factors contributing to safety. Air travel can be affected by any of the following factors: (1) the natural environment, (2) machine performance, (3) human errors, and/or (4) operational environment. These direct causes of aviation accidents are studied in the following sections.

Previous investigations into aviation safety generally studied the economy and its aspects. Most of the studies, conducted by the American academics, attached tremendous importance to the link between firms' financial conditions and their accidents rates, maintenance expenditures and service complaints (see Graham and Bowes, 1979). Others analyzed the relationship between accidents and profitability (Golbe, 1986). Dionne and Vanasse (1992), following the American example, proposed a framework for the analysis of the optimal safety behaviour of Canadian airlines in terms of their economic and financial success. Their econometric model was based on variables such as working capital, flight equipment maintenance expenditures and operating margins. Unfortunately, the described factors only indirectly influence any particular flight once the plane is in the air. It can be argued that all accidents occur because of human errors; since humans design the aircraft, operate the infrastructure, fly the planes, and introduce air laws and regulations. This research, however, investigates the most immediate causes of accidents in terms of the physical, environmental, or emotional factors leading to their occurrence. Engine failure, navigation aids malfunction, bad weather conditions, or air crew fatigue, to name just a few, are ultimately the probable causes mentioned in all final investigator's accident reports. Financial ratios, share value, dividend earnings, or union contracts and such, do not come up in the witnesses' or survivors'

---

* CAATS: Canadian Automated Air Traffic System, MLS: Microwave Landing System, RAMP: Radar Modernization Project.

accounts of a tragic experience, and travelers are not interested in these issues. The main concern is to get from point A to point B in one piece, without any disturbance. To know if the pilot is well trained on a particular type of aircraft, if the weather report is favorable, or if the machine itself has been adequately serviced and inspected before the flight, is to the traveler's advantage. Those aspects are of real importance to any passenger boarding at the gate.

In order to proceed with the statistical perspectives on Canadian commercial aviation and its safety record, it is imperative to review a few concepts, beginning with the definition of what constitutes an accident. The description of the factors affecting air travel and the measures of safety is also required.

DEFINING ACCIDENT/INCIDENT

An accident, as defined in the Merriam-Webster dictionary, is an event occurring by chance or unintentionally. In everyday use, however, at the minimum, an accident involves some damage to people, objects, or to both. In addition, to consider it worthwhile, the damage to objects or people must be sufficient to disrupt the ongoing task or future tasks that will be demanded of the objects or people. Consequently, to judge the accident important, criteria are needed, inevitably somewhat arbitrary, to distinguish between minor events and what would be called a real accident (Ramsden, 1976).

A scheme is also required, so that it can be applied equally to different situations. In order to exercise the criteria, specific tasks which make up an entire system, have to be studied. For example, if during approach, one engine fails and a successful emergency landing is performed, the trip will not be disturbed in any perceptible way, since all passengers will arrive at their destination without injuries or even major delay. However, the airline's system might be greatly disturbed if the plane has to be put out of commission to perform the necessary repairs. The degree of disturbance is related to what is defined as the system. If the trip is the system under analysis, there is no accident. As far as the airline is concerned, there is an accident. The event in question, then, involves damage to a defined system that disrupts the ongoing or future output of that system. Although, not all such disruptions should be classified as accidents; the criterion selection requires that the damage must be reasonably substantial (Perrow, 1984). The plane described, landed securely, and it had to be serviced - an unfortunate consequence - but repairing the engine will be enough to reinstate the aircraft back to the network of flights. This is called an incident. Though the plane was out of commission for a while, it did not sustain any permanent damage.

To clarify this distinction, the components of a system are defined as a number of parts making up a unit (the engine), an array of units will make up a subsystem (second engine), which with the other subsystems will come together to form the system. Beyond this is the environment. As a result, this scheme reserves the term accident for serious matters, those that affect the subsystems and the entire system while the term incident describes disruptions to the parts and units.

For the purpose of this study the above definition can be related to air accidents. An accident, as described by TSB and based on ICAO's definitions* is "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:

a) a person is fatally or seriously injured as a result of:

- being in the aircraft, or
- direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
- direct exposure to jet blast,

except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways, hiding outside the areas normally available to the passengers and crew; or

b) the aircraft sustains damage or structural failure which:

- adversely affects the structural strength, performance or flight characteristics of the aircraft, and
- would normally require major repair or replacement of the affected component,

---

* Contained in the International Civil Aviation, the Annexes thereto and the Procedures for Air Navigation Services (1991).

except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage to propellers, wing tips, antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin; or

c) the aircraft is missing or is completely inaccessible."*

An incident, as defined in the same document is "an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operations". **

Thus, safety assumes, an accident has occurred if the ongoing or future output of the system - safe operation of an aircraft - was disrupted due to a failure in a subsystem, or the system as a whole, that damages more then one unit and in doing so causes death or serious injuries to one or more persons. An incident will involve damage associated with the operation of a plane that is limited to parts or a unit, whether the failure disrupts the system or not, but impacts the overall operations safety.

FACTORS AFFECTING AIR TRAVEL

Having defined what constitutes an accident and incident, the next step is to study the factors contributing to their occurrence. As mentioned earlier, one or any combination of the following elements can adversely influence the successful completion of a flight: natural environment, machine functioning, human error, and/or operational issues. Closer review of all these factors will help better understand their role and importance in completing a successful trip.

Classifying accidents according to their cause immediately poses the most difficult problem of assigning a single antecedent to the event; many accidents have several contributing factors. In general, there are three principal approaches in ascribing the fault. One option is to select the cause that initiated the sequence of events that culminated in the accident. For example, if an engine fails during landing and

---

* For statistical uniformity only, an injury resulting in death within 30 days of the date of the accident is classified as a fatal injury by ICAO. Also, an aircraft is considered to be missing when the official search has been terminated and the wreckage has not been located.

** The type of incidents which are of main interest to the International Civil Aviation Organization for accident reporting prevention studies are listed in the ICAO Reporting Manual (Doc 9156).

the crew omits to take the proper action to land the plane safely, resulting in a fatal crash. one could say the engine failure is said to have caused the accident. In contrast, if cause is attributed to the last point at which the accident could have been prevented, then the pilot error is to blame. The final approach to classifying accidents then is to consider both factors as cause.

Unfortunately, with these methods pilot error will be listed as a cause much more often, in the last two cases, whereas equipment failure will come up more frequently if the first approach is used. However, the technique of identifying the sequence - initiating cause avoids the classification of some data. Also, pilot error accidents identified under this methodology are due to unforced human error rather than imposed errors. This means, using the above example, that the fact the pilot failed to respond appropriately to an engine failure is considered a direct result of the pressure and stress associated with the emergency. Attributing the cause to the pilot, while focusing on the last point at which the accident could have been prevented, confounds both forced and unforced pilot error. On the other hand, the interpretation of the distribution of causes becomes different when counting all contributing causes for all accidents. Since some accidents have many contributing factors, they therefore contribute more causes to the distribution than others (From the Ground up, 1991).

A) Natural Environment

The early days of aviation limited to flights in sunny weather, good visibility and light winds are long over. Research and training programs of modern airliners make it possible today to operate with the cloud base of zero, greatly reduced visibility, and the runway surface wet from various forms of precipitation. Except in extreme conditions, such as hurricane and violent winds or prolonged snow storms, rendering the landing strip unacceptable to use for reasons of great depths of standing water, snow or ice, airports are now open to travelers and planes around the clock, 365 days a year.

Although progress made in providing continuous service to carrier operations is inspiring, occurrences of severe natural phenomena sway experienced pilots to delay takeoffs, but also cause accidents to aircraft flown by less experienced, less cautious pilots (Taylor, 1988). Crashing a plane in heavy rain however is not necessarily classified it as a weather related accident.

In order for an accident cause to be attributed to the environment, specific conditions must prevail and point directly to it. Otherwise judgment (pilot) errors would be categorized incorrectly and the resulting recommendations and regulations inaccurate, and most likely, ineffective. For example, if a weather briefing is not obtained prior to flying, the cause is likely preflight judgment rather than weather. Also, windy conditions during takeoff or landing that are corroborated by weather data or witnesses are considered as weather accidents. Otherwise they can be categorized as flying skills or, if high winds are known to the pilot prior to landing (takeoff), as in flight judgment error (or preflight judgment error) (From the Ground up, 1991).

Thus, the environment category includes accidents resulting most likely from windshear, thunderstorm-related turbulence, slippery runway, emergency landing due to weather, and icing. The following description of each of these meteorological conditions should clarify their influence on the aircraft and its crew; in all instances, they invariably affect two aspects of flight: the aircraft response to controls and visibility.

One of the most dangerous forms of severe weather is the near invisible hazard of wind. Winds of great strength such as those found in hurricanes and typhoons, tornadoes and cyclones create turbulence sufficient to menace the structural integrity of transport aircraft. Most of those situations can be plotted and avoided through satellite or weather reconnaissance aircraft, or simply detected by on board weather radar equipment. Consequently, close encounters with these phenomena are rather rare, as pilots make detours or delay flights to avoid the hazard.

Another clear air turbulence (CAT) associated with strong upper-level (tropopause: 20,000 - 40,000 feet) winds known as jet streams can cause turbulence, although not as violent as hurricanes. It may create passenger discomfort or fear, and may speed up aircraft fatigue, but does not cause loss of aircraft (Taylor, 1988), although difficulty of flight may prove enormous. A more violent form of disturbance is found in mountainous areas. Substantial distortion of airflow, as strong up and downshifts develop, constantly changes the direction of air flows around hills. This rotor turbulence can be severe enough to destroy any transport plane. In the 1960s, on a clear day, a Boeing 707 leaving Tokyo Airport, requested and received approval to divert from the direct track to Hong Kong in order to show the passengers the gorgeous Mount Fuji. The plane flew into a rotor flow in the lee of the mountain and broke-up in extremely severe turbulence, causing the death of all on board (Taylor, 1988).

The most perilous form of severe weather is windshear; a sudden tearing or shearing effect encountered along the edge of a zone in which there is a violent change in wind speed or direction. It can exist in a horizontal or vertical direction and produces churning motions, and as a result, turbulence. Windshear, associated with thunderstorms, occurs as the result of two phenomena, the gust front and downpours. The gust front forms as a strong downdraft develops, strikes the ground and spreads out horizontally along the surface well in advance of the thunderstorm itself. The downburst is an extremely intense localized downdraft flowing out of the thunderstorm. It usually is much closer to the storm than the gust front. The power of the downburst can easily exceed aircraft climb capabilities. Under some conditions, wind direction changes of as much as 180 degrees and speed changes of as much as 80 knots have been measured, as far as 10 miles ahead of the storm (Taylor, 1988).

Other than occurring in visible and violent weather conditions such as thunderstorms, windshear can develop in hot dry climates and in other conditions where its presence may be more difficult to detect until it is too late. The effects of severe windshear on aircraft performance are brusque changes in airspeed and ground speed, with significant variations in aircraft functioning. Should a plane be in landing or takeoff configuration, it can lose airspeed and height to a degree that causes contact with the ground, in spite of the pilot's best efforts. It was in such conditions that a Lockheed 1011 Tristar aircraft crashed while attempting to land at Dallas, Texas, on August 2, 1985. Severe windshear conditions caused the aircraft to land short of the runway although full power was applied to all three engines. The Tristar touched down in the field, hit a car and then broke into two parts as it collided with a water tower. One hundred and thirty-three people were killed or fatally injured, and only thirty-one passengers survived; they were all sitting at the rear of the aircraft (Taylor, 1988).

Phenomena such as sandstorms, dust, snow, smoke, heavy rain and fog restrict surface visibility at airports and are factors adverse to safe and regular air transport. It took many years to develop the use of instrument flying techniques and equipment to free airline operators from the worst effects of poor visibility. Accidents were caused by unexpected encounters with fog at airports, or by paying too little attention to the possibility of rain or clouds development during flight planning. Small changes in wind speed or temperature are sufficient to form fog, or other adverse conditions, and forecasting of the problem is extremely difficult.

Although the majority of weather related accidents are attributed to the presence of poor visibility, low cloud, or wind, a smaller but significant number occur because pilots fail to appreciate the hazard of rain or other forms of precipitation. Hail and very heavy rain can cause severe damage to the fan blades of engines, airplane's nose, leading edges of wings and tail surfaces. One such incident was recorded on August 28, 1987, when a B737 lost power from both engines while penetrating a hail storm on its way from the Greek island of Skiathos to Solonika, and power was not restored until the aircraft had descended to only 5,000 feet above sea level. Heaviest rainfall affects unfavorable aircraft performance, which has consequences for safety during takeoff and landing, but not normally during cruising. Most serious consequences are experienced when flooded runways cause wreckage to wing flaps, the engines (through ingestion of water) and even more seriously, counteract aircraft performance by extending the takeoff run. Pools of water on the runway may cause the machine to aquaplane and over-run the paved surface due to lack of effective wheel breaking. Loss of directional control can cause it to exit the side of the runway. Similar conditions can also damage tires trapping water between tire and pavement turning it to super heated steam.

Many serious accidents have been caused by aircraft landing on ice or snow covered runways as well, leaving its surface either at the end or sides while still traveling at high speed. Other accidents have been caused by aircraft failing to gain enough speed to takeoff from slushy runways. A Japan Air Lines Boeing 737 at Anchorage, Alaska, was blown backwards off an icy taxiway into a ditch in March 1976. The incident caused severe damage to the plane but no serious injuries to its crew or passengers.

Another dangerous consequence of severe wind and cold temperatures is the formation of ice. Accidents have been caused by ice accretion on the wing, tail, or control surfaces of the aircraft. Takeoff or continued flight can be prevented by ice altering the shapes of the airfoils, thus impairing lift and controls. Areas frequently experiencing icing conditions equip their airports with de-icing facilities, capable of removing or preventing the accumulation of ice even on the largest aircraft. However, the ultimate responsibility for its removal lies in the hands of the captain and crew. Accidents due to aircraft icing continue to occur and one of the worst in recent years happened to a Boeing 737 in January 1982. Taking off at the Washington Airport it crashed into the Pontiac River leaving only five survivors from the 79 people on board. The subsequent investigation found that the tragedy occurred because airframe and engine icing impaired the performance of the plane and caused false indications of engine power to a degree that mislead the crew into believing the takeoff was normal until too late to become airborne or discontinue the takeoff (Taylor, 1988).

Other than wind, ice and rain, a few more phenomena can contribute to an accident. One form of aviation environmental hazard comes from birds (in flight) or deer and other animals. The risks incurred from in-flight encounters with birds were recognized as early as April 3, 1912. C.P. Rogers, the first man to fly an aircraft across the United States, plunged to his death after taking off from Long Beach, California, and running into a flock of sea gulls. On that unfortunate day, he became the 147th person to die in an aircraft accident and the first to be killed from a bird strike.

In Canada, in 1986 alone, 868 bird strikes were reported, causing 64 precautionary landings, 29 aborted takeoffs and an estimated $3 million damage. An example of such an event is a B737 taking off from Winnipeg and striking six Canada geese at 1,500 feet above ground level. The plane lost one engine, suffered severe damage to the fuselage and wing, and one of the birds penetrated the leading edge of the horizontal stabilizer and got stuck inside. The resulting repairs cost over $400,000 (Taylor, 1988).

Animal strikes are more common in general aviation rather than commercial operations. Accidents in North America are mostly caused by striking a wide variety of animals such as cattle, dogs, rabbits, sea gulls, and geese.

As familiarity is gained with the wide variety of issues where natural environment can adversely affect the safety of the aircraft and its occupants, new methods are developed to avoid them through radar and satellite images, as well as close communication between pilots and ground operators.

B) Machine Failure

Every component of every part of a civil aircraft is designed to meet the agreed airworthiness requirements set by national and international authorities. These do not dictate how the manufacturer must design, make, develop or test an aircraft, but define the most stringent standards which must be met. The quality and integrity standards of the civil airliner are much higher than those of a military aircraft. For example, an airliner's airframe has to last for at least 40,000 hours without a serious crack and this fatigue life has to be demonstrated and guaranteed by a test airframe. The Canadian Air Force, on the other, hand expect to get no more than 1,000 hours out of a combat aircraft before it starts to weaken with fatigue or corrosion. Many factors are considered during the process but a basic principle of designing structures that are fail safe, rather than having safe lives (as was formally the case) has achieved wide acceptance. Fail safe requires that no single failure may impede the aircraft and that structures provide multi-load paths. These multi-load paths ensure a redundancy feature, whereby a second part can accept the loads carried by a failed part. If an airliner engine or a vital system fails, the airworthiness authority require up to three back-ups. The fighter pilot of a single-engine or single-control-system aircraft however will use his ejection seat in such instances.

As a consequence, unless a Certificate of Airworthiness (C of A) has been issued by the appropriate authorities (in Canada: Transport Canada, Aviation Group), the aircraft can not carry passengers on board. This certificate is granted to the aircraft type manufacturer only if it has demonstrated compliance with the Airworthiness Requirements (ARs). These cover everything from the fatigue life of the structure and the loads which must be simulated on the test apparatus, to stability and performance.

Despite these rigorous requirements and the aviation industry's constant research efforts into the environment in which it operates, construction materials it uses and new types and methods it develops for aircraft design, technical malfunctions still occur. If the events leading to an accident were initiated by some sort of mechanical, structural, or electrical default in the aircraft, then the accident is considered caused by equipment failure. Equipment failure accidents are in most cases attributed to deterioration of the engine, instruments and electrical equipment, landing gear and tires, and structure fatigue or aircraft aging.

Engine collapse includes deficiency of the power plant including propellers, internal engine parts, carburetors, turbochargers, magnetos, exhaust systems, and fuel lines downstream of the fuel tank. The malfunction of any one of these components leading to an accident is considered as engine related accident. To illustrate, on August 22, 1985 a twin-jet airliner suffered an engine failure during takeoff at Manchester, UK. After abandoning the takeoff and ordering evacuation of the aircraft, the crew noticed a fire beak out. Because the evacuation process had been slowed by difficulty in opening one of the emergency exits and by the fierceness of the fire along one side of the aircraft, 55 lives were lost; mostly by inhalation of toxic gases. The flames engulfed the aircraft in only two minutes from the start time of the takeoff run. Investigation of the accident revealed that one of the combustion chambers of the number one (left) engine had suffered an explosive rupture and the debris punctured a fuel tank which initiated the fire. The resulting recommendations led to mandatory inspections of the subject engine parts ordered by the American authorities; NTSB and the FAA* (Taylor, 1988).

Since the continued operation of a modern aircraft is dependent on its systems, as much as on the integrity of its engines, an in-flight failure of the electrical or hydraulic equipment could prevent it from proceeding to a safe landing. These vital systems are therefore designed with considerable redundancy in order to operate essential services in case the primary unit fails and affects the safety of the flight. In many aircraft separate hydraulic systems are powered by each one of the engines, with additional backup being arranged by providing an alternative power source for each system. With the hydraulic systems powering separate groups of flight control surfaces, it would be extremely unlikely that an aircraft could ever suffer a complete loss of flight controls. It would require that all separate hydraulic systems be filled with the wrong type of fluid or for all the fluid to be lost, or for some form of explosion or structural failure to take place for a total failure to occur.

As the primary source of power comes from the engines, the level of system redundancy increases with the number of engines, and thus the level of safety. This is a factor in the choice of aircraft types for

---

* NTSB: National Transportation Safety Board, FAA: Federal Aviation Administration.

particular service routes. Flights crossing long ocean surfaces, remote areas, or inhospitable terrain far from alternate airfields have traditionally been flown by multi-engine aircraft; usually three or four engines. Operations with two-engine aircraft over those routes generally require major modifications including the installation of auxiliary power units to supply an acceptable level of redundancy.

As with everything man-made, even the required backups can not always prevent extremely improbable events from happening. The worst ever disaster attributable to a failure of engineering occurred on August 12, 1985. A JAL B747 aircraft was on a flight to Osaka when it crashed in a mountainous region north of Tokyo, killing 520 people; incredibly there were four survivors. While flying at an altitude of 24,000 feet the captain contacted Tokyo control tower to declare an emergency and requested an air traffic clearance to return to the airport. He never made it back. The aircraft lost rudder control, aileron and elevator hydraulic pressure and the captain was left with only differential engine power to provide a very small measure of control over the inevitably erratic flight path of the aircraft. The plane was rolling as much as 40 degrees in either direction and at the same time pitching 15 degrees up and five degrees down, producing load factors of up to 1.85G. The flight time till impact in those incredible conditions was 45 minutes, demonstrating the remarkable feat of airmanship for the captain to keep the plane flying so long without flight controls. The investigation into the accident recovered parts of the aircraft 95 miles from the site of the crash. Examination of the wreckage revealed that the rear pressure dome ruptured, creating air pressure in the tail of the aircraft. Air pressure destroyed the tail control surfaces and caused other damage, resulting in a total loss of hydraulic pressure (Taylor, 1988). That, in turn, caused the loss of all other flight control systems - statistically a highly unlikely event !

In addition to engines and hydraulic equipment, other aircraft components such as wheels, breaks and tires are vitally important. The latter suffering, however, the worst possible treatment. Compared to other aircraft elements they are small, light weight and subject to high temperatures during the taxiing, take-off and landing. These ground maneuvers exert tremendous pressure on the parts and subject them to extreme temperature changes; from -50°C at 40,000 feet to steaming hot immediately after the aircraft lands. Unlike engines and electrical components the pilot can not see the wheels and tires and usually has no information on their status after the aircraft starts to move. With up to 16 wheels carrying weights of over 350 tons at ground speeds of 200 miles per hour, there is a great potential for disaster in the event of failures; wheels can explode in flight or on the ground causing significant damage to the aircraft structure.

A Tristar aircraft of Saudi Arabian Airlines suffered such an exploding wheel in flight. The hole made in the fuselage of the aircraft was so large two children were pushed out to their deaths. Another typical example of wheel/tire failure occurred on March 31, 1986, when a Boeing 727 operated by Mexicana Airlines had a tire burst in flight after the gear had been retracted. The explosion pierced ducts carrying fuel, water, electric and pneumatics, and hot air from the ducts ignited fuel, setting off a fire that melted the structure of the fuselage. Next, the tail of the aircraft collapsed and the pilot lost control, with the aircraft breaking up at 15,000 feet. Everyone on board perished (Taylor, 1988).

Aircraft equipment aside, the most pressing area of concern in the '90s is the aging fleet of aircraft operated by most carriers. In Canada, more than 30 per cent of planes used by the two mega-carriers and their affiliates are more than 15 years old. To still take advantage of these operational aircraft the TC is looking more towards the concept of 'damage tolerant' instead of 'fail safe' and states that inspectability is a vital part of continued airworthiness. In order to assess the condition of aging aircraft, Boeing, the world's largest manufacturer of civil aircraft, has implemented a special program in 1987. Its survey of almost 100 old airplanes across 34 operators worldwide revealed that the most significant problems arose from corrosion, particularly in areas near to galleys and lavatories. They found that those operators with inclusive corrosion control programs suffered significantly reduced damage. Other reported problems were related to fatigue damage. A number of operators visited by Boeing requested easier access to major structural joints for thorough inspection and maintenance. All findings were extremely useful in improved aircraft design and maintenance of components affected by age.

Unfortunately, a number of accidents occurred before the problem of aircraft age was studied and the situation remedied. The first event caused by the age of an aircraft happened in May 1977, when the port tailplane of an all cargo Boeing 707 failed during an approach to land, killing its six-man crew. The tailplane had been designed on fail safe principles and a catastrophic failure was, in theory, impossible since the fatigue crack should have been detected before it became critical. It was found, after the crash, that the aircraft had flown 47,600 hours on 16,700 flights. Further inspection of the same type of planes found similar cracks in tailplanes of 26 other high time B707's. These discoveries raised concern that the age of aircraft will become a more significant factor in accidents, as the world-wide tendency is for aircraft to have their lives extended to limits never before contemplated.

An even more worrisome problem arising today, is the sale of civil aircraft approaching the end of their safe lives to third world airlines. Retired by the major western airliners, these aircraft need extensive maintenance but the new owners rarely have the necessary technical and financial resources to keep the fleet airworthy. The problem is compounded by a small but growing tendency for carriers that can not or will not meet the requirements of states that enforce safety regulations, to move their operations to other less demanding states.

It is the aviation industry's goal to produce aircraft that continue to operate for many thousands of flights and many thousands of hours. The servicing and maintenance activities are therefore essential if that extended machine life is to be achieved and the incipient failures identified and rectified before safety is prejudiced. The design for maintainability, metal fatigue resistance and component safe functioning are of greatest importance in achieving that objective.

C) Human Errors

Flight safety is the product of pilot and crew behavior as determined by flight environment, aircraft characteristics and ground personnel influences. Certainly in the early days of aviation, incidents and accidents were mainly caused by structural or mechanical failure. These usually happened shortly after the aircraft became airborne, and as such, the pilot rarely had time to make a mistake. Conversely, as aviation developed, the majority of accidents (50 - 60%) were attributed to pilot error, although to be fair, a number of these errors were compounded or even triggered by mechanical or systems failure. It does nevertheless appear that in most cases pilot error was primarily caused by such factors as lack of preparation, inadequate training, or an inability to make the correct decision and take positive action at the appropriate time (Rose, 1987).

Some accidents are caused by pilots relying on poor aircraft design, where identical or closely adjacent controls and instruments are being used for greatly dis-similar purposes. On March 31, 1986, for example, a United Airlines B767 lost power from both engines after taking off from San Francisco. The pilot wrongly operated both fuel cut-off switches - using only one hand - believing that he was operating adjacent and identical switches to isolate the electronic engine control units (the two sets of switches were separated by three inches). On June 30, 1987 an identical mistake was made by the crew of a Delta Airlines B767 taking off from Los Angeles with 205 people on board. Fortunately, in both cases the engines were successfully re-lit. As a result the FAA issued an Airworthiness Directive requiring all operators of B757 and B767 aircraft to modify the fuel control switch panel so that it was impossible to operate both fuel cut-off switches with only one hand. Later, the United Kingdom's CAA (Civil Aviation Authority) adopted the same airworthiness directive to apply to all British operators of the aircraft types.

Another problem stems from pilot's errors in reading flight instruments. A series of laboratory tests conducted in the USA demonstrated that when people were asked to read instruments with five different dial formats (vertical, horizontal, semi-circular, circular and 'open window'), although all with the same scale length, pointer width, graduation and design of numerals, significant differences were registered in the number of mistakes made. In each case the same value to be read was provided. The errors made were as follows:

Vertical	35.5%
Horizontal	27.5%
Semi-circular	16.6%
Circular	10.9%
Open window	0.5%

With such large discrepancies in performance, great care must be taken to ensure that the best choice is made in the design of flight instruments (Taylor, 1988).

An additional factor in the problem of ensuring that the pilot always has accurate information lies in the fact that ICAO failed to ensure a common system of units is used worldwide. The two systems in use are based on the meter and the foot. Although ICAO recommendation is for the eventual adoption of the metric system, it will be many years before standardization is achieved. Until then, pilots find themselves using altimeters calibrated in feet and being asked to report their altitude in meters - or vice versa - and having to use conversion tables to state the measure, only adding to the many flight tasks and an undesirable slow-down in communications between air traffic controllers and pilots.

Pilots are sometimes required to fly in deteriorating weather conditions and place great reliance on the perceived perspective of the runway during the last stages of a visual approach to land. In visually good conditions an experienced pilot can land the plane safely, easily detecting and correcting for even slight deviations from the required flight path. There are however a number of possible adverse conditions that make it unwise for any pilot to place much reliance on the acquired visual abilities.

Refraction caused by water on the windscreen is one such condition and it has caused landing accidents by convincing pilots that the aircraft flew higher (at a steeper flight path angle) than it actually was. In that case, the water refraction lead the pilot to land the plane short of the runway. A false judgment being made about the flight path angle also occurs when the pilot's eye is not at the reference position due to incorrect vertical adjustment of his seat. In addition to providing false perspective, the seating position causes the visual ground segment to be greatly reduced. When an aircraft is in a landing configuration, sitting too low can distort perspective and as a result the pilot, seeing too little of the runway, could decide that it is not possible to land safely.

Other adverse conditions causing landing accidents are: varying air temperatures, snow, fog, night, airport situated on sloping terrain, or irregular terrain on the approach to the runway. For example, an air temperature inversion, occurring usually at dawn, inducing the boundary between lower (cooler) air and higher (warmer) air causing it to act as a mirror, can create very misleading visual effects. These phenomena bring about serious refraction of all the pilot's visual references with sometimes fatal consequence. Rare exposure to any of these illusions can lead to a failure to recognize them when they occur. The known existence of these hazards is usually a major reason for the installation of non-visual and visual landing aids at airports. The research into these, sometimes not so obvious, problems of imperfect human perception was a major factor in the development of automatic landing systems that place little reliance on what is seen, or not seen, from the flight deck of an aircraft.

A more obvious factor to trace and leading pilots to make errors while operating an aircraft arises from the manufacturers and/or operators persuading airworthiness authorities to permit common type ratings from 'derivative' aircraft. When this occurs, pilots who are already qualified on a type such as B737-100, take only short 'differences' courses to become eligible to fly the 200 and 300 models of that type of aircraft. However, there may be significant operating differences between the models and crews may go months between flights in a particular make. As a result, pilot concern arises not because of the limited content and the brevity of the 'differences' courses but because of the length of time passed between flying a specific model, thus increasing the danger of reacting to an in-flight emergency in an incorrect manner. To remedy the situation some airlines place the differing models in separate fleets and assign pilots to fly only one model and to take refresher training before changing to another model. This practice is welcomed by pilots and safety experts.

The above causes of accidents were attributed to either aircraft design, impaired vision or insufficient training. There are more factors to consider however, most of them of a very personal nature and affecting people in different ways, but whose effects are very real, and almost invariably, extremely difficult to detect. They range from the variable performance of people under stress, the adverse influence of alcohol or drugs, the aging process, the effects of chronic fatigue, and the stress and psychological pressures created by family, by social problems or by employers (Taylor, 1988).

All humans experience stress at various times and it is widely recognized that minor stresses may be a good means of motivating a person and ensuring alertness. Too much or prolonged periods of stress however have been a contributing factor in some aircraft accidents and incidents. Recognizing that stress is a particular threat to the pilot's career, safety authorities have identified time constraints and associated limitations to situations known as common stress factors. Specific rules are put in place to assure as regular flight shifts as possible, with adequate rest periods. Identified sources of stress also include consideration of the supervisory and legal environment in which pilots work; requiring them to be subjected to numerous checks and tests annually. The possibility of involvement in accidents with inevitable investigations and inquiries, and a consequential risk of an assessment of blame further aggravate the stability of ones mind. After all, mental disease is the second most common cause of premature career termination among pilots ! To illustrate, an official inquiry into a major accident to a British Trident airliner near London Airport in 1972 heard evidence that there had been a grave disagreement between two pilots immediately before the flight (they were 'discussing' an industrial dispute affecting the airline). The premature retraction of the high-lift devices on the wing soon after takeoff and the captain suffering a major heart attack at about the same time were cited as the cause of the accident. It was put forward that the disagreement between the pilots created stress, resulting in mismanagement of the high-lift devices and perhaps causing the heart attack suffered by the captain (Taylor, 1988).

It could also be postulated that had the crew coordination been better, the accident would have been prevented - by minimizing the risk of crew member fighting. Good coordination between flight deck members means the co-pilot must be trained to perform his own designated duties, to provide whatever assistance the captain requires and more importantly, to act as a monitor of the captain's performance. For the credibility of these different roles to be accepted, he should be trained to the same standards as the captain. When, in the past, there were great discrepancies between the ages, experience, and qualifications of the two pilots, it was unrealistic to expect the co-pilot to offer advice or criticism, or for the captain to accept it if offered. Today, new systems of confidential and anonymous reporting of incidents have brought many such instances of poor coordination to light. Studies of unacceptable flight deck behavior cite inefficiency, passivity, laziness, incompetence, boredom, lack of monitoring other persons actions and absence from the flight deck, to mention just a few, as the main problems. The reasons provided for such behavior are mis-matched captains with co-pilot's level of experience, age difference and two captains flying together. It was also observed that crews that perform below average tend to communicate less. Frequent commands from the captain, on the other hand, are associated with lower incidence of flying errors. In other words, new techniques emphasizing the need to improve team performance through practice of a whole crew 'flying the mission' on flight simulators during training and on actual trips, have a powerful influence on crew behavior and its performance.

One of the most important factors considered when scheduling pilots for their duty, aside from putting together an effective and efficient crew, is fatigue. The early air travels had rest periods factored into the trips, simply because the design limitations and performance of aircraft made it impossible to fly long distances without refueling, or at night or in bad weather. Aircraft were scheduled to fly several short sections each day, and passengers and crew stayed overnight at some suitable location, the journey taking several days to complete. Thus, the crew were able to maintain a near-normal pattern of activity and sleep, as well as adjust to climatic and time-zone changes in an almost ideal way.

The introduction of improved aircraft and weather radar enabled airlines to reduce the time spent on each trip. Scheduling the aircraft to fly to its destination with stops to refuel and change crews, if necessary, reduced the airlines' operating costs. A major drawback of these changes were drastic climate and time-zone shifts for the team, without the necessary adjustment time. Also, the overzealous operations departments would schedule the crews to fly for as long as possible each day, in order to obtain an acceptable annual rate of aircraft utilization. Of course they were ignoring the basic fact that fatigue is cumulative but rest is not !

A further important factor was the unreliability of the aircraft, causing long delays because of technical deficiencies of systems and engines. These in turn placed additional psychological pressures on the crews to fly very long duty periods in an attempt to minimize disruption to passengers and to the airline. With duty times in excess of 24 hours (not unusual for them in those days) airlines were just asking for an accident to happen. Finally some commercial organizations and government agencies recognized the worst of these abuses. ICAO introduced a complicated formula to define the minimum amount of time of rest and the maximum scheduling for flight duty. Today, these time changes and restrictions save airlines money on sick leave due to stress and overwork, and promote the safe operation of aircraft.

As emphasized throughout, in order to pursue a professional pilot career, mental and physical health is of utmost importance. The issue of aging pilots is one of the most disputed subjects by international aviation organizations. Because not all humans age at the same rate - elderly can remain remarkably active in their life styles, habits and standards of performance in tasks that may be too demanding for persons who are much younger - regulatory authorities do not agree on a single method of determining how long a pilot my continue to exercise the privileges of a license.

Since retirement age varies among even the ICAO contracting states, a safeguard is provided in form of medical checks that pilots undergo at fixed intervals of time. These tests try to assess the ability to perform highly skilled tasks in a rapid fashion, to resist fatigue, to maintain physical stamina, to unlearn or discard old techniques and to apply the rapid judgment needed in changing and emergency situations. Simply because a person reaches a certain age, does not mean they all of a sudden become useless to society. The young are most efficient with respect to physical strength, but an older person compensates by acquiring experience and better judgment. Also, a mature man/woman is less able to adapt without fatigue to an immediate stress, but is likely to be able to endure stress for a longer period than a younger person. In addition, it is necessary for a pilot to coordinate his/her cerebral activity and visual function. With increasing age, cerebral functions slow down and consequently, the time to react. Also, less information per period of time may be physiologically stored and recalled, and the capacity of learning is reduced.

To verify these findings and relate them to aviation accidents, the FAA and NTSB funded a study correlating the pilots age and rates of accidents. The results showed a rapid decrease in the rate of accidents for pilots in their 30's or older. A likely cause of these results may be the older pilot's performance reflects the effects of increasing experience and judgment. Consequently, the FAA never placed an upper age restriction on general aviation pilots and a limit of 60 years old on airline pilots (as opposed to 55 in the UK). The statistics also imply that the safety record of airlines will worsen during periods of rapid expansion when median levels of experience are reduced and improve during periods of relative stability.

Since the investigation of aircraft accidents and incidents has become a highly specialized subject, and studies into their causes have revealed that a great majority of them can at least in part be attributed to human errors, almost all aspects of the human body and mind have been investigated. To the list of factors already mentioned in this section we can add a few more. The accuracy of information transfer between pilots and air traffic controllers, adherence to radio and instrument flight procedures, knowledge of English as the official aviation language, design and reliability of aircraft warning systems, as well as cockpit resource management, are all known to contribute in some fashion to the way the pilot and the machine interact/perform. Only time will tell how well we understand them all, and how we can avoid their fatal influence and promote greater airline safety.

In spite of great progress made in the design, manufacture and operations of civil aircraft, more needs to be done to provide a better match between the aircraft, environment and the crew members who operate them. In the last 40 years, aircraft manufacturers made great efforts to improve the plane's structure, systems, and engines, and the responsible authorities still make improvements in weather forecasting, air traffic control and aerodromes. The pilot's human nature and abilities, however, remain much the same as in the earliest days of aviation. Hopefully, the study of past mistakes will lead to better recognition of the most striking deficiencies and lead to their improvement, as well as to furthering the safety of air travel in the future.

D) Operational Environment

In addition to the human errors, committed by aircraft crews, the operational environment, consisting of air traffic controllers and ground maintenance crews, other aircraft and company operations can greatly influence flight safety.

Air traffic services are an important feature of the operational environment and include weather forecasting and reporting, aeronautical information systems, and most valuable to air safety, air traffic control (ATC). When air traffic control was first introduced in 1936, its objectives were to prevent ground collision and air collisions during landings and takeoffs, and signs were used in the form of flags, signal lamps and pyrotechnics. While en-route, pilots themselves were responsible for the avoidance of collisions. Any information sent from the aircraft by the radio operator usually signaled a progress report and 'all is well' message. In those days, there were few air collisions or even near-collisions, because aircraft flew in visual conditions most of the time, they were few in numbers and tended to keep separated from each other along the air routes due to inaccurate navigation.

In the 1950s a few mid-air collisions, the growth of air traffic and the availability of ground-based radar stimulated the American and European governments to make the necessary improvements to promote safety. Soon, the modernization of the air traffic control systems, introduction of ground radar and improved ground-based navigational and communications facilities were installed at the busiest airports, making possible a large increase in the number of airways and control centers. The next step after the introduction of radar and improved direct controller-to-pilot voice-radio links was the application of computers to process raw data. The growth of air traffic and airline pressure to reduce separation between aircraft in order to increase the rate of flow of air traffic and reduce ATC-caused delays, meant that the human controller was being overwhelmed by the data he/she was required to assimilate and use to make operational decisions. This impressive responsibility on the part of the controller was not matched by the number of people trained and hired for the job. In the USA, for example, although air traffic increased substantially, there were only half as many qualified controllers in 1986 as there were in the 1981 - President Reagan fired all controllers who went on strike in 1981. To illustrate the gravity of the situation it should be pointed out that at Chicago's O'Hare Airport - the world's busiest - traffic increased by 26 per cent in 1986 and there were 14 near-collisions in June of that year alone. In 1984 there were a record of 592 near-collisions in USA airspace and the rate increased to 758 in 1985, and 867 in 1986. At least 141 of the 1986 reports were classified as critical, meaning that the aircraft were so close that all collision avoidance was due to chance and not the safe action taken by either of the pilots (Taylor, 1988).

One of the worst ever collisions happened near Los Angeles in September 1986. A light aircraft collided with Aeromexico DC9, with the loss of all 64 passengers and crew of the airliner, all three occupants of the light aircraft and a number of fatalities to people on the ground. It was found that the light aircraft stayed in the airspace reserved for air traffic bound for Los Angeles Airport and it was not equipped with an altitude encoded transponder (Mode C)* as required for flight in that airspace. Therefore, the controllers were unable to see the altitude conflict and risk of collision between the two aircraft. When the accident hearing convened late in 1986 a testimony given by one of the controllers on duty that day revealed that one radar channel was turned off at that time and the light aircraft was not shown by any of the displays - the FAA main computer may not have been fully operative. Also, it was reported that another light aircraft had intruded into the airspace and the attention of the active controller was taken by that transgression. It was later shown that control violations were common in the Los Angeles Basin; a survey of 23 major airports during six consecutive hours found 175 intrusions of restricted airspace by general aviation aircraft. In addition the FAA stated that a total of 34 controllers

---

* A transponder is a piece of equipment installed on the aircraft fulfilling the role of a secondary surveillance radar system (in addition to the ATC's radar). The transponder returns a strong signal to the primary radar transmitter so that the target on the radar scope (the position of the plane) is stronger and more readily identified by the controller.

working at the Palmdale ATC Centre were temporarily suspended from duty during the summer of 1986 as the result of allegations that they used cocaine and hashish during off duty hours and that 13 of them were offered drug rehabilitation leave.* The final report released in mid-July 1987 cited air traffic control shortcomings as the probable cause of the accident.

ATC-related accidents are not confined however to the airspace it controls. Aircraft maneuvering on the operational areas of the airport are under the control of ATC as well and increased air traffic and operations in conditions of poor visibility tend to produce an alarming number of collisions. These can occur between aircraft as well as aircraft and ground vehicles. The worst ground collision was between two aircraft at Tenerife, Canary Islands, on March 27, 1977. KLM Boeing 747 initiated takeoff while a Pan Am Boeing 747 was still on the takeoff runway ahead. The KLM 747 became airborne, after the captain took off without a clearance, and collided with the Pan Am aircraft. 583 lives were lost on a fog shrouded runway that day (Perrow, 1994). Special investigations (USA, 1985) into runway incursions - defined as any occurrence involving an aircraft, vehicle, person, object or procedures that impedes the intended takeoff, landing, or intended landing of an aircraft - identified 65.4% as controller-induced/enabled; most of them resulted from individual controller actions, the rest from incomplete or misunderstood coordination between two controllers. The other 34.6% were deemed pilot-induced/enabled (Taylor, 1988).

In addition to air traffic control and other aircraft, fatal accidents can be assigned to ground crew sequence-initiating causes. One case involved, for example, an American Airlines accident in October 1978, where a service truck collided with a parked aircraft. Another case implicated a Tampa Air aircraft (Tampa, Florida) in January 1972, where a ground crew member walked into a spinning propeller while delivering a message to the pilot of an aircraft about to depart

Based on the problems of saturation of the ATC system, there have been numerous studies and a number of measures under consideration to improve the situation; including improved ATC and visual aids and flight operations procedures. Restricting authority to allow runway crossings to tower controllers,

---

* That revelation caused a call by Congressman Guy Molinari for mandatory drug and alcohol tests for controllers.

the development of automated procedures, standardized coordination between tower and ground controllers, and a facility for ground vehicle drivers to communicate directly with the tower controllers were also considered.

In addition to accepting loads imposed by flight manoeuvers, aircraft structures have to be able to withstand encounters with hail, lightning, bird-strikes, and the onset of corrosion and fatigue. All these factors have at one time or another caused aircraft to be destroyed. It is accepted therefore that a high standard of airworthiness can be achieved only by the dedicated efforts of many professionals.

The adoption of high standards of design requirements by the airworthiness authorities, good design, thorough testing and manufacture according to specifications, as well as maintenance and servicing can all further the goal of safe air travel. Also, exchange of technical information between operators and manufacturers, and the adoption of good operating practices by the user airlines and their pilots should continue throughout the life of the aircraft and particularly after a change of role or significant modification or repair of the aircraft or transfer to another operator. Only strict adherence to these and other safety regulations can further promote the relatively rare occurrence of fatal aircraft accidents.

MEASURING SAFETY

Air safety authorities' ultimate objective is to minimize the probability of an individual, be it a passenger or someone on the ground, being killed or injured as a result of a flight. This probability depends on a wide range of factors from the phase of the flight and prevailing weather conditions to the number of passengers and population density on the ground. The calculation of this probability therefore requires a great quantity and variety of information (Review Committee, 1993).

An analysis of the aviation safety record logically begins with a comparison of the airline carriers' performance over time. As described in the preceding sections, there are many potential causes of accidents. Since each accident has its own unique characteristics and almost each event involves more that one cause, developing measures and indexes of aviation safety is very difficult. No single measure can account for all possibilities and reflect everything about such event.

As with other modes of transportation, aviation tries to make use of a number of measures to assess the level of risk involved. At a minimum, these safety measures should reflect the likelihood that an individual passenger will be killed or injured while taking an airline flight, how that likelihood varies across segments of industry, and how it changes over time (Oster, Zorn, 1992). Such measures should also help in determining why safety performance varies and how it can be improved. They must combine the outcomes of exposure to risk, such as fatalities, injuries and accidents, with measures of the amount of exposure to risk, such as takeoffs, landings and flight hours, encountered during the various phases of flight.

A) Accidents and Accident Rates as Measures of Safety

Because safety can not be observed directly, a number of proxies has to be used in establishing its value. These can include accidents, incidents, government agencies' inspections and fines for violating regulations, as well as levels of safety inputs such as maintenance, training, operating expenditures and procedures. Each of these indicators has advantages and disadvantages, all depending on the questions of interest and availability of data.

For a variety of reasons the number of aircraft accidents, their rates and the resulting victims are the most appropriate and reliable elements for safety analysis. First, these historical accident outcomes are of most importance to travelers. Safety inputs such as training, maintenance, and the like are less reliable because not all input transformations are yet well understood. If the causal relation of inputs was clearly defined vis-a-vis the reduced accident probability, its use would be more valuable. At present, no indexes or measures of such transformations are available.

Second, accident reporting and detection is quite accurate, particularly for more serious accidents and larger airlines, relative to voluntary incidence reporting and detection of safety violations through Transport Canada inspections. Incidents reporting is less consistent over time and across industry segments. Some degree of judgment is involved in defining what constitutes an incident and if it should be reported on the part of the individual. The level of trust that the identity of the source will be protected under the confidentiality clause is also an issue. In addition, the detection of non-reporting is hard to assess and the quantity and quality of incident reporting may be sensitive to "campaigns" that attempt to improve reporting rates. Therefore, safety conscious carriers will appear to have higher incident rates than the less safe carriers, simply because the former encourage more complete reporting. Similarly, TC inspections may depend upon the intensity of the department's enforcement activities, based mainly on available resources, which is unlikely to be consistent over time.

Third, accidents are more appropriate to the study of air carrier safety as opposed to the safety of the whole airline system. The majority of accident causes are attributed to factors directly under air carriers control, such as equipment, pilot experience, lack of adherence to procedures and regulations, maintenance deficiencies and training. Incidents such as mid-air collisions and runway incursions may be an indication of a greater system problem of airport and airways congestion, lack of ATC personnel and economic deregulation, among others. Those issues will include a higher proportion of events attributable to ground crew or air traffic controller errors.

Finally, aggregate accidents data will yield fairly precise estimates of accident probabilities, especially given the large amount of flights per year. The substantial exposure of Canadian carriers, logging over two million flight hours and transporting over 32 million passengers each year, combined with an average of about 300 accidents a year, makes it possible to identify the probability of an accident with a great deal of precision. When an individual carrier is small relative to the frequency of accidents, one more or one fewer accident may significantly change its accident rate. Although this may be seen as an argument for disregarding accident statistics, the infrequency of accidents for individual carriers does not invalidate studies based on carrier accident rates. It may make the estimation of the relation between accidents and other factors more difficult and reduce its statistical power, but it does not bias the final results (Rose, 1987).

Given these considerations, the ensuing analysis uses accidents and accident rates to measure airline safety. Having established the element of analysis, the first step in constructing an appropriate measure of safety is to understand exactly what the measure is intended to describe, that is, the scope of analysis. Calculating the likelihood that a passenger will be killed or injured involves collecting data on the number of passenger fatalities, passenger serious injuries, and accidents resulting in fatalities; all the basic measures of incidents that pose a risk to passenger safety (Oster, Zorn, 1987).

Another beneficial component in the analysis is to include accident rates resulting in minor injuries or no injuries at all. By definition, an accident is an haphazard event. A robust safety measure would encompass all unintended happenings, regardless of their austerity. While fatal and serious injury accidents are newsworthy and cause for immediate concern, frequent non-injury accidents may be a precursor of more serious problems to come. In addition, the difference between an accident that kills many passengers and one in which the passengers escape unharmed is often very small (Oster, Zorn, 1987).

Fortunately, airline accidents are extremely rare compared to the number of daily flights. By studying all accidents, instead of just fatal occurrences, the analysis can be expanded. For example, an increased number of Transport Canada inspections and the resulting fines for infractions, would seem to lend credence to concerns about maintenance short cuts. However, these fines could also reflect changes in the department's inspection procedures. If only fatalities and fatal accidents were considered, the limited number of observations would make it difficult to establish whether the fines indicate increasingly dangerous maintenance practices or more rigorous inspections. However, by analyzing all accidents, it is easier to conclude whether the fines are a result of one or the other.

The second step in selecting the safety measure is the choice of the denominator, or the unit of observation of exposure to risk. Depending on data availability, the following methods can be used: conditional accident probability, passenger-kilometers and aircraft hours flown, as well as aircraft and passenger departures. The merits and disadvantages of each of these methods are discussed next.

B) Conditional Probability

Determining the probability of being killed on a particular flight is one possible approach to measuring flight safety. The measure is a conditional probability that is the product of the likelihood of a fatality-producing accident and the fatality rate (proportion of passengers killed) for that accident (Oster, Strong, Zorn, 1992). However, there is a number of difficulties with this approach. First, both the probability of an accident and the fatality rate depend on the type of accident. For example, one would expect to have a better chance of surviving an accident where the aircraft slides off the runway while taxiing, as opposed to a mid-air collision. Since air traffic accidents are rare events, accident risk measures would probably be difficult to obtain for each possible type of flight. While in theory one could estimate a larger set of conditional probabilities based on an accident type, there would be still potential problems with aggregation due to each accident's unique elements. Also, given that data aggregation is inevitable, such method would dilute the information and therefore considerably limit the conclusions that can be drawn about changes in air safety.

Another more serious measurement problem is the lack of a sufficient number of accidents to make reliable estimates of the probability of each type of accident and the fatality rate for each type of accident. Even if such estimates were available (a strong indication of the danger of flying in itself) neither the probability of an accident nor the fatality rate could be expected to remain stable over time. The constant striving for improved aviation safety by the Transportation Safety Board, Transport Canada, the airlines, the manufacturers and other world aviation safety organizations should lower these rates over time.

C) Passenger-Kilometers and Aircraft Hours Flown

As an alternative to the conditional probability method of calculating safety, the transport industry measures risk based on either the distance traveled or the number of trips. In the case of passenger air travel, distance-based measures are often expressed in terms of passenger-kilometers or aircraft hours flown. An interpretation of aviation safety based upon these figures is rather impractical. Such measures are biased against carriers carrying small passenger loads and flying short flight stages. They do not take into account the fact that a typical regional commuter must takeoff and land many more times than an average large carrier in order to compile the same number of passenger-kilometers. For example, if the distance or time measure is used and a comparison of a 500 miles flight lasting three hours is made with a 100 miles trip of 35 minutes, then it follows that the longer trip will be five times as risky. However, past studies have shown that the risk element of flying activity varies depending on the phase of flight. Since most accidents occur during takeoff and landing phases of flight, the risk of being injured or killed changes significantly when comparing the preceding flights on a per hours flown or distance traveled basis. If each trip involves only one takeoff and one landing (assuming there are no intermediate stops) then the risk of flying increases dramatically for the small carrier passenger as opposed to someone flying with Air Canada or Canadian, for example. Furthermore, since very few accidents are related to the length of the flight, the number of hours constitutes a less reliable measurement method (compared to the number of departures, for example) and the difference is increased when the data are aggregated.

A similar problem arises when comparing safety records of two types of aviation sectors; scheduled carriers and general aviation, for example. In 1991, the Canadian commercial scheduled and charter carriers flew a total of 2,098,000 hours and experienced 234 accidents. That translates into one accident every 8,965 hours. In comparison, the same year, private aviation flew 679,000 hours and incurred 215 accidents; for an average of one accident every 3,158 hours. The immediate impression is that the public transport is almost three times safer than the private sector. However, if safety was measured in relation to injury or death to people rather than just adding up the number of times a plane is damaged, different results are found. In the 234 commercial accidents 320 people died. If this figure is divided into the number of hours flown (2,098,000) this will equal to one person killed for every 6,556 hours flown. By comparison, private aviation flew 679,000 hours during which 215 persons lost their lives and this equates to one person killed every 13,857 hours flown. Thus, both measures present contradictory results.

D) Aircraft and Passenger Departures

In order to compensate for the limitations of the above mentioned methods, another measure is needed. A more robust method is that of aircraft departures or passenger departures rather than aircraft miles or passenger miles, since these may be misleading in assessing the risk of accidents associated with takeoff and landing*. Unfortunately, while aircraft departures data are frequently available, data on passenger departures are not. A reasonable proxy for passenger departures can be enplanement. Enplanement is the count of passengers as they board a flight, but this method accounts for a passenger only once, even if he/she is on a flight involving multiple stops. Thus, a passenger is counted as one enplanement regardless of the number of times the plane takes off and lands with the passenger on board. This also means that for flights with intermediate stops, enplanements and passenger departures are not equal and there is more danger associated with a trip with intermediate stops than with only one takeoff and one landing. There is little data to assess the magnitude of this divergence, however, there is no reason to believe any major systematic biases for or against any particular segment of the airline industry would be introduced by using enplanements instead of passenger departures (Oster, Strong, Zorn, 1992).

Departure-based measures are more accurate in comparing differences among segments of the industry, because every landing is associated with a prior takeoff. Such measures take into account the increased risk associated with those phases of flight. The departure based fatalities and serious injuries rates must be evaluated carefully though. A passenger fatality or injury per aircraft departure measure, for example, reverses the bias in favor of the smaller passenger load carrier. Thus, regionals generally will be

---

* Another measure to evaluate risk are the number of fatal accidents per million flight departures, and the measure of the "death risk" per million departures (developed by Barnett, Abraham, and Schimmel, 1989) known as the Q- statistic. Q is measured as:

$$Q = \sum_{i=1}^{n} X_i / N$$

where N is the number of flights performed by airline i and x_i is the proportion of passengers on the i-th of these flights who do not survive it. If a flight lands safely, then x_i equals zero (statistically, a traveler choosing a flight at random has a 1/N chance of picking that airline's i-th flight, and a conditional probability x_i of being killed on the flight he/she has chosen). Q is the death risk per flight, or Q multiplied by one million can be thought of as the odds of dying in one million flights, which is a measure roughly analogous to the fatalities per one million enplanements measure.

favored relative to jet carriers by the use of this statistic and carriers using similar equipment but with different passenger loads will receive different treatment (Oster, 1987).

To summarize, this study considers airline safety in the form of accidents, injuries and fatalities, using data from the Transportation Safety Board and the Aviation Statistics Center, Statistics Canada. The available aggregate information permits consideration of safety measures on an annual basis from 1976 through 1993. These measures are some of the most commonly accepted safety determinants. To normalize the data and provide a wider range of analysis results, the study uses the following measures of safety: number of accidents, passenger fatalities and passenger injuries per passenger-kilometers, hours flown, enplanements, and departures.

Unfortunately, at the time of this study, Canadian authorities were not collecting and reporting all the necessary data with the same degree of consistency. Figures on the number of enplanements or deplanements for commercially operated carriers were not readily available for the entire study period. Data was also missing if further breakdowns, such as hours flown by one, two or more engines aircraft, departures by air carrier level, etc. were required. Consequently, certain analysis had to be performed using only the raw accidents and fatalities numbers without any basis as a reference, whereas in other cases the time period was restricted to data availability. For more details on methodology and results, refer to subsequent chapters in this paper.

CHAPTER III

REVIEW OF THE CANADIAN COMMERCIAL AVIATION INDUSTRY

Thus far, the research into the Canadian air industry has provided a background look at the history of aviation regulatory agencies and a number of methods for measuring safety. Also, factors affecting air travel were defined in order to better understand and later analyze the accident data. The following sections convey a detailed picture of the people, the machines and the carriers involved in the aviation business environment.

SECTORS OF THE AVIATION INDUSTRY

When looking at the Canadian aviation industry today, one can appreciate the significant progress it has made since its beginnings at the end of World War I. From the gypsy flyers and barnstormers grew an elite of pilots and operators. From the Dominion Aerial Explorations Limited (formed in September 1922 by Harry Stephen Quigley), part of the modest inception of the modern day Pacific Western Airlines (PWA), flourished an impressive gamma of commercial carriers, servicing the entire country and providing access to all parts of the world.

The entire aviation industry can be divided into multiple groups depending on their primary function. On the one hand, there is either the civil or the military use of airplanes. The Department of National Defense and the Federal Government use military aircraft for national security, search and rescue, and other relief operations. Civil aviation, on the other hand, covers all remaining non-military airplanes, from private owners to trans-continental commercial passenger and/or cargo flights.

Civil aircraft are further divided into two groups: the commercial and the general aviation sectors. Commercial aviation encompasses the activities of all major airlines and large commercial ventures, which specialize in the transport of passengers or goods for profit; including scheduled and charter operations. These activities are defined as Levels I to III air carriers.

General aviation describes all other civilian aviation activities like private flying, used by individuals, groups and business firms, solely as not for-hire or compensation. It also includes flying for fun and specialty flying, consisting of sightseeing, flight training, aerial photography and survey. Other types of flying, such as that done by government-owned aircraft, and that which does not involve the transport of passengers or goods from one place to another, is part of general aviation as well. General aviation also includes commercial air carriers whose activities are limited to Levels IV to VI* (and Level VII prior to 1988).

This study is concerned with the commercial aviation aspects of the civilian air service operations. As demonstrated in later chapters, the various sectors differ with respect to the level of operations and in their safety records. A detailed review of the carriers, their fleets, and other operational statistics follows.

---

* Level definitions are use for purposes of statistical reporting. Canadian air carriers are classified into six reporting levels (seven prior to 1988) as defined by Statistics Canada and the National Transportation Agency:

Level I - includes every Canadian air carrier not classified in report Level II-VI that, in each of the two calendar years immediately preceding the report year, transported at least 1,000,000 revenue passengers or at least 200,000 tons of revenue goods.

Level II - includes every Canadian air carrier not classified in report Level I or III-VI that, in each of the two calendar years immediately preceding the report year, transported at least 50,000 revenue passengers or more, but fewer than 1,000,000 revenue passengers, or 10,000 tons of revenue goods or more but less than 200, 000 tons of revenue goods.

Level III - includes every Canadian air carrier not classified in report Level I, II or IV-VI that, in each of the two calendar years immediately preceding the report year, transported at least 5,000 revenue passengers or more, but fewer than 50,000 revenue passengers, or 1,000 tons of revenue goods or more but less than 10,000 tons revenue goods.

Level IV - includes every Canadian air carrier not classified in report Level I-III, V or VI that, in each of the two calendar years immediately preceding the report year, realized annual gross revenues of $250,000 or more for the air services for which the carrier held license.

Level V - includes every Canadian air carrier not classified in report Level I-IV or VI that, in each of the two calendar years immediately preceding the report year, realized annual gross revenues of less than $250,000 for the air services for which the air carries held a license.

Level VI - includes every Canadian air carrier that, in the report year, operated the air service for which the air carrier held a license for the sole purpose of serving the needs of a lodge operation.

COMMERCIAL AVIATION

As described in the first chapter, Canadian aviation took off with the dawn of the First World War. Developments in aircraft design and machine performance, as well as the increasing number of pilots and inexpensive planes generated an insatiable interest in the air travel industry. The vast land, scattered population and sense of adventure in exploring remote and Northern areas provided a powerful incentive for those early aviation entrepreneurs.

A) Historical Perspective on Canadian Air Carriers

The regulated airline

The first civilian use of aircraft in Canada, other than barnstorming, emerged with the need for exploration, photography, and forest fire patrol. Commercial aviation soon followed with the creation in 1922 of one of the earliest companies, the Dominion Aerial Explorations Limited (now PWA), and the national, non-profit carrier, Trans-Canada Air Lines (established in 1937, renamed Air Canada in 1964, and privatized in 1988). Ever since, the number of Canadian commercial airlines continued to grow (except for a few less explosive years of 1964-66, 1974, 1986 and the recession of 1988 - 1990), be it at a much slower rate, in the last decade (see Figure 3.1).

Soon after the government created its Crown corporation, establishing a transcontinental air service within Canada, an imposition of economic regulation of commercial aviation began with the Transport Act of 1938 (Baldwin, 1975). Between that year and 1959, it was government policy that Trans-Canada Air Lines have a monopoly on all domestic transcontinental routes. In order to maintain this policy and restrict competition between the national airline and a privately-owned carriers or between privately-owned carriers, Prime Minister Mackenzie King told Parliament in 1943, that rivalry over the same route would not be permitted.

In its most important aspects, the 1938 airline regulation system still existed in the 1970s and early 1980s. The major regulatory provisions at the time were:

- Air Transport Committee (ATC) had complete control over allowing new carriers entry into the industry; thus ensuring its stability.

- Complete control over access to routes; existing carriers were licensed on a route-by-route basis, to carefully monitor competition, so as to ensure the financial success of existing airlines.
- Regulators sought to impose extensive conditions of service to specific routes, including frequency of flights, amount of capacity offered (size of aircraft), and requirements of intermediate stops.
- Carriers were required to both file their tolls and tariffs and to have them approved by the regulator; later in the 1950s standardized practices were adopted and a distance-related fare formula ensured that all carriers on regularly scheduled flights on the same route charged identical fees. ATC sought to ensure a price wars did not occur.
- Detailed regulation of conditions or 'fences' surrounding discount fares was exercised; when limited discount fares were permitted in 1978, many conditions applied making it difficult and time consuming to implement.

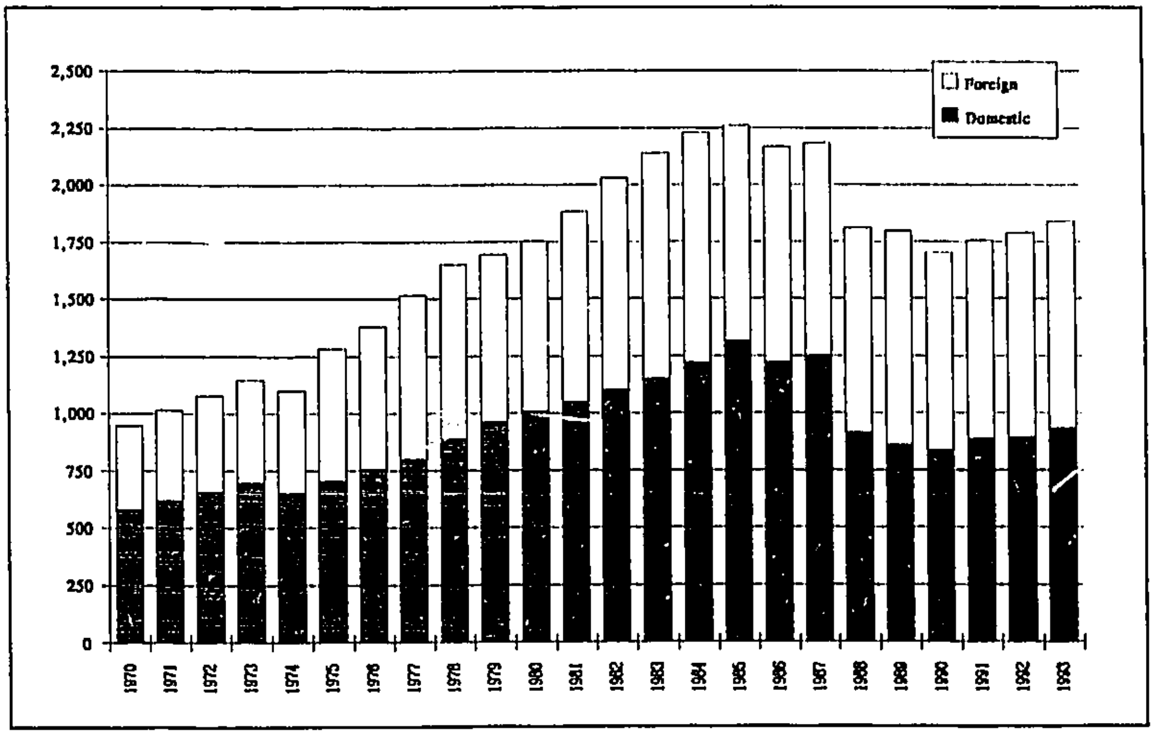


Figure 3.1 Number of Registered Carriers in Canada, 1970-1993

(Source: National Transportation Agency: Annual Reports, CTC Annual Reports)

During those strict regulatory policy days however, the national carrier received privileged treatment throughout. Although the government allowed Canadian Pacific Air Lines (established in 1941 under the name United Air Services Ltd. and renamed CPAL in 1942), the second largest carrier in the country, to provide transcontinental service in 1959, the Cabinet limited it to one flight per day each way between Vancouver and Montreal in order to protect Trans-Canada Air Lines' financial position. Between 1959 and 1965 CP Air obtained an average of 12.7% of the transcontinental market, until in 1979 with the capacity restrictions gradually removed, its share was increased to 45%. Trans-Canada retained most of the remaining market.

The same kind of Air Canada monopoly and favoritism was applied on all transborder routes (flights to the US) until 1967, when CP Air obtained the Vancouver-San Francisco route. Until that time the federal government has given Air Canada a large share of transborder routes negotiated with the US, as indicated by the 1974 contract when Air Canada received 14 of the 17 new routes; CP Air, PWA and Nordair obtained one each.

As might be expected, the early decades of government policy for Air Canada also established a complete monopoly on international routes. In 1948, CP Air was named Canada's flag carrier in the Pacific when it was awarded rights to Canada-Australia with stops in Honolulu and Fiji. Trans-Canada however retained all other international venues including the most profitable North Atlantic routes (Eastern Canada to the UK and northern Europe). It was not until 1965 that the Minster of Transport, announced that the two national carriers had agreed on the areas of the world in which each would be the sole Canadian carrier. CP Air's regions included the whole Pacific area, the entire continent of Asia and New Zealand, Southern and South Eastern Europe and Latin America, as well as continued service to Amsterdam. Air Canada on the other hand was assigned the UK, Western , Northern and Eastern Europe and the Caribbean. Both airlines were to be regarded as the nation's chosen instrument in their own areas. They were also to cooperate in selling the service of the other in competition with foreign carriers.

In addition to the mentioned advantages, the crown-owned airline was favored in its dealings with the federal government in other ways as well. Until 1984, Air Canada was closely involved with the Department of Transport in forming commercial aviation policies. The airline's top executives also had access to the minister and other members of the Cabinet who consulted Air Canada on the design and construction of major airports. The carrier in turn was able to obtain its own terminal at Toronto's Pearson airport (Terminal 2) for example, as well as preferred locations at most others including Mirabel. Another bonus came in the from of obtaining a lion's share of all air travel by federal public servants through the vehicle of Central Travel Service, not to mention benefiting greatly from the implicit guarantees of its debt by the federal government (Button, 1991).

The development of federal policy toward air industry did not limit itself exclusively to major carriers. Five regional carriers established during the late 1940s and 1950s were also governed by a number of specific principles greatly discussed by the policy makers between 1964 and 1969 (Baldwin, 1975). The finally established rules of operations were:

- Regionals were to operate local or regional routes to supplement and not directly compete with the domestic main operators.
- Operate within their region, and not become transcontinental carriers.
- Routes unsuitable because of their volume of traffic and equipment requirements were to be reserved for regional carriers, or sometimes transferred to them.
- Both national and regional operators were invited to develop joint fare and commission arrangements, and to cooperate on technical and services issues, interconnections, and even advertising and sales activities.
- Rules concerning the rights of regional carriers to operate domestic charters were to be relaxed. International charters were regarded as a useful addition for the regionals, but should not dominate domestic operations.

The latest ministerial statement concerning the regionals was made on August 15, 1969, and it specified the region in which each was to operate:

- **Pacific Western Airlines (PWA);**

B.C. and western Alberta

- **Transair**[*] **;**

---

[*] In 1977 PWA took over the failing carrier based in Winnipeg, reducing the number to four regionals.

the Prairies and northwestern Ontario (with access to Toronto)

- **Nordair;**

remaining areas of Ontario and northwestern Quebec

- **Quebecair;**

all of Quebec east of Montreal

- **Eastern Provincial Airlines (EPA);**

the Atlantic provinces (with access to Montreal).

As a result of the 1960s policies, a small number of regional carriers developed, each a 'chosen instrument' to operate local and regional routes as a supplement to the mainline operations of Air Canada and CP Air. Since their role was seen only as auxiliary, most of the growth of the regionals can be attributed to the mostly voluntary transfer of routes from the two major carriers (Greig, 1977). CP Air was pressured by the regulators to give up many routes to smaller carriers in 1947. Trans-Canada Air Lines was encouraged to do the same in the 1960s.

As time passed and the regional carriers grew, they felt their limited options more than constraining while trying to fulfill their ambitions of growth and expansion. It also made them vulnerable in the wake of the deregulation era. The regionals wanted access to the biggest hub (Toronto) and they wanted to offer at least some inter-regional service. In order to ensure future success some regionals began acquiring majority shares in other airlines, such as the one by PWA to purchase control of Transair in 1977. However, to ensure economic success PWA had to make a deal with Air Canada. The Crown carrier would drop certain points in Saskatchewan so the two regionals' routes could be linked, but had Transair agree to drop its points east of Winnipeg to Toronto. In the end, PWA paid a hefty price and did not regain access to Toronto till 1984 when CTC allowed it to fly the Calgary-Brandon-Toronto route.

Toward deregulation

With its environment highly structured and regulated, Canadian airlines found themselves not only trying to grow in a limited industry, but soon also losing market share to the already deregulated airline economy in the US (since 1978). Canadian consumers - in addition to the carriers themselves -

aware of the bargain airfares available south of the border, because of deregulation, put pressure on the politicians to implement similar reform at home; mostly through the Consumers Association of Canada. Also, since 80% of the Canadian population lives within 200 miles of the US border, many were able to drive to US gateways while traveling to an ultimate destination in that country or elsewhere in the world, or simply opt for US over Canadian destinations. Moreover, some diversion of domestic traffic to trans-continental US routes was observed. For example, in 1977, one tour operator provided bus transportation from Toronto to an airport in the US, where a consumer would fly to Seattle and then take a bus to Vancouver. In short, it was the demonstration effect of US deregulation on Canadian consumers and policy makers, as well as the diversion of air traffic from Canadian carriers and their strict-uncompetitive regulatory environment that provided the forces which made the airline deregulation necessary and inevitable.

Consequently, in the mid-1980s, a major change occurred in the structure of Canadian aviation industry. It was then that the highly regulated, overlapping routes and carefully controlled competition by the government allowed for establishing smaller carriers, to service the less vital and much less profitable routes; the best route licenses generally being held by Air Canada. Instead of multiple carriers, offering a wide range of services, the introduction of the deregulation policy, through the National Transportation Act (1987), induced the beginning of the evolution towards two mega-carriers and a network of associated feeder airlines, by way of mergers and acquisitions.

In 1980, with the impending decision to deregulate the industry, the aviation community began to prepare itself for the future. Following a round of discussions, studies, and inquiries on prevailing airline restrictions and potential for deregulation* the House of Commons Standing Committee on Transportation rejected US-style deregulation, or even a more cautious five-year phased deregulation as proposed by the Economic Council in 1981. Instead, in April 1982, the Committee endorsed the regulatory control of the CTC within a set of policy guidelines that would continue an 'evolutionary

---

* For further details on some of these studies see:

1) "Economic Regulation and Competition in the Domestic Air Carrier Industry", by Department of Transport, February, 1981 .
2) Final Report on the regulation by the Economic Council of Canada, June 1981.
3) "Proposed Domestic Air Carriers Policy (unit Toll Services)", by Department of Transport, Aug 1981.

process' by which greater but controlled. competition could occur. In addition, during the prevailing recession, hearings were held and fare and discounts restrictions were relaxed in order to help the troubled airlines.

Finally, on 10 May, 1985, the Minister of Transport, Lloyd Axworthy, announced The New Canadian Air Policy; it eased entry conditions and gave carriers more freedom to lower fares. Under the new policy Canada was divided into two regions; North and South (with 95% of the population) where the same restrictions still applied to the North, but in the South, carriers could exist freely and all restrictions on conditions of service on airline routes were removed, as well as unlimited freedom to reduce prices. In addition, Air Canada was directed to divest 85% shareholding of Nordair (the second largest of the four regional carriers), and the crown-carrier was prohibited to engage in anti-competitive pricing and scheduling practices unless private carriers were doing the same. The Regional Air Carrier Policy (dividing carriers into four regionals) was ended. Over the next two years, the effects of the New Canadian Air Policy included the following:

- consolidation of licenses,
- removal of restrictions on licenses of former regionals,
- introduction of competitive business class services,
- sale of Nordair to the private sector,
- first talks about Air Canada becoming partially privatized,
- regionals entering transborder routes, and
- introduction of frequent flyers programs by the two national carriers.

Deregulation

In 1985, under Brian Mulroney, the Progressive Conservative Minister of Transport, Don Mazankowski, issued his policy paper "Freedom to Move" (July 15, 1985). The report proposed virtually complete deregulation of the airline industry. The Tories however, were not able to enact legislation embodying total deregulation, nor were they able to legislate quickly. Following a number of readings in the House of Commons (first as Bill C-126, then Bill C-18) and a set of amendments, the National

Transportation Act of 1987, came into effect on January 1, 1988. Following is a general description of the principles governing the act as summarized by Kenneth Button in Airline Deregulation: International Experiences in 1991:

- Safety is not to be compromised by changes in economic regulation. The highest practicable safety standards are to be maintained.
- The transportation system exists to serve the needs of shippers and travelers.
- Competition and market forces are to be the prime agents of providing an efficient and adequate transportation system.
- Economic regulation is to be minimized in order to encourage competition within and between modes.

Canadian air carriers are subject to two distinct regulatory regimes based on the location of the points they serve. In (and to) the North - officially, the 'designated area' (see Figure 3.2) - carriers are subject to controls over entry, fares and other terms and conditions of service, although with reverse onus for the burden of proof. In the South, which contains 95% of Canada's population, there is almost complete deregulation:

- Entry to the industry is based on the 'fit, willing and able' test comprised of objective safety and insurance requirements, and 75% Canadian ownership (and control in fact).
- License restrictions were abolished.
- Exit or reduction in frequency below once per week requires 60 days notice.
- Fare levels and decreases are not subject to regulation. Carriers must publish fares and cannot charge above the published level.
- Fare increases on monopoly routes are appealable to the new National Transportation Agency.

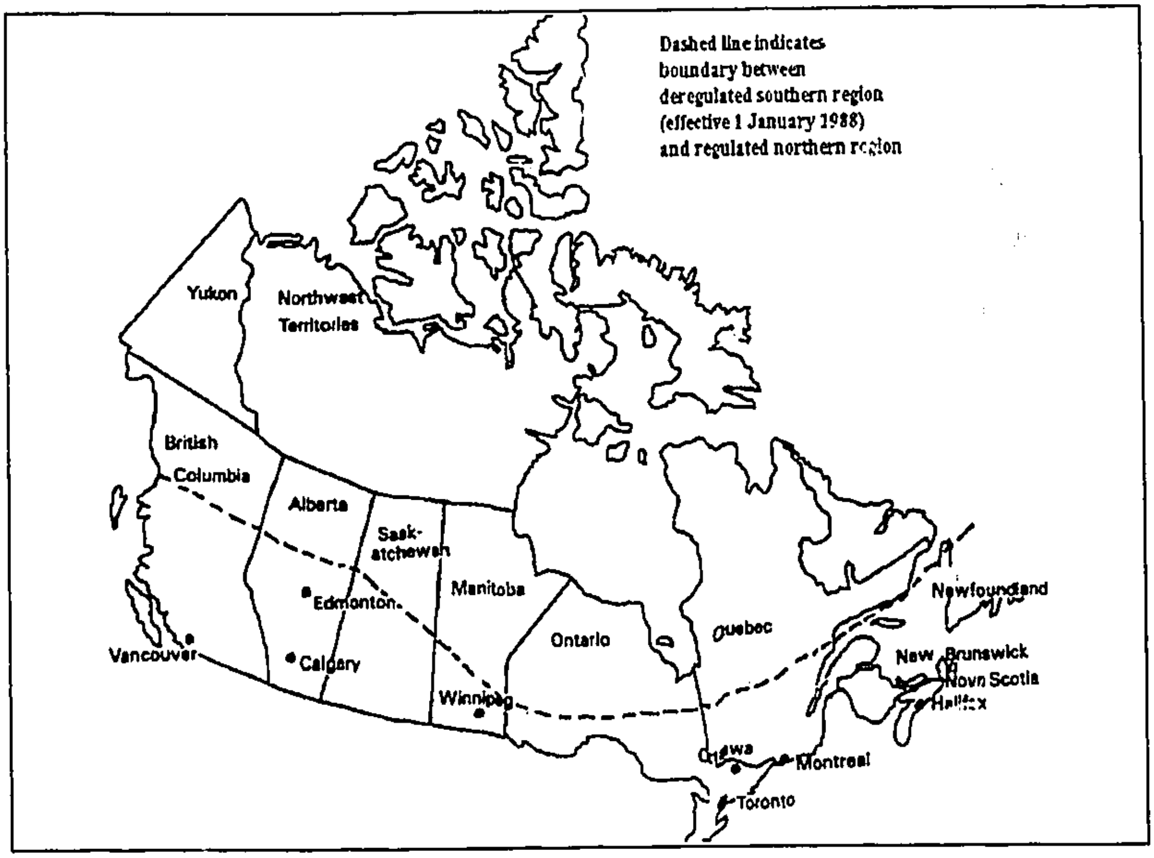


Figure 3.2 **Map of Canada with Southern and Northern areas delimited**

(Source: Button, K., Airline Deregulation - International Experiences, David Fulton Publishers, London, 1988)

The regulatory regime that applies to Northern Canada (the 'designated area') is as follows:

- Entry to the industry is based on the 'fit, willing and able' test.
- In the case of new entry to a route, interveners have to show there would be a 'significant decrease or instability in the level of domestic service'.
- The Agency can limit types of service, aircraft size and type, routes, points, and schedules through restrictions on licenses.
- Fare levels and increases are appealable to the Agency.
- Sixty days notice is required for dropping a route.

- Subsidies are possible for 'essential' existing services that cannot be provided on a purely commercial basis; to be awarded on the basis of competitive bids.
- The Agency can amend the definition of 'designated area' by altering its southern boundary, but also designate any area outside the designated area to be within it.

With respect to international commercial aviation, the new Act included the following provisions:

- International routes, including Canada-US transborder routes, will continue to be based on bilateral international agreements.
- The Minister is to seek fewer restrictions on the terms of bilateral agreements.
- The Minister is given a directive power regarding licensing to respond to actions prejudicial to Canada's interests.

Finally, the following general provisions are relevant to the airline industry:

- Carriers are to receive, as far as practicable, compensation for imposed public duties. Compensation is to be 'fair and reasonable'.
- The new National Transportation Agency which is made up of nine members must include at least one representative from each of five defined regions.
- The minimum size of reviewable mergers was set at $10 million in assets or gross sales in/from Canada.

The implementation of the above principles and the earlier relaxed regulations had a profound effect on the airline industry. Soon after its introduction, only seven large airlines still existed consisting of Air Canada and CP Air - the two major scheduled airlines - Wardair - the largest charter airline - and four regional airlines: Eastern Provincial Airways Limited, Nordair Ltd., Pacific Western Airlines Ltd. and Quebecair.

Most of the remaining carriers became marketing or equity partners with the two giants, in order to complement their networks*. This new order proved profitable for both the carriers and the passengers. Marketing agreements between carriers, be it domestic, international or both, allowed the airlines to

---

* For details on Air Canada and Canadian Airlines International and their affiliates see Appendix B.

reduce fixed costs by agreeing to honor each other's tickets. combining fares, and participating in marketing schemes, such as frequent flyer promotions. As a result, only one ticket office and one check-in area were necessary at the airport, and the passenger had the added comfort of coordinated schedules and ease of transfer with only one ticket. This kind of agreement was far less permanent than partial ownership and much easier to withdraw from than in an equity situation.

With lesser government control, an alternative to acquisition or other forms of agreements, was simply to enter another airline's routes and fight for the market share with a variety of service innovations, increased flight frequency and low fares. This method however proved long and costly, so acquisition or creation of a new airline from the existing carriers was generally preferred. The largest increase in the number of carrier mergers occurred in 1988 with the formal introduction of deregulation. The rapid pace of mergers still continued into 1989. By 1992 only two mega-carriers remained in the industry, Air Canada and Canadian Airlines International Limited, with a complete network of feeder carriers (see Figure 3.3).

The final result of these affiliations was a complete coverage of the country from north to south, and from the Atlantic to the Pacific. The major airlines continued to service the dense long-haul routes, passing their short-haul routes to their affiliates. Committed to honor their scheduled routes, additional traffic supplied by the affiliates could only positively affect their profits. The smaller carriers in the family, on the other hand, benefited from access to their parent's reservation systems, passenger handling facilities, marketing programs and the good and widespread reputation of their name.

Additional benefits of the formation of this hub and spoke feeder system was the increased airline efficiency and aircraft use by combining traffic from smaller communities to support increased frequencies at hub airports. Thus, with the alliances in place, the frequency of service was likely to be increased, resulting in better coordinated schedules of major carriers and their affiliates and, if route competition existed, discounted ticket prices.

As of today, with the size of the market and well established networks, it would be very difficult to make an entry into the industry, or even for an existing small carrier to expand to the size of a major airline. There are still a few remaining independent carriers available to become affiliated to the new competitor. However, defections to a new entrant would also be difficult, with the major carriers having purchased equity in the current feeder carriers. Without the affiliates' support, it would almost be impossible to compete in long-haul transcontinental market (see Figure 3.4). As well, with the 25% Canadian ownership requirement, international airlines would find it rigorous to compete against the majors within Canada.

As with scheduled services, the charter industry also experienced changes in the make-up of its air carriers. Prior to 1983, only two international charter carriers operated in Canada - Wardair and Worldways - complementing scheduled flights of the major transcontinental carriers; Air Canada and CP Air, and regional carriers; Nordair, Pacific Western, Quebecair and Eastern Provincial Airways. With the New Canadian Air Policy of May 1984, Wardair began operating scheduled services in April 1986, thus creating a perception that it would eventually abandon the charter market. In fact, Wardair actually increased the absolute amount of charter services it offered, but charter as a percentage of total services were declining, since the carrier was accommodating scheduled services by expanding its fleet. Believing that Wardair was leaving the charter sector, the industry ceased the opportunity to create more carriers. As a result, in addition to two previously established carriers; Nationair and Worldways, a number of new charter airlines were launched between 1986 and 1988. The new list of charter carriers included Nationair, Minerve Canada, Canada 3000 Airlines, Air Transat, Odyssey International, Points of Call Airlines, Vacationair, and Holidair and Crownair (Aviation in Canada, 1993). In the end, the charter capacity grew - unmatched by demand - until subsequent bankruptcies reestablished the market equilibrium. Within twelve months of their creation, nine independent airlines suspended operations leaving only three of the original 12 major charter carriers still operating.

One reason for the failure of some carriers was attributed to their fleet structure. While Worldways and Nationair operated with older aircraft, a number of the new charter carriers, such as Odyssey, used brand new leased aircraft. With these new planes, the carriers were forced to meet high monthly aircraft ownership costs. If charter prices were lowered because of excess capacity in demand, these carriers had nevertheless to continue flying in order to make some contribution to their ownership costs. Carriers with older aircraft were able to weather the storm and park aircraft when operations were not profitable.

The charter capacity problem was further aggravated by Air Canada's increased presence in the charter market. In 1990, for example, it increased the number of seats from Montreal/Toronto to Florida by 30%. The consequence of creating new charter carriers, Wardair's continued presence in the market and Air Canada's introduction of more charter services, was the failure of five of the fledgling charter carriers in late 1989 and 1990, namely Odyssey, Crownair, Ports of Call, Vacationair and Holdair.

Compared to scheduled demand, the charter market was small and profit margins were insufficient to support the competition. In addition, while the established charter carriers operated with older aircraft, some of the new airlines, such as Odyssey, used brand new leased aircraft. With these new planes, the carriers were forced to meet high monthly aircraft ownership costs. If charter prices decreased because of excess capacity, these carriers would still be forced to fly in order to cover at least some of their ownership costs. Carriers with older aircraft, on the other hand, were able to park their aircraft when operations were not profitable, thus temporarily reducing some costs.

By 1991, only Air Transat, Canada 3000 Airlines and Nationair were the remaining dedicated charter carriers providing air travel services along with the scheduled airlines, operating its flights to selected markets. Whereas Canada 3000 was prominent in the southern region of Mexico and the United States, Nationair and Air Transat chose to service mainly the southern regions, including Mexico, Dominican Republic, as well as Europe.

Today, the situations has changed yet again. In May 1993, Canada's largest charter carrier and third largest carrier, Nationair ceased its services. Events leading to Nationair's collapse include fare and market share battles in the Ottawa-Montreal-Toronto triangle, asset seizures by creditors and adversarial labor relations. At the time it withdrew from the Canadian charter sector the airline's available seat capacity was larger that the combined capacity of its competitors - Canada 3000, Air Transat, Royal Air to selected markets. Whereas Canada 3000 was prominent in the southern region of Mexico and the United States, Nationair and Air Transat chose to service mainly the southern regions, including Mexico, Dominican Republic, as well as Europe.

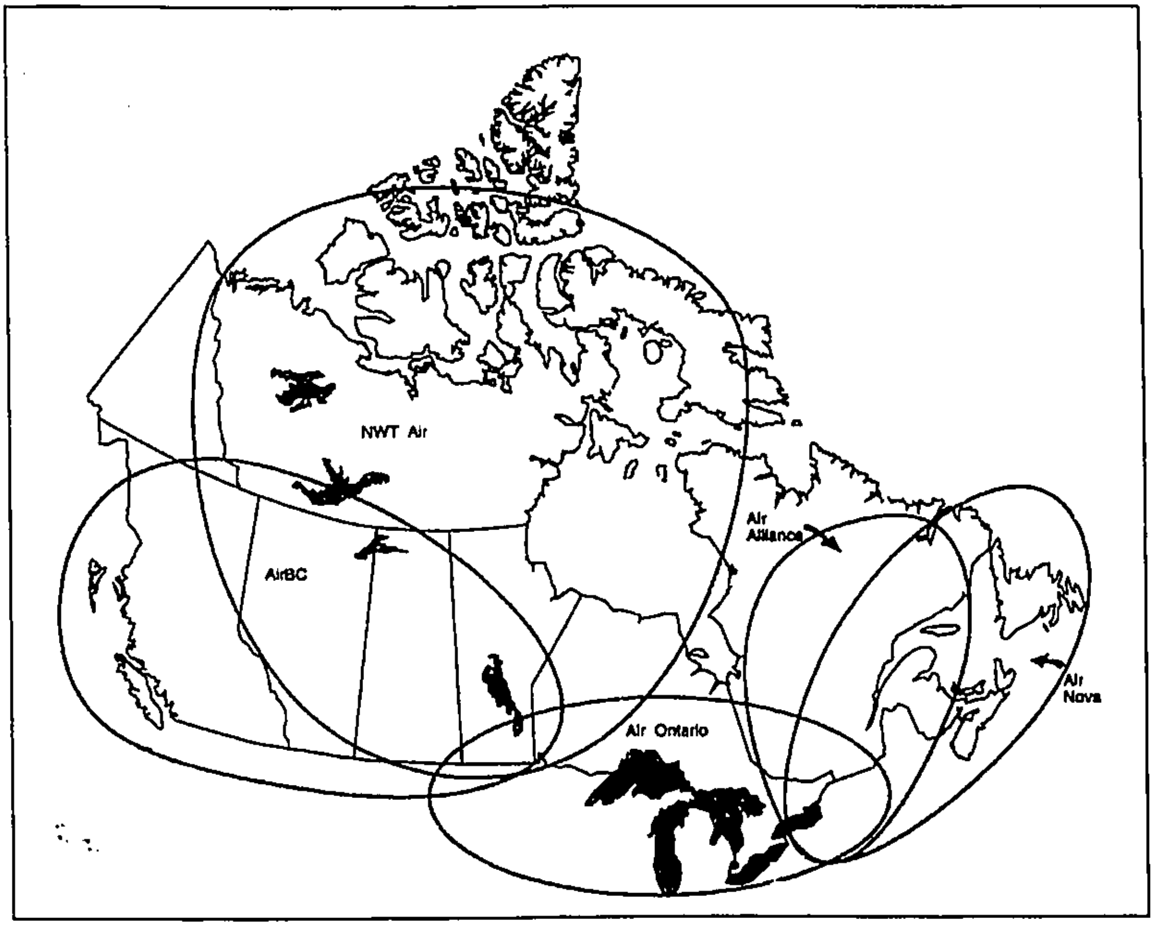


Figure 3.3 Geographic Areas Covered by the Two Mega-Carriers

A) Air Canada and its Connectors

and First Air. After Nationair stopped flying, Air Transat, a Montreal-based carrier emerged as Canada's largest charter carrier. It became the largest operator at Mirabel airport (Quebec) and by the end of 1993

Today, the situations has changed yet again. In May 1993, Canada's largest charter carrier and third largest carrier, Nationair ceased its services. Events leading to Nationair's collapse include fare and market share battles in the Ottawa-Montreal-Toronto triangle, asset seizures by creditors and adversarial labor relations. At the time it withdrew from the Canadian charter sector the airline's available seat capacity was larger that the combined capacity of its competitors - Canada 3000, Air Transat, Royal Air proceeded with the acquisition of Nationair's Technair hangar there to use as offices and for its heavy aircraft maintenance. Canada 3000 on the other hand positioned itself as the largest charter carrier in the

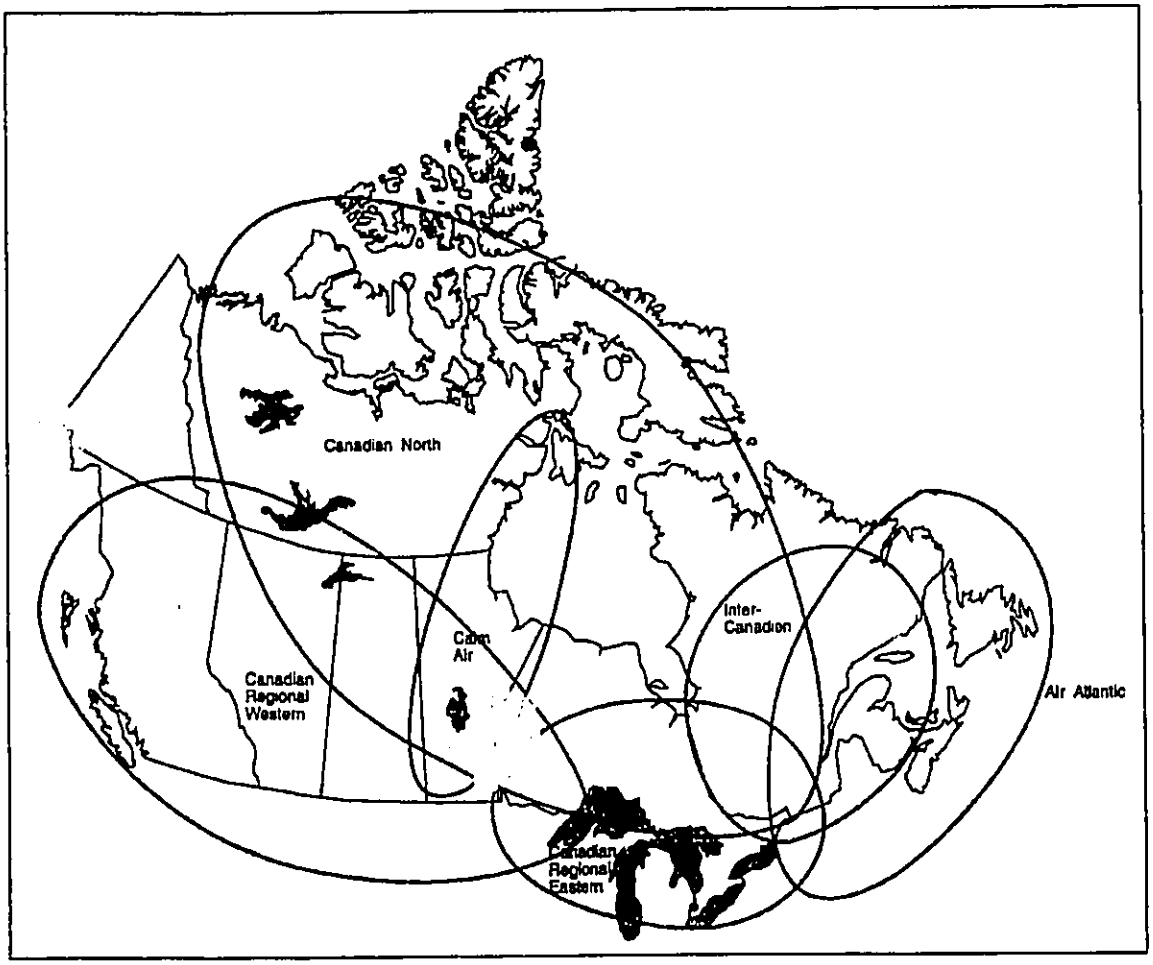


Figure 3.3 **Geographic Areas Covered by the Two Mega-Carriers - Continued**

B) Canadian and its Partners

(Source: National Transportation Agency: 1992 Annual Review)

domestic market and developed a major presence in the United Kingdom and numerous sunspot destinations.

With deregulation and the emphasis on alliances, the attention of major carriers has shifted in the last fifteen years from accumulating routes to constructing a feeder service to their hub and spoke networks. For as much as in the past the government regulated capacity and price, today, after deregulation, they are administered by competitive forces of supply and demand in the market place.

B) The Fleet and its Operators

The aircraft

The early Canadian commercial airline industry was dedicated primarily to the exploration and studies of remote and Northern regions. Appropriately, the planes used in the 1920s consisted mostly of war surplus, such as the Curtiss HS-2L flying boats, the Fairchild FC-2 single-engine, high-wing monoplanes, and Fokker Universal. Since all of these planes could be equipped with floats in the summer and skis in the winter, and because there was great demand for bush flights, the flying boat and the float plane dominated the Canadian commercial fleet. One of the first Canadian-built bush planes was the Noorduyn Norseman. In 1991 there were still twelve operating in the Canadian North.

As each decade brought about new technological innovations and changed daily lives, so did the aircraft used by air carriers. In the 1930s, new flying boats were introduced. The Martin M-130 and the Short Brothers S-23, were being used on long-haul, over-water commercial flights. Also, airlines began to replace their old machines with Douglas DC-2 and DC-3s. Those models were able to carry up to 21 passengers, making it profitable to schedule passenger flights without any mail subsidy. The national carrier (Trans-Canada Air Lines) opted for the new Lockheed Super Electra, judging the DC models too large for the prevailing market.

The advent and progress of World War II had a tremendous effect on the development of aviation technology. The design and manufacture of long range aircraft rendered it possible to make routine overseas flights without using flying boats. With such flights becoming more common, Trans-Canada used converted Lancaster bombers, built in Malton, Ontario, to fly over the North Atlantic. In addition, other long range aircraft such as Douglas DC-4, Lockheed Constellation and the Boeing Stratocruiser replaced the flying boats on long-haul trips. Most flying however was still over much shorter distances, so that the 10,000 DC-3s built during the war as military transport aircraft dominated the fleet of the world.

The 1950s introduced the jet engine to the world and with it a new breed of aircraft. Bristol Britannia, deHavilland Comet, and Lockheed C-130 Hercules for military transport and Electra for civilian use started to appear on the market. In 1950 Pratt & Whitney Canada launched the production of the engine which flew in the nose of a Boeing B-17 in 1950 and later Boeing C-133. At the same time another manufacturer, Canadair built the North Star, later used by both Trans-Canada and CP Air airlines, while Avro Canada unveiled its Jetliner (see Table 3.1).

	Fixed - Wing Aircraft			Rotary	Total	Hours
Year	Turbo Jet	Turbo Prop	Piston Engine	Wing	Aircraft	Flown
1970	98	97	2,395	389	2,979	1,605
1971	130	115	2,354	416	3,015	1,753
1972	139	124	2,462	484	3,209	1,855
1973	151	126	2,593	559	3,429	2,067
1974	182	144	2,765	581	3,672	2,221
1975	209	134	2,945	595	3,883	2,387
1976	223	145	3,217	640	4,225	2,392
1977	213	192	3,421	687	4,513	2,500
1978	201	188	2,632	717	3,738	2,578
1979	221	211	3,652	818	4,902	2,636
1980	249	218	3,806	873	5,146	3,002
1981	266	238	3,907	900	5,311	2,793
1982	273	249	3,646	868	5,036	2,454
1983	273	255	3,448	877	4,853	2,235
1984	260	268	3,485	831	4,844	2,290
1985	249	291	3,357	761	4,658	2,436
1986	270	333	3,314	771	4,688	2,365
1987	283	378	3,340	770	4,772	2,555
1988	300	400	2,552	777	4,029	2,052
1989	343	456	2,521	762	4,084	2,238
1990	340	496	2,548	868	4,253	2,259
1991	329	514	2,435	880	4,212	2,098
1992	334	534	2,458	891	4,217	2,055
1993	327	533	2,384	902	4,126	..

Table 3.1 **Canadian Commercial Air Carrier Fleet, 1970-1993**

(Source: Statistics Canada/National Transportation Agency: Fleet Report and Catalogue No. 51-206. Figures are as of July 15 for each year, Levels I to V)

Giant strides were also accomplished with the improvement of gas turbines, giving greater speed, using cheaper fuel and operating at high altitudes leaving bad weather well below. Vickers Viscount was the first successful commercial application of a gas turbine engine. Fifty one of these turbo-props were ordered by Trans-Canada Air Lines in 1954, in order to replace the North Stars and the DC-3s. With the Vanguard (turbo-prop) and the DC-8 (turbo-jet) arriving in 1960 the national carrier became the world's first all turbine airline (at the time it retired all of its piston aircraft). The Bristol Britannia became the CP

Air's designated aircraft when it used eight turbo-props in its long range trans-Pacific fleet in the late 1950s and early 1960s.

Boeing 707 and deHavilland Comet became the first commercially accomplished jets. Canadian airliners however chose the Douglas DC-8 in the early 1960s. Fast and comfortable, they revolutionized the long-haul air travel. By 1975 Air Canada and CP Air had 51 DC-8s and in 1991 the remaining 16 machines flying in Canada were used mainly as freighters. Later narrow-body models, including Boeing 727 and 737, as well as Douglas DC-9 designed for short range routes, became very popular in Canada and were quickly adopted by both Trans-Canada and CP Air. In 1985 there were over 73 Boeing 737's in use in Canada (see Table 3.2). By 1991, although in smaller number, the 737 model was still more common than any other jet. Since its massive introduction to the market around 1960, the turbo-jets grew by a factor of four, from 98 in 1970 to 327 in 1993.

The next decade was mostly characterized by the turbo-fan, wide-bodied jets; these included the Boeing 747, the McDonnell Douglas DC-10, the Lockheed L1011 and the Airbus A300. Their high fuel efficiency and large passenger capacity made air travel more economically viable for the carriers as well as the travelers. These jumbo jets were also responsible for the later rise of the commuter air carriers. The number of passengers required to fill the planes made it prohibitive to use them on short-medium routes. Smaller feeder airlines filled seats by supplying additional passengers from their connecting flights, thus creating the market for the hub and spoke networks.

In the early 1980s the commuter fleet started to replace its older turbo-props such as the Convair 580 and the Hawker Siddeley 748 seating up to 26 people, with a new generation of the deHavilland Dash 7 and Dash 8, the British Aerospace Jetstream, the ATR42, and the Embraer Brasilia. From 1970 to 1993, the number of commercial turbo-props grew by a factor of over five, from 97 to 533. In 1993, there were over 90 Dash-8s in service within the network of affiliates, accounting for 54% of the commuter fleet. This move towards fleet renewal was accelerated with the advent of economic recession of the early 1980s. Doubling fuel costs and decreasing ticket prices due to the pressures of competition, prompted demand for aircraft with lower operating costs. New technology airplanes with two engines instead of three or four, and computerized controls, requiring fewer flight crew (two instead three) were developed. Environmental concerns also played a major role in the fleet revival. In order to reduce noise and pollution Stage I aircraft, such as DC-8 and Boeing 707 jets, were banned from most major world airports by the end of 1991. Stage II aircraft with turbo-fan engines can still operate till 1996 at which point Stage III rules will limit noise and smoke levels even further.

Group (Kg)	Description	Designator	1970	1975	1980	1985	1990	1991	1992	1993
A	Champion Aircraft	CH7	..	46	25	18	6	10	10	11
< 1,950	Cessna Commuter	C150	287	472	518	404	127	134	128	116
	Cessna Skyhawk	C172	182	318	555	433	318	307	327	325
	Cessna Skywagon	C185	108	189	308	270	235	227	217	218
	Cessna 180	C180	255	199	145	105	72	73	77	67
	Piper Cherokee	PA28	153	251	230	137	84	85	90	73
	Other		..	428	727	701	582	553	583	557
B	deHavilland Beaver	DHC2	159	207	280	284	258	260	255	255
>= 1,950	Piper Aztec/Apache	PAZP/PA23	125	168	140	100	86	67	63	60
< 3,403	Piper Navajo	PA31	13	25	114	148	181	176	172	163
	Other		..	192	310	350	330	311	312	293
C	British Aerospace	BA14	-	-	-	-	29	29	20	8
>= 3,403	Beech Aircraft	BE90	-	3	14	18	12	12	14	14
< 8,166	Beech Aircraft	BE99	-	1	5	15	20	20	21	21
	Cessna Aircraft	C550	-	-	-	3	4	3	4	4
	deHavilland Otter	DHC3	63	89	121	122	106	104	106	106
	deHavilland Twin Otter	DH6	20	68	82	84	71	74	73	70
	Other		..	215	260	252	269	233	266	276
D	deHavilland Air	DH8	-	-	-	1	84	88	101	101
>= 8,166	McDonnell Douglas Dakota	DC3	62	104	80	56	45	32	32	28
< 15,877	McDonnell Douglas Invader	A26	2	20	24	24	-	-	-	-
	Short Brothers 2 Harland	SHD6	-	-	-	-	2	3	3	3
	Other		..	38	50	60	61	53	58	56
E	Vickers Viscount	VC7	32	-	-	-	-	-	-	-
>= 15,877	Canadair	CL60	-	-	-	1	4	3	5	5
< 34,020	Convair 580	CV58	-	-	5	14	8	23	23	34
	General Dynamics	CV34	-	-	-	2	13	1	3	-
	Hawker Siddeley 748	A748	-	3	15	27	29	31	31	33
	McDonnell Douglas Skymaster	DC4	13	3	5	15	13	6	8	8
	deHavilland Air	DH7	-	-	1	7	13	4	5	5
	Fokker	FA28	-	2	-	-	10	11	7	8
	Other		..	37	26	21	35	35	38	37

Table 3.2 **Principal Fixed-Wing Aircraft Types used by Canadian Commercial Air Carriers, 1970 - 1993**

Group (Kg)	Description	Designator	1970	1975	1980	1985	1990	1991	1992	1993
F	Boeing 737	B737	19	31	57	53	61	58	50	51
>= 34,020	Vickers Vamguard	VC8	12	-	-	-	-	-	-	-
< 68,040	British Aerospace	BA46	-	-	-	-	13	13	13	14
	McDonnell Douglas DC9 Series 30	DC93	38	45	43	35	35	35	35	35
	Other		.	28	18	23	20	15	18	18
G	Airbus Industrie A310	EA31	-	-	-	-	8	7	2	-
>= 68, 040	Airbus A320	EA32	-	-	-	-	4	18	38	48
< 158,758	Boeing 727	B727	4	20	31	38	40	32	25	17
	Boeing 757	B757	-	-	-	-	4	8	11	14
	Boeing 767	B767	-	-	-	12	31	33	33	33
	McDonnell Douglas DC8 Freighter	DC8F	-	-	-	8	8	8	7	7
	McDonnell Douglas DC8 Series 40	DC84	16	16	5	-	-	-	-	-
	McDonnell Douglas DC8 Series 50	DC85	11	10	11	-	-	-	-	-
	McDonnell Douglas Super DC8	DC88	22	25	24	18	14	8	4	1
	Other		..	13	10	4	31	1	1	1
H	Boeing 747	B747	-	12	15	13	9	13	18	18
>=158,758	Lockheed Tristar/Tristar 500	L101/L105	-	12	12	18	21	20	11	10
	McDonnell Douglas DC10	DC10	-	-	5	11	11	8	8	8
	Other		-	-	-	-	-	-	-	-

Table 3.2 **Principal Fixed-Wing Aircraft Types used by Canadian Commercial Air Carriers, 1970 - 1993 - Continued**

(Source: Statistics Canada/National Transportation Agency: Fleet Report.

Figures as of Jan. 15 for 1970, July 15 for other years. Levels I to V.)

The fleet of the mega-carriers and their affiliates

Before deregulation, the government policy towards the air industry was clearly reflected by Canada's commercial fleet. The national carrier used a large fleet of jet airplanes, flying both domestic and international routes, whereas CP Air had a much smaller jet fleet and proportionately smaller portion of the market.

With increased deregulation and increasing costs of operations in the 1980s, the airlines opted for greater use of medium-size aircraft, offering their customers higher frequency and more competitive service. Small communities were better served by the affiliates with their fleet of turbo-props. Also, the portion of total operations started to be more balanced, distributing the market share between Air Canada and CP Air, and later Air Canada and Canadian Airlines International Ltd.

The carriers moved from the fleet of piston and turbo-props on their long distance flights and today deal almost exclusively with jet aircraft, leaving the former with their affiliates on short-haul routes. The fleet of Air Canada consists exclusively of jet aircraft, with 30% of it dedicated to McDonnell Douglas Aircraft DC-9s, and 40% equally divided between Boeing B767s and Airbus Industrie EA32s (see Table 3.3). These replaced the older three-engine wide-body aircraft, including a major portion of its Boeing B727s. The remaining planes are earlier models of Boeing, McDonnell Douglas and Lockheed California L-1011.

Canadian Airlines, whose fleet had both turbo-props and jet aircraft in the late 1980s, also moved exclusively to jets such as Boeing B737 and B767s, as well as McDonnell Douglas Aircraft DC10s, making up over 80% of its planes, although its number of B737 has diminished in favor of the Airbus A320s. Recently, both airlines made a move towards the Airbus product. At the end of 1992 Air Canada operated 25 of the Airbus A320s, and Canadian acquired another eleven between 1991 and 1992. In their buying behavior, the concept of uniformity seems to dominate the purchasing policies of the mega-carriers. The simple economical reason of keeping a reduced number of spare parts in inventory and the amount of time spent on training maintenance and flight crews, prompted the carriers to standardize their fleets.

The fleet of the affiliates plays a major role as well in the success of operations of the parent carriers. Dependènt on the feeder source for additional passengers the major carriers slowly transferred some of their routes, thus allowing the family network to use some jet aircraft. From a meager four Fokker FA28 jets in Canadian partners' fleet in 1987, the number grew to 22 or 12.5% for both carriers in 1992. Whereas Canadian still uses its Fokkers, both carriers seem to favor the British Aerospace BAE146s designed especially for the commuter market; only thirteen are still left in Canada.

	Designator	1987	1988	1989	1990	1991	1992	1993
Air Canada								
Jet								
Boeing 727	B727	33	33	33	30	19	4	-
Boeing 747	B747	5	6	6	6	9	9	9
Boeing 767	B767	14	18	21	21	21	21	22
Douglas Aircraft	DC6F	5	6	6	5	5	5	5
McDonnell Douglas Super	DC86	3	2	-	-	-	-	-
McDonnell Douglas DC-8-71F	DC87	-	-	-	-	-	-	1
McDonnell Douglas DC-9-32	DC93	35	36	36	35	35	35	35
Airbus Industrie	EA32	-	-	-	4	12	31	34
Lockheed California L-1011	L101	10	9	8	8	8	7	5
Lockheed California L-1011-500	L105	6	5	6	6	4	-	-
Total Jets		111	115	116	115	113	112	111
Air Canada Connectors								
Piston								
Cessna Aircraft	C402	13	3	-	-	-	-	-
Douglas Aircraft	DC3	5	3	2	-	-	-	-
Total Pistons		18	6	2	-	-	-	-
Turbo-Prop								
Hawker Siddeley HS 748	A748	6	8	-	-	-	-	-
British Aerospace Jetstream 31	BA14	-	5	14	15	15	6	6
Beech Aircraft 200	BE20	1	6	-	-	-	-	-
Beech Aircraft B99	BE99	9	9	-	-	-	-	-
Convair 580	CV58	9	7	2	-	-	-	-
de Havilland DHC-6	DH6	12	9	6	8	8	8	4
de Havilland DHC-7	DH7	6	5	4	4	-	-	-
de Havilland DHC-8	DH8	13	26	38	50	59	63	64
Lockheed 382G	L100	-	-	-	-	-	-	1
Lockheed 188A, C	L188	3	3	2	3	-	-	-
Swearinger	SW4	5	1	1	1	1	-	-
Total Turbo-Props		64	79	67	81	83	77	75
Jet								
Boeing 737	B737	-	-	2	2	2	3	3
British Aerospace BAE 146	BA46	-	5	8	10	10	10	11
Fokker F28,F28MK	FA28	-	1	-	-	-	-	-
Total Jets		-	6	10	12	12	13	14

Table 3.3 Fleet of Air Canada, Canadian and Affiliates, 1987 - 1993

	Designator	1987	1988	1989	1990	1991	1992	1993
Canadian Airlines Int'l								
Turbo-Props								
Hawker Siddley HS 748	A748	1	-	-	-	-	-	-
Fairchild FH 227	FA22	5	1	1	-	-	-	-
Lockheed 188C	L188	1	2	-	-	-	-	-
Total Turbo-Props		7	3	1	-	-	-	-
Jet								
Airbus Industrie	A310	-	-	-	8	3	2	-
Boeing 737	B737	66	67	62	58	54	50	46
Boeing 747	B747	-	-	-	-	2	3	3
Boeing 767	B767	-	4	8	10	12	12	11
Douglas Aircraft	DC10	12	13	11	11	8	8	8
Airbus A320-122	EA32	-	-	-	-	5	10	11
Total Jets		78	84	81	87	84	85	79
Canadian Partners								
Piston								
Douglas Aircraft	DC3	1	-	-	-	-	-	-
Piper	PA31	11	8	8	1	1	1	1
Total Pistons		12	8	8	1	1	1	1
Turbo-Prop								
Hawker Siddley HS74	A748	4	4	4	4	4	4	4
ATR	AT42	-	2	11	5	14	14	14
British Aerospace Jetstream 31	BA14	6	12	14	14	14	14	-
Beech Aircraft 1900C	BE02	-	-	-	-	-	-	1
Beech Aircraft 100	BE10	-	-	-	-	-	-	1
Beech Aircraft 200	BE20	1	2	1	6	6	1	1
Beech Aircraft B99	BE99	-	2	2	2	1	-	1
Convair 580	CV58	10	11	1	1	1	1	1
Convair 640	CV64	4	1	-	-	-	-	-
de Hailland Air DHC-6	DH6	3	3	3	3	2	2	2
de Hailland Air DHC-7	DH7	4	5	4	3	-	-	-
de Hailland Air DHC-8	DH8	9	11	22	27	33	31	31
Embraer	E120	-	-	-	3	5	6	1
Fairchild	FA27	2	2	-	-	-	-	-
Swearingen	SW4	5	5	8	-	-	-	-
Short Brothers	SHD6	2	2	2	2	3	3	3
Total Turbo-Props		50	62	72	70	83	76	70
Jet								
British Aerospace BAE 146	BA46	-	-	-	3	3	3	3
Boeing 737	B737	-	3	-	-	-	-	-
Fokker	FA28	4	5	3	-	7	6	8
Fokker 100	FK10	-	-	6	-	-	-	-
Total Jets		4	8	9	3	10	9	11

Table 3.3 **Fleet of Air Canada, Canadian and Affiliates, 1987 - 1993 - Continued**

(Source: Statistics Canada/National Transportation Agency: Fleet Report.

Figures are as of July 15 for each year. Levels I to V.)

As the majors standardized their fleets, so did the feeder carriers. Merging regional carriers into the family introduced a large variety of planes. But with cost reduction programs in place, standardization quickly reduced the 20 different types to only eight types for the Air Canada connectors and to five types for Canadian Airlines partners. In 1987, the most common aircraft type was the 1950s Vintage Convair 580. At that time 19 were in service in the two networks accounting for 16% of all turbo-prop types in use. By far, the preferred aircraft today is the Dash 8, with 94 in service by 1992, from only 21 in 1987. These account for 61% of turbo-props, or 53% of all aircraft operated by the feeder carriers.

The major effect of the standardizing programs since deregulation took place was the high proportion of new aircraft. Overall, 30% of the mega-carriers' fleet and about 68.5% of the partners' planes were less than five years old (see Table 3.4). Also, over 43% of the major and 79% of the feeder carriers' aircraft were under 10 years old. This meant the newer fleet required less maintenance and was most likely to comply to recent noise and pollution restrictions. By the same token, the planes were constructed with latest technology, using lighter and better materials, as well as equipped with computerized controls and safety features.

Airline	Age:	0 - 5	6 - 10	11-15	16-20	Over 20	Total
Air Canada		34	15	7	18	41	115
Air Canada Connectors:							
Air Alliance		13	1	-	-	-	14
AirBC		24	4	-	-	8	36
Air Nova		8	4	-	-	-	12
Air Ontario		25	-	-	7	3	35
Northwest Territorial		-	-	1	2	1	4
Sub-total:		70	9	1	9	12	101
Canadian Airlines		27	13	36	7	5	88
Canadian Partners							
Air Atlantic		8	7	-	-	-	15
Calm Air		-	-	1	2	5	8
Inter-Canadien		13	-	-	-	-	13
Ontario-Express		22	3	-	-	1	26
Time Air		20	3	-	4	4	31
Sub-total:		63	13	1	6	10	93
Total:		194	50	45	40	68	397

Table 3.4 **Age of Fleets: Air Canada, Canadian and Affiliates, 1992**

(Source: Statistics Canada: Cat. 51-501)

The operators

The description of the Canadian fleet would not be complete without mentioning the personnel involved. Aircraft operators, as well as those looking after their maintenance and safety, on the ground and in the air are the major causes of accidents after all. The total number of pilots licensed to fly in Canada increased by 544%, from 8,543 in 1955 to over 55,000 in 1991 (see Table 3.5). Flight training seems to have been most popular and affordable, in the 1960s and in the 1970s; the number of pilots grew by more than 80% and 65% respectively.

The recession years contributed to an overall decline in the number of pilots by 13% between 1982 and 1991; most of which is attributed to private licenses whose number dropped 29%. The largest annual decline occurred between 1990 and 1991, when the number of senior commercial pilots dropped by 39%. Similarly, private pilots and total flight instructors decreased in numbers in the 1980s by close to 20% each. Also, the number of air traffic controllers showed annual decline since 1983, when the total dropped by 24% by 1991.

Year	1970	1975	1980	1985	1990	1991	1992	1993	1994
Private	23,750	31,656	40,582	38,581	32,534	29,358	31,628	31,491	30,649
Commercial	4,631	6,522	7,905	9,824	9,266	9,416	9,712	9,991	10,129
Senior Commercial	698	876	1,122	1,194	1,091	667	628	498	449
Airline Transport	2,664	3,999	4,969	6,345	7,520	7,900	8,786	9,128	9,178
Sub-total:	31,747	43,053	54,578	55,924	50,411	47,341	50,752	51,108	50,405
Glider	1,342	1,821	3,604	4,701	5,143	5,271	5,494	5,654	5,750
Gyroplane	4	6	7	14	10	10	11	16	19
Free Balloon	..	..	84	199	282	271	287	288	299
Ultra-light - Private	..	..	..	..	1,953	1,413	1,461	1,630	1,732
- Comm.	..	..	..	..	857	700	704	707	739
Total Pilots:	33,093	44,880	58,273	60,838	58,656	55,006	58,709	59,403	58,944
Flight Navigators	217	186	131	118	93	82	81	68	65
Flight Engineers	91	141	156	241	382	381	420	438	443
Air Traffic Controllers	931	1,818	1,895	1,863	1,514	1,494	1,619	1,744	1,854
Aircraft Maint. Eng.	3,001	4,009	5,264	6,674	9,307	10,000	9,876	10,186	10,246
Licenses	4,240	6,154	7,446	8,896	11,296	11,957	11,996	12,433	12,608
Total Licenses:	37,333	51,034	65,719	69,734	69,952	66,963	70,705	71,836	71,552
Airplane Instructors	1,085	1,175	1,547	1,361	1,248	1,334	1,502	1,602	1,606
Helicopter Instructors	51	81	140	83	81	93	90	98	108
Total Instructors:	1,136	1,266	1,687	1,444	1,329	1,427	1,592	1,700	1,714

Table 3.5 **Pilot Licenses in Canada, 1970 - 1994**

(Source: Transport Canada: Internal Files, as of January of each year)

C) Operational Statistics

Passenger and cargo traffic

Since its beginnings, Canadian aviation caught public and private interest very quickly. Some saw it as a way of livelihood and profit, others as an efficient and affordable mode of transport for all. Between 1921 and 1931, mail and cargo transport increased more than 30 fold. Becoming a viable and dependable means of transport, by reducing travel time, air transport of people also skyrocketed by flying over 100,000 passengers in 1931 from just nine thousand a decade earlier.

In the 1940s and 1950s, air travel assumed a more prominent role in the overall transportation system of the country. Trains and ships had to give up some of their market share to aviation; a new yet financially strong and expanding industry. Ever since, there has been an overall trend upwards. Between 1960 and 1970 the number of passengers has doubled from just over five million to ten million, and in the next decade doubled once more from twelve to over twenty-eight million. The only two exceptions in the past half century were the recession years of 1981-83 and beginning of 1990 (see Table 3.6).

The gradual expansion in the aviation industry was prompted mostly by technological improvements. With the introduction of turbo-props in the 1950s and turbo-jets in the 1960s, the carriers provided larger seating capacity and state-of-the-art equipment, thus allowing for very comfortable and quick long distance traveling. This was further improved with the implementation of the wide-body aircraft and high efficiency engines, making aviation a reliable and economical mode of transport.

Another contributor to the industry's expansion was the consumers' response to marketing efforts of carriers anxious to grasp a larger share of the market. The 1980s saw an increasing variety of services at attractive prices; airline differentiation strategies, frequent flyer programs and discounts were all part of the effort to lure new customers and keep them loyal to the airline.

When looking at the industry growth, another point becomes clear. The number of passenger-kilometers flown has also increased. The number of kilometers flown by each passenger has been increasing steadily since the mid 1930's, doubling every four years between 1940 and 1955, and then every six years until mid 1960's. Beginning in 1966 the average per passenger distance doubled every seven years, until its growth slowed even further in the 1980's.

Year	Passengers ('000)	Passenger-Kilometers ('000)	Cargo-Kilograms ('000)	Mail-Kilograms ('000)	Hours Flown ('000)
1960	4,830	4,507	95,401	15,709	879
1961	5,102	5,323	91,955	16,216	865
1962	5,425	5,882	93,895	17,432	843
1963	5,599	6,182	100,325	19,002	887
1964	6,031	7,435	110,386	21,230	948
1965	6,832	8,729	128,618	22,870	1,128
1966	7,727	10,044	170,909	22,235	1,375
1967	9,213	12,267	149,618	25,150	1,569
1968	9,577	13,808	185,407	26,648	1,647
1969	10,593	15,261	232,042	28,625	1,670
1970	12,031	18,605	256,420	30,068	1,669
1971	12,889	18,527	280,887	35,568	1,813
1972	14,422	21,739	307,333	38,093	1,923
1973	17,493	25,897	340,226	43,315	2,145
1974	19,601	29,168	344,429	48,096	2,301
1975	20,493	31,539	362,711	45,032	2,468
1976	20,994	32,797	341,021	55,892	2,487
1977	22,318	35,553	390,502	58,143	2,578
1978	23,649	38,249	410,204	56,756	2,684
1979	27,123	44,901	447,817	57,576	2,928
1980	28,554	46,096	399,418	59,978	3,091
1981	27,189	46,086	374,893	60,525	2,515
1982	24,447	44,179	344,703	65,431	2,454
1983	23,789	43,370	357,152	68,768	2,235
1984	27,701	46,444	464,088	80,604	2,290
1985	29,056	49,968	328,013	81,457	2,273
1986	30,818	53,084	334,750	79,464	2,365
1987	31,863	55,364	334,230	69,011	2,555
1988	36,009	62,292	631,242	..	2,052
1989	37,175	65,789	658,403	..	2,238
1990	36,613	66,778	654,484	..	2,267
1991	31,779	58,077	624,668	..	2,092
1992	32,231	62,188	616,838	..	2,055

Table 3.6 **Passenger and Cargo Transport, 1960 - 1992**

(Source: Historical Statistics of Canada, MacMillan, 1965 and Statistics Canada:

Catalogue Nos. 51-002, 51-202, 51-206 and Internal Reports.

Cargo and Mail data do not include Charter Services in 1985 - 1987.

Hours Flown data do not include Specialty Operations in 1988 - 1992)

These increases over the last three decades were somewhat expected as with any growing industry. Savings in time spent traveling, good service and comfort, as well as excellent safety record, all contributed to the public's acceptance of air travel as just another way of getting around. Technological changes, lessened regulations and healthy competition made flying more than a luxury. It made it a necessity. These and other factors contributing to the success of aviation are easily noticeable when looking at the total number of hours flown. The industry showed a dramatic 350% increase in flight time between 1960 and 1980, reaching over 3 million hours in 1990.

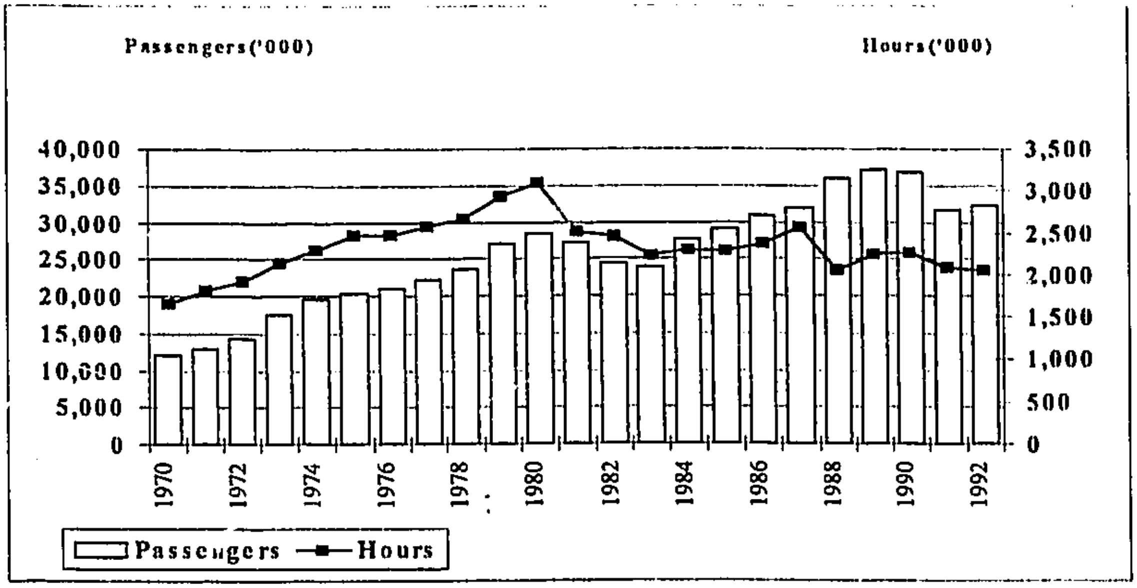


Figure 3.4 Passengers and Hours Flown, 1970-1992

The aviation industry went through many changes in the '80s, varying fuel costs and the move to larger aircraft, all of which influenced the total number of hours flown. The industry has not fully recovered from the drop in both passengers and hours flown from its high prior to the recession before it was hit again by the decrease in air travel in 1991 (see Figure 3.4).

International scheduled services

The majority of air travel growth can be attributed to the Canada-United States and other international scheduled services. It greatly outgrew the domestic scheduled market on an origin and destination basis from 1975 to 1980. The number of passengers flying international routes increased by over 66% from over eight million in 1975 to nearly 14 million in 1991 (see Figure 3.5). Over half of these passengers were carried by major Canadian airlines in 1975, whereas in 1991, these carriers transported 41% of all international scheduled passengers; a loss of eight percentage points.

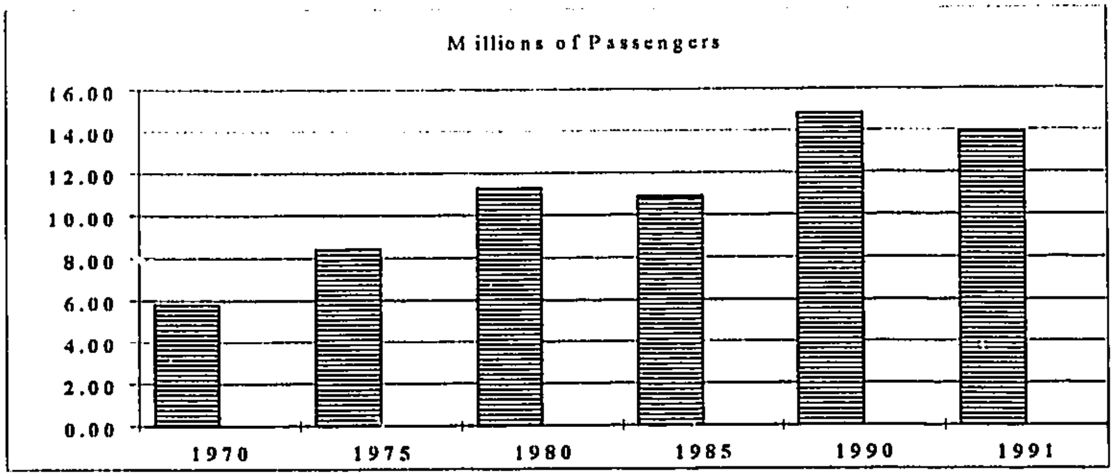


Figure 3.5 **Passengers Flying International Scheduled Services on Major Canadian Carriers, 1970 - 1991**

(Source: Statistics Canada: Catalogue No. 51-205, Internal Reports)

With 80% of population living within 200 miles of the US border, by far Canada's most popular international market was the continental United States. Over the years, despite industry's slow growth during recession years, on average three of every five international scheduled passengers headed south of the border (see Table 3.7 and Figure 3.6). In the scheduled Canada-United States market, Toronto occupied the key position with four of the top five city-pairs including this city and just under half of all scheduled transborder passengers originating from or destined for Toronto in 1992.

Other than the United States, Canadians preferred flying to Europe, with over 20% of the international traffic destined for that part of the world. The Asian region was next with about 10% of the market, expanding from 4% in 1980 due to growing interest in economic partnerships and business opportunities in the Pacific Rim. The remaining international scheduled market was divided into smaller portions between Southern regions with 7% (including Bermuda, the Bahamas, the Caribbean Islands, Mexico, Central and South America), Africa with 2%, while the Pacific region (composed of Australia, New Zealand, Melanesia and Polynesia) accounted for only 1% in 1993.

1992 Ranking	City - Pair	1970	1975	1980	1985	1990	1992
				Passengers ('000)			
1	Toronto - New York	450	488	683	037	839	742
2	Montreal - New York	382	331	354	410	382	309
3	Toronto - Chicago	140	172	210	228	321	297
4	Toronto - Los Angeles	70	105	188	162	260	276
5	Toronto - Boston	63	87	137	171	264	223
6	Toronto - Miami	80	115	157	134	214	223
7	Toronto - Tampa/St.Petersburg	47	89	172	100	215	212
8	Vancouver - Los Angeles	01	123	197	184	252	206
9	Toronto - San Francisco/Oakland	32	66	137	129	184	185
10	Montreal - Miami	80	172	240	168	182	168
11	Vancouver - San Francisco	81	120	145	133	158	158
12	Calgary - Los Angeles	14	34	103	92	131	127
13	Montreal - Boston	89	110	134	129	114	87
14	Toronto - Washington/Baltimore	36	58	80	92	115	73
15	Toronto - Detroit	47	54	64	89	76	71
	Others	1,667	3,201	4,649	3,975	5,384	5,345
	Total:	3,538	5,324	7,650	6,839	9,091	8,702

Table 3.7 Passengers Flying International Scheduled Services, Top 15 City-Pairs Ranked by Traffic Volume, Canada - USA, 1970 - 1992

(Source: Statistics Canada: Catalogue 51-205)

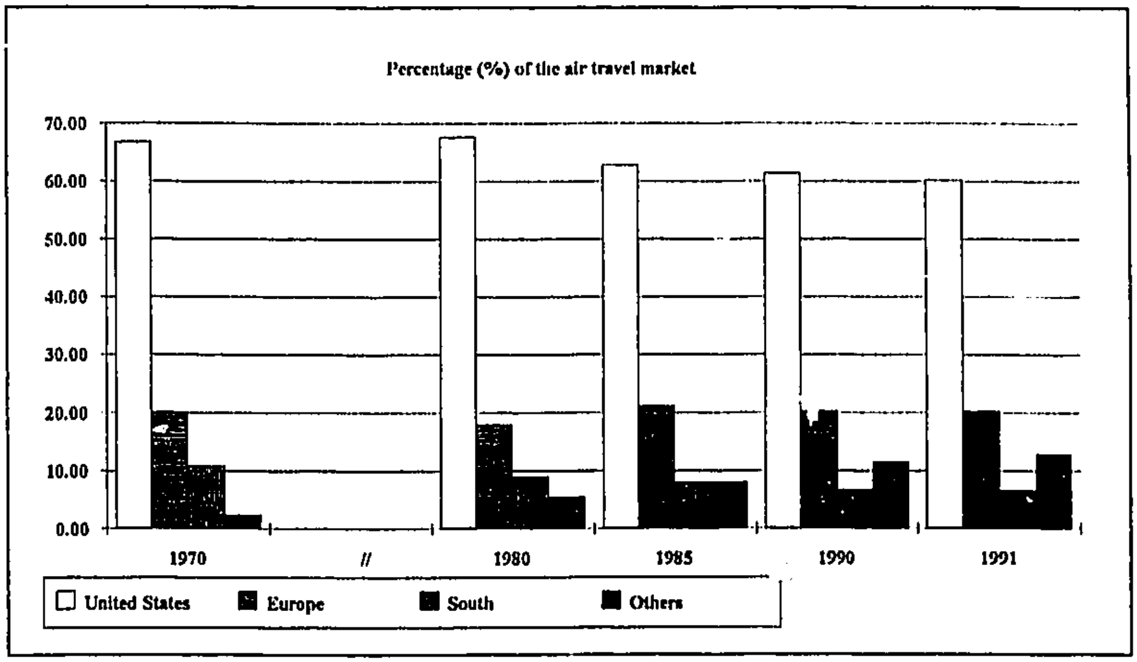


Figure 3.6 International Scheduled Passengers, by World Area, 1970-1991

(Source: Statistics Canada: Catalogue No. 51-205, Internal Reports)

Domestic scheduled services

Similarly to the transborder and the international scheduled air services, Toronto has always been the focal point for much of the domestic traffic flow throughout the country. Of the top ten domestic scheduled city-pairs in 1992, seven involved Toronto. The Montreal - Toronto ranked as number one since 1970, covering Canada from east to west, and accounted for 10% of all domestic flights. This city-pair carried over twice as many passengers as the second city-pair, Ottawa - Toronto (see Figure 3.7).

From 1970 to 1992, 15 of the top 25 Canadian city-pairs grew by over 100%; Calgary - Toronto and Ottawa - Vancouver registering the highest passenger gains, thus adding to the traffic flow between central and western Canada. Only two city-pairs, Toronto - Windsor and Sault Ste. Marie - Toronto, showed decreases during that same period.

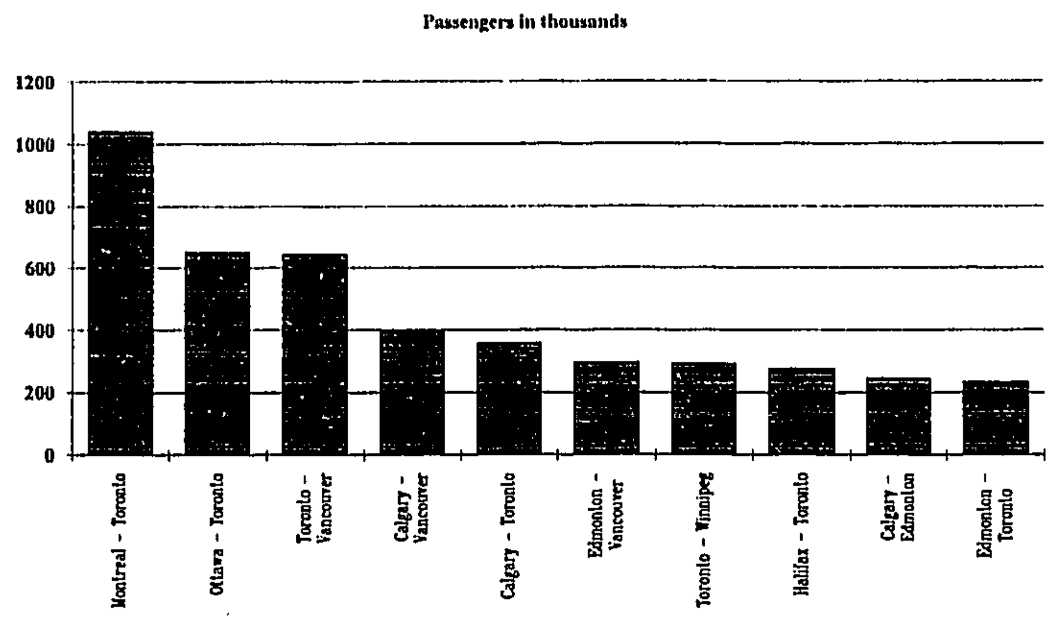


Figure 3.7 **Scheduled Air Passengers, Top 10 Domestic City-Pairs, 1992**

(Source: Statistics Canada: Internal Reports)

Overall, the number of passengers traveling on domestic scheduled services increased from about 6 million in 1970 to the all time maximum of almost 14 million in 1980; a surge of traffic of 127% (see Table 3.8). However, once again, as with other sectors of aviation, the recessions of 1981-83 and 1991 negatively affected most domestic city-pairs. The hardest hit was Prince George - Vancouver, with a decrease of 35% between 1980 and 1985. As quickly as western Canada expanded in the late 1970s, it was also severely affected by the recession. Six west city-pairs still remained below their 1980 level in 1991; Calgary - Edmonton, Edmonton - Vancouver, Calgary - Vancouver, Vancouver - Winnipeg, Calgary - Winnipeg and Prince George - Vancouver. Some areas showed a degree of rebound from the decline by 1985, such as Kelowna - Vancouver and Toronto - Windsor, this recovery however was once again depressed beginning 1991. All top 25 city-pairs showed decreases from the peak in 1988 to 1991, with total domestic passenger traffic declining about 17%.

1992 Ranking	City - Pair	1970	1975	1980	1985	1990	1992
				Passengers ('000)			
1	Montreal - Toronto	675	963	1,127	1,198	1,448	1,041
2	Ottawa - Toronto	306	498	575	633	785	654
3	Toronto - Vancouver	163	302	532	458	070	045
4	Calgary - Vancouver	166	201	455	430	421	403
5	Calgary - Toronto	83	174	397	400	418	357
6	Edmonton - Vancouver	139	254	377	349	331	296
7	Toronto - Winnipeg	171	236	318	322	354	293
8	Halifax - Toronto	99	168	220	260	328	278
9	Calgary - Edmonton	235	413	723	351	288	246
10	Edmonton - Toronto	70	139	208	270	290	233
11	Montreal - Vancouver	78	118	169	147	169	181
12	Thunder Bay - Toronto	85	144	192	198	197	180
13	Vancouver - Winnipeg	90	133	192	173	171	156
14	Ottawa - Vancouver	32	70	94	108	148	151
15	St. John's - Toronto	35	69	96	100	128	114
	Others	3,693	6,398	8,229	6,517	6,888	6,143
	Total:	6,120	10,360	13,920	11,919	13,030	11,369

Table 3.8 **Passengers Flying Domestic Scheduled Services, Top 15 City-Pairs Ranked by Traffic Volume, 1970 - 1992**

(Source: Statistics Canada: Catalogue No. 51-204)

Regional and local scheduled carriers

In addition to scheduled international and transcontinental routes, there were over a hundred carriers offering services to communities locally. These regional and local carriers service remote areas in support of seasonal operations or large resource development projects. Transporting a few hundred passengers a month on one or two-piston aircraft, or tens of thousands of travelers on the fleets of turbo-props providing domestic or transborder services every month, these airlines play a vital role in the economic life of a large number of communities.

Passenger traffic on regional and local carriers increased by an incredible 314% between 1970 and 1980, and further by 487% up to 1990. As a result, the market share of these carriers grew from 3% in 1970 to 6% and then 28% in 1980 and 1990 respectively (see Table 3.9).

The agent responsible for the dramatic growth of local and regional services was the transfer of routes from the major carriers to smaller affiliates in setting up the hub and spoke networks. Revisions to air regulations removed some licensing restrictions and entry barriers in Southern Canada, thus allowing for affiliations and increased growth (see Appendix C).

Closer analysis of the passenger loads by province shows a fluctuation of first rank between Ontario and British Columbia throughout the years. In the early 1980s, Ontario had the largest number of local service passengers followed by British Columbia and then Alberta; result of increased activity in the oil industry in western Canada. In 1988 however, Quebec became the third largest in terms of passenger traffic when Air Canada brought Air Alliance as its feeder carrier. The province still continues to hold that position. Nova Scotia increased substantially its passenger traffic between 1985 and 1986 with Air Atlantic and Air Nova competing for market share in that province. As well, Manitoba, Saskatchewan and Alberta increased their passenger movements in the prairies in 1990 and 1991 when they recorded growth of 11%, 59% and 8% respectively. Although the overall traffic declined in these provinces, major airlines stimulated local carrier movements by passing their routes to feeder airlines.

TOTAL ENPLANED/DEPLANED PASSENGERS

Year	New-found-land	Prince Edward Island	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskat-chewan	Alberta	British Columbia	Yukon	North West Territory	Total for Canada
	Province												
1983	48,897	-	11,685	3,690	343,294	924,289	226,912	85,271	436,393	742,389	25,070	199,954	3,047,844
1984	52,712	-	11,652	3,678	319,350	1,163,510	243,480	96,997	520,016	1,224,808	24,941	224,520	3,885,664
1985	73,478	-	12,643	682	392,452	1,845,805	243,972	114,373	657,193	1,570,400	19,360	244,654	5,175,312
1986	193,207	19,965	219,621	96,158	653,449	2,169,298	276,447	152,981	666,308	2,301,494	12,176	259,606	7,020,710
1987	357,426	83,280	576,494	169,808	918,731	2,770,773	331,058	202,626	749,023	2,622,698	11,567	297,393	9,090,879
1988	463,362	108,540	741,627	274,077	2,048,372	3,142,540	400,327	239,928	971,630	3,614,147	39,731	391,446	12,435,727
1989	623,216	130,680	980,661	467,903	2,629,336	3,691,691	424,646	308,445	1,475,359	4,145,046	38,098	428,342	15,343,423
1990	761,180	152,378	1,177,948	549,486	2,991,650	4,412,913	482,967	284,398	1,571,297	4,411,445	32,342	417,820	17,245,824
1991	676,186	146,030	1,030,088	460,341	2,439,415	3,653,211	537,649	451,239	1,694,065	4,140,315	24,871	398,464	15,651,874
1992	677,532	161,091	1,084,436	500,078	2,238,428	3,580,691	618,142	625,291	1,792,466	4,163,621	38,348	387,328	15,867,452

Table 3.9 Passenger Traffic on Regional and Local Carriers, 1983 - 1992

(Source: Statistics Canada: Catalogue No. 51-005, 51-004)

Charter passenger services

No analysis of the commercial aviation activity would be complete without mentioning the charter sector of the industry. The charter business began with the introduction of wide body jets in the 1970s and loosening of regulations in the 1980s. As with scheduled services, charter flights service domestic, transborder and international destinations.

The number of passengers traveling on charters within Canada increased almost 300% from 1980 to its high in 1985. Later, during the time when Wardair received permission to operate in the scheduled market, we notice a decrease of 95% in 1988, from 360,200 in 1985 to less than 20,000 passengers in 1988; despite an increased number of new carriers in the market. With deregulation, starting a new airline was made substantially easier and there was no longer a distinction made between a charter and scheduled carrier in Southern Canada. The domestic charter passenger traffic increased another 20 fold from 1988 onwards, reaching over half a million passengers.

Generally, domestic charter services are long-haul in nature and in 1985 the top five city pairs involved Toronto and four of the five city-pairs involved cities 1,500 kilometers or more apart (Toronto - Halifax was the exception). By 1991 four of the city-pairs still involved Toronto, and all five were over 1,500 kilometers apart.

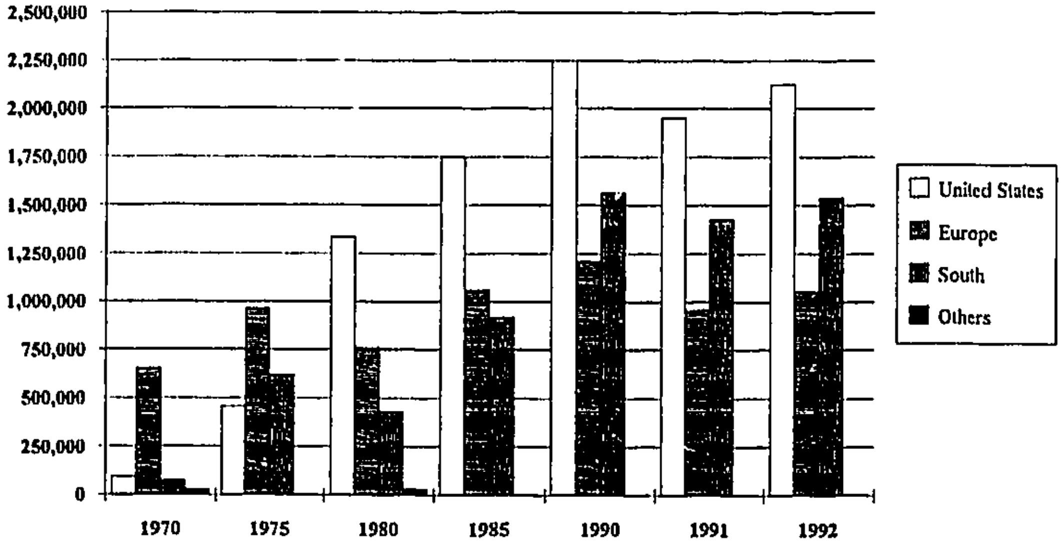
International charter service also showed great growth in the last 15 years. Traditionally, international charter activity was from Canada to Europe, with about 77% of international charter passengers flying there in 1970. The most popular destinations were London, Manchester and Glasgow in England.

Then, in 1972, regulations of the charter services were modified to allow for easier access to the service by the general public (previously, one had to be a member of a club or a group for at least six months prior to flight departure to be allowed to buy a charter ticket and those on the flight were assumed to travel from the same point to the same destination and return as a group). Following the introduction of advanced booking charters, the number of passengers traveling on international charters annually surpassed two million, hitting its high in 1989 with over five million passengers. Of those 1,122,000 were still traveling to Europe, but preferred Paris, France since the second half of the 1980s.

The change in charter service regulations also coincided with Canadian's discovering destinations in southern US and other sunspots of the globe. Since 1985, the number of passengers flying to southern vacation spots grew dramatically from 74,000 in 1970 to just under one million in 1985, to 1.73 million at its high in 1989 (see Figure 3.8). The cities of choice were Acapulco and Cancun, Mexico. The favorable economic conditions and the value of the Canadian dollar both contributed to the increase in traffic to those areas.

Today, the same trend in travel patterns still prevails. One reason could be that Canadian's are electing to discover places closer to home first, before venturing out further. Another could be that the younger generation has no reason to go to Europe as their parents and grandparents did. After the Second World War many veterans kept in touch and visited old friends from that period, thus generating a flow of traffic to that part of the world.

As a result, by far the most popular vacation spots beginning 1980 were and still are in the south



OTHERS values are less than 5,000 passengers, except for 1970 (29,214) and 1980 (31,699).

Figure 3.8 **International Charter Passengers, by World Area, 1970 - 1992**

(Source: Statistics Canada, Catalogue No. 51-205) of US. Charter service between Canada and United States increased almost 400% between 1970 (95,000) and 1975 (458,000 passengers). Of the ten top city-pairs in 1985, eight involved either Florida or Hawaii. Preference varied though depending on ones point of departure. Vacationers from Quebec and Ontario preferred Florida in 1980 as much as in 1991, westerners on the other hand tended to go to Hawaii in 1985, but switched to Reno and Las Vegas by 1991 (see Table 3.10)

1992 Ranking	City - Pair	1970	1975	1980	1985	1990	1992
				Passengers ('000)			
1	Montreal - Fort Lauderdale	..	15	37	137	255	310
2	Toronto - Orlando	2	1	82	108	264	217
3	Toronto - Clearwater/St. Petersburg	-	49	71	103	197	204
4	Toronto - Las Vegas	5	22	15	117	205	197
5	Toronto - Fort Lauderdale	..	26	49	135	201	160
6	Toronto - Fort Myers	1	-	2	33	85	87
7	Quebec - Fort Lauderdale	-	..	8	35	54	88
8	Montreal - Orlando	..	1	34	28	70	72
9	Vancouver - Reno	-	15	86	92	111	58
10	Vancouver - Las Vegas	2	3	56	37	42	53
	Others	85	326	894	921	705	682
	Total:	95	458	1,334	1,746	2,249	2,128

Table 3.10 Passengers Flying International Charter Services, Top 10 City-Pairs Ranked by Traffic Volume, Canada - USA, 1970 - 1992

(Source: Statistics Canada: Catalogue 51-207)

In comparison to international scheduled services, Canadian carriers increased their market share of passengers in the international charter services, although the number of scheduled air passengers was three times larger than the 4.3 million of charter passengers in 1991 (about 14 million). In 1991, they transported 94% of all the international charter passengers to the United States and 82% of charter passengers flying to other destinations. To compare, in 1975 the figures were 84% and 69% each.

Financial performance

As described in previous sections, the aviation industry has enjoyed a relatively steady growth since its beginnings in the 1920s. As with other aspects in this sector of commerce, financial performance was greatly affected by technological improvements, deregulation and the recession years.

One way of evaluating the success of an industry, other that its safety record, is by looking at its operating revenues and expenses. In 1955 total operating revenues generated by Canadian carriers added up to about $153 million. These increased steadily till 1985 at which point the revenues reached over $5.5 billion. In 1992 the amount reached $ 7,540 billion; an increase rate much lower than the previous three decades (see Figure 3.9).

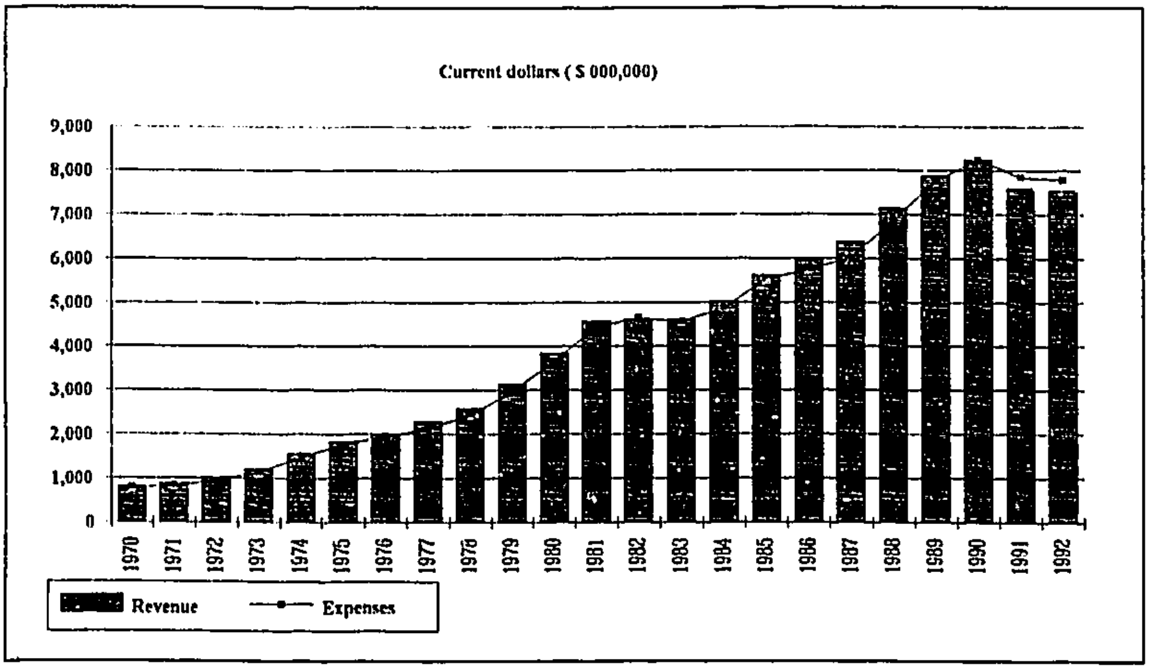


Figure 3.9 **Operating Revenues and Expenses, 1970 - 1992**

(Source: Statistics Canada: Catalogue No. 51-002, 51-202, 51-206)

From 1955 to 1992, total operating expenses followed a similar trend to that of the revenues. From the $147 million reported in 1955, operating expenses grew to over $7,776 billion in 1992. Upon closer analysis of these figures, it is easy to notice the few exceptions of steady growth however. During the years 1973 to 1976, 1979 to 1982 and 1988 to 1991, operating expenses increased faster than operating revenues. The significant increase in the cost of fuel, high interest rates on debt, economic slowdown and stagnating financial performance, all contributed to these decreased gains. The largest net income loss was recorded in 1982, adding to almost $ 89 million.

The industry returned to profitability by 1984 with a recorded net income of $75 million, but the slowdown was repeated several years later. From 1987 until 1990, operating incomes declined constantly to a new record of operating loss of $ 843 million 1992. The margin between the operating revenue and expenses continues to narrow down with each year.

In 1988, with the advent of the hub and spoke system between major carriers, Air Canada and Canadian, and their affiliates, the financial performance of airlines took on a new form. Delegating short-haul routes to their family of carriers, major airlines were able to concentrate more on their servicing the longer haul routes. Consequently, financial success depended to a greater degree on the scheduled service; over 80% of Air Canada and Canadian's operating revenue resulted from carrying scheduled passengers between 1988-91 (see Table 3.11). This importance of scheduled revenue increased more for the affiliates, growing from 80 to 90% in these same years.

Operating expenses, on the other hand, were affected by strong market share competition, increased fuel costs, lower overall market for air travel, and renewal of fleets, only to be exacerbated by the coming recession. The only exception in this growth of operating expenses occurred in 1991, when both major carriers flew less passenger-kilometers and attempted intense cost cutting wherever possible. These strategic moves translated into laying off employees, taking aircraft out of service, centralizing or closing functions and facilities, and rationalizing domestic and international routes. If any increase took place, it was primarily due to adding new partners to the family, as done by Canadian in acquiring Canadian Frontier and Inter-Canadien. The greatest contributor to operating expenses is the cost associated with direct flying, accounting for over half of the total (see Figure 3.11). Aircraft operations, the largest portion of direct flying expenses, generally comprise over a quarter of Air Canada's total operating expenses and more than a third in the case of Canadian Airlines. The largest increase in aircraft operations for the parent carriers occurred in 1989, with aircraft rentals exceeding $ 110 million and $209 million for Air Canada and Canadian respectively. These expenditures depicted greater use and cost of leased equipment.

Year	1988	1989	1990	1991	1992
AIR CANADA			($ '000,000)		
Total Operating Revenue	2,849.1	3,081.6	3,238.2	2,741.9	2,702.1
Scheduled Passenger Revenue	2,349.1	2,550.6	2,670.9	2,280.6	2,244.9
Total Direct Flying Expenses	1,541.1	1,685.8	1,878.7	1,673.1	1,589.4
Aircraft Operations	791.6	902.0	1,029.0	880.0	827.9
Aircraft Rental	54.3	97.2	108.5	110.6	120.4
Fuel & Oil	449.8	485.6	569.9	433.3	395.3
Total Operating Expenses	2,706.0	2,972.1	3,279.5	2,947.6	2,932.9
AIR CANADA CONNECTORS					
Total Operating Revenue	252.5	366.2	488.5	492.0	499.7
Scheduled Passenger Revenue	201.5	330.2	444.1	452.9	459.3
Total Direct Flying Expenses	.	.	.	.	.
Aircraft Operations	90.7	136.5	173.8	166.4	163.4
Aircraft Rental	.	.	.	.	.
Fuel & Oil	40.0	56.0	72.2	63.2	64.5
Total Operating Expenses	237.7	327.8	427.9	430.7	437.1
CANADIAN AIRLINES					
Total Operating Revenue	2,136.1	2,118.0	2,543.9	2,445.3	2,441.5
Scheduled Passenger Revenue	1,712.0	1,674.3	2,115.6	2,037.9	2,061.0
Total Direct Flying Expenses	1,169.9	1,716.2	1,876.7	1,497.6	1,422.8
Aircraft Operations	667.1	712.3	886.8	849.1	814.2
Aircraft Rental	125.3	248.1	178.0	209.6	251.9
Fuel & Oil	351.8	338.8	475.5	396.1	339.3
Total Operating Expenses	2,097.8	2,179.9	2,608.2	2,694.1	2,553.4
CANADIAN PARTNERS					
Total Operating Revenue	297.1	387.3	295.4	375.0	408.3
Scheduled Passenger Revenue	234.7	314.6	272.7	343.3	352.5
Total Direct Flying Expenses	.	.	.	.	.
Aircraft Operations	123.2	157.3	120.4	156.2	178.2
Aircraft Rental	.	.	.	.	.
Fuel & Oil	47.2	60.5	47.3	57.0	56.4
Total Operating Expenses	276.0	374.8	290.7	381.4	422.4

Table 3.11 Revenue and Expenses of Major Carriers and Their Affiliates, 1988 - 1992

(Source: Statistics Canada: Catalogue No. 51-206, Internal Reports)

Aircraft oil and fuel, as part of aircraft operating expenses, generally showed increases until 1990, with small decline in 1991. The elevated cost of fuel and oil, for feeder airlines, mostly represented the increased number of passenger-kilometers they flew on their short-haul routes.

Canada has the largest land mass in the world, yet its population is barely 27 million. Air transportation is a vital link in unifying the nation and conducting its business trade. Because of its importance to both the economy and the social interactions of the nation, air transport has been a focus of much public policy making; as early as 1919, Canada was developing policies toward the industry. By the end of 1930s it has established a government-owned airline to provide transcontinental services and had established a regulatory system to control entry and prices. Every decade since that time, major air transport policy issues were debated and resolved. Then, in the late 1970s, as the US moved to deregulate its airline industry, forces were set in motion to do the same in Canada.

Today, Air Canada, the former national flag carrier, is a private enterprise. A new structure of hub and spoke network exists between the two remaining mega-carriers and their affiliates. Relaxed government controls constantly lead to, on the one hand, increased flight frequency, better service and lower fares for the passengers, on the other, a streamlined work force, improved computer reservation systems and smaller, more economical aircraft, as well as improved load factors for the air carriers. Overall the industry in growing at a steady pace and penetrating its markets throughout the country and the world. Recessions of 1981 and 1991 have temporarily halted that development but air travel should be able to conquer these challenges and emerge stronger, streamlined and competitive in the coming years.

CHAPTER IV

ACCIDENT RATES IN CANADIAN AVIATION

Canadian air industry has enjoyed a fairly steady growth and success in the last fifty years. Its overall financial and operational well-being was affected throughout by the changing structure of the industry, regulatory control, technological advances, productivity improvements and the whole business climate of the country, as well as the world economy. These same factors contributed to the improved safety of flight, thus affecting the way the general public perceives and has confidence in air travel. This part of the study provides a general overview of the safety levels in commercial flying and factors which weigh heaviest on Canada's accident record.

AIRLINE ACCIDENTS DATA

This section presents a synthesis of all the steps undertaken to build the final Canadian commercial aviation accidents data set. The collected information ultimately contains the factors affecting air transport accidents.

A) Data Collection

The overall study presented in this paper made use of two sets of data. The first, containing economic and operational aggregate information, was provided by the Aviation Statistics Center, Statistics Canada. Variables such as, passenger-kilometers, revenue-passenger-kilometers, hours flown and load factors, as well as licensed carriers and their financial statistics for the years 1976 to 1993 were included. The second set, containing data relating more directly to individual accidents, was obtained from the Transportation Safety Board. The information included such variables as the type of aircraft, passenger and crew injuries and fatalities, type of landing gear and number of engines of any aircraft involved in an accident.

The data were provided in two different formats. The economic aggregate information was tabulated and in hard copy. Its data spanned the years from, in some cases, 1930 to 1993. The individual accident information, on the other hand, was contained in three separate data files. The distinct databases of a) accident information, b) aircraft specifics and c) phase of fight data, were subsequently merged into one complete data file. The final accident data set contained information on 4,344 Canadian commercial aviation accidents over the period from 1976 to 1993, for all levels of air carriers.

In addition to merging files, some coding and manual searches of data were required. Many variables such as terrain, weather conditions, type of landing gear and operator type had to be assigned a numerical code in order to prepare it for further analysis. Also, the air carrier level variable had to be researched from yearly Fleet Reports and added into the data set manually. This is not to say that the final data set was an exhaustive one. The original list of variables to be collected also required information on such elements as:

accidents - time into flight from the time of takeoff, distance covered from the time of takeoff, number of intermediate stops, if any,

machine - total hours flown (time of service), total flights made since introduction into operation, years in operation, years of service with the airline, time of last maintenance, known malfunctions since takeoff, if any,

human - years of experience on particular route (pilot & co-pilot), years of experience on particular aircraft (pilot & co-pilot), years with the airline (pilot & co-pilot), time flown with the particular crew (pilot & co-pilot),

weather - ground conditions, flight conditions as perceived by crew, true (actual) flight conditions,

company - years in business, financial situation (earnings, financial ratings, public image), safety record (accidents, awards, reprimands), above regulatory maintenance procedures, if any, fleet of aircraft, geographic outline of serviced routes, performance or profit on specific routes, participation in safety programs, number/experience of crews assigned to routes, improvements as a result of an accident.

However, in order to collect this additional information, individual accident reports and airline documents would have to be scrutinized. Due to obvious time and financial constraints the collection was not performed. In addition, there was no guarantee that such information would have been available. In the case of specific accidents, the TSB and other government authorities only register the details that are deemed necessary and useful in assigning a probable cause to the event. With respect to documents of airlines involved in an accident, because almost all of them are privately owned, there is no incentive or obligation on their part to disclose any information, especially if it is regarded as damaging to the successful conduct of future operations. Therefore, only certain, more easily accessible and available information was collected. Subsequent studies may use this as a starting point and certainly expand their data sets and frame of analysis in the future.

Since this analysis concentrated on two separate aspects of accidents, confirmation of factors causing aircraft accidents as well as prediction of the aggregate number of accidents, two separate data sets were required. The analysis of the factors affecting air travel made use of the TSB accident specific variables. In order to predict the total number of fatalities and accidents per year, both economic data tables and aggregate accident variables were used. The two data sets provided an overall picture of the financial, operational and safety aspects of the Canadian aviation industry.

B) Data Set Variables

This section describes all the variables contained in the final accident data sets. Both economic and accident variables are listed. Each variable is characterized in terms of its name, field type, field length and content.

The first set of variables was used in the analysis focusing on predicting the total number of accidents and fatalities per year. For that purpose, aggregate yearly results were needed. The second set of variables represents those statistics used in the general assessment of Canadian aviation safety record and the exploratory factor analysis.

Field name	Field type	Field length	Description
Aggregate variables			
YR	N	4	Year (1976-1993)
PASS	N	5	Passengers flown in a year
PASSKM	N	5	Passenger-kilometers flown in a year
HRSFWN	N	4	Hours flown in a year
OPEREV	N	4	Total operating revenues of commercial air carriers
ACCNO	N	3	Number of accidents in a year
REVPAKM	N	5	Revenue per passenger-kilometer
LOADFCTR	N	4	Load factor
DEPTS	N	7	Departures per year
FATALACC	N	3	Number of fatal accidents in a year
VICTIM	N	3	Number of victims in a year (serious, minor and fatal)
JET	N	3	Number of jet aircraft in Canada
PROP	N	3	Number of propeller aircraft in Canada
PISTON	N	4	Number of piston powered aircraft in Canada
MOVE	N	4	Total itinerant movement in Canada
AIRLINES	N	4	Number of Canadian airlines operating in Canada
PPL	N	5	Number of private pilots in Canada
CPL	N	5	Number of commercial pilots in Canada
ATPL	N	4	Number of air transport pilots in Canada
Individual accident variables			
OCC_NO	C	9	Accident occurrence number as assigned by the TSB
LOCATION	C	35	Site of the accident
PROVINCE * (PROV)	C	25	Province of accident
LIGHT * (LITE_NO)	C	25	Light condition: day light, night dark, night bright, dusk, dawn
WEATHER_S * (W_S_NO)	C	50	Specific weather conditions: gusty wind, windshear, hurricane, turbulence in cloud, thunderstorms, squall line, CAT, inversion, lightning, none or other
TERRAIN * (LAND_NO)	C	30	Type of terrain: flat, mountainous, hilly, rolling, level/flat, water
DATE	C	10	Date of accident (dd/mm/yy)
TIME	C	10	Time of accident (hh/mm) based on a 24 hour clock
REG	C	11	Aircraft registration number
GEAR * (GEAR_NO)	C	30	Type of landing gear: float, ski, skid, tricycle fixed, tricycle all retractable, tail wheel fixed, amphibious or hull-wheel
NO_ENGIN	C	10	Number of engines: 1, 2, 3 or 4
FLIGHTPLAN * (FPLAN_NO)	C	30	Flight plan information: VFR, IFR, flight note or itinerary, none
AIRCRAFT * (PLANE_NO)	C	15	Type of aircraft: airplane, helicopter, balloon, glider, gyroplane
OPRTOR	C	65	Operator name (air carrier)
FATAL_CR	C	10	Number of crew fatalities
FATAL_PA	C	10	Number of passenger fatalities
SER_CREW	C	10	Number of crew serious injuries
SER_PASS	C	10	Number of passenger serious injuries
MINOR_CR	C	10	Number of crew minor injuries
MINOR_PA	C	10	Number of passenger minor injuries
T_PLT_HR	C	10	Total pilot flight hours
PLT_TYP_HR	C	10	Total pilot flight hours on type of aircraft

Table 4.1 **Data Dictionary**

Field name	Field type	Field length	Description
PLT_BIRTH * (AGE)	C	10	Pilot's birth day (dd/mm/yy)
LIC_TYP * (LIC_NO)	C	30	Pilot licence category: CPL, ATPL, PPL, SCPL, student, military, tourist, glider, ultralight
T_CO_HR	C	10	Total co-pilot flight hours
CO_TYP_HR	C	10	Total co-pilot flight hours on type of aircraft
OPERATION * (OPRTN_NO)	C	25	Type of operation: business, pleasure/travel, scheduled or non-scheduled - domestic or international, construction, charter, advertising, photo/survey, fire fighting/management, ambulance
OPRTOR_TYP * (OPRTOR_NO)	C	25	Type of operator: air carrier, commercial, corporate, manufacturer, military, flying school or club, other private
LEVEL	N	1	Levels I to VI used for purposes of statistical reporting at SC and NTA; generally defined by revenue & passengers transported per year
PHASE * (PHASE_NO)	C	50	Phase of flight at the time an event occurred: take-off, landing, taxiing, en route, maneuvering, on approach

Note: an asterisk (*) indicates that the originally collected variable had to be coded and its name is included in the parenthesis (name) next to the original variable name.

Table 4.1 Data Dictionary - continued

FLIGHT RISK ASSESSMENT

The results presented in the following sections give general indication of the types of accidents occurring in the Canadian commercial airline sector. However, before looking at the key factors and specific causes influencing flight safety, the risk of air travel is first represented as a function of total accidents, passenger fatalities and injuries per passenger-kilometers, hours flown, enplanements and departures per year.

The tables included throughout this section contain a number of differing methods of measuring airline safety for the studied period from 1976 to 1993. Each method tries to assess the overall accident rate as well as the rate of fatalities, serious and minor injuries as a result of yearly accidents. As described in chapter two, an argument can be made for and against each one of these methods the reader is therefore presented with as many varied measures as the existing data would permit. It should be noted however, that the aggregate number of enplanements was not available for the years 1976 to 1979. Consequently, the accidents and victims rates calculated using this method were possible only for a restricted years.

Year	Hours flown	Accidents	Enplanements	Departures	Pass-Km
1976	2,327,000	327	na	3,209,296	32,797,000,000
1977	2,397,000	287	na	3,302,512	35,553,000,000
1978	2,555,000	317	na	3,389,764	38,249,000,000
1979	2,574,000	367	na	3,597,080	44,901,000,000
1980	2,844,179	344	55,381,000	3,533,234	46,996,000,000
1981	2,661,879	359	55,265,000	3,299,065	46,086,000,000
1982	2,343,394	232	49,071,000	2,711,742	44,179,000,000
1983	2,173,278	183	49,426,000	2,502,689	43,370,000,000
1984	2,176,118	177	53,732,000	2,453,675	46,444,000,000
1985	2,203,812	183	54,514,000	2,330,246	49,968,000,000
1986	2,302,952	198	57,947,000	2,471,849	53,084,000,000
1987	2,349,659	201	59,734,000	2,631,618	55,364,000,000
1988	2,652,314	232	66,015,000	2,771,712	62,292,000,000
1989	2,848,561	248	66,021,000	2,954,511	65,789,000,000
1990	2,620,259	226	66,928,000	3,053,084	66,778,000,000
1991	2,513,724	209	60,702,000	2,789,844	57,888,000,000
1992	2,509,812	170	62,023,000	2,631,634	62,527,000,000
1993	2,385,000	185	61,289,745	2,060,134	61,098,000,000

Table 4.2 **Historical Operational Statistics, 1976 - 1993**

(Source: ASC figures, Cat. TP2468, and TSB accidents data file)

The first table presents the overall operational figures of the Canadian commercial airline industry. The continued success and expansion in the air travel business can be attributed to two primary factors. First, the enormous changes in aircraft technology, during the previous 15 to 20 years, allowed for the introduction of faster and bigger aircraft, therefore providing the public with larger seating capacity and more comfortable accommodations on long distance flights. These aircraft helped change air travel into more economical mode of transport providing its more affordable services to a greater range of the population.

The second contributor to the industry's expansion in the 1980s was the consumers' response to intense marketing efforts from carriers anxious to go after greater market shares. The increasing number and variety of services offered at attractive prices, attracted more and more travelers. This increased interest and use of aircraft as a mode of transport is apparent as seen in the Table 4.2. During the period from 1976 to 1993 the number of passengers increased by 20% and the distance flown by these same travelers almost doubled. It should be noted that although the total number of hours flown and aircraft

Year	Fatalities	Serious Injuries	Minor Injuries	Accidents
1976	1.309	1.620	0.966	10.189
1977	1.453	0.545	0.454	8.690
1978	2.714	2.508	1.977	9.352
1979	2.780	1.362	1.140	10.203
1980	1.500	1.415	0.991	9.736
1981	1.273	1.000	0.455	10.882
1982	1.659	0.885	0.627	8.555
1983	1.079	1.119	0.400	7.312
1984	1.426	1.630	0.448	7.214
1985	0.944	1.888	0.644	7.853
1986	0.890	1.214	0.850	8.010
1987	0.798	0.798	0.684	7.638
1988	0.722	0.902	0.325	8.370
1989	1.760	2.132	1.252	8.394
1990	0.557	0.459	0.262	7.402
1991	9.929	0.538	0.502	7.491
1992	0.494	0.760	0.646	6.460
1993	1.359	0.437	0.582	8.980

Table 4.3 **Historical Fatality and Aircraft Accident Rates,**

Per 100,000 Departures, 1976 - 1993

(Source: ASC figures, TSB accidents data file)

Year	Fatalities	Serious injuries	Minor injuries	Accidents
1976	1.805	2.235	1.332	14.052
1977	2.003	0.751	0.626	11.973
1978	3.601	3.327	2.622	12.407
1979	3.885	1.904	1.593	14.258
1980	1.863	1.758	1.231	12.095
1981	1.578	1.240	0.564	13.487
1982	1.920	1.024	0.725	9.900
1983	1.242	1.288	0.460	8.420
1984	1.608	1.838	0.505	8.134
1985	0.998	1.997	0.681	8.304
1986	0.955	1.303	0.912	8.598
1987	0.894	0.894	0.766	8.554
1988	0.754	0.943	0.339	8.747
1989	1.825	2.212	1.299	8.706
1990	0.649	0.534	0.305	8.625
1991	11.020	0.597	0.557	8.314
1992	0.518	0.797	0.677	6.773
1993	1.174	0.377	0.503	7.757

Table 4.4 **Historical Fatality and Aircraft Accident Rates,**

Per 100,000 Hours Flown, 1976 - 1993

(Source: ASC figures, TSB accidents data file) departures have been fluctuating around 2.45 million hours and 2.86 aircraft departures, respectively, the total number of accidents has decreased by almost 50% over the last two decades. A great achievement for such technologically advanced, complex and challenging field.

The included tables show the results of assessing the risk of flying, based on accidents and the resulting victims rates. Table 4.3 presents the rate of yearly accidents, fatalities and injuries per 100,000 departures. The rates of Table 4.4 are expressed in terms of 100,000 hours flown and those of Table 4.5 per 100,000 passenger-kilometers.

Both measures (see Tables 4.3 and 4.4) show continually improving safety throughout the years, except for a few setbacks in 1978-1979 and 1989. The extreme increase in the accident and fatalities rates in 1991 is explained by the crash in Jeddah, Saudi Arabia, when 261 passengers and crew perished. The remaining accidents record shows that the probability of being involved in a plane crash has declined almost 50% and the chance of being killed in an air crash declined from over 3.8 per 100,000 hours flown or over 2.7 per 100,000 departures in 1979 to 0.5 per 100,000 hours flown and per 100,000 departures in 1992. This general conclusion about improved airline safety does not seem particularly sensitive to the choice of measure; both departures and flight hours-based rates move in congruence during the same years*.

The rates based on passenger-kilometers also indicate that the probability of being involved in aircraft accident has diminished. The chance of being in an air crash decreased from over ten per 100,000 passenger-kilometers in 1976 to 6.5 per 100,000 passenger-kilometers in 1992. The rates of fatalities calculated using the same method also show dramatic declines over the same period (see Table 4.5). The probability of being killed was reduced from 0.128 in 1976 to 0.046 by 1993. In addition to overall accident and fatalities rates decrease, the tables provide a more detailed look at the resulting injuries. Both serious and minor injuries rates closely followed the trend of accidents and fatalities. It should be noted that the combined rates of injuries are almost always higher than those of fatalities. Although no passenger wants to think of being involved in a crash, it is somewhat encouraging to know that there is a

---

* However, due to lack of accurate enplanements data for the first four years of the studied period, similar comparison would not be appropriate between enplanements and departures or hours flown-based rates.

better chance of surviving with serious or minor injuries than of being killed should an accident occur. Once again, this conclusion is supported by all measures used (see Tables 4.3, 4.4 and 4.5).

Year	Fatalities	Serious Injuries	Minor Injuries	Accidents
1976	0.128	0.159	0.095	10.189
1977	0.135	0.051	0.042	8.690
1978	0.241	0.222	0.175	9.352
1979	0.223	0.109	0.091	10.203
1980	0.113	0.106	0.074	9.736
1981	0.091	0.072	0.033	10.882
1982	0.102	0.054	0.038	8.555
1983	0.062	0.065	0.023	7.312
1984	0.075	0.086	0.024	7.214
1985	0.044	0.088	0.030	7.853
1986	0.041	0.057	0.040	8.010
1987	0.038	0.038	0.033	7.638
1988	0.032	0.040	0.014	8.370
1989	0.079	0.096	0.056	8.394
1990	0.025	0.021	0.012	7.402
1991	0.479	0.026	0.024	7.491
1992	0.021	0.032	0.027	6.460
1993	0.046	0.015	0.020	8.980

Table 4.5 **Historical Fatality and Aircraft Accident Rates,**

Per 100,000 Passenger-Kilometers, 1976 - 1993

(Source: ASC figures, TSB accidents data file)

The results presented thus far are fairly unanimous in their assessment of aviation safety. Figure 4.1 compares total accident rates calculated using all three methods (accident rates per 100,000 hours flown, 100,000 passenger-kilometers and 100,000 departures). Although the values may differ, the overall trend is supported throughout (notice how accident rates per departures are almost the same as those per passenger-kilometers). However, as encouraging as these overall figures are, further analysis shows that the improved capability to offer safe air travel has not spread equally to all regions of the country [•]. In addition to calculating the overall accidents rates and their tendency over time, safety must also be considered by examining what factors contribute to their occurrence. Regional difference of flight safety is one of the factors which can be properly assessed based on its rate per 100,000 enplanements and hours

---

[•] Only regional difference can be assessed based on the data available. Rates per number of engines, time of day, type of pilot license and age group, etc. Are not collected regularly by Canadian authorities, if at all.

flown (see Table 4.7) There is no enplanement or other base breakdown of data available for additional factors studied in this paper.

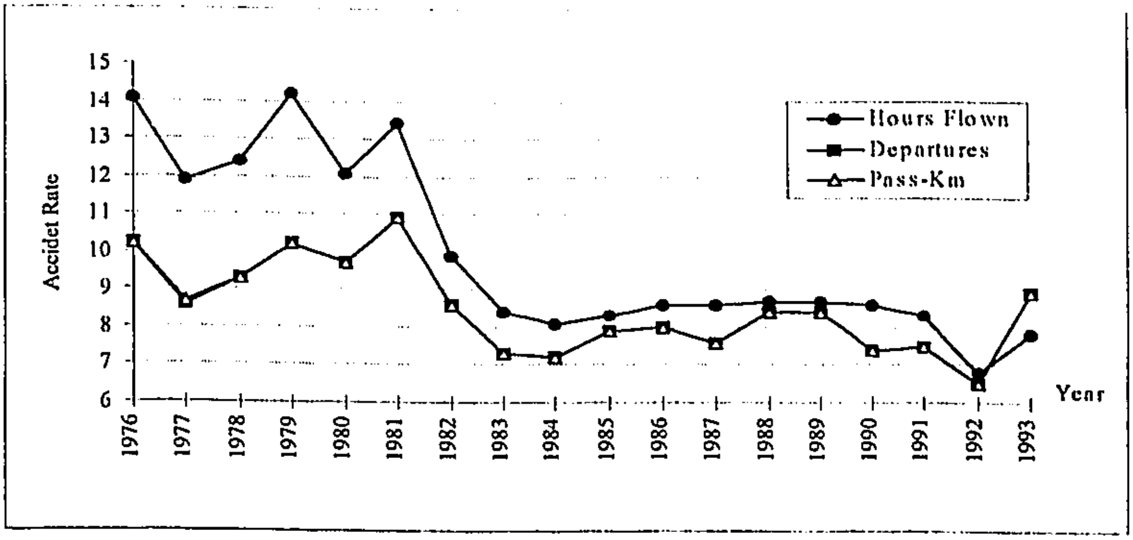


Figure 4.1 **Comparative Analysis of Accidents Rates**

(Source: based on data in Table 4.2, accident rates are based per 100,000 hours flown, 100,000 passenger-kilometers and 100,000 departures)

Year	Fatalities	Serious Injuries	Minor Injuries	Accidents
1976	na	na	na	na
1977	na	na	na	na
1978	na	na	na	na
1979	na	na	na	na
1980	0.096	0.090	0.063	0.621
1981	0.076	0.060	0.027	0.650
1982	0.092	0.049	0.035	0.473
1983	0.055	0.057	0.020	0.370
1984	0.065	0.074	0.020	0.329
1985	0.040	0.081	0.028	0.336
1986	0.038	0.052	0.036	0.342
1987	0.035	0.035	0.030	0.336
1988	0.030	0.038	0.014	0.351
1989	0.079	0.095	0.056	0.376
1990	0.025	0.021	0.012	0.338
1991	0.456	0.025	0.023	0.344
1992	0.021	0.032	0.027	0.274
1993	0.046	0.015	0.020	0.302

Table 4.6 **Historical Fatality and Aircraft Accident Rates,**

Per 100,000 Enplanements, 1976 - 1993

(Source: ASC data, TSB accidents data file)

Year	Atlantic	Quebec	Ontario	Prairies	Pacific	Total
1976	na	na	na	na	na	na
1977	na	na	na	na	na	na
1978	na	na	na	na	na	na
1979	na	na	na	na	na	na
1980	0.460	0.788	0.415	0.664	0.796	0.614
1981	0.620	0.780	0.289	0.869	0.883	0.644
1982	0.321	0.582	0.285	0.629	0.522	0.460
1983	0.573	0.375	0.284	0.407	0.394	0.366
1984	0.545	0.352	0.207	0.425	0.333	0.324
1985	0.458	0.395	0.225	0.470	0.325	0.338
1986	0.358	0.276	0.237	0.570	0.356	0.340
1987	0.456	0.307	0.165	0.435	0.575	0.336
1988	0.290	0.402	0.190	0.461	0.517	0.344
1989	0.266	0.339	0.164	0.700	0.512	0.365
1990	0.280	0.375	0.167	0.417	0.540	0.329
1991	0.340	0.233	0.164	0.535	0.467	0.318
1992	0.246	0.210	0.193	0.300	0.396	0.261
1993	0.280	0.193	0.189	0.348	0.463	0.282

Table 4.7 Historical Aircraft Accident Rates, by Region,

Per 100,000 Enplanements, 1976 - 1993

(Source: ASC data, TSB accidents data file)

Closer look at the regional accident rates, for the period from 1980 to 1993, points to the conclusion that flights in the Prairies region posed most threat to passengers during the first half of the 1980s. During that time the regions accident rates were 1.5 times as high as those for the entire country. The year 1987 seems to have been a transition year, where the Pacific provinces and Territories rates surpassed that of Canada and then gradually approached the overall average for the remaining of the studied period. In Ontario, the accident rate was almost always 30% lower than that of Canada. Quebec also followed an increased safety trend, however still remaining more dangerous than the overall average flight. The remaining Atlantic region fluctuated in its adherence to safe operations. It was split on the safety rates half the time surpassing the Canadian overall record, and rating below the average during the remaining seven years.

The same regional data was used in calculating the accident rates per 100,000 hours flown (see Table 4.8). However, unlike the consistency in results experienced using aggregate information (where per hours flown, per departures and per passenger kilometers information remained compatible) in this case, regional differences are somewhat altered. Results based on accidents per 100,000 hours flown show that the Atlantic provinces pose the most threat with Prairies, Pacific and Ontario regions being more dangerous during the last six years of the studied period. Also, this degree of danger is quite significant compared to the overall Canadian average, as opposed to the almost minimal differences shown in safety levels when calculated per 100,000 enplanements.

Year	Atlantic	Quebec	Ontario	Prairies	Pacific	Total:
1976	na	na	na	na	na	na
1977	na	na	na	na	na	na
1978	na	na	na	na	na	na
1979	na	na	na	na	na	na
1980	14.549	9.483	13.184	12.028	13.199	11.954
1981	18.650	9.700	10.489	17.658	14.703	13.374
1982	8.779	7.244	10.298	13.118	9.110	9.729
1983	17.620	4.810	10.446	9.998	7.377	8.328
1984	16.677	4.832	9.171	9.586	7.442	7.996
1985	15.525	5.382	9.938	10.894	6.748	8.349
1986	17.652	3.928	10.633	12.866	6.992	8.554
1987	21.022	4.913	7.954	10.745	8.969	8.563
1988	9.741	6.236	9.582	7.038	12.499	8.559
1989	7.560	4.689	7.418	11.074	11.295	8.460
1990	5.678	6.050	8.201	11.319	9.778	8.396
1991	6.835	3.353	7.709	14.324	7.987	7.678
1992	4.993	3.161	9.364	8.148	6.818	6.456
1993	6.900	2.846	8.767	7.941	7.682	6.707

Table 4.8 **Historical Aircraft Accident Rates, by Region,**

Per 100,000 Hours Flown, 1976 - 1993

(Source: ASC data, TSB accidents data file)

These final results also emphasize the mentioned difference in reaching conclusions based not only on measuring safety through different methods, but also on raw as opposed to rate-based data. As will be seen in the next section, the raw overall number of accidents indicates that most accidents occur in Ontario and Quebec. That is true, however, these same provinces are also engaged in providing more air travel services than any other province in the country. Therefore, more accidents do not necessarily mean more risk, especially when evaluated against the sum of all industry activities.

The decline in aggregate accident, fatality and injury rates, also does not, by itself, demonstrate that years of flight experience had positive impact on safety. Airline safety has been improving steadily since the beginning of airline service as aircraft technology, navigational aids, weather detection equipment, pilot training methods, and international cooperation have improved*. In addition to calculating the rates of accidents and their tendency over time, safety must also be examined by studying the causes of accidents and by considering what types of accidents would be expected to have increased their rate. The following sections provide the necessary details.

COMMERCIAL FLIGHT ACCIDENTS

Overall rates, as presented in the preceding section, provide little understanding about why safety has been worse in some segments than in others. They also provide little guidance about where to focus the efforts to improve safety. A more promising approach begins with classifying accidents according to their cause and comparing the distribution of causes both over time and across segments of the industry. It should be kept in mind, however, that this part of analysis is not based on rates but on raw numbers. The number of departures, flight hours or enplanements is not available per day/night flights, per type of engine, etc. Therefore, some conclusions may be different for various segments of industry if they were looked at from the rates point of view. It does not however diminish the lessons learned from their analysis.

A detailed statistical review of the safety record of the commercial aviation in Canada over the 18-year period from 1976-1993 revealed that flying continues to be increasingly safe (TSB, 1993). There was substantial improvement between 1976 and 1984 and, after slight increase in the occurrence of accidents between 1985 through 1989, additional improvement in safety was shown in 1992. In Canada, the worst years proved to be 1979 and 1981 both with 356 accidents. The lowest rate of accidents occurred in 1992 when only 162 accidents were recorded. A 55% decrease over ten years.

A) Regional differences

The study of accident occurrences in Canada, must include a closer look at any significant differences among regions. The Rockies in the west and the vast lakes- covered areas in Ontario offer less than friendly environment for a long distance flight.

---

* Some of these qualitative factors are examined further in the last chapter of this paper.

As expected, when looking closer at the figures, it becomes clear that individual provinces of Ontario, British Columbia and Quebec contributed most to the occurrence of accidents during the 1976-1993 period, with 949, 808 and 791 accidents respectively. They were followed by the Prairies, the Territories and the Atlantic provinces. On average 52.7 accidents occurred on the Pacific coast (B.C.) compared to 0.89 accidents no the Atlantic side (P.E.I.). In all, there were three times as many accidents on the West coast (B.C. and Yukon), as in the East (all of Atlantic).

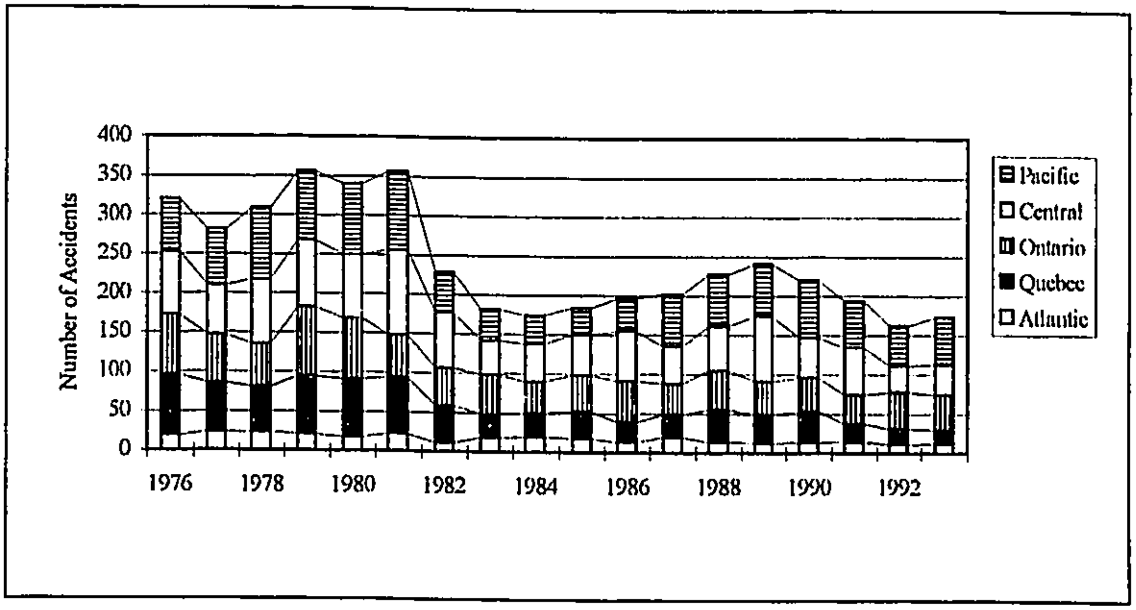


Figure 4.2 **Accidents by Region, 1976-1993**

(Source: TSB accident data file)

Once again, it should be noted that over 80% of Canadians live along the US border where there is greater access to large airports providing flight services to all parts of the world. Since these regions are also the major centers for economic development and prosperity, they can offer its inhabitants better resources to use alternate modes of transport at better prices. Consequently, if the southern part of the province of Ontario has higher per capita resources, it follows that the area will also have more and larger airports, as well as more airway and airport congestion. Therefore, the number of accidents will also be more pronounced in the region.

B) Fatal Accidents and Casualties

Since the severity of an occurrence is an important aspect of accident analysis, consideration must also be given to the number of *fatal* accidents when evaluating air safety. Fatal accidents are those resulting in at least one death.

Statistics relating to fatal accidents, and those involving minor and serious injuries, reveal that since 1976 a total of 1,951 (or 44.9%) of these type of accidents occurred, involving 3,293 persons who either died or were in some way injured. Fatal accidents accounted for 37.42% of those occurrences, whereas accidents that involved minor and serious injuries accounted for 36.39% and 26.19% of incidents, respectively. In all, 1,495 or 45.39% of all victims died, 1,076 or 32.68% of the crew and passenger victims sustained minor injuries and 722 or 21.93% of crew and passenger victims suffered serious injuries.

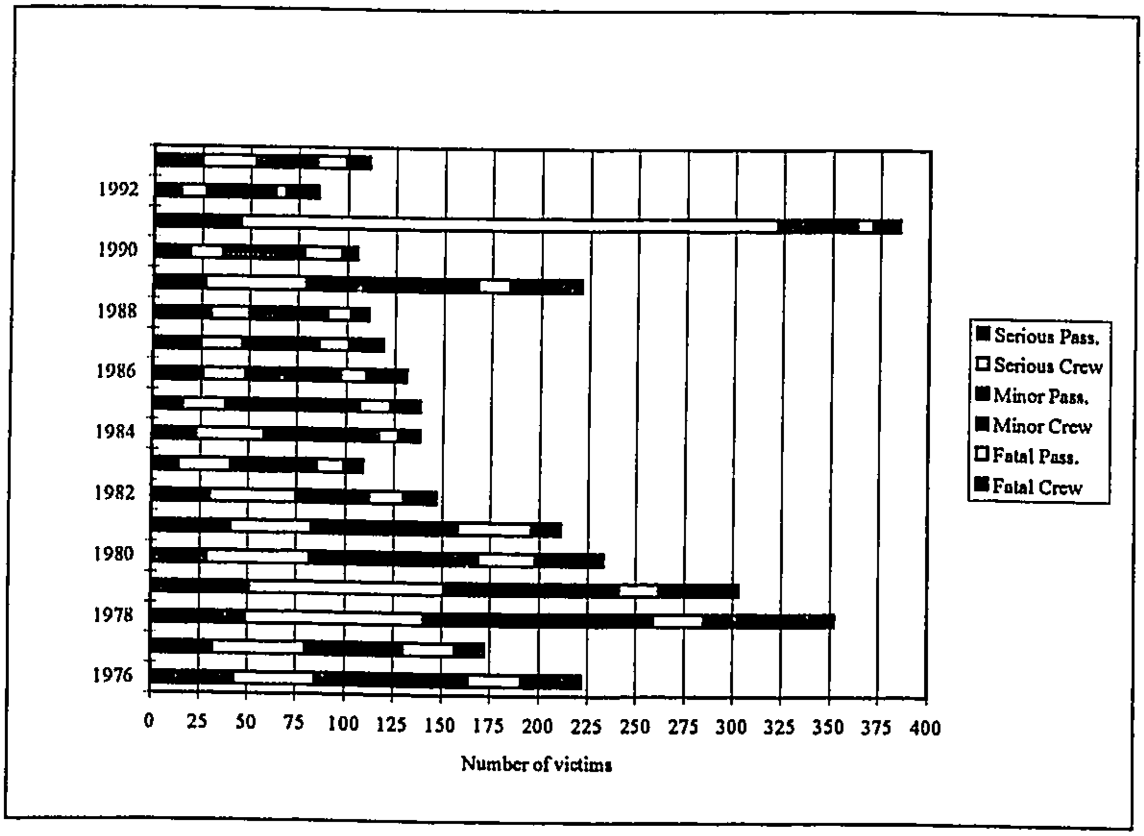


Figure 4.3 **Yearly Accident Injuries and Fatalities, 1976-1993**

(Source: TSB accidents data file)

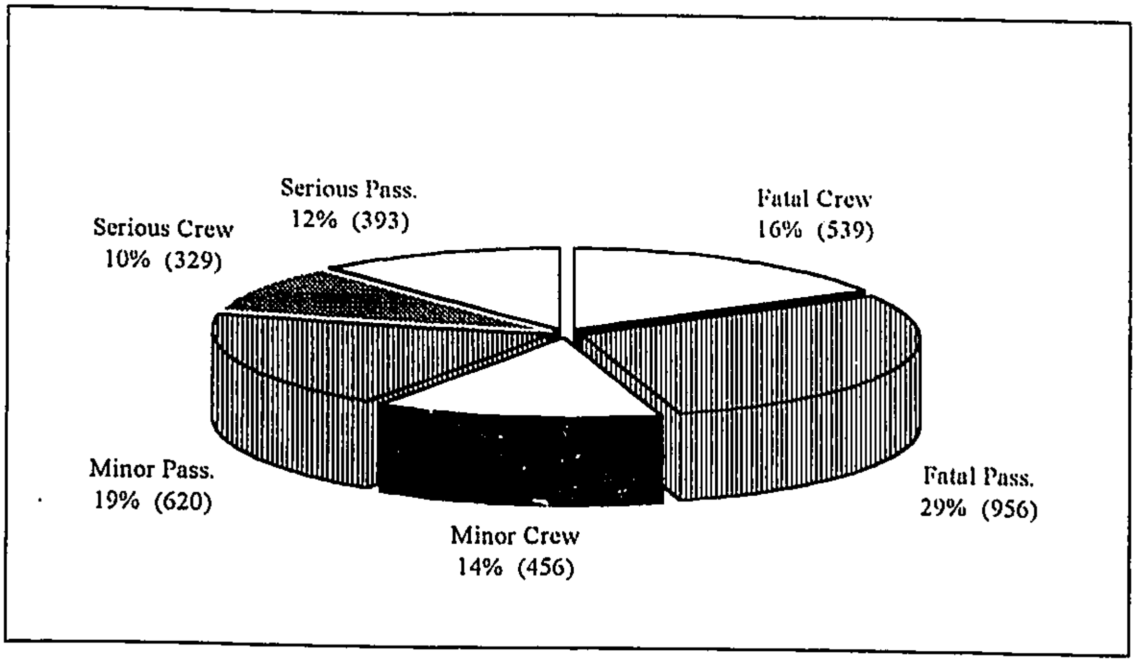


Figure 4.4 **Total Accident Victims, 1976-1993**

(Source: TSB accident data file)

As wide-body aircraft became more popular in the 1960's and 1970's, the possibility of a single accident contributing greatly to the total number of victims also dramatically increased. Consequently, the number of fatalities fluctuated significantly from year to year, depending on the type of aircraft involved in the incident. The high figure of almost 400 victims in 1991, most of which were passenger fatalities, is attributed to the crash of a Canadian charter aircraft in Jeddah, Saudi Arabia, in which 261 lives were lost. In all 208 accidents were recorded resulting in 385 victims that year. In comparison, there were 356 accidents in 1981 involving 211 fatalities. And, in 1993, 173 incidents resulted in only 111 victims. Over the last 18 years, passengers have accounted for approximately 60% of total fatalities, with crew members accounting for the remaining 40%. Fatalities on the ground average about two per year.

The statistics discussed thus far provide an indication of aviation trends in safety across the country. This aggregate data represents a distinct number of aviation sectors, a variety of aircraft and types of operators. The discussion in the following sections briefly profiles accident data according to these varied categories.

C) Accidents by Operator Type

Canadian commercial operators are classified according to their size of operation. Based on their profits generated from the transport of cargo and passengers, carriers are divided among six levels. Throughout the last two decades, only a small proportion of Canadian commercial aircraft accidents involved Level I and Level II carriers. The total number of accidents by these carriers represented less than 2.5%, although Level II carriers have increasingly been part to tragedy. This is a reflection of the significant increase in activity; an estimated 210% increase in annual flying hours between 1984-1987 and 1988-1993 periods.

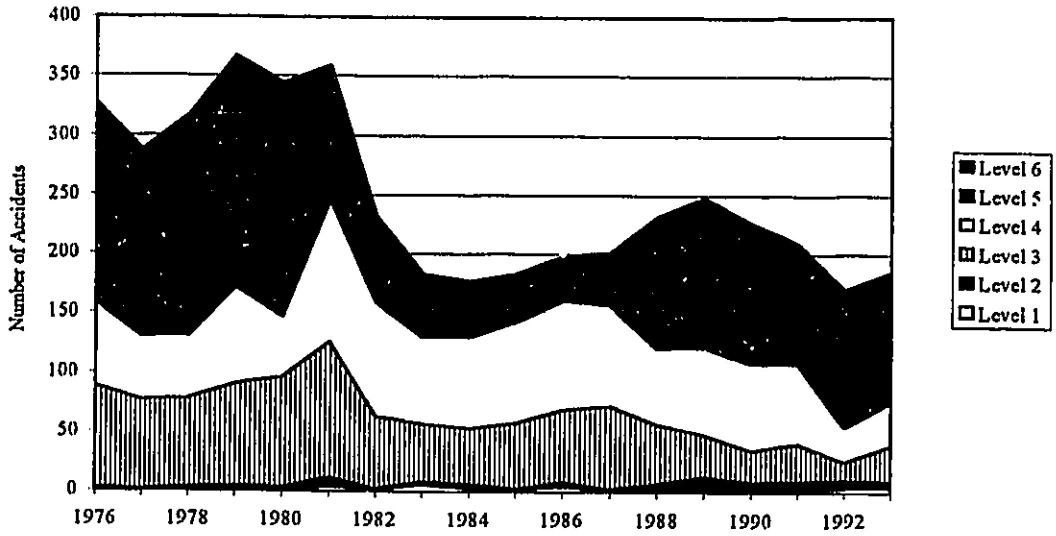


Figure 4.5 **Accidents by Air Carrier Level, 1976-1993**

(Source: TSB accident data file)

It should be noted that Level I and II carriers in 1993 accounted for some 95% of fare-paying passengers and approximately one-third of total hours flown with only 1.03% of fatal accidents belonging to the mentioned categories.

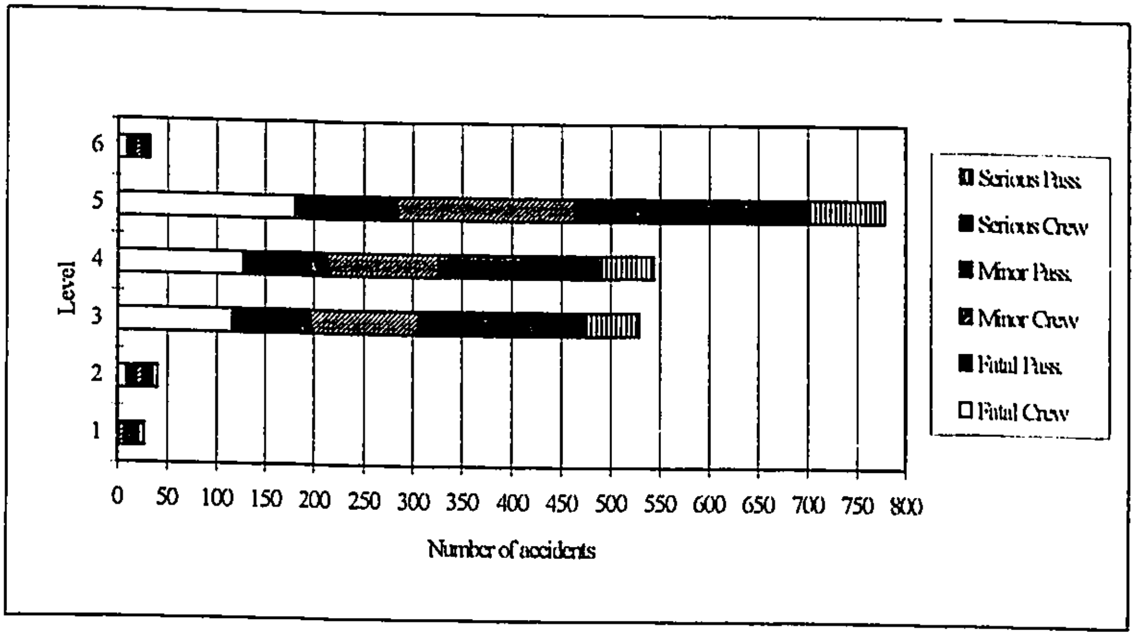


Figure 4.6 **Fatalities and Casualties by Air Carrier Level, 1976-1993**

(Source: TSB accident data file)

The next group of carriers, those belonging to Levels III and IV, was mostly engaged in charter operations. These small carriers were involved in over 50% of reported accidents and represented 55% of all fatal events. In this group, the non-scheduled domestic flights accounted for the majority of accidents, followed by pleasure/travel and business flights.

The great majority of accidents can be accounted for by a single Level V group of carriers, namely the smallest charter, contract and specialty operators. Their instance of accidents represented over 42.6% of all accidents in the last two decades. It also accounted for 40% of fatal accidents and those involving injuries. This group singled out the flying clubs, flight schools as well as commercial operations. Unfortunately, contrary to the overall industry safety indicators, Level V carriers are part of an increasing number of air travel accidents.

The smallest group of aviators, represented by Level VI (lodge operators), accounted for a relatively insignificant number of accidents. Their proportion reached only 2.09% of all crashes.

CONTRIBUTING FACTORS

A) The Aircraft

Over the last two decades, the vast majority of accidents to Canadian-registered air carriers has been accounted for by powered fixed-wing aircraft. On average approximately 80% of accidents involved airplanes. The remainder belonged to helicopters, and a total of only 1% involved balloons, gliders and gyroplanes. It should be noted that airplanes represent about 80% of total aircraft flown (ASC, 1993).

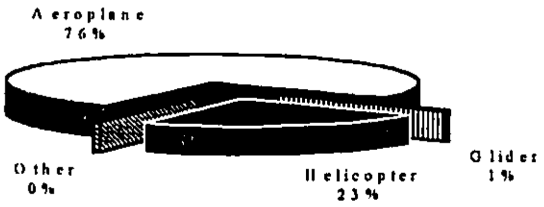


Figure 4.7 Accidents by Airframe Type, 1976-1993

(Source: TSB accident data file)

Aeroplanes primarily equipped with one or two engines accounted for the largest proportion of accidents; over 99% for the two categories. It should be noted however that the number of one engine aircraft accidents has been diminishing in the past decade, whereas those involving four engines has been slowly increasing. This phenomenon follows closely the move from smaller to more sophisticated type of aircraft used in the industry (see chapter three for details).

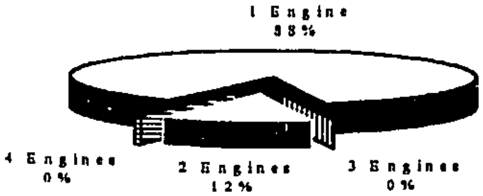


Figure 4.8 Accidents by Number of Engines, 1976-1993

(Source: TSB accident data file)

In addition to the type of aircraft used and its engine configuration, the sort of landing gear used also played a critical role in the safety of flights. As indicated in the figure below, aircraft equipped with wheels, skis and floats are frequently involved in accidents. This may be explained by the type of terrain and weather these flights encounter. As mentioned earlier, BC mountains and Ontario lakes are the primary destinations of Levels III, IV and V flights. Also, further analysis indicates that over 46% of accident-flights take place during the summer months of May, June, July and August, and over 26% occur in winter (December, January, February and March). Again, increased activity during the summer months explains the increase in the number of accidents.

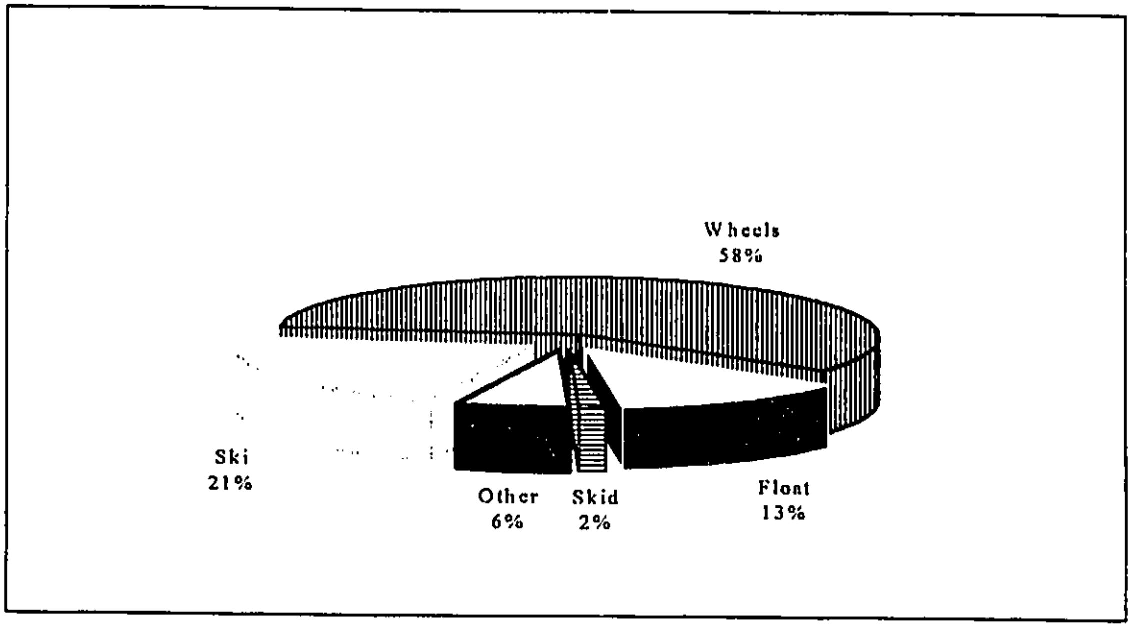


Figure 4.9 **Accidents by Type of Landing Gear, 1976-1993**

(Source: TSB accident data file)

So far the operators and the aircraft involved in accidents were described. However, the environment and the personnel operating these machines also play a significant role in the success or failure of a flight. The following sections indicate the degree to which these factors are responsible for air disasters.

B) The Environment

The geographic distribution of accidents ultimately dictates the terrain which pilots have to contend with. In case of an emergency landing the choice of flat or mountainous terrain could make a difference between survival and death. According to the collected data over 51% of accidents take place on level/flat terrain and approximately 30% in elevated areas. It should be noted however that only 40% of fatal accidents occur in level/flat regions, whereas the mountainous areas accounted for the remaining 60% of fatal events.

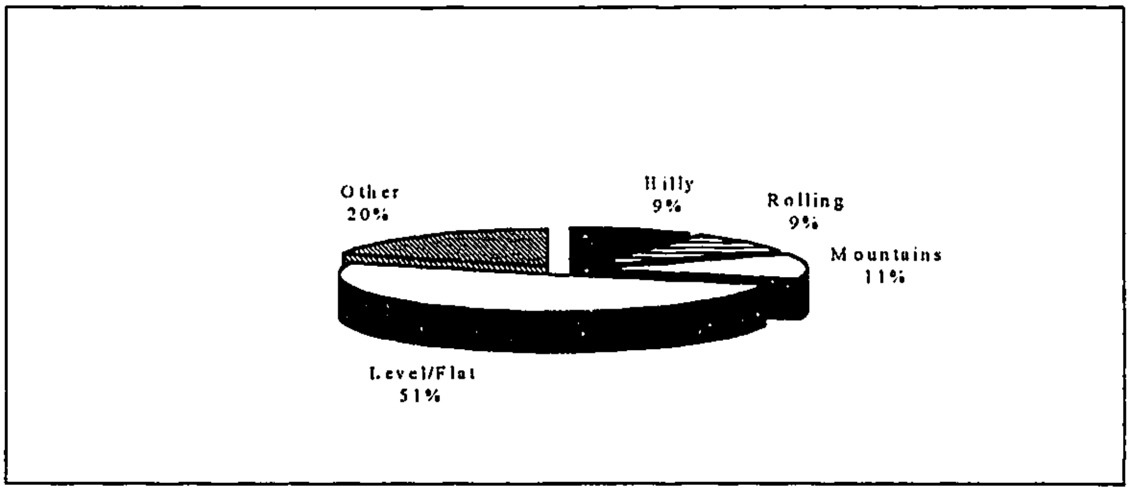


Figure 4.10 **Accidents by Terrain, 1976-1993**

(Source: TSB accident data file)

Another factor in accident occurrence is the time of flight. An overwhelming 85% of crashes happened during day time. Only 6% of accidents occurred at night. This may be due to the fact that pilots are more cautious and vigilant when flight conditions are less inviting and they have to rely on the help of others to make it back home in one piece. In addition, the lower transport activity during the night greatly reduces the chance of such occurrences.

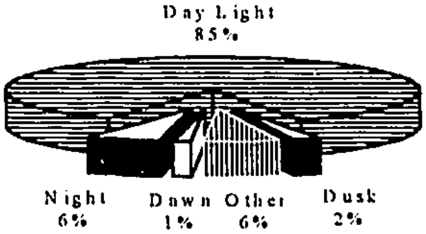


Figure 4.11 Accidents by Time of Day, 1976-1993

(Source: TSB accident data file)

The same type of prudence shown during night flying applies to pilots filling out their flight plans. Whenever a flight is conducted beyond a radius of 25 nautical miles from the airport of departure, the pilot in command is required to file a flight plan or flight modification with Air Traffic Control staff or leave a flight itinerary with a responsible person. A flight plan must be filed for any flight to or from a military aerodrome and for a transborder flight. Unfortunately, there is still a large number of pilots ignoring these rules. Over 26% of accidents occur when no notification whatsoever was filed, only making the search efforts more difficult and, by the same token, decreasing the passenger's chances of survival.

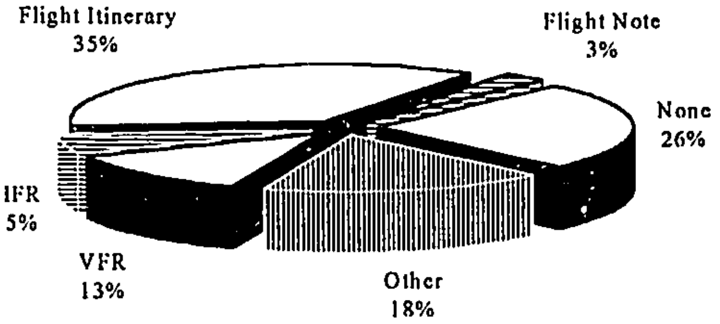


Figure 4.12 Accidents by Flight Plan, 1976-1993

(Source: TSB accident data file)

C) The Accident Pilots

One other determinant of aircraft accidents should be evaluated: the human factor. Based on the investigation, middle-aged pilots are the most likely participants of a crash. This can most probably be explained by the fact that once a pilot has accumulated enough flight hours and experience on a small aircraft, employment with larger and better equipped airlines is favored. However, smaller airplane experience is not readily transferable to the larger, more sophisticated cockpits. The lack of training may contribute to the increase in accident rates at this point of a pilot's career. Also, this group of veterans may represent the majority of flying crew. However, more detailed statistics are not readily available.

Analysis indicates that over 33% of accidents were contributed by pilots in the 36-45 age group, followed by those between the age of 46 to 55. Most of them were employed by Level IV and V air carriers. Younger than 35 years old rated third, with much older pilots closing the ranks and participating in 4% of all accidents.

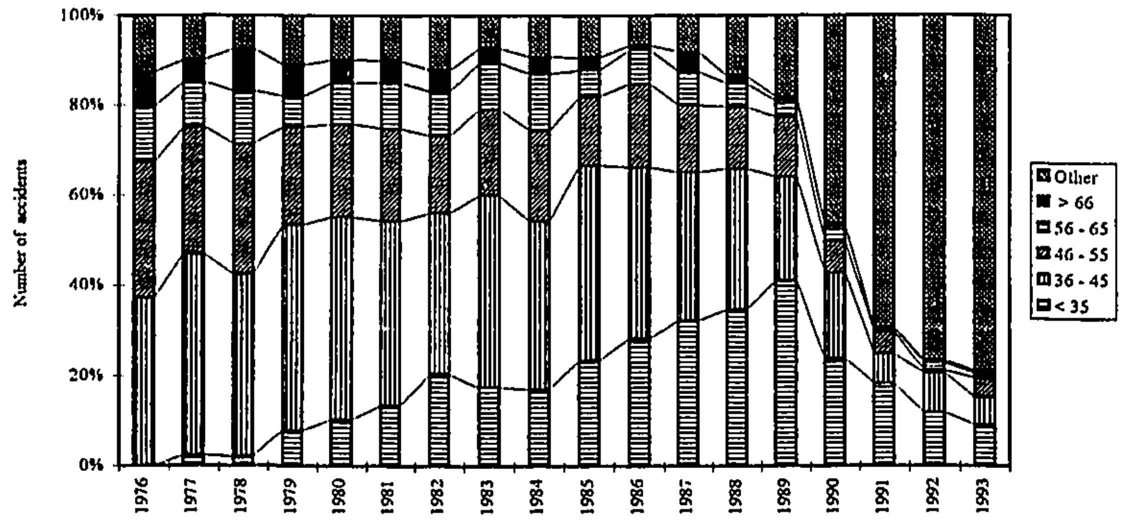


Figure 4.13 **Accidents by Year by Pilot Age, 1976-1993**

(Source: TSB accident data file)

Level/Age	< 35	36 - 45	46 - 55	56 - 65	> 66	Total
1	0	1	12	4	2	31
2	12	18	11	3	4	78
3	147	421	193	74	44	1,061
4	260	450	208	91	40	1,284
5	275	586	368	157	84	1,898
6	17	30	10	12	4	93
Totals:	711	1,506	802	341	178	4,445

Table 4.9 **Accidents by Level by Pilot Age, 1976-1993**

(Source: TSB accident data file)

Figure 4.14 **Accidents by Pilot License Type, 1976-1993**

(Source: TSB accident data file)

When looking at the type of licenses held, over the last two decades, 52% of accidents involved commercial pilots. Air transport and private pilot licensees accounted for another 25% of accidents. The remaining quarter was due to pilots holding student, foreign and other licenses. This is not surprising since, logically, only air transport and commercial pilots should be flying commercial application aircraft.

D) Phase of Flight

The last stage of this analysis evaluates the importance of phase of flight as a safety factor. Confirming the theory presented in earlier chapters, the numbers indicate that 70% of accidents occur while taking-off (18.6%) or landing (50.8%) and 25% during the en route/maneuvering phase.

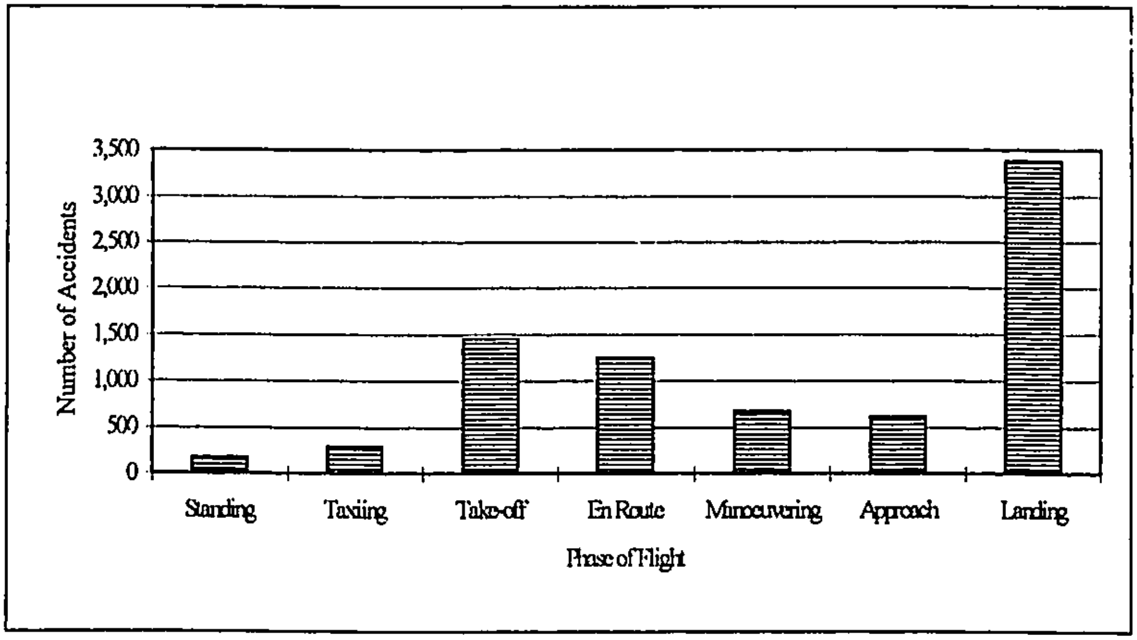


Figure 4.15 **Accidents by Phase of Flight, 1976-1993**

(Source: TSB accident data file)

During the studied period, the highest proportion of accidents was attributed to either airborne control loss or power loss, as the first contributing event. The second largest portion of accidents was that where the first event involved a collision with terrain or an object.

During an accident investigation, other explanatory factors are examined. These are judged the contributing causes and classified as either, human, machine or environment induced. Most accidents are the result of interrelated factors. During the last 20 years, at least 80% of all accidents have had at least one human factor. These errors were caused by flight deck members, maintenance engineers, flight service personnel and weather forecasters. Approximately 40% of accidents involved at least one environmental factor, such as snow storm or gusty winds. Additional 25% of accidents had at least one machine factor, including engine failure or gas leaks.

SUMMARY OF FINDINGS

The preceding analysis of raw data of Canadian commercial accidents, over the past twenty years, points to the conclusion that:

1. The number of accidents is decreasing despite increased air activity.

2. Only a very small percentage of Canadian aircraft crash abroad.

3. Most accidents occur in Ontario and Quebec on flat terrain, as well as in the B.C. mountains, although rate-based figures indicate that it is more dangerous to fly in the Prairie and the Atlantic provinces.

4. Level I & II operators have very few accidents in spite of the greatest number of flights. Most accidents occur with smaller operators.

5. Most accidents occur during day-light flights (more than 70%), especially in the June, July, August and September months.

6. Operators such as small carriers and flying schools have most accidents.

7. Operations such as, non-scheduled domestic, application, business, and charter domestic flights are involved in most crashes.

8. Pilots aged 36 to 55 participate in most accidents. From 1976 to 1988 pilots aged 36-45 had most accidents, since 1988 those aged 26 to 35 participated in the greatest number of air disasters.

9. On average, pilots with CPL, PPL, ATPL, and student licenses cause most accidents.

10. 1 and 2 engines aircraft have most accidents.

11. Aircraft equipped with landing gear such as wheels and ski take part in most accidents.

12. Over 44% of accidents are fatal or with injuries, most of them in non-scheduled domestic, solo training and pleasure/travel air carrier operations.

13. 70% of accidents occur on take-off and landing, 26.9% in flight.

14. There were 6 major manufacturing companies involved in 81% of accidents: Cessna aircraft (1,675 accidents), Piper Aircraft (633), Bell Helicopter (619), DeHavilland (392), Hughes Helicopters (159), and Beech Aircraft (128).

15. 9 different aircraft models were involved in 41.78% of accidents, 5 of them made by Cessna with 58.8% of accidents of the top 9 models (or 24.6 of all accidents).

CHAPTER V

EXPLORATORY ANALYSIS OF SAFETY FACTORS

In light of the descriptions of factors influencing the safety of air travel, presented in chapter two, it is important to verify how statistical methods can duplicate and generate similar distinction among the four principal causes of aircraft accidents: natural environment, machine failure, human error, and operational environment. For that purpose the theory of Exploratory Factor Analysis is used.

FACTOR ANALYSIS THEORY

The principal concern of factor analysis is the resolution of a set of variables, linearly, in terms of a small number of categories or factors. This resolution is accomplished through the analysis of the correlations among variables. A satisfactory solution will yield factors which convey all the essential information of the original set of variables. Therefore, the main aim is to attain scientific parsimony or economy of description.

In mathematical terms, the objective of factor analysis is to take p variables, $X_1, X_2, \ldots, X_p$, and find combinations of these to produce indices $Z_1, Z_2, \ldots, Z_m$ that are uncorrelated. Hence, clarify the relationship between these variables (Harman, 1986). The lack of correlation is a useful property because it means that the indices are measuring different dimensions in the data. When performing a factor analysis there is always the hope that the variances of most of the indices will be so low as to be negligible. In that case, the variation in the data set can be adequately described by the few Z variables with variances that are not negligible. Some degree of economy is then achieved since the variation in the p original variables is accounted for by a smaller number of Z variables. The best results are obtained when the original variables are highly correlated (positively or negatively). In that case, the large number of variables can be adequately represented by two or three principal factors.

Factor Analysis is typically used to study a complex product or service in order to identify the major characteristics (or 'factors') considered to be important by consumers of the product or service. Once this information is available, it can be used to guide the overall style or functions to be designed into the product or to identify advertising themes that potential buyers would consider important. Using data from a large sample, factor analysis takes advantage of advanced correlation theory in order to determine if the responses in several variables are highly related. If three or four of such statements are, then it is believed they measure some factor common to all of them. Since studies usually involve many statements, there are likely to be multiple sets of such correlated statements. The statements in one set will be highly related within the group but not between sets. Consequently, each set represents a special collection of characteristics of highly correlated statements which researchers try to define as having a single 'theme' or 'factor' tying them together.

The above theory can be related to aviation safety by contrasting the product characteristics with accident causes, and product design with procedures and regulations. In other words, factor analysis can help pinpoint groups of accident causes and guide authorities in designing and promoting safety issues most important to the industry operators as well as its customers.

In order to better understand the results of factor analysis three important measures used in the procedures are reviewed first: variance, standardized scores of responses and correlation coefficients.

Variance: Factor analysis, similarly to regression analysis, tries to fit the best set of variables in a model, so that the factors explain the variance associated with the value of each response. Just as regression analysis aims to explain 100% of the variance in a dependent variable, factor analysis strives to explain 100% of the variance associated with each statement in the study. The goal of this analysis is to account for all or at least most of the variance associated with each data value of each accident included in the set.

Standardized scores of responses: In a number of studies, responses to different statements or questions may be recorded using different scales. Such was the case in this analysis, where for example, responses to the number of engines ranged from 1 to 4, and those of pilot age from 17 to 85, and still those of pilot flight hours ranged between 100 and 10,000. To facilitate the comparisons of the responses from such different scales, all of the values are standardized. An individual actual response to a statement is standardized by using the following relationship:

$$\text{Standardized Score} = \frac{(\text{Actual Response}) - (\text{Mean Response})}{\text{Standard Deviation of all Responses}}$$

Correlation Coefficient: Correlation coefficient associated with the standardized scores of the responses to each statement is calculated and plotted on a scatter diagram. The resulting matrix R of correlation coefficients is the basis of factor analysis.

VARIABLES AND MODEL USED

The factor analysis model was first developed by Charles Spearman. His work in developing a psychological theory involving a single general factor and a number of specific factors goes back to 1904. His paper "General Intelligence, Objectively Determined and Measured" was first published in the American Journal of Psychology. The next half century saw the theory of a general and specific factors in Spearman's original form be superseded by theories of many group factors, but always employing the same method to determine these many factors (Harman, 1960). The model essentially shows a constant ratio between rows of a correlation matrix and that the square of a factor loading is the proportion of the variance of X_i that is accounted for by the factor. The following relationship exists:

$$\mathbf{X_i = a_{i1}\ F_1 + a_{i2}\ F_2 + \ldots + a_{im}\ F_m + e_i,}$$

where X_i is the ith standardized score with a mean of zero and a standard deviation of one, a_i is a constant called factor loading, F is a factor value, which has mean of zero and standard deviation of one for individuals as a whole, and e_i is the part of X_i that is specific to the ith observation only (Harman, 1986).

In this research project, the above model is applied to the collected accident data set. However, as was previously mentioned, only "Accident Variables" and not "Aggregate Variables" are used in this part of the study. Factor analysis is applied to the following variables: NO_ENGIN, T_PLT_HR, PLT_TYPH, T_CO_HR, CO_TYP_H, LEVEL, GEAR_NO, FPLAN_NO, LIC_NO, OPRTOR_N, AGE, MONTH_NO, LITE_NO, PROV, LAND_NO, PHASE_NO (for more details, refer to Table 4.1). It should be noted that variables whose values were collected as a result of an accident were not included in this analysis. For example, data on accident fatalities and casualties was omitted because victims do not cause or contribute to accidents, they are an unfortunate result of an air disaster.

Since the primary goal is to amalgamate the data, collected on the various variables, into specific groupings, each group should represent at least part of the four major factors affecting air travel safety. Based on the theories presented in chapter two on Factors Affecting Air Travel, the following clusters are expected as a result of subsequent exploratory factor analysis:

$$X_i = a_{i1}\ \mathbf{HUMAN} + a_{i2}\ \mathbf{MACHINE} + a_{i3}\ \mathbf{WEATHER} + a_{i4}\ \mathbf{OPER.ENV}_4 + e_i,$$

where X_i is the ith standardized score with a mean of zero and a standard deviation of one, a_i is a constant, and e_i is the part of X_i that is specific to the ith observation only. The factor values are represented by the following variables:

HUMAN	Flight plan (IFR, VFR), Type of license (COMMLIC, OTHLIC), Age (AGE35, AGE45), Pilot and Co-pilots' Total and On Type Hours of flight, (T_PLT_HR, PLT_TYPH, T_CO_HR, CO_TYP_H),
MACHINE	Number of engines (ENG12, ENG34),
NATURAL ENV.	Month (SUMMER, WINTER), Province (EAST, WEST), Day light (DAY, NITE), Terrain (HILL, FLAT, WATER),
OPERATIONAL ENV.	Carrier level (LEV12, LEV34, LEV56), Type of Operator (CARRIER, SCHOOL), Phase of flight (TAKEOFF, FLY, LANDING, STAND).

In the next section factor analysis concepts are applied to the above-mentioned variables in order to verify if previously defined accident causes are adequate. It should be mentioned that all of the categorical variables such as type of pilot license or air carrier levels had to coded and used as dummy variables. Variables such as total number of hours flown by the pilot, on the other hand, were used in the original form they were collected.

THE NECESSARY ASSUMPTIONS

So far it was assumed that the data set is appropriate to factor analysis. However, before proceeding with the investigation, the suitability of the data for further analysis must be established.

Sample size and distribution of data, among others, can easily influence the results and decrease the reliability of estimates (Green, 1978).

Assumption 1: ***Sample size*** *- correlation coefficients tend to be less reliable when estimated from small samples. As a general rule of thumb, it is advised to have at least five cases for each observed variable.*

The condition is satisfied, since a total of 298 cases were included in the analysis with 21 variables. That represents more than 10 cases per variable.

Assumption 2: ***Normality*** *- as long as factor analysis is used descriptively as convenient ways to summarize the relationships in a large set of observed variables, assumptions regarding distributions of variables are not in force. If variables are normally distributed, the solution is enhanced. If normality fails, the solution is degraded but may still be worthwhile.*

The coefficient of skewness measures the symmetry of the distribution; a skewed variable is one whose mean is not in the center of the distribution. Kurtosis, on the other hand, measures the peakness of the same distribution: the values of variables can be either too peaked (with too few cases out in the tails) or too flat (with too many cases out in the tails). The skewness and kurtosis values of the majority of the variables used indicate normality. Only the Day-light conditions variable shows significant skewness and kurtosis values. This is simply because, as indicated in the previous chapter, over 85% of all accidents occurred during the day.

Assumption 3: ***Linearity*** *- multivariate normality also implies that relationships among pairs of variables are linear. Since correlation measures linear relationship and does not reflect nonlinear relationship, the analysis is degraded when linearity fails.*

Analysis of scatter plots of pairs of variables indicated linearity.

Assumption 4: ***Multicollinearity*** *- in order to estimate factor scores singularity or extreme multicollinearity can not be present. If the determinant of R and eigenvalues associated with some factors approach zero these conditions may be present.*

No such condition was detected.

Assumption 5: ***Factorability of R*** *- A matrix that is factorable should include several sizable correlations. The expected size depends on N, but if no correlation exceeds .30, use of factor analysis is questionable because there is probably nothing to group into factors.*

The correlation matrix was inspected for greater than .30 values.

Based on these preliminary tests of suitability of data, further study can proceed by determining the provisional factor loadings a_{ij}. The second stage in the analysis, involves factor rotation, where the initial factors are transformed in order to find new indicators (from among the infinite number of alternative solutions) that are easier to interpret. The last step involves the selection and naming of factors.

OUTPUT OF FACTOR ANALYSIS

Once the factor analysis has been run, a set of results is generated including such information as factor loadings, communalities and eigenvalues*. Their values and interpretation of results follows.

A) Suitability of Factor Analysis

In addition to the tests of assumptions performed in the introductory part of this chapter, some auxiliary methods of verifying the suitability of factor analysis for a particular data set are available.

Plot of eigenvalues: a straight line of plotted eigenvalues indicates no possibility of reducing the original number of variables, therefore no need for factor analysis. As the following figure illustrates, this is not the case with the variables used. The first nine eigenvalues (factors) fall on a much steeper line than the remaining variables.

Correlation coefficients: as described in the previous section, small correlation values indicate little relationship or interdependence among variables, thus no reason for factor analysis. The study of the original matrix indicates a number of strong associations among collected variables.

Anti-image correlation matrix: the anti-image of a variable is that part which can not be predicted from the other variables. If the anti-image matrix does have a large number of non-zero off-diagonal entries,

---

* For a complete output refer to Appendix D.

then the correlation matrix is not appropriate. This is not an issue with the collected data set; there are only 11.9% off-diagonal elements of anti-image correlation (AIC) matrix greater than 0.09.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy: an overall MSA measures the extent to which the variables belong together and are thus appropriate for factor analysis. The analysis produced an MSA statistic equal to 0.542; i.e. an acceptable fit.

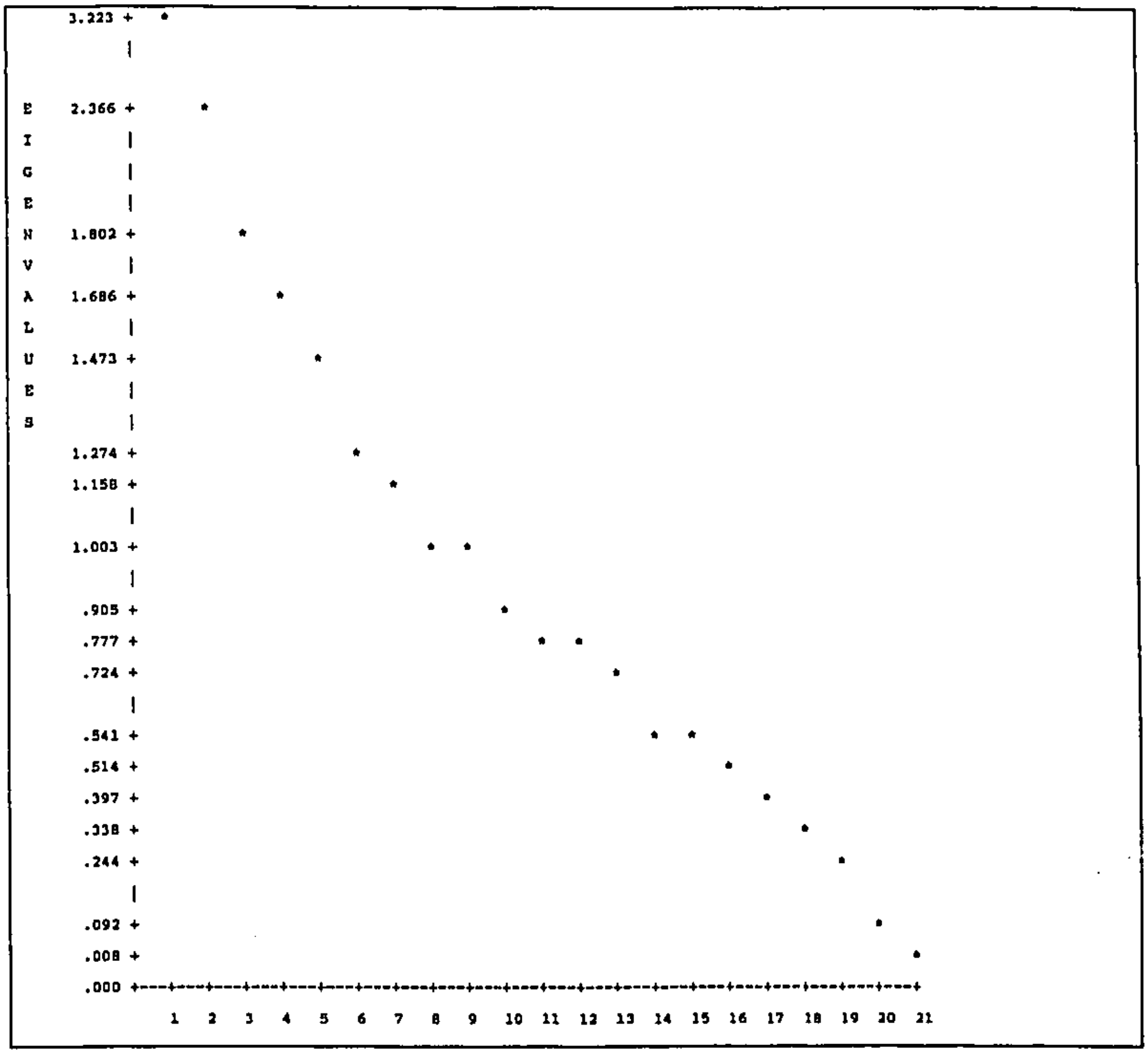


Figure 5.1 Plot of eigenvalues

Bartlett's test of sphericity: the test verifies the following hypothesis:

H_o : all off-diagonal elements of the correlation matrix are zeros

H_1 : the elements are not all zeros.

The analysis produced a value of 2,688.6893 at 0.0000 level of significance. Therefore, not all off-diagonal elements of the correlation matrix are zeros, and factor analysis is justified.

Since it was proven, based on the preceding results, that factor analysis is appropriate for the accidents data set, the next step is to interpret the results generated through the use of this method.

B) Factor Loadings

In order to perform factor analysis, a number of extraction techniques are available, such as Principal Factors, Image Factor, Maximum Likelihood Factor, to Generalized Least Squares, Unweighted Least Squares and Alpha Factoring. For the purpose of an initial look at the data, the Principal Component method is recommended and therefore used in this analysis. The goal is to extract maximum orthogonal variance from the data set with each succeeding factor. The advantage is that it conforms to the factor analytic model in which common variance is analyzed with unique and error variance removed. The application of this technique lead to the results presented next.

Variable	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	FACTOR 7	FACTOR 8	FACTOR 9
LEV12	.46806	.17930	-.05034	.53429	.04873	-.38694	-.08018	.05940	.06182
LEV34	.13534	-.20032	-.02166	-.58442	.10640	.54923	.03593	-.14909	.18239
ENG12	-.27615	.00906	.01304	-.14453	.03427	.03918	-.06850	.66173	.32383
IFR	.57425	.04726	-.25030	.04413	.34839	-.05011	-.02316	-.07437	-.27350
COMMLIC	.75959	-.10705	-.04125	-.28325	.06042	.10656	-.03325	.13199	-.09199
CARRIER	.77387	-.18725	-.06969	-.23311	.11499	.10607	-.07581	.11839	-.10151
AGE35	-.31695	.27532	-.44245	.31590	.04032	.43547	-.26372	-.03725	.08604
AGE45	-.03795	-.17969	.01556	-.58149	.13535	-.57579	.21089	.12199	.02427
SUMMER	-.02648	-.02768	.28679	-.00014	-.34993	.04298	.41771	.12743	-.39508
DAY	-.25698	.16178	.52652	.05807	-.38847	.00584	.12024	.09969	.02353
EAST	-.13916	.06754	-.20512	.00010	.21104	-.23367	.44635	-.53489	.26360
HILL	.03452	-.87156	-.16733	.32502	-.03940	.08470	.23324	.08944	.12744
FLAT	-.03610	.87214	.17038	-.31725	.02016	-.08445	-.24022	-.09074	-.13326
TAKEOFF	-.19438	.25648	.35205	.08279	.65161	.24974	.39244	.13370	.03165
FLY	-.21498	-.60339	.30081	.07525	.08528	-.16725	-.48714	-.12658	-.24756
LANDING	.29444	.22510	-.55848	-.14018	-.64181	-.06116	.13540	.03914	.18354
WHEEL	.08526	.24211	-.36540	.27869	.09584	.10407	.31155	.24607	-.44252
T_PLT_H	.53491	.00052	.40191	.04408	-.26316	.24168	.09728	-.19125	-.08046
PLT_TYP	.51309	.05174	.40647	.21841	-.15686	.12141	.03922	-.15776	.22769
T_CO_H	.54186	.14368	.04017	.01679	.11369	-.15176	-.08083	.10811	.20853
CO_TYP	.43816	.14965	.29469	.30735	.14385	-.05467	-.00114	.13210	.32497

Table 5.1 **Provisional Factor Matrix**

As described previously, factor loadings are values associated with a variable and each selected factor. It is simply the correlation between that factor and that response's standardized scores. Thus, as presented in the table above, Factor 1 is highly correlated with the responses to the CARRIER variable (0.77387 correlation) and to the COMMLIC variable (0.75959 correlation). Consequently, a factor loading is a measure of how well the factor fits the standardized response to a variable.

C) Communalities

The second output from the factor analysis indicates how well all of the identified factors fit the data obtained from all of the records on any given variable. Communalities record the proportion of the variance in the values which, in this study, is explained by the nine selected factors (see Table 5.2).

VARIABLE	COMMUNALITY	FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
LEV12	.70510	1	3.22272	15.3	15.3
LEV34	.77022	2	2.36581	11.3	26.6
ENG12	.64755	3	1.80201	8.6	35.2
IFR	.60135	4	1.68621	8.0	43.2
COMMLIC	.71237	5	1.47337	7.0	50.2
CARRIER	.74768	6	1.27407	6.1	56.3
AGE35	.74142	7	1.15835	5.5	61.8
AGE45	.78190	8	1.03199	4.9	66.7
SUMMER	.55482	9	1.00284	4.8	71.5
DAY	54870				
EAST	.71997				
HILL	.98181				
FLAT	.98284				
TAKEOFF	.89422				
FLY	.85631				
LANDING	.93812				
WHEEL	.65052				
T_PLT_HR	.62978				
PLT_TYPH	.59647				
T_CO_HR	.41381				
CO_TYP_H	.54243				

Table 5.2 Communalities and Eigenvalues

The Table shows that the factors explain 0.98284 (or 98.3%) of the variance in all of the studied cases with regards to the FLAT variable, but only 0.41381 (or 41.38%) of the variance regarding the T_CO_HR variable. The results also show that nine factors explain 60% or more of the variance associated with 16 variables and 55% or less of the variance associated with only 5 other variables. Consequently, since the selected factors account for most of the variance in each of the twenty variables, they fit the data set quite well.

D) Eigenvalues

Eigenvalues indicate how well any given factor fits the data from all of the variables on all of the records. There is an eigenvalue associated with each of the factors. Its value is the proportion of the variance in the entire set of standardized response scores which is explained by that factor. This figure can be used as a measure of how well, overall, the identified factors fit the data. In general, according to Kaiser-Meyer-Olkin's measure of sampling adequacy (MSA), a factor analysis accounting for 50-60% or more of the total variance can be considered as an acceptable fit to the data.

SELECTION OF FACTORS

As the primary goal of factor analysis is to reproduce as accurately as possible the original intercorrelation matrix from a small number of hypothetical variables to which the original variables are linearly related, a few methods are available to help select those few representatives of the entire set of variables. The analysis in the following sections will attempt to isolate the reduced number of factors and provide an interpretation as to their meaning, as well as significance in the model.

A) Lambda greater than one (l > 1)

One approach to the problem of deciding how many components to retain has been proposed by Kaiser (Green, 1978). He recommended that only principal components of *R* with eigenvalues greater than one be retained. The argument is based on the common sense rationale that any principal component, being a measure of common variance, should account for more variance than any single variable in the standardized score space. Under this rule, as shown in Table 5.2 the first nine components are retained.

B) Scree test

A technique called scree test has been proposed by Catell (Green, 1978). This procedure entails plotting the variance accounted-for by each principal component in the order extracted and then looking for an elbow in the curve. Figure 5.1 illustrates a case where the elbow appears with the extraction of the tenth eigenvalue. Presumably, one should retain only the first nine factors.

C) Residual Correlation

In addition to the preceding methods, one rather flexible approach is to examine the residual correlation matrix, as well as individual residual matrices after each successive component has been extracted. This technique tries to locate small and normally distributed residuals as a graphical aid to when to stop component extraction. Using the eigenstructure decomposition, and looking at the entire residual correlation matrix, it can be concluded that no additional factors are present.

IMPROVED MODEL

In any scientific field the observed occurrence can be described in a great variety of ways; all usually consistent. The choice of a particular interpretation must then depend upon its utility. This arbitrary interpretation is recognized by scientists, expressed by F.R. Moulton (philosopher of science) as:

> " ... every set of phenomena can be interpreted consistently in various ways, in fact, in infinitely many ways. It is our privilege to choose among the possible interpretations the ones that appear to us most satisfactory, whatever may be the reasons for our choice. If scientists would remember that various equally consistent interpretations of every set of observational data can be made, they would be much less dogmatic than they often are, and their beliefs in a possible ultimate finality of scientific theories would vanish."

The factor analysis results are similarly indeterminate, given the correlations of a set of variables, because the coefficients of a factor pattern are not uniquely determined. Thus, the system of orthogonal, or uncorrelated factors may be chosen, consistent with the observed correlations, in an infinity of ways. This indeterminacy in the model (factor loadings are not unique) is due to the fact that a solution determines the space containing the common factors, but not the frame of reference, or the exact position of these factors. After a factor solution has been found, fitting the empirical data, it may be transformed or rotated to another solution (fitting the data equally well) which may have greater meaning to the investigator. This same flexibility was used in this study where the first nine factors were rotated in order to render the loadings more interpretable.

A) Rotated Factor Loadings

Rotation of factors is a process by which the factor solution is made more interpretable without changing its underlying mathematical properties. Factor rotation can be orthogonal or oblique. With orthogonal rotation the new factors are uncorrelated with each other. With oblique rotation the new factors are correlated. Whichever type of rotation is used, it is desirable that the factor loadings for the new factors be either close to zero or very different from zero. A near zero a_{ij} means that X_i is not strongly related to the factor F_j. A large (positive or negative) value of a_{ij} means that X_i is determined by F_j to a large extent. If each variables value is strongly related to some factors, but not at all related to the others, than this makes the factors easier to identify than would otherwise be the case.

One method of orthogonal factor rotation often used is called varimax rotation; also applied in this study. This is based on the assumption that the interpretability of factor j can be measured by the variance of the square of its factor loadings, i.e. the variance of a^2_{1l}, a^2_{12}, ..., a^2_{pj}. When the variance is at the maximum, the factor has the greatest interpretability or simplicity since its components' values of a^2_{ij} tend toward zero or unity. The criterion of maximum simplicity of a complete factor matrix is defined as the maximization of the sum of these simplicities of the individual factors. Varimax rotation therefore maximizes the sum of these variances for all the factors.

The following Table presents the resulting rotated factor matrix with variables rearranged so that each factor contains the heaviest weighing scores. The factor loadings were regrouped in this manner so that it is easier to interpret their meaning.

Variable	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	FACTOR 7	FACTOR 8	FACTOR 9
IFR	.70870	.03034	-.03957	.03754	.07150	.18443	-.03426	-.07825	-.22085
COMMLIC	.73566	.29489	.00813	.05842	-.13328	-.16574	.14835	.06691	.09499
CARRIER	.77798	.28107	.07999	-.00519	-.12219	-.14314	.12213	.01930	.07937
DAY	-.51774	.24239	-.16181	-.05029	.01620	.00542	.05390	.40624	.15794
LEV12	.23451	.35742	.01576	.07548	-.06718	.69611	-.04312	-.14512	-.06643
LEV34	.22763	.05599	.04603	.06715	.03827	-.83497	.01497	-.09853	.00841
ENG12	-.19736	-.12204	.04755	.14143	.11586	-.05076	.10633	-.13878	.72448
EAST	-.21477	-.07913	.09017	.34017	.16186	-.00503	.22357	-.28239	-.62272
T_PLT_H	.20549	.61444	-.03087	-.05010	-.09179	-.15167	-.06731	.37772	-.16708
PLT_TYP	07405	.75321	.01730	.00699	-.02235	.01130	-.05908	.09310	-.10264
T_CO_H	.35533	.40429	-.09960	.12608	-.02948	.17586	.13729	-.19625	.09553
CO_TYP	.12062	.61310	.00371	.08361	.19493	.26585	.00642	-.14124	.12775
AGE35	-.14454	-.26293	-.06605	.15784	-.00564	-.00538	-.73212	-.28898	.05057
AGE45	.06350	-.25321	-.03221	.02519	-.01268	-.05227	.83904	-.05857	.04194
HILL	.03031	-.00638	.98289	-.10784	-.05008	-.01534	.00392	.01968	.00127
FLAT	-.03779	.00993	-.98437	.10213	.03518	.02049	-.01215	-.00935	-.00047
SUMMER	-.09900	.01487	.04728	.05559	.01662	.01018	.10321	.72678	-.01527
TAKEOFF	-.07387	.04058	-.09872	.14052	.92234	-.06091	-.02342	.03765	.03528
LANDING	.09063	.01160	-.03045	.63808	-.72083	.01433	-.02297	.03570	.01038
FLY	-.07572	-.10436	.22683	-.88130	-.05789	.01898	.08063	-.03517	-.00946
WHEEL	.31135	-.31362	.02285	.36415	.17364	.33486	-.29137	.31869	-.02313

Table 5.3 Rotated Factor Matrix

B) Naming and Importance of Factors

As stated earlier, the fundamental purpose of factor analysis is to comprehend a large class of phenomena (the values of a set of variables) in terms of a small number of concepts (the factors), and this description is taken to be a linear function of the factors. Although it may be sufficient in mathematical theory to know that twenty variables can be described linearly in terms of only nine new hypothetical ones, in this study, we are also interested in the practical identification of these new variables. Thus, the naming of factors.

The coefficients of a factor pattern indicate the correlations of the variables with the respective factors and furnish the basis for naming them. The magnitude of the factor weights guides the selection of the appropriate name. The description is usually chosen by the nature of the variables having the largest correlations in the factor under consideration. This name should be consistent however with the nature of the remaining variables which have low correlations with the factor.

From Table 5.3, it is apparent that Factor 1 is a good fit of the data from statements IFR, COMMLIC, CARRIER and DAY but a very poor fit on the remaining statements. This indicates that all of these statements are measuring the same basic characteristic which proves that a factor exists. The variable types contained in Factor 1 could represent the overall circumstances in which pilots have to operate, and consequently be called the Operational Environment. The selection of variables dictates the day-to-day aspect of providing air travel services to the customers. The same can be said about Factor 9 which correlates highly the ENG12, EAST and to a lesser degree the IFR variables. The relationship among these variables stems from the fact that certain types of operators also fly specific types of aircraft on particular routes. For example, larger aircraft will fly transatlantic routes, adhering to IFR flight rules and employ commercial and transport pilots. Smaller carriers ,on the other hand, will fly VFR, to remote areas using smaller, less sophisticated, one or two engined aircraft. Another operational factor is included in Factor 6. The emphasis here is on the market share side of the industry by including the LEV12 and LEV34 variables. Once again, the level of the air carrier dictates its operational structure, that is types of planes flown and routes serviced.

Variables grouped in Factor 2, on the other hand, represent the amount of experience a pilot-in-command and his crew have accumulated. T_PLT_HR, PLT_TYPH, T_CO_HR, CO_TYP_H all have high loadings. This factor can be called the Human Error - Flight Crew's Experience factor. As indicated in chapter two, flight crew's skills as well as alert and clear state of mind can affect the successful completion of a flight. In addition, Factor 7 including the AGE, EAST and WHEEL variables can be added to this category. These elements certainly represent the practical experience in a particular environment and on a specific type of aircraft suited to the flight circumstances. For example, a B.C. pilot would need experience on a floats-equipped aircraft. Also, pilot's age and total hours of flight experience are likely to be highly related and dictate the types of planes flown. More advanced age usually means more experience, employment with larger carrier and wheel equipped aircraft.

The next two factors make up the Natural Environment aspects of flight environment. Factor 3 is represented by the HILL, FLAT variables (or the type of land elements) with DAY also loading higher than other variables. The SUMMER and DAY elements constitute Factor 8. Their contribution to the natural obstacles to flight can be appreciated by many pilots.

And finally, Factors 4 and 5 can be interpreted as the Phase of Flight factors, where the more dangerous phase during takeoff and landing is emphasized by factor 5.

RESULTS AND CONCLUSIONS

The purpose of this chapter was to set up a factorial model that would confirm previously theorized groups of air travel characteristics. This task was accomplished through exploratory factor analysis. The study first established preliminary factors which later were rotated in order to facilitate their interpretation.

A set of nine factors was created, each representing a part of a particular group of safety determinants. The Operating Environment, Human Errors and Natural Environment causes were replicated exactly as expected. The Machine Failure element was not singled out, however, through further analysis, interpretation and inclusion of additional variables it would probably be possible to emphasize its existence. Therefore, it can be concluded that the original premise of specific safety-related factors is accurate. However, closer analysis of these elements indicates that the influence of specific factors, such as flight crew experience and phase of flight is much greater that usually reported. Their separation as individual factors, as opposed to grouping them together, emphasized that importance. Overall, the factor analysis was useful in defining separate factors and replicating the original accidents data set. It provides a solid base for subsequent analysis.

CHAPTER VI

REGRESSION ANALYSIS OF AGGREGATE DATA

The overview of the Canadian commercial airlines' safety record, of the past twenty years, so far described a number of variables directly related to accident occurrences, and established the validity of distinct factors as principal causes of air travel disasters. The analysis performed in this chapter further considers the airlines' safety record by developing a model for predicting rates of total accidents and fatal accidents * using yearly aggregate data. The available information permitted consideration of these risk rates on an annual basis from 1976 through 1992. As described in Measuring Safety section (refer to chapter two), these measures are some of the commonly accepted risk determinants, collected and reported with some degree of consistency each year.

REGRESSION ANALYSIS THEORY

The purpose of most research projects is to assess the relationship among a set of variables. Multivariate techniques, regression among them, concern the statistical analysis of such relationships, particularly when at least three variables are involved. Regression analysis is typically used to study the relationship between one dependent or response variable, in this case the rate of accidents and fatal accidents, and other independent or predictor variables. The main objective is to choose a model which will help predict the dependent variable, or yearly rates of commercial accidents, from variables representing previously established causal factors, such as types of aircraft flown, flight crew experience, number of passengers and departures, and others. The model is a formal means of expressing an essential ingredient of a statistical relation, i.e. a tendency of the dependent variable Y (rates of accidents) to vary with the independent variables X_i (passengers, aircraft used, hours flown, etc.) in a systematic fashion.

The construction of a regression model involves a selection of independent variables and a choice of the functional form of the equation. Since reality must be reduced to manageable proportions whenever we construct models, only a limited number of independent or predictor variables can be included in a

---

* It should be noted that an attempt was made to predict the risk of being killed or injured in an accident using the same data set, however, none of the results proved significant.

regression model. A major consideration in making this choice is the extent to which a chosen variable contributes to reducing the remaining variation in Y after allowing for the contributions of other independent variables that have tentatively been included in the regression model. Also, the importance of the variable as a causal agent in the process under analysis, the degree to which observations on the variable can be obtained more accurately, or quickly, must be considered. For this reason the number of enplanements could not be used. The data was not readily available for the entire period under study.

The choice of the functional form of the regression equation is also related to the choice of independent variables. Relevant theory may indicate the appropriate functional form. More frequently however, the form is not known in advance and must be decided upon once the data has been collected and studied. The basic multiple regression model takes the following form:

$$Y_i = \beta_o + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_{ij} X_{ij} + e_i$$

where Y_i is the response variable, also called dependent variable, β_o and β_{ij} are constant unknown parameters representing the intercept and the slopes, respectfully. The X_i designates the various independent variables (also called regressors or predictors), and e_i in an unobservable random error term whose values are unknown but which is assumed to have a mean value of zero. In the case of multivariate model, as illustrated above, the regression equation is the space described by the mean values of Y at various combinations of values of X_i . In this preliminary study, a simple linear model is used.

The best fitting solution is determined by the least-squares method. The best-fitting plane is determined by minimizing the sum of squares of the distances between the observed values Y_i and the corresponding predicted values $Y^{I}_{i} = \beta^{I}_{o} + \beta^{I}_{1} X_{1i} + \beta^{I}_{2} X_{2i} + \ldots + \beta^{I}_{ij} X_i$ based on the fitted plane. The fitness of the final model is assessed by looking at the overall *F-value* and R^2 results, as well as individual *t-values* of used variables. The remaining sections of this chapter concentrate on selecting the best model to predict the yearly rates of accidents, as well as testing its overall fit to the collected data.

VARIABLES AND MODEL USED

There have been very few studies of aviation accidents in Canadian literature and those in existence were sponsored only by interested officials of the TSB or Transport Canada. Similarly to their counterparts in the USA, all of the academic studies were primarily concerned with economic influences on aviation safety. For example, Dionne and Gagne (1990) used a number of economic factors in order to predict the total yearly number of accidents. Their data set included current ratio, debt-equity ratio, cash flow and expenditures on flight equipment maintenance variables, among others. The final conclusion linked economic conditions and the number of accidents, although the correlation of these factors was quite weak. In their subsequent papers (Dionne, Gagne and Vanasse, 1992, Dionne, Gagne, Gagnon and Vanasse, 1994) the authors furthered their previous study on the significance of economic factors as influences on airline safety. Their econometric model of total accidents for Level I, II and III airlines confirmed earlier findings, again based exclusively on economic variables. In addition to relating airline safety to economic trends, these research papers simply confirmed that when companies are more successful (more profitable) that's because they operate at high capacity (flying more passengers) and this translates into more accidents. Such statements, although statistically, do not bring anything new into the safety debate. Predicting an increasing number of accidents does not necessarily imply more risk. A reference point is needed to assess the actual importance of such conclusion. Therefore, accident and victims rates would have been more successful for assessing safety as a function of profit and loss variables.

Other government sponsored studies concerned more specific elements of safety, such as Risk of collisions involving aircraft on or near the ground (CASB, 1987), Carriage and use of over water life-support equipment (CASB, 1988), Relationship between pilot background, experience, and personality, and repeated aviation occurrences (CASB, 1989), Air traffic control services (CASB, 1990), Influence of harness in aviation safety (TSB, 1990), Commercial pilot survey (TSB, 1991), Comparative analysis of aviation level safety between Canadian level I and II air carriers and US air carriers operating under 14 CFR 121 (TC, 1991), Aircraft accidents in the Yukon and Northwest Territories (TSB, 1993), as well as Study of piloting skills, abilities, and knowledge in seaplane operations (TSB, 1994). However, as the titles indicate, the mentioned papers treated only one safety related issue at a time and in tabulated or descriptive form. None of these studies attempted to quantify safety factors and study them through time as an overall measure of security.

In order to introduce such a measure and develop an overall safety model, the regression analysis and results discussed in this chapter include previously detailed factors directly related to flight. It is a logical extension of the selection process dictated by previously reported accident inducing factors.

It should be emphasized that the data presented in antecedent chapters was only available for analysis once an accident has occurred. Creating a model that would predict the rates of total accidents and fatal accidents each year, would require not only detailed information of accident prone flights, but also on every single flight made in a particular year, or at least a large sample there of[*]. In order to simplify this mammoth collection task, a smaller number of variables and aggregate data was used. Keeping in mind the preceding analysis, the new aggregate data was selected based on the four causal factors criterion. In particular, variables measuring human, machine, natural and operational environment were included (see Aggregate variables in Table 4.1). The regression models used are of the following form:

$$\mathbf{Y_i\ (Rate\ of\ Total\ Accidents) = \beta_o + \beta_1\ Human + \beta_2\ Machine + \beta_3\ Oper.\ Env. + e_i}$$

$$\mathbf{Y_i\ (Rate\ of\ Fatal\ Accidents) = \beta_o + \beta_1\ Human + \beta_2\ Machine + \beta_3\ Oper.\ Env. + e_i}$$

In order to construct additional models other aggregate variables were considered. However, information on pilot age groups, number of day and night flights, distribution of flights by terrain, and many others (all of the variables used in previous chapters) were not readily available in aggregate or per flight form. Also, the relatively short time frame did not allow for including a large number of independent variables. While the full study measured airline safety in the form of thirteen different variables, the results for accidents and fatal accidents rates normalized by 100,000 hours flown and 100,000 departures, were calculated and reported using only some variables. The following specific

---

[*] It should be noted that an attempt was made to predict the number of fatalities and injuries from the individual accidents data set. A regression analysis was run using total fatalities as dependent variable and the remaining variables as the predictors. The same was tried with total injuries as a dependent variable. However, none of the models developed were significant. The highest R^2 obtained was under 20%. Consequently, the aggregate data set was chosen.

aggregate variables were used to represent the human, machine and operational factors: year, number of accidents (both total and fatal), departures, hours flown, number of operating jet aircraft, number of pilots with commercial pilot licenses, passenger-kilometers and aircraft movements per year. The following sections describe the contribution of these variables and their application to the prediction of the yearly rate of accidents.

THE NECESSARY ASSUMPTIONS

Before proceeding with analysis, the first step in any attempt to determine the best model describing the relationship between dependent and independent variables is the test of statistical assumptions. Any conclusion based on a set of data which does not satisfy these requirements would be false or inaccurate in the least. The following assumptions apply to the multiple regression model:

Assumption 1: ***Existence*** *- for each specific combination of values of the (basic) independent variables* $X_1, X_2, \ldots, X_k$, *Y is a (univariate) random variable with a certain probability distribution having finite mean and variance.*

Assumption 2: ***Independence*** *- the Y observations are statistically independent of one another.*

Assumption 3: ***Linearity*** *- the mean value of Y, $m_{Y|X}$, for each specific combination of* $X_1, X_2, \ldots, X_k$ *is a linear function of* $X_1, X_2, \ldots, X_k$.

Assumption 4: ***Homoscedasticity*** *- the variance for Y is the same for any fixed combination of* $X_1, X_2, \ldots, X_k$.

Assumption 5: ***Normal Distribution*** *- for any fixed combination of* $X_1, X_2, \ldots, X_k$, *the variable Y is normally distributed.*

Based on these assumptions, further study can proceed first by determining the preliminary models followed by the analysis and evaluation of the regression parameters for their reliability and fitness to the data.

OUTPUT OF REGRESSION ANALYSIS

Once the regression analysis has been run, a set of results is generated including such information as F- value, individual t- tests and R^2. The analysis involved the prediction of two elements: 1) the rate of total accidents per year and 2) the rate of fatal accidents per year. In addition, each independent variable was forecasted using two models: a) accidents and fatal accidents per 100,000 departures and 2) accidents and fatal accidents per 100,000 hours of flight. The subsequent sections present the results of regression analysis as applied to the aggregate data.

A) Suitability of Regression Analysis

Before proceeding with the analysis and assessment of the overall suitability of selected models, the pre-defined assumptions must be verified.

Independence: it is recommended to plot the residuals against time to verify if there is any correlation between the error terms over time. When the error terms are independent, the residuals are expected to fluctuate in a more or less random pattern around the base line zero. Lack of randomness can take the form of too much or too little alternation of points around the zero line. Also, the error data points may fall into a distinguishable pattern. Such is not the case with the rate of total accidents and fatal accidents for both per hours flown and per departures models (see output in Appendix D).

Homogeneity: the residual plot against the residuals is not only helpful in studying if a linear regression function is appropriate, but also in examining whether the variance of the error terms is constant. If the residuals spread as time increases, then there may exist a tendency that the error variance increases with time. However, no such condition exists in studied models.

Randomness: the Durbin-Watson statistic tests the correlation of error terms. By lagging the errors by one or more period, a test of correlation over time is performed. When the D-W value is close to 2.0 no autocorrelation is present. Although, the D-W values deviate slightly from the ideal 2.0 in a few cases (see tables 7.1 and 7.2), the difference is not large enough to warrant concern at this point.

The above results prove that the required assumptions hold for the collected data set, further analysis of generated results is appropriate. The following sections present these results and assess their importance.

B) Overall model significance

In order to determine the best model to suit the collected data set, regression analysis uses the method of least squares. This procedure determines the best-fitting line as that line which minimizes the sum of squares of the distances between the observed responses and those predicted by the fitted model. To asses the best-fit of the regression line, results of the Anova table are considered first.

The simplest way of testing the selected model is to look at the contribution that the independent variables considered collectively make to prediction. The total sum of squares measures that contribution. SSY represents the total variability in the Y observations before accounting for the joint effect of using independent variables. The term SSE is the residual sum of squares (or the sum of squares due to error) and represents the amount of Y variation left unexplained after the independent variables have been used in the regression equation to predict Y. If the fitted-line is accurate and helpful in predicting Y, its residual sum of squares term is close to zero. In an ideal case, if the line fit the data points perfectly, the SSE is zero. Finally, the difference between SSY and SSE is the regression sum of squares and measures the reduction in variation (or the variation explained) due to the independent variables in the regression equation. Tables 7.1 and 7.2 show these values for the accidents and fatal accidents models, respectively. In each case, the results indicate an accurate model selection, with high regression sum of squares values and small SSE measure. In the ACC_DEPT and ACC_HRS models the total sum of squares is 24.8 and 92.3, respectively, and SSE is equal to 4.76 and 7.51, respectively. The figures for FAT_DEPT and FAT_HRS are 12.5 and 32.7 with SSE equal 3.53 and 4.81, respectively. In other words, only a very small fraction of the total error.

Dependent Variable: ACC_DEPT

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	6	20.04469	3.34078	7.018	0.0039
Error	10	4.76037	0.47604		
C Total	16	24.80506			

Root MSE	0.68995	**R-square**	0.8081	**Durbin-Watson D**	2.332
Dep Mean	8.43113	**Adj R-sq**	0.6929	**(For Number of Obs.)**	17
C.V.	8.18341			**1st Order Autocorrelation**	-0.238

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	530.83	424.54	1.250	0.2396
YR	1	-0.267	0.21	-1.243	0.2422
HRSFWN	1	0.0000025	0.0000025	0.988	0.3462
JET	1	0.000885	0.0118	0.075	0.9416
CPL	1	0.000106	0.000228	0.466	0.6512
PASSKM	1	2.6896-11	0.000000	0.260	0.7999
MOVE	1	0.000134	0.000877	0.152	0.8820

Dependent Variable: ACC_HRS

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	6	84.83602	14.13934	18.827	0.0001
Error	10	7.51014	0.75101		
C Total	16	92.34617			

Root MSE	0.86661	**R-square**	0.9187	**Durbin-Watson D**	2.588
Dep Mean	10.05465	**Adj R-sq**	0.8699	**(For Number of Obs.)**	17
C.V.	6.61901			**1st Order Autocorrelation**	-0.374

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	897.034988	973.325155	0.922	0.3784
YR	1	-0.453039	0.49336159	-0.918	0.3801
DEPTS	1	0.000001643	0.00000392	0.420	0.6837
JET	1	0.002869	0.01447609	0.198	0.8469
CPL	1	0.000048269	0.00028296	0.171	0.8680
PASSKM	1	5.822964-11	0.00000000	0.342	0.7396
MOVE	1	0.000951	0.00242721	0.392	0.7034

Table 6.1 ANOVA Table for Total Accidents per Year Model

The second method of measuring the selected models' accuracy, and directly related to the sums of squares results, is the F statistic. The null hypothesis for the test of overall model significance is generally stated as H_o: all k independent variables considered together do not explain a significant amount of the variation in Y. The F statistic is obtained by calculating the ratio of the mean-square regression to the mean-square residual. Compared with the critical point at 1% significance level, all of the selected models were significant with F ratios ranging from 4.2 to over 18.8 . Therefore, the independent variables contribute significantly to the prediction of Y.

The last measure of the overall linear association of one (dependent) variable Y with several independent variables X_1 , X_2 , ..., X_k is the square of the multiple correlation coefficient R^2 . All of the models have an R^2 greater than 0.71, a very strong relationship between the dependent and independent variables.

C) Slope and Intercept tests

In addition to testing for an overall significance of the model, individual contribution of each independent variable should also be assessed. Doing so, ensures superfluous variables are not introduced to the model. The slope and intercept are the measures used in detecting such variables.

The most important test of the hypothesis dealing with the parameters of the model concerns whether the slope of the regression line is significantly different from zero or, equivalently, whether X helps to predict Y. The appropriate null hypothesis for this test is H_o: $b_1 = 0$. Rejecting H_o implies that a model in X is better than a model that does not include X at all. Results presented in Appendix D tables indicate that no such variable exists.

```
Dependent Variable: FAT_DEPT
                              Sum of        Mean
         Source      DF       Squares       Square       F Value                  Prob>F
         Model       6        8.98301       1.49717      4.243                    0.0220
         Error       10       3.52879       0.35288
         C Total     16       12.51180
         Root MSE    0.59404  R-square      0.7180       Durbin-Watson D          2.371
         Dep Mean    3.69710  Adj R-sq      0.5487       (For Number of Obs.)     17
         C.V.        16.06762                            1st OrderAutocorrelation -0.248

                              Parameter     Standard     T for H0:
         Variable    DF       Estimate      Error        Parameter=0              Prob > |T|
         INTERCEP    1        300.819809    365.518599   0.823                    0.4297
         YR          1        -0.152114     0.18559026   -0.820                   0.4315
         HRSFWN      1        0.000001725   0.00000215   0.802                    0.4410
         JET         1        -0.004496     0.01014779   -0.443                   0.6671
         CPL         1        0.000072809   0.00019617   0.371                    0.7183
         PASSKM      1        2.108277E-11  0.00000000   0.237                    0.8174
         MOVE        1        -0.000055779  0.00075532   -0.074                   0.9426

Dependent Variable: FAT_HRS
                              Sum of        Mean
         Source      DF       Squares       Square       F Value                  Prob>F
         Model       6        27.85667      4.64278      9.653                    0.0011
         Error       10       4.80982       0.48098
         C Total     16       32.66649
         Root MSE    0.69353  R-square      0.8528       Durbin-Watson D          2.456
         Dep Mean    4.43388  Adj R-sq      0.7644       (For Number of Obs.)     17
         C.V.        15.64157                            1st Order Autocorrelation -0.282

                              Parameter     Standard     T for H0:
         Variable    DF       Estimate      Error        Parameter=0              Prob > |T|
         INTERCEP    1        283.450100    778.929905   0.364                    0.7235
         YR          1        -0.143268     0.39482602   -0.363                   0.7243
         HRSFWN      1        0.000001936   0.00000313   0.618                    0.5506
         JET         1        -0.005668     0.01158489   -0.489                   0.6352
         CPL         1        0.000065785   0.00022644   0.291                    0.7774
         PASSKM      1        1.789483E-11  0.00000000   0.131                    0.8982
         MOVE        1        -0.000150     0.00194244   -0.077                   0.6400
```

Table 6.2 ANOVA Table for Fatal Accidents per Year Model

Another hypothesis tested concerns whether the population line goes through the origin; whether its Y intercept b_0 is zero. The null hypothesis here is $H_o: b_0 = 0$. If the null hypothesis is not rejected, it may be appropriate to remove the constant from the model. Again, the generated results indicate that the value of the intercept is different from zero, therefore, the regression line does not pass through the origin and the intercept should remain in the model.

ADDITIONAL REGRESSION MODELS ANALYSIS

The discussion in the preceding sections concentrated on assessing the risks involved in choosing air travel as a mode of transport. It was mentioned that since 1976 there was a steady decline in both fatal and total accidents, with a few exceptions, which was sustained after economic deregulation of the industry in 1988. Although accident rates continue to fall through the deregulated period, it is possible that deregulation has caused the rate of decline to deviate from its long term trend (Rose, 1987). To estimate the effect of deregulation on accident trends, a logarithmic model was developed in order to show accidents as declining over time and to allow for the possibility that the accident trend changes after deregulation. This suggests an equation of the following form:

$$\mathbf{Ln\ (Accident\ Rate) = \beta_o + \beta_1 * TIME + \beta_2 * TIME * DEREG + e_i}$$

where Ln denotes the logarithm, TIME is a linear time trend and DEREG is a dummy variable equal to 1 for the years 1976 to 1987, otherwise zero (0). The value of β_2 measures the change in the time trend after deregulation. The above equation was estimated using ordinary least squares regression using various measures of accident rates: the total number of accidents in a given year (ACCLN), total accidents per 100,000 hours flown (ACC_HRS), total accidents per 100,000 departures (ACC_ DEPT), as well as rates of fatal accidents using the same methods (FATLN, FAT_HRS and FAT_DEPT).

The results of running these models are presented in Table. The decline in accidents is quite strong, with the number of total and fatal accidents declining by 6.6 (standard error, 1.3) to 7.1 (1.9) percent per year throughout the period. The total accident rate per 100,000 hours flown declining by 5.4 (0.9) percent per year and that of fatal accidents per 100,000 departures by 3.0 (0.7) percent. The fatal accidents rate per

100,000 hours flown also decreases at an annual rate of 3.0 (0.07) and that of fatal accidents per 100,000 departures declining by 3.6 (1.5) percent per year. The equations based on the three measures explain over 63% of the variance in accident rates over time. The fatal accidents equations explain over 54% of the variation over the same period. Moreover, in the case of fatal accidents per 100,000 departures, accident levels decline slower after deregulation. However, in all other models, the advent of deregulation seems to have accelerate the trend of increasing rates of accidents in Canada, although by almost negligible amount.

TOTAL ACCIDENTS MODELS

		Dependent variable	
	Log(Total accidents)	Total accidents/100,000 HRS	Total accidents/100,000 DEP
Constant (β_o)	135.526807	109.459573	61.814650
	(25.88915248)	(16.86633331)	(15.11714706)
Year (β_1)	-0.065601	-0.054050	-0.030104
	(0.01306541)	(0.00851189)	(0.00762913)
Year*Dereg (β_2)	0.000193	0.000098610	0.000055808
	(0.00007059)	(0.00004599)	(0.00004122)
R^2	0.6766	0.8168	0.6305
F-value	14.645	11.946	31.201
	(0.0004)	(0.009)	(0.001)

FATAL ACCIDENTS MODELS

		Dependent variable	
	Log(Fatal accidents)	Fatal accidents/100,000 HRS	Fatal accidents/100,000 DEP
Constant (β_o)	145.693667	119.626432	71.981509
	(39.32617982)	(30.93967319)	(29.53038399)
Year (β_1)	-0.071131	-0.059580	-0.035633
	(0.01984664)	(0.01561425)	(0.01490302)
Year*Dereg (β_2)	0.000126	0.000031982	-0.000010820
	(0.00010723)	(0.00008436)	(0.00008052)
R^2	0.5902	0.7029	0.5433
F-value	10.080	8.329	16.564
	(0.0019)	(0.0041)	(0.0002)

Table 6.3 Assessment of the Effect of Deregulation on Accident Rates

This preliminary analysis of aggregate accident data for the Canadian commercial accidents provides very little support for the view that safety levels have deteriorated in the aftermath of deregulation. The results of this section are consistent with findings by American researchers studying the US experience of deregulation (Rose, 1987, McKenzie and Shugart. 1986). As in Canada, deregulation had no discernible effect on aggregate airline fatalities, either directly or through its effects on increased air passenger miles. One explanation may be structure of industry expansion following economic deregulation. Deregulation produced lower air fares and therefore substantially raised demand for air travel. This, in turn imposed pressure on the industry for ever increasing number of flights. With this mounting activity, new entrants and existing carriers vowed to maintain safety levels, in order to sustain consumer confidence. The additional movement gave many of those involved in the industry more experience. Coupled with safety consciousness, this may have improved the trend toward increased safety. However, in the longer term, the vigilance may have relaxed and growing pressures of more flights may be taking its toll on performance.

While the aggregate data results indicate no adverse change in accident rates after 1988, they provide a weak test of the hypothesis that deregulation reduced safety. Differences among differing air carrier accident rates would permit more precise and more powerful tests of deregulation's effects on accidents.

RESULTS AND CONCLUSIONS

As was illustrated in detail in chapter four, there is a steady decline in both total and fatal accidents over time, which was sustained to a large degree after economic deregulation of the industry in 1988. The number of accidents declined even though the number of flights and aircraft departures increased sharply through time, implying even lager declines in the accident rates per 100,000 hours flown and 100,000 departures. This improvement in safety is attributable primarily to the substantial improvements in aircraft and aviation technology over the past 40 years. These include the diffusion and upgrading of radar technology, developments of the jet aircraft, metallurgical and materials advances, the introduction and continual improvement of navigational and landing aids, weather forecasting and reporting, as well as more sophisticated simulators employed in pilot and crew training. These advances in aviation directly translated into greater safety for passengers and flight crews, as clearly shown by the results presented in this chapter.

The purpose of the preceding sections was to develop a model which would accurately predict the rate of the total number of accidents and that of fatal accidents in Canada each year. The study has shown that the use of other than financial airline data, in contrast to generally proposed models, contributes significantly to predicting the distribution of risk of air travel. The danger of flying can be forecasted not only for the total number of accidents but also the fatal accidents. The least squares regression equation estimates measured these rates on aggregate operational variables normalized per 100,000 hours flown as well as per 100,000 departures. The reported results show a decline in rates of accidents through time, irrespective of model and base used. Particularly, the modeling results indicate that variables directly related to the flight environment have an important effect on accidents frequency in Canada. These preliminary results also point to the conclusion that although financial conditions, such as profit margins and cash flows, are useful is assessing potential safety problems, flight operations indicators reveal a much stronger and immediate relationship. Such a direct correlation is probably more useful in ascertaining the potential problem areas in the prevailing safety issues and suggest solutions to them. Finally, the main results of this analysis provide no support for the view that safety levels will drastically deteriorate in the initial period of adjustment to the deregulated economic environment. Some difficulties may occur in surviving in the new structure, but the overall trend seems to have been maintained, so far, by Canadian air carriers.

CHAPTER VII

CANADIAN AND WORLD SAFETY ISSUES

While the number of air travel accidents worldwide has steadily decreased since the introduction of bigger, faster and more sophisticated airplanes, various national government agencies, ICAO and other international organizations continue to strive towards an even better safety record. The efforts of the airline community have made it possible to fly across the Atlantic, exchange a wider range of goods between countries, promote passenger and cargo movement across borders. In addition, probably the most important contribution of all was the establishment of a set of rules and regulations to be followed by all. However, large and persistent differences still remain across industry segments and across regions of the world. With the recent extent of deregulation in countries such as Australia and New Zealand, EC liberalization in Europe, and the ongoing privatization developments in Asia and the Pacific, public concern about safety has been mounting for some time. The final chapter of this research project reviews the world safety record and contrasts its results with that of Canadian commercial aviation's performance. Some additional issues of interest to safety proponents are discussed in more detail as well.

WORLD AVIATION SAFETY RECORD

There is a wide range of sources of concern for airline travelers' safety. This preoccupation arises primarily due to the highly publicized airline accidents of the mid-1980's. Rapid growth in air travel in Canada and abroad has increased the demand for aircraft, forcing many carriers to keep older aircraft in service longer than previously estimated by their manufacturers. The increase in traffic, coupled with crew retirements has also sharply increased demand for pilots. This leads to questions if flight crews have enough experience and training in order to deal effectively with growing responsibilities ?

Another source of concern is based on economic deregulation. Ease of entry and exit from the market, globalization of the airline industry through marketing agreements, operational ties and cross-ownership relationships (British Airways with USAir, Air France with Belgium's Sabena and Czech Republic's CSA, as well as Air France with Air Canada and Aeromexico, for example), also heighten concerns about safety. One of them is the fact that North American and European airlines, historically among the safest in the world, are engaging in business and affiliations with markets, carriers and facilities which may not have the same excellent safety record. The following analysis of worldwide air travel safety will help assess the effects of these regional differences and cross-border associations.

Before presenting the results however, calculations of safety rates must be defined. Data limitations and different approaches in making safety comparisons across countries are discussed next. First, it is necessary to distinguish between the probability of a fatal accident and the likelihood of being killed if such an accident occurred. This is particularly important in light of the continuous efforts to improve the survivability of airline crashes. The measures used to evaluate these risks (as discussed in detail in chapter two) are the number of fatal accidents per 1 million flight departures, and the 'death risk' per 1 million departures. The death risk is the probability of being involved in a fatality producing accident multiplied by the proportion of people killed in fatality producing accidents; this is roughly equivalent to the measure of fatalities per 1 million enplanements. Such measures reflect the aggregate level of safety, allowing the passengers to know if it is safer to fly in Europe, Africa or Australia.

Second, the ICAO data which is the only comprehensive set of accident records worldwide suffers from a significant time lag before its numbers are compiled. In addition, the amount of information reported to ICAO from individual countries or airlines varies greatly. Many of the reports published in the summaries are missing objective information, such as weather. More importantly, descriptions are generally insufficient to establish an accident event sequence which is essential to determining the initiating cause. Finally, even the definitions and standards used in accident determinations vary across countries and across organizations which ultimately collect safety data.

Third, assigning a safety rate to a particular region does not show whether the airline or the region is the principal source of danger. With the limited data reported it is not possible to construct safety rates by carrier by regional market, so a direct test of whether it has been safer to fly in Africa on a European carrier or than on an African carrier can not be made. Although, individual accident records can be examined in order to verify the proportions of accidents in each country that were accounted for by that country's own airlines, other airlines in the same region, or airlines from other regions of the world.

Consequently, care should be taken in reading some of the information and drawing conclusions.

The analysis provided is very useful, but the information is not directly comparable to the Canadian accident analysis presented in previous chapters.

Based on a worldwide study performed by Oster and Strong (1992), there is considerable variation in accident occurrences among regions. For example, in Canada and the United States, the chance of being killed on a scheduled flight was less than 0.6 in one million, the best safety record of any region (see Table 7.1). Western Europe and Australia/New Zealand had safety records about 50 and 100 percent worse respectively, but still very good compared with the rest of the world. Eastern Europe and Asia came in next with rates 4.6 and 5.8 times worse, and Middle East and Latin America were 7.2 and 8.9 times more dangerous. Africa had the world's worst safety record, with a death risk per flight of nearly 10.6 per one million, over 18 times greater than in North America.

Since the charter airlines also play an important role in much of the world, their performance was also evaluated. Over the same period, the probability of a fatal accident by a jet charter operator was nearly 8 in one million and the death risk was almost 6 in one million.

Region	Number [a] of Fatal Accidents	Number of Fatalities	% People Killed in Crash	Fatal Accidents per 1 Million Departures	Death Risk per 1 Million Departures
North America	63	1,971	60	0.88 [b]	0.53 [c]
Latin America	64	2,326	81	6.04	4.87
Western Europe	30	1,663	70	1.15	0.80
Eastern Europe	33	1,662	62	4.11	2.53
Asia	63	2,439	64	4.66	2.97
Africa	31	1,110	79	13.25	10.62
Middle East	17	1,373	69	5.47	3.78
Australia / New Zealand	5	33	81	1.34	1.09

[a] Data does not include regional and commuter operations

[b] The North American rate is lower than the Latin American , Eastern European, Asian, African, and Middle Eastern rates at the 90 percent confidence level.

[c] The North American rate is lower than the Eastern European rate at the 90 percent confidence level and the Latin American, Asian, African, and Middle Eastern rate at the 95 percent confidence level.

Table 7.1 **Accident and Fatality Record by Region, Scheduled Passenger Flights, 1977 - 1989**

(Source: Oster and Strong, The Worldwide Aviation Safety Record, March 1992)

It should be noted however that the safety performance improved between 1983 and 1988 over the 1977 to 1983 period. Consequently, while scheduled carriers had a safety record about three and one-half times better than nonscheduled airlines, their relative performance was somewhat rectified in the last five years of the study period. For the years 1983 - 1988 the charter airline fatal accident record declined to a little over twice that of scheduled airlines.

As with Canadian commercial accidents, it is necessary to look deeper into worldwide accidents in order to determine their primary cause and suggest solutions to improve safety. It is essential to look at the different mix of causes as well as the regional differences which account for some of the discrepancies in these events. In other words, the analysis shows how likely was an accident in Africa due to pilot error, and how much more likely is a fatal accident due to pilot error in Africa as compared to its occurrence in North America.

Again as in Canada, with few exceptions, pilot error was the culprit of the majority of fatal accidents (see Table 7.2). The overall North American fatal accident rate per 1,000,000 departures for 1977 - 1989 was 0.88, which can be divided into its twelve primary cause classifications. The most common cause, assigned to pilot error, was 0.32 per 1,000,000 departures; this is equivalent to saying that 0.32/0.88 = 0.36 or 36.6 percent of the fatal accidents in North America were due to pilot error. The same factor was listed first for three other regions and came in second for two more. Middle East was the only world area where weather and terrain both ranked first and terrorism appeared second. Latin America, Africa and Asia's rates in pilot error seemed particularly high.

It is also interesting to see regional variations in engine failure rate. Latin America's accident rate of 0.66 is eleven times greater than that of engine failure accidents in North America. The data also show high rates in Eastern Europe and Africa. Incidentally, the rate of engine failures was particularly high on Soviet-built aircraft.

Weather was a much more frequent factor in fatal accidents in the developing countries than in North America or Western Europe. Difficult climate in monsoon whipped Asia, dry deserts of Africa and tropical forests of South America, all contributed to the tragic events. Another reason seems to show

Primary Cause	USA/ Canada	Latin America	West Europe	East Europe	Asia	Africa	Middle East
Engine Failure	.06	.66	.09	1.03	.23	2.25	.00
Equipment Failure	.17	.66	.05	.45	.47	1.46	.38
Weather	.10	1.45	.32	.45	1.30	.80	1.69
Pilot Error	.32	2.11	.41	.78	1.54	2.52	.38
Air Traffic Control	.02	.12	.00	.00	.09	.00	.00
Ground Crew	.02	.12	.00	.12	.00	.00	.00
General Aviation	.04	.00	.00	.12	.00	.53	.00
Terrorism	.00	.12	.05	.25	.42	2.92	1.16
Icing	.04	.00	.09	.25	.00	.00	.00
Terrain	.04	.30	.07	.25	.14	1.86	1.59
Fire	.00	.00	.00	.00	.00	.53	.00
Other	.07	.48	.07	.41	.47	.40	.38
Total Accident Rate	.88	6.04	1.15	4.11	4.66	13.25	5.47
Number of Fatal Accidents	63	61	30	33	63	31	17

Table 7.2 **Fatal Accident Rate by Primary Accident Cause by Region, 1977 - 1989**

(Source: Oster and Strong, The Worldwide Aviation Safety Record, March 1992)

through these numbers as well; frequency of weather-related accidents may be due in part by untimely and less detailed weather information available to pilots flying in the region. Unfortunately, the advanced technological facilities of weather forecasting and reporting are not accessible to them. Also, the frequent lack or inadequacy of landing aids in less developed countries make it more difficult to deal with weather-related factors.

Returning to the issue of accident rates associated to the region's carriers or other carriers flying in the area, figures show that sixty-eight (68%) percent of the fatal accidents between 1977 and 1989 involved an airline of the country in which the crash occurred. Fourteen (14%) percent involved airlines of the same region, and 18% of the fatal accidents implicated carriers from another part of the world. In addition, the overwhelming majority of these cases were accidents in which a carrier from a developing region crashed either in Europe or in another developing country. This leads to the suspicion that, while there is no direct evidence on safety performance of different airlines in the same markets, it is possible that North American and Western European airlines have a better safety records than their counterparts in the developing countries.

In general, the largely disparate accident rates across regions are repeated in the main accident causes. The relatively poor accident records of Africa and Latin America can not be attributed to just a few factors which would suggest areas in need of major improvements. The progress in airline safety in the developing world therefore seems to require improvements in all areas of aviation: maintenance, weather watch, airports and airways organization, as well as training of flight crews. This is not the case in developed countries where human error is the priority item on every safety issues list.

In order to make this study complete however, it is important to also mention today's areas of concern for the modern pilot and the aviation industry as a whole. The remainder of this investigation will present some of the issues ICAO as well as Canadian officials are faced with, and their solutions to the problems at hand.

TODAY'S PRESSING SAFETY ISSUES

Every aspect of the aviation operations, such as the flight crew, the aircraft, the weather reporting system and even ground personnel, have been improved upon throughout the aviation industry's development. The constant challenge of 'risk free' operation has kept the airlines and national governments on their toes and lead to the coordinated efforts to promote safety. Today, teams of engineers and researchers from various fields and countries, with the assistance of ICAO and other world organizations, are able to exchange information and help one another in developing and implementing new approaches to aviation safety. Recent studies of human behavior, for example, have suggested new methods of crew and ground personnel training. Sharing technological advances has promoted the implementation of a world-wide satellite network for improved air traffic control and weather forecasting services. Also, ICAO's central role as a safety promoter lead to the standardization of accident investigations and data reporting, although it still needs improvement in many areas. The following sections discuss some contemporary aviation safety issues in more detail.

A) Flight Crew

New approaches to crew training

Traditional methods of training pilots usually consisted of two independent areas of study: the ground school and the flight instruction. The first covered theoretical aspects of flight; aircraft operations, aeronautical rules and regulations, meteorology and navigation. The second was concerned with practical ability to fly the airplane. Treated separately, theory was often difficult to assimilate before one set foot in an aircraft. Conversely, flight instructors did not take the time to relate what was covered in class by demonstrating its application in the air; they simply taught the mechanics of flying the machine. Consequently, this lack of integration tended to consolidate the perception that theory was inferior to practice. In addition, topics such as human factors or team work were of secondary importance, if discussed at all.

Today, with studies of accident trends revealing a staggering 70 to 80 per cent of causal factors as human related, the aviation industry is starting to appreciate the importance of including these elements as an integral part of pilot training. With the various pilot judgment training manuals produced in the late 1980's by Transport Canada, the USA Federal Aviation Administration and Australia's Civil Aviation Authority, the gap between ground school and flight instruction is beginning to disappear. Increasing emphasis is put on merging real situation examples with theory presentations, thus motivating to learn and promoting deeper understanding of the subject matter. At the University of Newcastle in Australia, for example, the B.Sc. (Aviation) course consists of four sections: aeronautical engineering, aviation science, aviation management and human factors. Each of the four subject areas is designed to link theory and practice. Each is also integrated with flight training and the safe operation of an aircraft (Tefler, 1993). Ultimately, the instructor's tasks include devising a suitable case study, undertaking a task analysis to reveal all the factors involved and providing appropriate response as well as cooperating and coordinating teaching material with flight instructors.

Not everyone of course has the required time, facilities and capital to offer such an extensive training program. Shortages of experienced pilots and strained finances of airlines prohibit the wide-spread implementation of new training programs. Also, it is much harder to enforce new approaches and methods to veteran pilots with long developed preconceptions about the importance of human issues in flight operations. As much as the industry and the regulatory bodies would like the education of human factors to be administered to all, the best hope probably remains with the student pilot just starting the flying career (Odegard, 1994).

First of all, it is easier to include an additional section dedicated to human factors in a training curriculum for student pilots, than it is to put senior flight crew in the classroom. Airlines need those experienced people on the job not in school. Second, for the inexpert and inexperienced pilot, there tends to be a ready acceptance of human factors as an integral aspect of training (Tefler, 1993). Third, it is vital that the pilot does not classify learning into the strict groupings of technical and human factors, which seem to haunt the airlines' efforts to integrate the line oriented flight training* (LOFT).

Understanding human aspects such as sensory illusions, fitness and health have received some attention in the old training curriculum. More recent developments in cockpit organization, crew-coordination and decision making are only beginning to generate similar interest. Specifically, new training programs are being developed for crew-coordination, emphasizing good communication among flight crew, as well as simulation of real situations; not just practice of predetermined emergency procedures. The study of human behavior, individually and in a group, has prompted some changes in teaching methods. Gradually, the move toward training the whole flight crew together as a team - as opposed to just training the individual pilots one at a time - is getting established at major airlines.

The development and promotion of the LOFT concept by NASA in the USA, for example, has evolved from a simple need for simulator training to an entirely integrated full-mission program. Propelling the aviation industry into an even higher level of flight deck technology, the era of glass cockpit has arrived. The CRM and recurrent training programs modules demand that the crew coordination and workload management required to successfully fly the high-tech cockpit emphasize not hardware and systems but crew cooperation demanded by automation (Weiner, 1993). The technological advances make it possible to teach not only systems knowledge, operating skills, and aircraft handling-

---

* Line oriented flight training (LOFT) is a method of pilot training by use of a simulator programmed to initiate scenarios which require the crew to coordinate their efforts in order to complete the flight safely. This method is mostly applied during the Cockpit Resource Management (CRM) programs.

abilities, but also the crew-coordination, decision-making, leadership and management skills; all important elements of the airline pilot's job (Lauber, 1981).

In addition to general behavior, specific human traits are put under the microscope. Individual characteristics of the team members, such as leadership and cooperation, are being examined in more detail. A study sponsored by NASA in 1993 researched the impact of leadership and teamwork on the successful completion of a flight. Particular attention was directed at recording the amount of interaction, or put simply, at the amount of talking done by both the captain and his team members (Oslund, 1994). Mr. Ginette, a Colorado psychologist who has studied leadership in high-performance teams, was responsible for flying with captains judged effective leaders by their airline managers, as well as with less effective captains. He also taped flight briefings of the same captains and later analyzed the data. His final conclusion: 'The effective leader really engages the crew in the process of the team's work - right from the beginning'; the length of the briefing or the amount of time the captain talks does not count, as long as other members of the team get to discuss the issues as well. This kind of human behaviour analysis is being used in developing the cockpit resource management (CRM) courses. They are designed to teach pilots how to make best use of all the resources available to them - be it other pilots in the cockpit, other crew members or even maintenance technicians on the ground. An ideal leader would assess the skills of the people involved and the difficulty of the task at hand before deciding what kind of message should be sent. The emphasis is put not only on the knowledge of the aircraft and what it can do, but also of its crew and on the ability to recognize people's strong points and making the most of their abilities, to operate the aircraft safely.

Airline pilot training has changed in the last decade. Technological advances have radically transformed the way pilots learn their craft. The most significant change is the perception that the aircraft are not flown by individuals but by crews (Orlady, 1994). The advance from simple flight training to the integration of human and machine qualities into one coordinated effort to promote safety, points to the conclusion that the airline industry has reached maturity. The invention and improvement of the aircraft (technology) and the development of skills and abilities to fly it (human aspects) have already been fulfilled. The next step will be to teach pilots how to perfect and integrate these two aspects. The airline industry has reached a point of defining the broader sense and direction of its inventions; i.e. the conceptual application and effects of human actions and technology.

Flight duty rules

Human error, as described earlier, presents itself in many forms; there is more to safe flight than just crew coordination. One crucial aspect, presently under review by federal authorities, is flight duty. Canada's impressive safety record seems to have overshadowed the need to regulate the number of hours pilots spend flying each day. Flight duty rules in Canada are among the most permissive in the world and, as often demonstrated, invite disaster.

On July 31, 1987, a Perimeter Airlines, twin-engine Beach A65 crashed only a few minutes after take-off. The TSB report attributed the accident to, among other factors, the pilot suffering from chronic fatigue (Oslund, 1994). Unlike the acute fatigue due to flying too many hours without rest, chronic fatigue is caused by working too many days without proper sleep. In the case of the above described accident, the pilot's log indicated that he had flown 410 hours in the preceding 90 days, including 372 hours since he joined the company only 67 days earlier. During his employ, the pilot had only two non-flying days !

The flight duty regulations in effect today, allow for up to 15 hour days; including flying and other duties, such as refueling and loading cargo. This can add up to 150 hours a month and on duty for 24 hours at a stretch, with the pilot's consent. Pilots can also be ordered to work as many as 156 days without a full day off. Such a hectic schedule causes pilots not only to fall asleep at their controls, its dangers include taking risks they would ordinarily never take. In a 1986 fatigue study, the Canadian Aviation Safety Board found 85% of accidents were the result of unexplainable pilot error: "Pilots reported that they heard the gear warning horn, but inexplicably failed to lower the landing gear. A helicopter pilot working in a confined area flew in a manner which he knew even at the time to be hazardous". A rather frightening statement considering the crews' responsibility for the lives of its many passengers.

Pilot comments from more recent Commercial Pilot Survey (1991) conducted by TSB reflect more of the same unfortunate reality. With regards to duty time one reads:

> "Personally, I have worked last year once for 35 hours and at least 10 times for 24 hours without a rest period. Pilots on call do not start duty times until they start flying, i.e. on their own time all day on call but do not get called out until 2300. Their duty time starts at 2300 for possibly 15 hours even if they were up all day."
>
> "At even a 10-hour duty day, I will have been awake for approximately 27 hours at the end of my "legal" duty day!!! I have actually fallen asleep during such flights, and I am sure that others have as well. Our employer tells us that this is just the nature of the unscheduled charter business, and there is nothing that can be done to change the situation."
>
> "One day off every week plus statutory holidays would be greatly appreciated."
>
> "A pilot should have at least one day off per week, particularly in summer time."
>
> "On your landings, Thursday or Friday especially, you're just hoping you'll hit the ground. It just starts slipping. It's just crash it down, hit the breaks and that's it. Your night vision starts to go, decision making starts to go." (TSB Survey, 1991)

The primary cause of excruciating flight schedules and consequently overworked pilots is the inadequacy of the above mentioned regulations. Present rules allow employers to take advantage of their flight crew by imposing long working hours, minimum wages and few if any benefits. Only a fortunate minority of unionized pilots working for major carriers such as Air Canada and Canadian Airlines International, can make use of the little regulations that exist with respect to flight duty. The sort of despair and unfair treatment comes through in more of the previous survey's quotes:

> "We don't have benefits such as retirement plans, disablement insurance, etc."

> "I would like to see legislation forbidding pilots to work for free and standards for minimum salaries for pilots pertinent to the type of equipment flown."
>
> "Low wages are often structured to increase fatigue as they depend on miles or hours flown."
>
> "Pilots are responsible for people in the air and on the ground and we make less than a garbage man."

The task at hand unfortunately is not as simple as changing the rules. Airline representatives point to Canada's good safety record and argue that additional limits on their operations will only put further strain on already limited financial resources; shorter hours would mean hiring more staff. Creating regulations that will fly with both pilots and airlines proves even more difficult when addressing the issue of accidents due to pilot error. Fatigue, difficult to prove, had always been considered a possible contributing factor. Also, naming other factors than human error made it easier for carriers to collect insurance; the manufacturer of a faulty or failed part usually took the blame and the burden of reimbursement for damages resulting from an accident. However, in June, 1994, the US National Transportation Safety Board ruled that a DC8 accident (which occurred on August 18, 1993) was caused by pilot fatigue, which impaired judgment, decision making and flying abilities. For the first time, a North American air disaster was officially attributed to pilot fatigue.

That same ground breaking report also called for a review of US flight duty times to reflect more recent research on fatigue and sleep deprivation. Ironically, American laws are already much more strict than Canadian flight regulations. In light of these new developments south of the border, our government authorities began to look more closely at the prevailing laws in Canada. As a result, Transport Canada asked several groups made up of pilots, airline officials and other experts to work on new flight duty regulations. The following changes were proposed, however, no decision has been made so far for their enforcement.

The working group proposes:

a) - if pilots must work 15 hours, they should get 15 hours off right after duty,

- no additional rest is required if flight duty is limited to 14 hours,

- if any flight occurs between 2 a.m. and 6 a.m. the maximum duty period would be 12 hours,

b) - a maximum of 150 hours of flight is allowed only on daytime flights using visual (not instrument) navigation,

c) - allow one day off a week, or three days off each 21 days and 13 days for each 90 days,

d) - maximum flight times would be reduced by one hour for each sector: over 6 sectors for turbojet planes, over 8 sectors for turboprop planes and 10 sectors for commuter planes (a sector is a flight which requires more than one takeoff and landing),

e) - helicopter and taxi pilots would be allowed a maximum of 120 hours for night or instrument flights, and 180 hours a month for daytime, visual navigation flights.

As in the US, the TSB has put special emphasis on studying accidents caused by human error and specifically fatigue in recent years. Unfortunately, to date nothing has been done. In 1993, a major accident had the neighboring federal aviation authorities looking at strict new regulations. Canadian pilots worry that it may take a disaster here to effect any major changes as well. "It would be a great shame to have to wait for another accident to occur" said a chairman of human factors for the CALPA, Terry Angus. Hopefully we are more responsible to allow for such an eventuality.

B) Flight Environment

As previously reported data indicate, commercial accidents have declined with each new generation of jet aircraft and despite some regional differences, the overall distribution of primary cause factors has remained unchanged. Unfortunately, as we study the trends of past accidents and learn more about their causes and ways of elimination, or at least their limitation, we also discover that it is much more difficult to improve the human than the flaw in an aircraft design. As studies show, in addition to weather conditions and difficult work environment, today's pilots must also contend with new sources of danger: other pilots and outdated equipment. As the number of pilots and flying machines increases, the danger of them 'meeting' in the sky or on the ground also grows. In the last decade the number of near-misses, mid-air colusions and ground accidents has augmented dramatically. Also, the incidence of metal fatigue or equipment failure due to age has increased. The additional factors of ever increasing traffic congestion and fleet aging contribute to the incidence of accidents and call for improvement in order to promote air travel safety.

Traffic congestion

When there were but few planes flying, the danger of collisions between the aircraft in flight or on the ground was negligible, but as traffic increased and began to concentrate in particular areas, the danger increased rapidly. It then became apparent that some control over traffic was needed to keep the aircraft at a safe distance from each other. This was especially the case for fast aircraft, often traveling in conditions of low visibility. Although the classic 'see and be seen' dictum might still provide adequate separation for slow-moving aircraft in lightly traveled areas, it was not adequate in heavy traffic and low visibility situations. This lead gradually to the need to organize space and to provide the now familiar air traffic control system.

The early basis for the system was the filing by the pilot of a flight plan detailing where the aircraft was intending to go and when. This requirement relied on the pilot adhering closely to the plan and reporting his position to the air traffic control services at specific points on the itinerary. The control service could then request the pilot to adjust the position both vertically and horizontally to avoid conflict with other aircraft. This situation was further aided by the establishment of specific routes between navigation facilities, called airways, and fixed altitudes, called flight levels, as well as the introduction of radar. However, the advent of faster planes and increased demand for air travel posed new challenges to air traffic control in the air as well as on the ground.

The first and most destructive indicator of an increasing aviation traffic was demonstrated 20 years ago in Tenerife, a Spanish island in the Atlantic. A KLM Boeing 747 tore through the top of a taxiing Pan Am 747, during its take off roll. Both aircraft were destroyed, killing 583 passengers and crew. Aviation's worst disaster occurred not in the air but on the ground !

The only unique aspect of the Tenerife tragedy (March 27, 1977) was the scale of its destructiveness. Accidents involving more than one aircraft occurred before and more have taken place since. On average, five surface and/or mid-air collisions arose in the past 10 years in Canada. However, an astonishing 863 near-collision incidents were reported to the TSB since 1987. Although accidents involving more than one aircraft are rare, clearly such close calls, or incidents are not.

ICAO defines runway incursion as 'any occurrence at an airport involving an aircraft, vehicle, person or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, landing or intending to land'. As with other accidents, the cause on the ground, creating a collision hazard is more often than not, attributed to human error. As illustrated by another accident, the issue of congested airports and skies represents a constellation of problems.

In December of 1991, a Northwest Airlines DC-[illegible]ered into the path of a departing Northwest 727 in Detroit. Eight people on the DC-9 died in the ensuing crash. The subsequent NTSB report cited human performance failures on the part of both the DC-9 pilots and the ground controller. While trying to navigate in heavy fog, the DC-9 pilots were anything but a coordinated team, with the captain tacitly relinquishing his command to the first officer. The two became lost but omitted to notify the tower. Even without the notification, the ground controller realized that the plane might have taxied onto an active runway, yet he failed to take steps to avert a collision. In addition, the investigators found inadequate lighting and marking of taxiways and runways at the Detroit Metropolitan/Wayne Country Airport. Furthermore, NTSB identified deficiencies in the equipment used by controllers. It was concluded that effective ground radar would have been enough to prevent the accident.

There are many examples of such situations, ranging from distracted pilots to preoccupied controllers, to equipment failure. The main point is that the ever increasing number of flights, all wishing to operate at a limited number of economic levels, has placed heavy loads on the system and its operators. Although the introduction of automated air traffic control has significantly increased the traffic volume which can be handled in an efficient manner. it also added to the stress and already full list of tasks of pilots and controllers.

Presently ICAO and its member states are conducting several studies aimed at increasing the traffic handling capacity through the introduction of reduced separation minima. Combined with extensive safety analysis, it has been concluded that with modern technology, systems have the capability to perform with a much higher level of accuracy. Provided that specified conditions are met and subject to regional air navigation agreements, satellite surveillance, collision avoidance and meteorological service developments would be incorporated so as to provide the most accurate tracking of aircraft to ensure their safety. In addition, programs are also being developed to train those responsible for using the sophisticated system and provide the best and secure service available.

Aging fleet

The issue of aging aircraft, although not a new concern, became the subject of intense scrutiny by airlines, their regulators, manufacturers and the research community soon after the Aloha Airlines accident. Following is a description of what happened, as reported by the NTSB:

> "On April 28, 1988, a Boeing 737-200 operated by Aloha Airlines, Inc. experienced an explosive decompression and structural failure at 24,000 feet, while en route from Hilo to Honolulu, Hawaii. Approximately 18 feet from the cabin skin and structure aft of the cabin entrance door and above, passenger floorline separated from the aircraft during flight. There were 89 passengers and six crew members on board. One flight attendant swept overboard during the decompression was presumed fatally injured. The flight crew performed an emergency descent and landed at Kahului Airport, Maui. The National Transportation Board determined that the probable cause of this accident was the failure of the Aloha Airlines maintenance program to detect the presence of significant disbanding and fatigue

> damage, which ultimately led to failure of the lap joint and the separation of the fuselage upper lobe."(Special Report, 1989)

According to some experts, the Aloha accident is just an indication of the tragic events that may occur and which may engender more victims in the future. One cause of the aging aircraft situation, is the success of airlines themselves. Many must retain older aircraft in their fleets and pay the higher maintenance costs because they need the equipment to meet traffic demands. New aircraft are very expensive and delivery times are stretching toward the turn of the century. Another factor in extending aircraft operation is the emergence of new airlines in the developing countries which can not afford new aircraft and purchase older models, often without proper maintenance facilities or personnel to service them. With hundreds of transports reaching their design lifetimes in the 1990's, the carriers are facing difficult decisions.

Even aircraft manufacturers are surprised by how few aircraft are being retired each year. Boeing, for example, predicted that 250 to 300 aging transports would be retired in 1988; in fact the total was 60. This indicates that the life expectancy of many of the aircraft exceeded original design assumptions and some officials take this as evidence that the airlines and traveling public have confidence in the safety of older aircraft. However, as time passes, more labor intensive and costly maintenance and inspections will be necessary in order to ensure continuous safe operation of these machines. One of the consequences to emerge from this aging aircraft issue, is the potential shortage of facilities, trained personnel and parts that will be needed to meet the inspection and repair requirements (Special Report, 1989). This presents an opportunity for the private modification and repair centers as well as subcontractors to expand their capabilities to handle the expected surge of business. The question is, are the airlines prepared to spend more money to maintain this level of safety, or is another Aloha accident just waiting to happen ?

This has been the officials' concern for a number of years now and the industry seems to move in the right direction by setting up working groups to address the aging aircraft issue. Canada, with other ICAO member states, is participating in the effort to establish an international standard to maintaining older aircraft. The Airworthiness Branch of Transport Canada Aviation is engaged in a program of activities to improve the airworthiness of aging aircraft. The program includes activities specific to Canadian conditions as well as activities in support of or in parallel with the aging aircraft programs originating in the US. The areas of study are: measures to improve regulatory control of aircraft nondestructive testing (NDT), aging fleet evaluation projects, measures to address the airworthiness of aging Canadian-manufactured passenger aircraft, and many others (Didrikson, 1991).

One of the first programs put in place by Transport Canada Aviation was the Aging Aircraft Sampling Evaluation (AASE) project. Initiated in 1989, its goal was to survey the condition of older passenger aircraft in service in Canada by visiting repair and overhaul facilities to observe high time aircraft undergoing heavy maintenance. In recent years emphasis has been placed on commuter airplanes and the project has been extended to include Canadian-manufactured airplanes operated outside Canada. Also, Canadian-manufactured airplanes operated in other than passenger carrying roles, water bombers, for example, were included. Results of the study were most encouraging; the aging aircraft were in good condition even after a long regular scheduled service. A few returning problems were detected however; there was a lack of substantiation of some repairs and the existence of at least one rogue repair, such as patch upon a patch, on many of the inspected aircraft. These items are presently under further study. The final assessment will ultimately lead to the establishment of the degree of relevance of these problems and definition of steps to their elimination.

Another aging aircraft program established by TC has been progressing slowly, but some progress has been made in the last few years. The Canadian manufacturers' activities study involved the inspection of aircraft by Transport Canada officials and the original aircraft manufacturers. The combined expertise is used to revise and improve the corrosion prevention, control manual and other manufacturer and operators' manuals in order to perform the best preventive maintenance procedures possible. The preliminary work has been done with companies such as Douglas, Boeing and Lockheed.

In addition to regularly scheduled inspections program and the resulting improvements in procedures, the review is also trying to develop training courses for maintenance personnel as well as TC inspectors, to better service the high time aircraft. Major airlines are presently participating in the elaboration of such material on corrosion. Other activities presently under development include continued cooperation with the FAA in sponsoring the research and development of a novel nondestructive testing method. The D-sight method was originally developed by a Canadian company, and is being refined in the expectation that it will provide a useful tool for the detection of airframe corrosion.

Since the aging aircraft issue was first diagnosed and concrete measures were taken to deal with the impending problems, Canada has taken an active role in researching the relevant causes. Also, the establishment of specific programs to understand distinct Canadian conditions, such as frequency of use of the fleet, and the climate effect on flying equipment, clearly indicate the authorities' and other members' commitment to improved air travel safety.

C) Operational Environment

The Federal government is the key financial provider and project manager of the Canadian air transportation system. It assumed that role in the 1930's when Transport Canada was delegated the task of constructing, operating and maintaining air transport facilities. In order to support the established infrastructure, a number of Air Transportation Taxes were introduced. The first tax was levied on sales of airline tickets and freight charges. Subsequently, fuel excise tax was introduced on fuel purchases. In addition, airlines were required to pay for the use of facilities operated by Transport Canada. Although revenues from these tax collections have increased over the decades, so did aviation requirements.

In addition to regular maintenance and expansion of facilities, advances in technology and increasing awareness of safety issues as well as their resolution and promotion became of greater importance. In order to accommodate the growing demand of Canada's airports, Transport Canada initiated the recruiting and training of a large number of air traffic controllers, developed plans to construct new runways and scheduled privatization of airports through local airport authorities. Capital was essential for the everyday maintenance needs, as well as more elaborate safety programs, including RAMP and CAATS projects. The latter are described in more detail in the following sections.

Radar Modernization Project (RAMP)

The conventional control of air traffic relied on aircraft following their flight plan and pilots reporting their position accurately; any lack of precision in their area would obviously compromise the safe separation between aircraft. This situation was eased by the introduction of radar. It meant that the controller no longer had to rely on position reports from aircraft but could determine their location independently, provided radar coverage was available. In its early and simple forms, radar indicated the position of all aircraft within the area of coverage, but did not allow the controller to identify a particular aircraft. This problem was solved by the development of secondary surveillance radar (SSR). Radar however, suffered from the same limitation as VHF for communication and navigation; it has only limited range and there were, therefore, large areas of the world where radar coverage could not be provided.

In response to growing operating and support costs, together with forecasts of dramatic increases in commercial air traffic into the next century, Canada developed a comprehensive plan to modernize its entire Air Traffic System. This plan, the Canadian Airspace System Plan (CASP), was initiated in 1984 with the objectives of improving safety, capacity, productivity and economy through the use of greater automation, by consolidating services and facilities, and by the application of new technologies to reduce air traffic control system operating costs and provide wider coverage of space.

One of the components of this most enterprising, large scale, government sponsored aviation safety improvement project was the Radar Modernization Project (RAMP). Its main objective was to replace the antiquated radar and display systems installed across Canada with new state of the art equipment.

The need to plan gradual replacement of the radar and display systems became obvious in the late seventies. An essential element of the air traffic control system is the surveillance of aircraft by radar. The first radar were installed in Canada between 1958 and 1961. The sky's surveillance was provided by strategically placed radar systems located in more than 30 air traffic control facilities across the country. Primary surveillance radar (PSR) sent out a signal which bounced off an aircraft and was reflected back and displayed on a screen as a blip. Secondary surveillance radar (SSR) transited a coded signal to activate equipment on the aircraft which replied with coded messages which then permitted that aircraft to be identified. Between 1975 and 1978 additional radar were purchased and installed at key airports.

But all of Canada's air traffic surveillance radar, like those of many nations at the time, were based on a vacuum-tube technology. Although safe and efficient, their capacity to respond to new operational requirements was limited. In addition, the cost of maintaining the equipment in place was rising rapidly and modern technology was allowing for better and cheaper techniques and methods to be applied in order to enhance the Canadian air transport system. The need for improved equipment was further reinforced by the findings of the Dubin Inquiry into aviation safety in 1982. The commission recommended that speedy modernization of the radar network, to ensure an efficient and current air navigation service into the next century, was of highest priority.

Following the world-wide approval of Operational Requirements and Technical Specification documents, the project team was formed and by mid 1985, the development of manufacturing contract for the necessary Radar Site Equipment (RSE), Display Site Equipment (DSE) and Radar Data Processing System (RDPS) was awarded to Raytheon Canada Ltd./Raytheon Company. The plan called for the purchase of 39 new, state of the art radar systems which would incorporate the latest in hardware and software technologies. While the old system used vacuum-tube technology, RAMP radar would use solid state and computer technology involving considerable data processing at the radar site. The entire system would provide more accurate information, especially in terms of aircraft position. In addition to the new radar, 29 radar processing and display systems were bought by Transport Canada. These display systems also used modern, state of the art computer technology by combining aircraft position data from the radar with flight plan data and then displaying all this essential information onto air traffic control display screens. All the vital parts, in other words, were brought together to form a composite picture of a safe, reliable and accurate air traffic control system.

The effort and money invested in the RAMP project translated into many advantages for the entire country, not only from the safety point but also economic point of view. Without an efficient radar system, the major airports and the national air transportation system would work at only a fraction of their potential with resultant delays and cost. Modernization improved air travel by allowing more direct flights, which reduce flying time, and by providing more precise information on air traffic and on hazardous weather conditions. This meant fewer delays for the traveling public due to more timely aircraft arrivals and departures, as well as comfortable flights while avoiding bad weather regions. Overall, the movement of aircraft became more efficient. RAMP also gave a greater capability to accommodate international aviation and the demands it makes for increased automation of air-ground exchange of weather information, flight plans and air traffic control data.

Canadian Automated Air Traffic System (CAATS)

Another vital component of the Canadian Airspace System Plan is the Canadian Automated Air Traffic System. In the same manner as RAMP integrated a wide range of radar capabilities, CAATS will upgrade the flight data processing facilities and will integrate a number of functions presently provided by separate systems.

The need for the CAATS project stems from the fact that, although Canada has a comparatively small population of only about 25 million people, its very large land area and a vast airspace of 5.8 million square miles, encompass both domestic and international aviation responsibilities. The majority of the population and consequently the major airports and busy terminals are located in the southern part of the country. This corridor is well served by radar-sites, following the recent radar modernization program (RAMP, described above). However, northern and oceanic regions are largely without radar coverage. In addition, much of the land mass is far from maintenance and support centers and the terrain makes access difficult.

CAATS will provide the Canadian ATC system with improved capacity, productivity and efficient operations while maintaining or improving safety through the use of increased automation. In late 1989 Transport Canada awarded the contract to Hughes Aircraft of Canada Limited. The prime contractor for this development task is Hughes Canada Systems Division (HCSD) from Richmond, B.C. Specific project objectives are to upgrade current ATS control centers, towers, remote terminal control units, support centers and other facilities. Also, CAATS is to provide timely generation and distribution of accurate flight data, automated data exchange with other ATC units, common display of radar and flight plan data, conflict prediction and resolution, as well as electronic flight strips, all within the constraints of controller/maintainer usability, system safety, and cost-benefit improvement over the current system. The new system is to be designed to support ATC operations by taking on the labor intensive tasks intrinsic to ATC, by furnishing information on a timely basis so that controllers have data when it is needed and by providing warnings and alerts that will help ensure the safe and expeditious flow of air traffic.

By assuming time-consuming and burdensome tasks such as flight plan and route analysis, elapsed time calculations, flow control calculations and routine data communications, CAATS will help give controllers more time to consider critical decisions; and this, together with automated flight progress monitoring, and conflict detection, prediction and resolution, will help provide more capacity to handle routine traffic.

Transport Canada has estimated that CAATS will provide great operational savings distributed amongst the users and the government of Canada. Additional benefits to users will include savings when delays due to sector capacity restraints in the existing system are alleviated by CAATS, and reduced flying times through the use of optimum routes. The new system will provide real-time flight data processing through transfer of data to and from Canadian and International Air Traffic Services units, airlines, general aviation and other agencies. Controller traffic handling capacities will be increased by the introduction of state of the art workstations, modern communication links, and advanced automation tools. However, the controller will retain the function of the decision maker in providing control services. The centralized control and monitoring functions provided will also boost the efficiency of engineering staff while servicing the equipment.

Despite the large growth in the number of passengers and aircraft traffic, the described projects, among many others, although requiring substantial capital expenditures, contributed, and will in the future, to an increased level of safety at Canadian airports and high above the ground. Being the world leader in safety issues, it is only fitting that Canada be the initiator, developer and user of the latest advances in research and technology, to pave the way toward the 21-st century space travel.

FINAL CONCLUSIONS

The objective of this paper was to study, in detail, the safety record of the Canadian commercial aviation industry using accident rates data for the period from 1976 to 1993.

The historical overview of Canada's aviation industry showed a legacy of great technological and economic market development, as well as the public's ready acceptance of this new mode of transportation. The rapid growth in the industry was also accompanied by the continuous search for improving the safety of its passengers and operators with the advent of faster, better ,and more numerous, aircraft.

Closer analysis of this safety record, using aggregate accidents, fatalities and injuries, normalized by the number of departures, hours flown, passenger-kilometers, as well as enplanements, confirmed the continuing downward trend of the risk of air travel. In addition to assessing the dangers of flight, a closer look at specific aviation accidents revealed the prominent causes of such incidents. The analyzed raw data pointed to the effect of regional differences, types of equipment flown, as well as level of air carrier, among others, as providing more opportunity to the occurrence of accidents.

Subsequent detailed research and analysis of the factors directly affecting air travel safety, revealed a specific grouping of variables, reflecting the particular aspects of air travel safety. Natural and operational environments and human errors were all confirmed as significant elements of safe flight. In addition, crew experience and phase of flight, emerged as distinct and greatly influential factors. Therefore, they should be given more consideration as contributors to air travel accident causes in future studies. The exploratory analysis was useful in that it reinforced previous beliefs in distinct safety factors and in ascertaining other equally important elements which may have previously been given less weight in studying accident causes.

The last section applied the methods of regression analysis to the studied factors and demonstrated the value of using variables directly related to flight, as opposed to economic indicators. The design of the models predicting the rate of total and fatal yearly accidents was established based on 100,000 departures, as well as per 100,000 hours flown. The final results pointed to the close relationship between flight variables and flight safety. The suggested models accurately predicted the risk of air travel be it for the rate of total accidents or that of fatal accidents in Canada each year. Finally, the study of the effect of deregulation on these rates of safety provided no substantial support for the view that safety levels will drastically deteriorate in the era of economic deregulation. So far, the downward trend of accidents has been maintained by Canadian carriers over the years.

MAIN CONTRIBUTIONS

The main contribution of this paper to the overall study of aviation safety was the introduction of scientific and quantifiable proof of the existence of distinct factors as causes of aviation accidents. Although studies have been conducted as to the safety of air travel, not one of them tried to assess if the generally held assumption of safety factors was statistically true.

Also, the assessment of risk of flight, with the use of multiple measures of safety, duplicates results previously obtained by American studies, but largely omitted from Canadian literature. The overall safety study underlined the need for more research into the field of aviation, where so far, only tables of raw data are available. There has been very limited attempt at explaining the meaning and potential consequences of the available raw statistics on Canadian aviation accidents, and especially providing specific recommendations for making improvements to air safety in this country.

Finally, the designed model for predicting total and fatal yearly accidents in Canada was based on specific flight-related variables as defined by the factor analysis model. Up to this point, all research concerned itself with evaluating safety by means of economic indicators. The new set of variables presented a deviation from econometric models generally used in transport-related modeling. The direct relationship between the studied variables and the resulting accidents, pointed more readily to the areas in need of improvements.

SUGGESTIONS FOR FURTHER RESEARCH

Although this paper presented a new approach to studying safety issues, there are areas where an improvement in methodology or research would offer even greater benefits.

The main lessons learned from conducting this research and which should be evaluated in the following studies is the importance of collecting additional variables; those omitted in the developed models. There is certainly room for improvement in the way aviation-related data is being collected and the degree of detail recorded. Accident information on such variables as distance covered and time elapsed from takeoff at the time of the accident, number of years an aircraft was in operation and in service with the particular airline, specific flight environment conditions, as well as carrier maintenance record and participation in safety programs (for a complete list of variables omitted from this study due to lack of information see chapter four). Such data is not readily available, if at all collected by the TSB today. International organizations such as ICAO should not only provide general guidelines but also be more pro-active in enforcing standardized methods of collecting and registering accidents, as well as economic aviation information. The advantages of a more complete set of information in this field would definitely improve on research results, not to mention a better understanding of the true degree of safety provided by all sectors of aviation in all countries.

With respect to the proposed regression models, a Poisson distribution model should be evaluated, in order to predict not only the rates of accidents per year, but also their expected time of occurrence. Such a model would greatly benefit the public and the airlines in scheduling the trips as well as down periods for maintenance and servicing of aircraft.

As well, exact probabilities could be calculated based on various accident inducing variables in order to develop a decision diagram for travelers to use in deciding among various modes of transport. Exact evaluation of risk would help travelers make informed decisions and alleviate some of the anxiety of flight. It would also point directly to the areas needing more industry and regulatory efforts in promoting flight safety.

REFERENCES

Airline Deregulation, International Experiences, edited by Kenneth Button. David Fulton Publishers. London, Great Britain, 1991.

Aviation in Canada: Historical and Statistical Perspectives on Civil Aviation, published by the authority of the Minister responsible for Statistics Canada, Catalogue No. 51-501E, 1986 and 1993 editions, Ottawa.

Baldwin, J.R., The regulatory agency and the public corporation, Cambridge, Mass., Ballinger, 1975.

Brancker, J.W.S., IATA and what it does, AW Sijthoff, Leyden, 1977.

Campbell R.D., Flight Safety in General Aviation, Collins Professional Books, Great Britain, 1987.

Commercial Pilot Survey (1991), Levels III to VI Air Carrier Operations, prepared by Accident Prevention Branch, TSB, Ottawa, Canada, 1991.

Didrikson, S.R., "Transport Canada aging aircraft activities", presented at the 1991 International Conference on Aging Aircraft and Structural Airworthiness in Washington, D.C.

Dubin, C.L., Report of the Commission of Inquiry on Aviation Safety, Vol.1, Ottawa, 1981.

Filotas Les, Improbable cause; Dissent and Deceit in the Investigation of Canada's Worst Air Disaster, McClelland-Bantam, Inc., Toronto, 1991.

Flury, Bernhard, Riedwyl, Hans, Multivariate Statistics - A Practical Approach,Chapman and Hall, USA, 1988.

From the Ground Up, Aviation Publishers Co. Ltd., Ottawa, Twenty-sixth revised edition, 1991.

Fuller, G.A., Griffin, J.A., Molson, K.M, 125 years of Canadian Aeronautics: A Chronology of 1840-1965, The Canadian Aviation Society, T.H. Best Printing Co. Ltd., Willowdale, Canada, 1983.

Gillen David W., Oum Tae H., Tretheway Michael W., Canadian Airline Deregulation and Privatization: Assessing Effects and Prospects, Centre for Transportation Studies, University of British Columbia, Vancouver, 1985.

Green, Paul E., Analyzing Multivariate Data, The Dryden Press, Hinsdale Il, USA, 1978.

Greig J.A. Regional air carrier safety. Report #40-77-2. Ottawa. Canadian Transportation Commission. 1977.

Harman, Harry H., Modern Factor Anlysis, The University of Chicago Press, Chicago. USA. 1960.

Harris, Richard J., A Primer of Multivariate Statistics, Academic Press. USA. 1975.

Hurst Ronald and Leslie R., Pilot Error, The Human Factors, Granada, Great Britain. 1982.

International Air Transport in the Eighties, Proceedings of The First Netherlands Colloquium on International Air Transport, Wassenaar, August 25-29, 1980, Kluwer Law and Taxation Publishers, Deventer, The Netherlands, 1981.

International Civil Aviation Organization, Annual Report of the Council - 1990, ICAO. Canada, 1992.

Kleibaum, David G., Kupper, Lawrence L., Muller, Keith E., Applied Regression Analysis and Other Multivariable Methods, PWS-Kent Publishing Company, Boston, USA, 1988.

Lauber, John K., Foushee, H. Clayton, "Guidelines for line-oriented flight training", Vol. 1, Proceedings of a NASA/Industry Workshop held at NASA Ames Research Centre, Moffett Field, California, Jan. 13-15, 1981, pp.1-9.

Manly, Bryan F.J., Multivariate Statistical Methods - A Primer, Chapnam and Hall, USA.

Marriott, F.H.C., The Interpretation of Multiple Observations, Academic Press, USA, 1974.

Marx Joseph Laurance, Crisis in the Skies, David McKay Company, Inc., New York, 1970.

Measurement of Safety Effectiveness - Air, University of Montreal, Canada, 1993.

Milberry, L., Aviation in Canada, McGraw-Hill Reyson Ltd., Canada, 1979.

National Transportation Agency of Canada, Annual Report 1992, Minister of Supply and Services Canada. 1993.

Neter, John, Wasserman, William, Kutner, Michael H., Applied Linear Statistical Models - Regression, Analysis of Variance and Experimental Designs, Irwin, USA, 1985.

Odegard, John, "Expert pilots can be cultivated through a shift in the way students are taught", ICAO Journal, Vol. 49, No. 3, April 1994, pp.11-14.

Orlady, Harry W., "Airline pilot training programs have undergone important and necessary changes in the past decade", ICAO Journal, Vol. 49, No. 3, April 1994, pp.5-10.

Oslund, John J., "Leadership Qualities", The Ottawa Citizen, Saturday, June 18, 1994, Worklife Section.

Oster Jr. Clinton V., Strong John S., "The Worldwide Aviation Safety Record", The Logistics and Transportation Review, Faculty of Commerce and Business Administration of the University of British Columbia, Vancouver, Canada, Vol. 28, No. 1, March, 1992.

Oster Clinton V. Jr., Strong John S., Zorn Kurt C., Why Airplanes Crash, Aviation Safety in a Changing World, Oxford University Press, New York, 1992.

Oster Clinton V. Jr., Zorn C. Kurt, Airline Deregulation: Is it still safe to fly?, Transportation Research Center, Indiana University, USA, 1987.

Perrow Charles, Normal Accidents, Living with High-Risk Technologies, Basic Books, Inc., New York, 1984.

Ramsden J.M., The Safe Airline, Macdonald and Jane's Ltd., Great Britain, 1976.

Reschenthaler, G.B., Roberts, B., Perspectives on Canadian airline regulation, Buttrrworth & Co, Canada, for the Institute for Research on Public Policy, Montreal, 1979.

Rose Nancy L., "Financial influences on airline safety", MIT, USA, 1987.

Statistics Canada, Aviation Statistics Centre, Canadian commercial aviation economic data, 1976-1993.

Special report: The world airline fleet grows older,"Aging aircraft issue presents major challenge to industry", Aviation Week & Space Technology, July 24, 1989.

Taylor Laurie, OBE, FRAeS, Air Travel, How safe is it ?, BSP Professional Books, Great Britain, 1988.

Telfer, Ross W., "Teaching of human factors to the ab initio student pilot", ICAO Journal, Vol. 48, No. 7, September, 1993, pp. 10 - 13.

Tench, W.H., Safety is no accident, Collins, London, UK, 1985.

Transport Canada, 1993-1994 Estimates, Part III, Expenditure Plan, Minister of Supply and Services Canada, 1993.

Transportation Safety Board Canada, 1992-1993 Estimates to the Treasury Board of Canada, Part III, Expenditure Plan, Minister of Supply and Services, 1992.

Transportation Safety Board of Canada, Annual Report 1992, Minister of Supply and Services Canada, 1993.

Transportation Safety Board, Canadian commercial aviation accidents data set, 1976-1993.

Transportation Safety Board, TSB Statistical Summary - Air Occurrences 1993, Ottawa, 1993.

Transportation Safety in an Age of Deregulation, edited by Moses Leon N., Savage Ian, Oxford University Press, New York, 1989.

Weiner, Earl L., "Cockpit resource management and flight training for the advanced-technology cockpit", ICAO Journal, Vol. 48, No. 7, Sept. 1993.

Wetherill, Barrie G., Regression Analysis with Applications, Chapman and Hall, USA, 1986.

Wilson, J.A., Development of Aviation in Canada, 1879-1948, Dept. of Transport, Air Services Branch, Canada, 1948.

ANNEX A

SELECTED LISTING OF AVIATION ORGANIZATIONS IN CANADA[*]

AEROSPACE INDUSTRIES ASSOCIATION OF CANADA (1962)
60 Queen Street, Suite 1200
Ottawa, Ontario, K1P 5Y7
Tel: (613) 232-4297

AIR TRANSPORT ASSOCIATION OF CANADA (ATAC, 1934)
747 Metropolitan Life Building
99 Bank Street
Ottawa, Ontario, K1P 6B9
Tel: (613) 233-7727

CANADA'S AVIATION HERITAGE FUND
c/o Reynolds-Alberta Museum
P.O. Box 6360
Wetaskiwin, Alberta, T9A 2G1
Tel: (403) 361-1351

CANADIAN AERONAUTICS & SPACE INSTITUTE (CASI, 1954)
130 Slater Street, Suite 818
Ottawa, Ontario, K1P 6E2
Tel: (613) 234-0109

CANADIAN AIR TRAFFIC CONTROL ASSOCIATION (CATCA, 1959)
162 Cleopatra Drive
Nepean, Ontario, K2G 5X2
Tel: (613) 225-3553

---

[*] For more on Canadian and International aviation organizations consult the following sources:
(1) Canadian Almanach & Directory, 1994
(2) Canadian Transportation Logistics Guide, July, 1992
(3) Aviation and Aerospace Directory and Buyers Guide, March/April, 1993
(4) World Aviation Directory, Winter 1993.

CANADIAN AIRPORTS COUNCIL (CAC, 1991)
1100 Rene-Levesque Blvd. West
Montreal, Quebec, H3B 4X8
Tel: (514) 394-7200

CANADIAN AVIATION HISTORICAL SOCIETY (CAHS, 1963)
P.O. Box 224, Stn A
North York, Ontario, M2N 5S8
Tel: (416) 488-2247

CANADIAN AVIATION INSURANCE MANAGERS LTD.
Royal Bank Plaza, South Tower
200 Bay Street, Suite 2450
Toronto, Ontario, M5J 2J1
Tel: (416) 865-0252

CANADIAN AVITION MAINTENANCE COUNCIL (CAMC, 1991)
955 Green Valley Cr., Suite 330
Ottawa, Ontario, K2C 3V4
Tel: (613) 727-8272

CANADIAN BUSINESS AIRCRAFT ASSOCIATION (CBAA, 1961)
50 O'Connor Street, Suite 1317
Ottawa, Ontario, K1P 6L2
Tel: (613) 236-5611

CANADIAN OWNERS & PILOTS ASSOCIATION (COPA, 1952)
75 Albert Street, Suite 1001
Ottawa, Ontario, K1P 5E7
Tel: (613) 236-4901

CANADIAN SOCIETY OF AIR SAFETY INVESTIGATORS
1900 Markwell Cres.
Orleans, Ontario, K1C 5E4
Tel: (613) 837-0814

CIVIL AVIATION TRIBUNAL
344 Slater Street, Suite 405
Ottawa, Ontario, K1A 0N5
Tel: (613) 998-1275

INSTITUTE FOR AEROSPACE STUDIES (UTIAS, 1949)
University of Toronto
4925 Dufferin Street
Dowmsview, Ontario, M3H 5T6
Tel: (416) 667-7701

INTERNATIONAL AIR TRANSPORT ASSOCIATION (IATA, 1945)
1000 Sherbrooke Street West
Montreal, Quebec, H3A 2R2
Tel: (514) 844-6311

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO, 1947)
1000 Sherbrooke Street West
Montreal, Quenec, H3A 2R2
Tel: (514) 285-8219

NATIONAL TRANSPORTATION AGENCY OF CANADA (NTA)
Ottawa, Ontario, K1A 0N9
Tel: (819) 997-0677

NATIONAL AVIATION MUSEUM
Rockliffe Airport
P.O. Box 9724
Ottawa, Ontario, K1G 5A3
Tel: (613) 993-2010

RECREATIONAL AIRCRAFT ASSOCIATION CANADA (RAAC, 1983)
152 Harwood Ave.
South Ajax, Ontario, L1S 2H6
Tel: (905) 683-3517

ROYAL CANADIAN AIR FORCE ASSOCIATION
P.O. Box 2460, Stn. D
Ottawa, Ontario, K1P 5W6
Tel: (613) 992-7482

THE DE HAVILLAND MONTH CLUB OF CANADA (1981)
305 Old Homestead Rd.
Keswick, Ontario, L4P 1E6
Tel: (905) 476-4225

TRANSPORTATION SAFETY BOARD (TSB, 1990)
Alta Vista Terminal
P.O. Box 9120
Ottawa, Ontario, K1G 3T8
Tel: (819) 994-3741

Government references:
ENERGY, MINES & RESOURCES CANADA (EMR)
Canada Map Office
615 Booth Street
Ottawa, Ontario, K1A 0E9
Tel: (613) 952-7000

INDUSTRY, SCIENCE & TECHNOLOGY CANADA (ISTC)
Aeronautics Branch
235 Queen Street
Ottawa, Ontario, K1A 0H5
Tel: (613) 954-3145

NATIONAL DEFENCE HEADQUARTERS (ND)
General Inquiries
MGen George R. Pearkes Bldg.
12th floor, CBN
Ottawa, Ontario, K1A 0K2
Tel: (613) 995-2534

NATIONAL RESEARCH COUNCIL CANADA (NRC)
Institute for Aerospace Research
Montreal Road
Ottawa, Ontario, K1A 0R6
Tel: (613) 993-0141

STATISTICS CANADA (SC)
Aviation Statistics Centre (ASC)
15 Eddy St. 16th floor
Hull, Quebec,
Tel: (613) 951-8116

PUBLIC WORKS & GOVERNMENT SERVICES
(formerly SUPPLY AND SERVICES CANADA, SSC)
Aerospace, Marine & Electronics Systems
Ottawa, Ontario, K1A 0S5
Tel: (613) 956-0010

TRANSPORT CANADA (TC)
Transport Canada Aviation
Ottawa, Ontario, K1A 0N8
Tel: (613) 990-3888

ANNEX B

MEGA-CARRIERS AND THEIR AFFILIATES

Passenger Operations	Airline-related Businesses
Air Canada	
- Air Nova Inc. (100%)	- Galileo Canada
- AirBC Limited (85%)	- Touram Inc. (100%)
- Air Ontario Inc. (75%)	- Express Messenger Syst. Inc. (38%)
- Air Alliance Inc. (75%)	- Dynamex Express Inc. (100%)
- Continental Airlines Inc. (24.5%)	- GPA Group plc (Ireland) (10.2%)
- Northwest Territorial Airways Ltd. (100%)	- Air Canada's cargo operations
	- maintenance, ground & other services
Canadian Airlines International Limited	
- Air Atlantic Ltd. (45%)	- Canadian Holidays Ltd. (100%)
- Calm Air International Ltd. (45%)	- Transpacific Tours Can.Ltd.(100%)
- Inter - Canadien Inc. (70%)	- GPA Airbus Ltd. (25%)
- Canadian North (100%)	- AMR (Sabre)
- Canadian Regional Airlines Ltd. (100%) (comprised of: Canadian regional, Time Air, Ontario Express, and Canadian Frontier)	

Source: Air Canada Share Offering Prospectus of 25 November 1993, NTA: Annual Review 1992.

ANNEX C

AIR CANADA, CANADIAN AND THEIR AFFILIATES' MARKET SHARE

Year		1988	1989	1990	1991	1992
Air Canada						
Passengers	'000	13,680	13,693	12,971	10,879	10,855
Market Share	%	45.33	44.55	42.74	41.67	41.35
Passenger-km	'000	22,810,591	23,910,081	24,504,026	20,300,363	21,454,150
Market Share	%	46.92	48.11	48.89	47.68	47.60
Available Seat-km	'000	32,298,044	34,760,746	34,821,303	30,065,131	32,579,750
Load factor	%	70.63	68.78	70.37	67.52	65.85
Hours		341,895	361,138	354,395	318,878	334,844
Passenger-Revenue	$'000	2,349,114	2,550,570	2,670,875	2,280,641	2,244,886
Market Share	%	47.45	47.14	46.29	43.02	42.54
Yield	$	0.103	0.107	0.109	0.112	0.105
Air Canada Connectors						
Passengers	'000	2,282	3,389	4,065	3,698	3,838
Market Share	%	7.56	11.03	13.39	14.17	14.62
Passenger-km	'000	819,128	1,250,784	1,687,873	1,620,007	1,685,089
Market Share	%	1.69	2.52	3.37	3.81	3.74
Available Seat-km	'000	1,614,018	2,812,815	3,429,774	3,590,484	3,610,430
Load factor	%	50.75	44.47	49.21	45.12	46.67
Hours		132,455	167,839	207,564	212,383	230,714
Passenger-Revenue	$'000	201,454	330,175	444,052	452,912	459,278
Market Share	%	4.07	6.10	7.70	8.54	8.70
Yield	$	0.246	0.264	0.263	0.280	0.273
Canadian Airlines International Limited						
Passengers	'000	8,814	7,675	8,550	7,257	7,355
Market Share	%	29.21	24.97	28.17	27.80	28.02
Passenger-km	'000	17,924,523	17,521,416	21,623,624	18,582,117	19,817,081
Market Share	%	36.87	35.26	43.15	43.65	43.97
Available Seat-km	'000	25,936,602	25,353,673	32,190,163	29,775,893	30,063,243
Load factor	%	69.11	69.11	67.17	62.41	65.92
Hours		282,454	254,813	299,637	269,359	266,513
Passenger-Revenue	$'000	1,712,036	1,674,266	2,115,599	2,037,852	2,061,002
Market Share	%	34.58	30.95	36.66	38.44	39.06
Yield	$	0.096	0.096	0.098	0.110	0.104
Canadian Partners						
Passengers	'000	2,203	3,087	2,590	2,939	3,029
Market Share	%	7.30	10.04	8.53	11.26	11.54
Passenger-km	'000	839,116	1,151,930	1,023,949	1,109,956	1,410,678
Market Share	%	1.73	2.32	2.04	2.61	3.13
Available Seat-km	'000	1,863,640	2,961,461	2,352,021	2,796,879	3,036,539
Load factor	%	43.85	42.87	44.07	43.98	46.46
Hours		126,557	212,667	173,976	184,907	202,971
Passenger-Revenue	$'000	200,045	314,594	272,699	343,341	352,498
Market Share	%	4.04	5.81	4.73	6.48	6.68
Yield	$	0.238	0.273	0.266	0.309	0.250

Sources: Statistics Canada: Catalogue No. 51-206.

ANNEX D
ADDITIONAL COMPUTER PRINTOUTS

1) EXPLORATORY FACTOR ANALYSIS OUTPUT

```
- - - - - - - - - - - - - - - - - - - - - - - -  F A C T O R   A N A L Y S I S  - - - - - - - - - - - - - - - - - - - - - - -

ANALYSIS NUMBER 1   LISTWISE DELETION OF CASES WITH MISSING VALUES

EXTRACTION  1  FOR ANALYSIS  1, PRINCIPAL-COMPONENTS ANALYSIS (PC)

   PC EXTRACTED    9 FACTORS.

VARIMAX   ROTATION  1  FOR EXTRACTION  1  IN ANALYSIS  1 - KAISER NORMALIZATION.

  VARIMAX CONVERGED IN    18 ITERATIONS.

FACTOR SCORE COEFFICIENT MATRIX:

              FACTOR  1    FACTOR  2    FACTOR  3    FACTOR  4    FACTOR  5    FACTOR  6    FACTOR  7    FACTOR  8

LEV12           .03090       .13276       .02453       .00311     -.03560       .44341       .02092     -.12522
LEV34           .07994       .06313       .01891       .08072      .05615     -.58301      -.06616     -.10056
ENG12          -.06868       .00323       .07775       .16742      .07695       .00488       .09547     -.12897
IFR             .34186      -.12524      -.04955      -.05887      .09462       .11314      -.03823      .00091
COMMLIC         .29592       .02926      -.01777       .00396     -.02417      -.10787       .05018      .06304
CARRIER         .31995       .01855       .00826      -.03874     -.01571      -.09182       .02774      .02941
AGE35          -.01690      -.07041      -.01175       .04900     -.02836      -.06631      -.48839     -.20641
AGE45           .03367      -.15726      -.02962       .06512      .00662       .05328       .59090     -.03125
SUMMER         -.00569      -.06533       .03862       .07053      .03469       .03638       .06802      .60408
DAY            -.25659       .17813      -.05086       .01125     -.02462       .00885       .04952      .26635
EAST           -.17549       .04251       .09441       .27201      .10966      -.04092       .20504     -.23140
HILL           -.02489       .02624       .49412       .06341      .01744       .00731      -.01250      .01651
FLAT            .02126      -.02465      -.49595      -.06857     -.02834      -.00395       .00660     -.00904
TAKEOFF         .02093       .04002       .02638       .15384      .62328      -.06300       .00490      .04931
FLY             .03923      -.06758      -.01567      -.59246     -.08677       .07133      -.00472     -.03280
LANDING  .     -.06188       .00632       .03467       .39761     -.44244      -.01379       .01827      .01922
WHEEL           .24061      -.28659       .04891       .18979      .16548       .22239      -.16516      .36272
T_PLT_HR        .00763       .26862      -.01927      -.04178     -.03890      -.14296      -.09158      .25106
PLT_TYPH       -.10664       .40440       .03428       .02032     -.00567      -.05078      -.05604     -.01113
T_CO_HR         .07391       .17510      -.03135       .06125      .00348       .10018       .10203     -.18817
CO_TYP_H       -.05575       .33198       .05174       .07658      .14025       .13808       .02469     -.17578
```

```
               FACTOR  9

LEV12          -.00804
LEV34          -.01898
ENG12           .68167
IFR            -.16684
COMMLIC         .11465
CARRIER         .10323
AGE35           .05061
AGE45           .03585
SUMMER         -.02706
DAY             .11588
EAST           -.57552
HILL            .02600
FLAT           -.02579
TAKEOFF         .03532
FLY            -.04137
LANDING         .03466
WHEEL           .01704
T_PLT_HR       -.16124
PLT_TYPH       -.08709
T_CO_HR         .12270
CO_TYP_H        .15202

COVARIANCE MATRIX FOR ESTIMATED REGRESSION FACTOR SCORES:

             FACTOR  1   FACTOR  2   FACTOR  3   FACTOR  4   FACTOR  5   FACTOR  6   FACTOR  7   FACTOR  8   FACTOR  9
FACTOR  1     1.00000
FACTOR  2      .00000     1.00000
FACTOR  3      .00000      .00000     1.00000
FACTOR  4      .00000      .00000      .00000     1.00000
FACTOR  5      .00000      .00000      .00000      .00000     1.00000
FACTOR  6      .00000      .00000      .00000      .00000      .00000     1.00000
FACTOR  7      .00000      .00000      .00000      .00000      .00000      .00000     1.00000
FACTOR  8      .00000      .00000      .00000      .00000      .00000      .00000      .00000     1.00000
FACTOR  9      .00000      .00000      .00000      .00000      .00000      .00000      .00000      .00000     1.00000
```

```
ANALYSIS NUMBER 2   LISTWISE DELETION OF CASES WITH MISSING VALUES
                 MEAN      STD DEV   LABEL

LEV12          .07718       .26733
LEV34          .61745       .48683
ENG12          .97987       .14070
IFR            .23826       .42673
COMMLIC        .67114       .47059
CARRIER        .61745       .48683
AGE35          .18456       .38860
AGE45          .40604       .49192
SUMMER         .42282       .49484
DAY            .83557       .37129
EAST           .54698       .49863
HILL           .26510       .44213
FLAT           .73154       .44390
TAKEOFF        .21141       .40899
FLY            .20805       .40660
LANDING        .51678       .50056
WHEEL          .91275       .28267
T_PLT_HR   3796.44060   4435.23489
PLT_TYPH   1142.47987   1829.93064
T_CO_HR    1265.64530   2362.77602
CO_TYP_H    361.56141   1370.38197

NUMBER OF CASES  =      298


CORRELATION MATRIX:

               LEV12       LEV34       ENG12         IFR     COMMLIC     CARRIER       AGE35       AGE45      SUMMER         DAY        EAST        HILL

LEV12        1.00000
LEV34        -.36741     1.00000
ENG12        -.13758     -.01452     1.00000
IFR           .28099      .03503     -.14415     1.00000
COMMLIC       .17568      .22795     -.10034      .35795     1.00000
CARRIER       .22764      .26125     -.11283      .44021      .71295     1.00000
AGE35        -.00794      .01851      .06820     -.04272     -.25616     -.26625     1.00000
AGE45        -.13670      .11653      .06987     -.01329      .04061      .03218     -.39335     1.00000
SUMMER       -.04390     -.01116     -.02240     -.06410     -.00815     -.03912     -.07450      .02544     1.00000
DAY          -.07524     -.08839      .06532     -.30443     -.19490     -.23741     -.09233     -.09409      .21475     1.00000
EAST          .01060     -.00894     -.03447      .05007     -.12048     -.14764      .03330      .07983     -.03984     -.05816     1.00000
HILL         -.00277      .05039     -.02216     -.01467      .03204      .09732     -.08977     -.01668      .02458     -.12327     -.00323     1.00000
FLAT          .00495     -.05615      .02099      .01885     -.03721     -.10289      .09301      .00745     -.01800      .13985     -.00368     -.99146
```

```
                 LEV12     LEV34     ENG12       IFR   COMMLIC   CARRIER     AGE35     AGE45    SUMMER       DAY      EAST      HILL

TAKEOFF        -.05735    .01861    .07422   -.03878   -.12739   -.13358    .00789   -.04319    .00603    .07443    .07496   -.14340
FLY            -.11725   -.02180    .01462   -.09260   -.11633   -.05582   -.11599    .06440    .01314    .02664   -.09820    .23150
LANDING         .10352    .01261   -.04300    .06792    .16644    .15078    .06192    .00642    .01204   -.08475    .01032   -.05820
WHEEL           .08941   -.14549   -.04432    .17291    .01138    .00131    .14709   -.10758   -.00016   -.10507    .00529   -.02983
T_PLT_HR        .10710    .07747   -.14281    .14540    .33121    .27637   -.29694   -.18683    .10396    .06922   -.10297   -.01235
PLT_TYPH        .25195    .02448   -.11439    .12743    .19957    .23245   -.18865   -.13424    .04611    .02656   -.08841   -.00713
T_CO_HR         .30354    .06301   -.11981    .22751    .35190    .27201   -.09791    .02682   -.05203   -.04226   -.04959   -.07472
CO_TYP_H        .29485   -.05681   -.06829    .16732    .16234    .18918   -.07810   -.07801    .01180    .00238   -.07013   -.03939

                  FLAT   TAKEOFF       FLY   LANDING     WHEEL  T_PLT_HR  PLT_TYPH   T_CO_HR  CO_TYP_H

FLAT           1.00000
TAKEOFF         .12820   1.00000
FLY            -.28646   -.26538   1.00000
LANDING         .06580   -.53545   -.53005   1.00000
WHEEL           .02737    .07271   -.22237    .12936   1.00000
T_PLT_HR        .01752   -.06205   -.04640    .06480   -.00854   1.00000
PLT_TYPH        .00875   -.02079   -.06927    .03274   -.05351    .46148   1.00000
T_CO_HR         .06847   -.05858   -.14238    .07668    .03588    .16216    .16897   1.00000
CO_TYP_H        .03996    .10348   -.07185   -.01720    .01204    .18479    .34667    .29005   1.00000

DETERMINANT OF CORRELATION MATRIX =      .0000916

INVERSE OF CORRELATION MATRIX:
                 LEV12      LEV34      ENG12        IFR    COMMLIC    CARRIER      AGE35      AGE45     SUMMER

LEV12          1.63246
LEV34           .71133    1.50878
ENG12           .09913     .06538    1.07054
IFR            -.19323     .01852     .07717    1.47704
COMMLIC         .01651    -.11542    -.03255    -.07347    2.30602
CARRIER        -.34458    -.48176    -.00716    -.49744   -1.33752    2.57017
AGE35          -.14635    -.35989    -.09756    -.06122     .15798     .37023    1.70458
AGE45           .06131    -.21069    -.09825    -.02293    -.00362     .12072     .78935    1.48929
SUMMER          .03057     .01533     .04017    -.00237    -.04937     .04593    -.00384    -.08496    1.07716
DAY             .00270     .00982    -.05909     .29820     .12398     .14705     .25397     .20988    -.23555
EAST           -.08295    -.06065     .05450    -.14861     .05343     .22201     .03117    -.07924     .02746
HILL           -.13441    -.00727     .02181    -.87676     .14613     .44255    -.03273     .41981    -.19359
FLAT           -.06766     .08483     .01839    -.97288     .12369     .55748    -.18432     .28184    -.13796
TAKEOFF         .03587    -.15329    -.12261     .06929     .18599    -.02977     .24620     .07322    -.08160
FLY             .09971     .00998    -.04587     .06912     .24615    -.14054     .22704    -.04180    -.06812
LANDING        -.01397    -.05983    -.06842     .16126     .09515    -.21726     .09032    -.07001    -.10777
```

```
                LEV12      LEV34      ENG12        IFR    COMMLIC    CARRIER      AGE35      AGE45     SUMMER

WHEEL          .04479     .20615     .03983    -.19801     .00235     .02160    -.13878     .04135    -.03154
T_PLT_HR       .06546    -.10726     .07179    -.06517    -.31105     .06178     .47928     .43528    -.10642
PLT_TYPH      -.24564    -.11018     .02287     .02008     .10159    -.08874     .14134     .10517    -.01929
T_CO_HR       -.31968    -.16316     .06063    -.07360    -.34264     .08908     .02941    -.08496     .06365
CO_TYP_H      -.18628     .05296    -.00137    -.06175     .01558    -.08146    -.01897     .01833    -.01544

                  DAY       EAST       HILL       FLAT    TAKEOFF        FLY    LANDING      WHEEL   T_PLT_HR

DAY           1.30629
EAST           .04417    1.08897
HILL         -1.03310     .36630   61.97455
FLAT         -1.21090     .42022   61.44319   62.09164
TAKEOFF       -.00614    -.01465     .96281    1.04126    3.72661
FLY            .02538     .15466    -.24280     .22881    2.83084    3.92304
LANDING        .05997     .02642    -.21107    -.01273    3.43659    3.49149    4.66738
WHEEL          .07123     .04380     .15781     .21197    -.14497     .13776    -.13751    1.15672
T_PLT_HR      -.06217     .02877    -.18114    -.25748     .07989     .01583    -.01377    -.04613    1.60436
PLT_TYPH       .00764     .04850     .10471     .10942     .17629     .21628     .18780     .08210    -.52355
T_CO_HR       -.07890     .04232     .53441     .48318     .35560     .36622     .35596    -.02952    -.02428
CO_TYP_H      -.02109     .04691    -.15400    -.18074    -.33872    -.19256    -.19715     .02053    -.00756

             PLT_TYPH    T_CO_HR   CO_TYP_H

PLT_TYPH      1.48076
T_CO_HR        .03850    1.36377
CO_TYP_H      -.34094    -.26839    1.30070

KAISER-MEYER-OLKIN MEASURE OF SAMPLING ADEQUACY =  .54182

BARTLETT TEST OF SPHERICITY = 2688.6893, SIGNIFICANCE =     .00000

THERE ARE   50 (11.9%) OFF-DIAGONAL ELEMENTS OF AIC MATRIX > 0.09

ANTI-IMAGE COVARIANCE MATRIX:

                LEV12      LEV34      ENG12        IFR    COMMLIC    CARRIER      AGE35      AGE45     SUMMER

LEV12          .61257
LEV34          .28880     .66279
ENG12          .05672     .04047     .93411
IFR           -.08014     .00831     .04881     .67703
COMMLIC        .00438    -.03315    -.01318    -.02155     .43327
```

CARRIER	-.08213	-.12424	-.00260	-.13103	-.22548	.38908

	LEV12	LEV34	ENG12	IFR	COMMLIC	CARRIER	AGE35	AGE45	SUMMER
AGE35	-.05259	-.13993	-.05347	-.02431	.04015	.08451	.58665		
AGE45	.02522	-.09376	-.06162	-.01042	-.00105	.03154	.31094	.67146	
SUMMER	.01739	.00943	.03484	-.00149	-.01986	.01659	-.00536	-.05296	.92836
DAY	.00126	.00498	-.04225	.15455	.04112	.04380	.11406	.10788	-.16740
EAST	-.04666	-.03692	.04675	-.09239	.02126	.07932	.01679	-.04886	.02341
HILL	-.00133	-.00008	.00033	-.00958	.00102	.00278	-.00031	.00455	-.00290
FLAT	-.00067	.00091	.00028	-.01061	.00086	.00349	-.00174	.00305	-.00206
TAKEOFF	.00590	-.02726	-.03078	.01259	.02162	-.00311	.03876	.01319	-.02033
FLY	.01557	.00169	-.01092	.01193	.02719	-.01394	.03395	-.00716	-.01612
LANDING	-.00183	-.00850	-.01369	.02339	.00883	-.01811	.01135	-.01007	-.02144
WHEEL	.02372	.11812	.03216	-.11590	.00088	.00726	-.07039	.02400	-.02531
T_PLT_HR	.02499	-.04431	.04180	-.02750	-.09400	.01498	.17526	.18217	-.06158
PLT_TYPH	-.10162	-.04932	.01443	.00918	.02973	-.02332	.05600	.04769	-.01209
T_CO_HR	-.14359	-.07929	.04153	-.03654	-.10886	.02541	.01265	-.04183	.04333
CO_TYP_H	-.08773	.02699	-.00099	-.03214	.00519	-.02437	-.00856	.00947	-.01102

	DAY	EAST	HILL	FLAT	TAKEOFF	FLY	LANDING	WHEEL	T_PLT_HR
DAY	.76553								
EAST	.03105	.91830							
HILL	-.01276	.00543	.01614						
FLAT	-.01493	.00621	.01597	.01611					
TAKEOFF	-.00126	-.00361	.00417	.00450	.26834				
FLY	.00495	.03620	-.00100	.00094	.19774	.25490			
LANDING	.00984	.00520	-.00073	-.00004	.19758	.19068	.21425		
WHEEL	.04714	.03477	.00220	.00295	-.03363	.03036	-.02547	.86451	
T_PLT_HR	-.02967	.01647	-.00182	-.00258	.01336	.00251	-.00184	-.02486	.62330
PLT_TYPH	.00395	.03008	.00114	.00119	.03195	.03723	.02717	.04793	-.22038
T_CO_HR	-.04429	.02850	.00632	.00571	.06997	.06845	.05592	-.01871	-.01110
CO_TYP_H	-.01241	.03312	-.00191	-.00224	-.06988	-.03774	-.03247	.01364	-.00362

	PLT_TYPH	T_CO_HR	CO_TYP_H
PLT_TYPH	.67533		
T_CO_HR	.01907	.73326	
CO_TYP_H	-.17702	-.15130	.76882

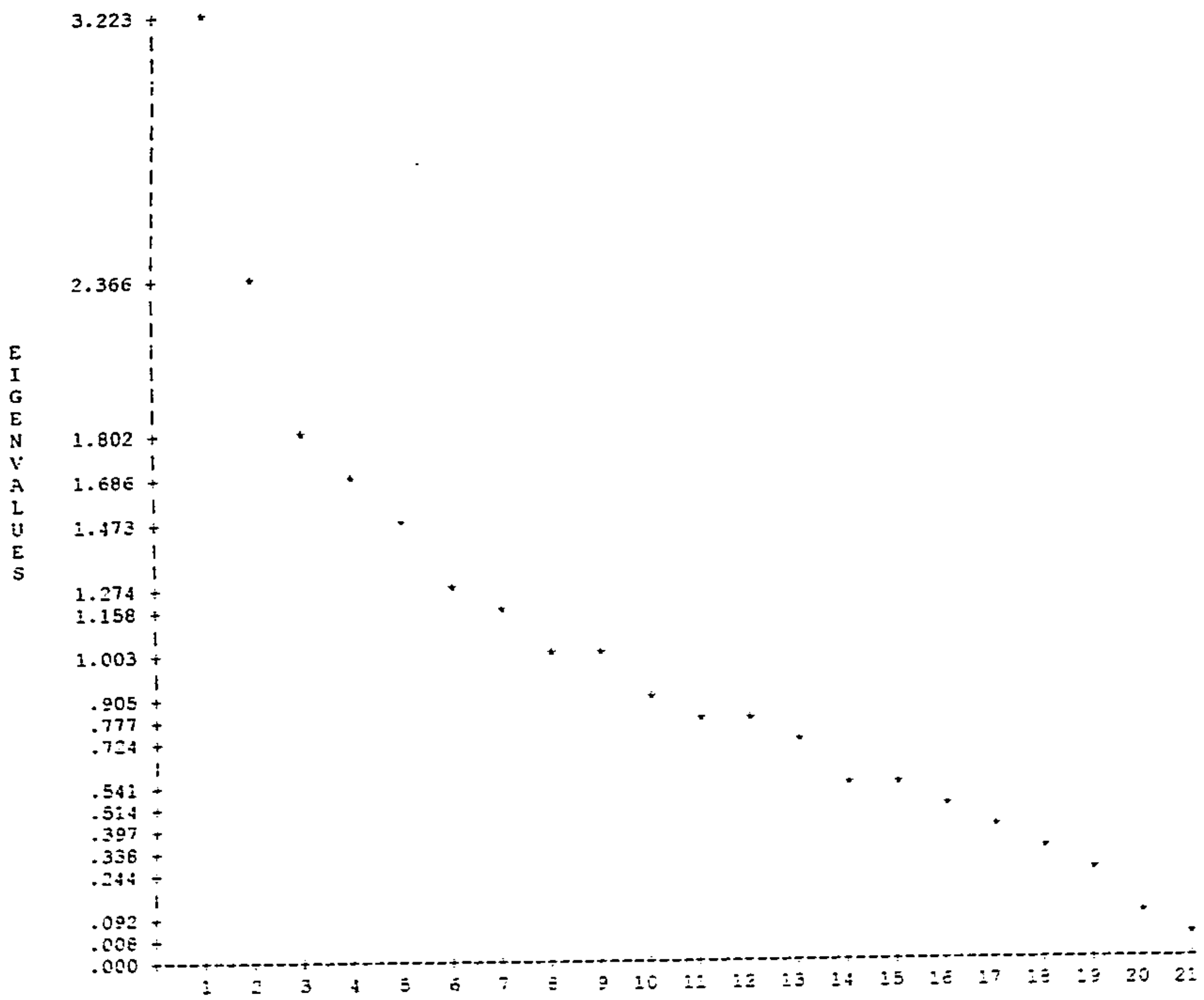
```
ANTI-IMAGE CORRELATION MATRIX:

               LEV12     LEV34     ENG12       IFR   COMMLIC   CARRIER     AGE35     AGE45    SUMMER       DAY      EAST      HILL

LEV12        .63672
LEV34        .45325    .44576
ENG12        .07498    .05144    .76837
IFR         -.12444    .01240    .06137    .77307
COMMLIC      .00850   -.06185   -.02071   -.03979    .75166
CARRIER     -.16822   -.24465   -.00432   -.25531   -.54916    .70832
AGE35       -.08773   -.22441   -.07222   -.03858    .07965    .17688    .50513
AGE45        .03932   -.14055   -.07781   -.01546   -.00195    .06170    .49542    .41787
SUMMER       .02305    .01202    .03741   -.00188   -.03131    .02760   -.00726   -.06708    .54979
DAY          .00185    .00699   -.04997    .21468    .07140    .08026    .17019    .15047   -.19858    .63597
EAST        -.06221   -.04732    .05048   -.11718    .03370    .13270    .02288   -.06222    .02535    .03704    .59404
HILL        -.01336   -.00075    .00268   -.09164    .01222    .03506   -.00318    .04370   -.02369   -.11482    .04459    .52794
FLAT        -.00672    .00876    .00226   -.10159    .01033    .04413   -.01792    .02931   -.01687   -.13445    .05110    .99049
TAKEOFF      .01454   -.06465   -.06149    .02953    .06342   -.00962    .09769    .03108   -.04073   -.00278   -.00727    .06335
FLY          .03940    .00410   -.02238    .02871    .06180   -.04426    .08780   -.01730   -.03314    .01121    .07483   -.01557
LANDING     -.00506   -.02255   -.03061    .06142    .02899   -.06273    .03202   -.02655   -.04806    .02429    .01172   -.01241
WHEEL        .03259    .15604    .03579   -.15149    .00144    .01253   -.09884    .03151   -.02825    .05794    .03903    .01864
T_PLT_HR     .04045   -.06894    .05478   -.04234   -.16164    .03042    .28982    .28160   -.08095   -.04295    .02177   -.01817
PLT_TYPH    -.15799   -.07372    .01816    .01358    .05495   -.04549    .08896    .07082   -.01527    .00549    .03820    .01093
T_CO_HR     -.21425   -.11374    .05018   -.05186   -.19313    .04758    .01929   -.05962    .05251   -.05912    .03473    .05613
CO_TYP_H    -.12784    .03781   -.00116   -.04455    .00899   -.04455   -.01274    .01317   -.01305   -.01618    .03941   -.01715

                FLAT   TAKEOFF       FLY   LANDING     WHEEL  T_PLT_HR  PLT_TYPH   T_CO_HR  CO_TYP_H

FLAT         .52602
TAKEOFF      .06845    .26129
FLY          .01466    .75606    .33793
LANDING     -.00075    .82401    .81595    .32862
WHEEL        .02501   -.06982    .06467   -.05918    .68098
T_PLT_HR    -.02580    .03267    .00631   -.00503   -.03386    .67322
PLT_TYPH     .01141    .07504    .08974    .07144    .06273   -.33967    .71342
T_CO_HR      .05251    .15774    .15833    .14109   -.02351   -.01641    .02709    .70509
CO_TYP_H    -.02011   -.15385   -.08524   -.08001    .01673   -.00523   -.24567   -.20151    .73789

MEASURES OF SAMPLING ADEQUACY (MSA) ARE PRINTED ON THE DIAGONAL.

1-TAILED SIG. OF CORRELATION MATRIX:

' . ' IS PRINTED FOR DIAGONAL ELEMENTS.
```

	LEV12	LEV34	ENG12	IFR	COMMLIC	CARRIER	AGE35	AGE45	SUMMER
LEV12	.								
LEV34	.00000	.							
ENG12	.00874	.40147	.						
IFR	.00000	.27350	.00637	.					

	LEV12	LEV34	ENG12	IFR	COMMLIC	CARRIER	AGE35	AGE45	SUMMER
COMMLIC	.00117	.00004	.04168	.00000	.				
CARRIER	.00004	.00000	.02584	.00000	.00000	.			
AGE35	.44572	.37513	.12026	.23126	.00000	.00000	.		
AGE45	.00911	.02221	.11457	.40961	.24248	.29004	.00000	.	
SUMMER	.22511	.42391	.35011	.13500	.44428	.25058	.09983	.33094	.
DAY	.09761	.06396	.13050	.00000	.00036	.00002	.05586	.05250	.00009
EAST	.42774	.43895	.27671	.19453	.01883	.00536	.28348	.08465	.24664
HILL	.48100	.19302	.35161	.40043	.29085	.04677	.06103	.38718	.33626
FLAT	.46609	.16701	.35913	.37296	.26112	.03808	.05454	.44904	.37847
TAKEOFF	.16189	.37449	.10069	.25244	.01395	.01054	.44605	.22883	.45873
FLY	.02156	.35388	.40081	.05533	.02240	.16843	.02272	.13390	.41064
LANDING	.03719	.41418	.22982	.12123	.00198	.00457	.14334	.45603	.41890
WHEEL	.06177	.00596	.22297	.00137	.42244	.49099	.00551	.03182	.49889
T_PLT_HR	.03242	.09115	.00680	.00599	.00000	.00000	.00000	.00060	.03657
PLT_TYPH	.00001	.33693	.02425	.01392	.00026	.00003	.00053	.01022	.21388
T_CO_HR	.00000	.13911	.01937	.00004	.00000	.00000	.04578	.32236	.18638
CO_TYP_H	.00000	.16418	.11993	.00189	.00248	.00052	.08939	.08964	.41962

	DAY	EAST	HILL	FLAT	TAKEOFF	FLY	LANDING	WHEEL	T_PLT_HR
DAY	.								
EAST	.15850	.							
HILL	.01670	.47787	.						
FLAT	.00785	.47481	.00000	.					
TAKEOFF	.09991	.09846	.00661	.01345	.				
FLY	.32344	.04531	.00000	.00000	.00000	.			
LANDING	.07222	.42959	.15833	.12875	.00000	.00000	.		
WHEEL	.03506	.46377	.30399	.31895	.10536	.00005	.01277	.	
T_PLT_HR	.11676	.03797	.41593	.38164	.14283	.21241	.13240	.44161	.
PLT_TYPH	.32396	.06391	.45121	.44021	.36036	.11660	.28675	.17866	.00000
T_CO_HR	.23365	.19685	.09917	.11933	.15677	.00694	.09340	.26864	.00251
CO_TYP_H	.48370	.11370	.24911	.24600	.03724	.10809	.38376	.41799	.00068

```
             PLT_TYPH     T_CO_HR     CO_TYP_H

PLT_TYPH        .
T_CO_HR      .00172          .
CO_TYP_H     .00000       .00000         .


EXTRACTION  1  FOR ANALYSIS  2, PRINCIPAL-COMPONENTS ANALYSIS (PC)

INITIAL STATISTICS:

VARIABLE     COMMUNALITY  *  FACTOR   EIGENVALUE   PCT OF VAR   CUM PCT
                          *
LEV12          1.00000    *     1      3.22272       15.3         15.3
LEV34          1.00000    *     2      2.36581       11.3         26.6
ENG12          1.00000    *     3      1.80201        8.6         35.2
IFR            1.00000    *     4      1.68621        8.0         43.2
COMMLIC        1.00000    *     5      1.47337        7.0         50.2
CARRIER        1.00000    *     6      1.27407        6.1         56.3
AGE35          1.00000    *     7      1.15835        5.5         61.8
AGE45          1.00000    *     8      1.03199        4.9         66.7
SUMMER         1.00000    *     9      1.00284        4.8         71.5
DAY            1.00000    *    10       .90546        4.3         75.8
EAST           1.00000    *    11       .83720        4.0         79.8
HILL           1.00000    *    12       .77690        3.7         83.5
FLAT           1.00000    *    13       .72427        3.4         87.0
TAKEOFF        1.00000    *    14       .60436        2.9         89.8
FLY            1.00000    *    15       .54091        2.6         92.4
LANDING        1.00000    *    16       .51358        2.4         94.9
WHEEL          1.00000    *    17       .39707        1.9         96.7
T_PLT_HR       1.00000    *    18       .33807        1.6         98.4
PLT_TYPH       1.00000    *    19       .24425        1.2         99.5
T_CO_HR        1.00000    *    20       .09245         .4        100.0
CO_TYP_H       1.00000    *    21       .00809         .0        100.0
```



PC EXTRACTED 9 FACTORS.

```
FACTOR MATRIX:

              FACTOR  1    FACTOR  2    FACTOR  3    FACTOR  4    FACTOR  5    FACTOR  6    FACTOR  7    FACTOR  8

LEV12           .46806       .17930      -.05034       .53429       .04873      -.38694      -.08018       .05940
LEV34           .13534      -.20032      -.02166      -.58442       .10640       .54923       .03593      -.14909
ENG12          -.27615       .00906       .01304      -.14453       .03427       .03918      -.06850       .66173
IFR             .57425       .04726      -.25030       .04413       .34839      -.05011      -.02316      -.07437
COMMLIC         .75959      -.10705      -.04125      -.28325       .06042       .10656      -.03325       .13199
CARRIER         .77387      -.18725      -.06969      -.23311       .11499       .10607      -.07581       .11839
AGE35          -.31695       .27532      -.44245       .31590       .04032       .43547      -.26372      -.03725
AGE45          -.03795      -.17969       .01556      -.58149       .13535      -.57579       .21089       .12199
SUMMER         -.02648      -.02768       .28679      -.00014      -.34993       .04298       .41771       .12743
DAY            -.25698       .16178       .52652       .05807      -.38847       .00584       .12024       .09969
EAST           -.13916       .06754      -.20512       .00010       .21104      -.23367       .44635      -.53489
HILL            .03452      -.87156      -.16733       .32502      -.03940       .08470       .23324       .08944
FLAT           -.03610       .87214       .17038      -.31725       .02016      -.08445      -.24022      -.09074
TAKEOFF        -.19438       .25648       .35205       .08279       .65161       .24974       .39244       .13370
FLY            -.21498      -.60339       .30081       .07525       .08528      -.16725      -.48714      -.12658
LANDING         .29444       .22510      -.55848      -.14018      -.64181      -.06116       .13540       .03914
WHEEL           .08526       .24211      -.36540       .27869       .09584       .10407       .31155       .24607
T_PLT_HR        .53491       .00052       .40191       .04408      -.26316       .24168       .09728      -.19125
PLT_TYPH        .51309       .05174       .40647       .21841      -.15686       .12141       .03922      -.15776
T_CO_HR         .54186       .14368       .04017       .01679       .11369      -.15176      -.08083       .10811
CO_TYP_H        .43816       .14965       .29469       .30735       .14385      -.05467      -.00114       .13210

              FACTOR  9

LEV12           .06182
LEV34           .18239
ENG12           .32383
IFR            -.27350
COMMLIC        -.09199
CARRIER        -.10151
AGE35           .08604
AGE45           .02427
SUMMER         -.39508
DAY             .02353
EAST            .26360
HILL            .12744
FLAT           -.13326
TAKEOFF         .03165
FLY            -.24756
LANDING         .18354
WHEEL          -.44252
T_PLT_HR       -.08046
PLT_TYPH        .22769
```

```
                FACTOR   9

T_CO_HR          .20853
CO_TYP_H         .32497


FINAL STATISTICS:

VARIABLE      COMMUNALITY  *  FACTOR   EIGENVALUE   PCT OF VAR   CUM PCT
                           *
LEV12           .70510     *    1       3.22272       15.3        15.3
LEV34           .77022     *    2       2.36581       11.3        26.6
ENG12           .64755     *    3       1.80201        8.6        35.2
IFR             .60135     *    4       1.68621        8.0        43.2
COMMLIC         .71237     *    5       1.47337        7.0        50.2
CARRIER         .74768     *    6       1.27407        6.1        56.3
AGE35           .74142     *    7       1.15835        5.5        61.8
AGE45           .78190     *    8       1.03199        4.9        66.7
SUMMER          .55482     *    9       1.00284        4.8        71.5
DAY             .54870     *
EAST            .71997     *
HILL            .98181     *
FLAT            .98284     *
TAKEOFF         .89422     *
FLY             .85631     *
LANDING         .93812     *
WHEEL           .65052     *
T_PLT_HR        .62978     *
PLT_TYPH        .59647     *
T_CO_HR         .41361     *
CO_TYP_H        .54243     *
```

```
REPRODUCED CORRELATION MATRIX:

              LEV12      LEV34      ENG12        IFR    COMMLIC    CARRIER      AGE35      AGE45     SUMMER

LEV12        .70510*    .12411     .01659    -.04935     .02206     .04864     .04228     .00352     .07199
LEV34       -.49152     .77022*   -.04262     .01722    -.09003    -.05035     .03636     .05421     .08269
ENG12       -.15417     .02810     .64755*    .14986     .00391     .01103    -.01012    -.07945     .04931
IFR          .33033     .01780    -.29401     .60135*   -.10283    -.05795     .02402    -.00886     .05937
COMMLIC      .15362     .31798    -.10425     .46078     .71237*   -.00956     .04051    -.06754    -.00192
CARRIER      .17900     .31160    -.12386     .49816     .72251     .74768*    .01571    -.05705     .00830
AGE35       -.05022    -.01785     .07831    -.06674    -.29667    -.28196     .74142*    .13802     .19595
AGE45       -.14022     .06233     .14932    -.00443     .10815     .08922    -.53138     .78190*   -.00703
SUMMER      -.11590    -.09385    -.07171    -.12347    -.00623    -.04742    -.27046     .03247     .55482*
DAY         -.11021    -.15691     .12317    -.42142    -.26654    -.32315    -.13514    -.06274     .34314


              LEV12      LEV34      ENG12        IFR    COMMLIC    CARRIER      AGE35      AGE45     SUMMER

EAST         .00679     .01000    -.26474     .01721    -.22634    -.23051    -.01487     .18828    -.12676
HILL         .00176     .05356     .01986    -.03002     .03334     .11024    -.09277    -.02721     .05108
FLAT         .00068    -.06152    -.02342     .02385    -.03747    -.11481     .09526     .01818    -.04422
TAKEOFF     -.10493     .07274     .15258     .00285    -.14541    -.15801     .03189    -.03713     .05018
FLY         -.09864    -.08529    -.08725    -.09744    -.12284    -.05275    -.16482     .06117    -.05018
LANDING      .12660     .01940    -.01463     .03654     .20079     .15276     .09759     .00733     .03681
WHEEL        .17729    -.23076    -.06084     .28785     .05470     .05364     .20912    -.17645     .19347
T_PLT_HR     .12331     .15990    -.30766     .13872     .36597     .34909    -.26412    -.21932     .25161
PLT_TYPH     .29260     .03908    -.20145     .09280     .26595     .25821    -.19756    -.24604     .06795
T_CO_HR      .37639    -.01837    -.00768     .29265     .37827     .38044    -.17093     .04845    -.15548
CO_TYP_H     .43749    -.13186     .03530     .15267     .20804     .21235    -.12563    -.14295    -.09599

                DAY       EAST       HILL       FLAT    TAKEOFF        FLY    LANDING      WHEEL   T_PLT_HR

LEV12        .03497     .00381    -.00453     .00427     .04758    -.01861    -.02308    -.08788    -.01621
LEV34        .06852    -.01894    -.00317     .00537    -.05413     .06348    -.00678     .08527    -.08243
ENG12       -.05785     .23027    -.04202     .04440    -.07836     .10186    -.02837     .01653     .16485
IFR          .11699     .03287     .01534    -.00500    -.04163     .00484     .03138    -.11494     .00668
COMMLIC      .07163     .10587    -.00130     .00025     .01803     .00651    -.03435    -.04331    -.03476
CARRIER      .08574     .08286    -.01292     .01192     .02443    -.00307    -.00198    -.05233    -.07272
AGE35        .04281     .04816     .00301    -.00225    -.02399     .04883    -.03567    -.06203    -.03282
AGE45       -.03135    -.10845     .01053    -.01073    -.00605     .00323    -.00090     .06887     .03248
SUMMER      -.12839     .08692    -.02650     .02622    -.04415     .06332    -.02477    -.19363    -.14764
DAY          .54870*    .07995     .04007    -.03242    -.01673     .01739    -.01678     .03892    -.10196
EAST        -.13811     .71997*   -.03566     .03721    -.08836     .13224    -.04518     .03912     .04137
HILL        -.16334     .03244     .98181*   -.00940     .01585    -.02707     .00136    -.01680    -.00361
FLAT         .17227    -.04088    -.98206     .98284*   -.01765     .02730    -.00090     .01503     .00289
TAKEOFF      .09121     .16332    -.15925     .14585     .89422*   -.06242     .04158    -.09685    -.00229
```

```
FLY           .00926   -.23043    .31858   -.31376   -.20297    .85631*   .00847    .11359    .01082
LANDING      -.06797    .05550   -.05956    .06670   -.57702   -.53852    .93812*  -.01796   -.00721
WHEEL        -.14399   -.03383   -.01303    .01234    .16956   -.33596    .14732    .65052*   .06151
T_PLT_HR      .17118   -.14434   -.00874    .01463   -.05976   -.05722    .07201   -.07005    .62978*
PLT_TYPH      .15921   -.05083    .01611   -.01230    .00433   -.09200    .03927   -.16113    .53376
T_CO_HR      -.13296   -.05343   -.10773    .10419   -.02743   -.18070    .13497   -.02477    .19489
CO_TYP_H      .04910   -.05366   -.02205    .01990    .18999   -.14792   -.06929   -.05199    .26395

            PLT_TYPH   T_CO_HR   CO_TYP_H

LEV12        -.04065   -.07285   -.14263
LEV34        -.01460    .08139    .07505
ENG12         .08706   -.11213   -.10359
IFR           .03463   -.06513    .01465
COMMLIC      -.06639   -.02637   -.04569
CARRIER      -.02575   -.10843   -.02317
AGE35         .00871    .07301    .04754
AGE45         .11180   -.02163    .06494

            PLT_TYPH   T_CO_HR   CO_TYP_H

SUMMER       -.02165    .10345    .10779
DAY          -.13265    .09070   -.04672
EAST         -.03758    .00384   -.01647
HILL         -.02325    .03301   -.01733
FLAT          .02105   -.03573    .02006
TAKEOFF      -.02513   -.03115   -.08650
FLY           .02274    .03831    .07607
LANDING      -.00653   -.05829    .05209
WHEEL         .10762    .06065    .06404
T_PLT_HR     -.07228   -.03273   -.07906
PLT_TYPH      .59647*  -.12748   -.09671
T_CO_HR       .29645    .41381*  -.09267
CO_TYP_H      .44338    .38271    .54243*

THE LOWER LEFT TRIANGLE CONTAINS THE REPRODUCED CORRELATION MATRIX;  THE
DIAGONAL, COMMUNALITIES; AND THE UPPER RIGHT TRIANGLE, RESIDUALS BETWEEN
THE OBSERVED CORRELATIONS AND THE REPRODUCED CORRELATIONS.

THERE ARE   79 (37.0%) RESIDUALS (ABOVE DIAGONAL) THAT ARE > 0.05


VARIMAX   ROTATION  1  FOR EXTRACTION  1  IN ANALYSIS  2 - KAISER NORMALIZATION.


  VARIMAX CONVERGED IN   18 ITERATIONS.
```

ROTATED FACTOR MATRIX:

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	FACTOR 7	FACTOR 8
LEV12	.23451	.35742	.01576	.07548	-.06718	.69611	-.04312	-.14512
LEV34	.22763	.05599	.04603	.06715	.03527	-.83497	.01497	-.09853
ENG12	-.19736	-.12204	.04755	.14143	.11586	-.05076	.10633	-.13878
IFR	.70870	.03034	-.03957	.03754	.07150	.18443	-.03426	-.07825
COMMLIC	.73566	.29489	.00813	.05842	-.13328	-.16574	.14835	.06691
CARRIER	.77798	.28107	.07999	-.00519	-.12219	-.14314	.12213	.01930
AGE35	-.14454	-.26293	-.06605	.15784	-.00564	-.00538	-.73212	-.28898
AGE45	.06350	-.25321	-.03221	.02519	-.01268	-.05227	.83904	-.05857
SUMMER	-.09900	.01487	.04728	.05559	.01662	.01018	.10321	.72678
DAY	-.51774	.24239	-.16181	-.05029	.01620	.00542	.05390	.40624
EAST	-.21477	-.07913	.09017	.34017	.16186	-.00503	.22357	-.28239
HILL	.03031	-.00638	.98289	-.10784	-.05008	-.01534	.00392	.01968
FLAT	-.03779	.00993	-.98437	.10213	.03518	.02049	-.01215	-.00935
TAKEOFF	-.07387	.04058	-.09872	.14052	.92234	-.06091	-.02342	.03765

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	FACTOR 7	FACTOR 8
FLY	-.07572	-.10436	.22683	-.88130	-.05789	.01898	.08063	-.03517
LANDING	.09063	.01160	-.03045	.63808	-.72083	.01433	-.02297	.03570
WHEEL	.31135	-.31362	.02285	.35415	.17364	.33486	-.29137	.31869
T_PLT_HR	.20549	.61444	-.03087	-.05010	-.09179	-.15167	-.06731	.37772
PLT_TYPH	.07405	.75321	.01730	.00699	-.02235	.01130	-.05908	.09310
T_CO_HR	.35533	.40429	-.09960	.12608	-.02948	.17586	.13729	-.19625
CO_TYP_H	.12062	.61310	.00371	.08361	.19493	.26585	.00642	-.14124

	FACTOR 9
LEV12	-.06643
LEV34	.00841
ENG12	.72448
IFR	-.22085
COMMLIC	.09499
CARRIER	.07937
AGE35	.05057
AGE45	.04194
SUMMER	-.01527
DAY	.15794
EAST	-.62272
HILL	.00127
FLAT	-.00047
TAKEOFF	.03526

```
FLY            -.00946
LANDING         .01038
WHEEL          -.02313
T_PLT_HR       -.16708
PLT_TYPH       -.10264
T_CO_HR         .09553
CO_TYP_H        .12775


FACTOR TRANSFORMATION MATRIX:

            FACTOR  1    FACTOR  2    FACTOR  3    FACTOR  4    FACTOR  5    FACTOR  6    FACTOR  7    FACTOR  8

FACTOR  1     .76067       .59026       .02131       .13497      -.18502       .08518       .08055       .03348
FACTOR  2    -.08742       .07565      -.82383       .44859       .12048       .21433      -.21485      -.00764
FACTOR  3    -.29713       .57944      -.19806      -.45402       .36273      -.08301       .24151       .35064
FACTOR  4    -.17670       .23396       .35203      -.05128       .14554       .67687      -.54293       .01385
FACTOR  5     .34621      -.16712      -.01744      -.13648       .78599       .03348       .07461      -.45003
FACTOR  6     .09443       .10766       .09399       .09532       .19821      -.63306      -.69179       .16168
FACTOR  7    -.10149      -.00987       .31776       .63328       .35369      -.03574       .29717       .43618
FACTOR  8     .13474      -.11805       .10841       .16123       .12263       .22151       .08152       .17835

            FACTOR  1    FACTOR  2    FACTOR  3    FACTOR  4    FACTOR  5    FACTOR  6    FACTOR  7    FACTOR  8

FACTOR  9    -.37012       .44925       .18932       .34209      -.03595      -.17184       .12309      -.65168

            FACTOR  9

FACTOR  1    -.07211
FACTOR  2    -.00624
FACTOR  3     .10420
FACTOR  4    -.11482
FACTOR  5    -.07926
FACTOR  6     .12961
FACTOR  7    -.28747
FACTOR  8     .90973
FACTOR  9     .19339
```

```
FACTOR SCORE COEFFICIENT MATRIX:

             FACTOR  1    FACTOR  2    FACTOR  3    FACTOR  4    FACTOR  5    FACTOR  6    FACTOR  7    FACTOR  8

LEV12          .03090       .13276       .02453       .00311      -.03560       .44341       .02092      -.12522
LEV34          .07994       .06313       .01891       .08072       .05615      -.58301      -.06616      -.10056
ENG12         -.06868       .00323       .07775       .16742       .07695       .00488       .09547      -.12897
IFR            .34186      -.12524      -.04955      -.05887       .09462       .11314      -.03823       .00091
COMMLIC        .29592       .02926      -.01777       .00396      -.02417      -.10787       .05018       .06304
CARRIER        .31995       .01855       .00826      -.03874      -.01571      -.09182       .02774       .02941
AGE35         -.01690      -.07041      -.01175       .04900      -.02836      -.06631      -.48839      -.20641
AGE45          .03367      -.15726      -.02962       .06512       .00662       .05328       .59090      -.03125
SUMMER        -.00569      -.06533       .03862       .07053       .03469       .03638       .06802       .60408
DAY           -.25659       .17813      -.05086       .01125      -.02462       .00885       .04952       .26635
EAST          -.17549       .04251       .09441       .27201       .10966      -.04092       .20504      -.23140
HILL          -.02489       .02624       .49412       .06341       .01744       .00731      -.01250       .01651
FLAT           .02126      -.02465      -.49595      -.06857      -.02834      -.00395       .00660      -.00904
TAKEOFF        .02093       .04002       .02638       .15384       .62328      -.06300       .00490       .04931
FLY            .03923      -.06758      -.01567      -.59246      -.06677       .07133      -.00472      -.03280
LANDING       -.06188       .00632       .03467       .39761      -.44244      -.01379       .01827       .01922
WHEEL          .04061      -.28659       .04891       .18979       .16548       .22239      -.16516       .36272
T_PLT_HR       .00763       .26862      -.01927      -.04178      -.03890      -.14296      -.09158       .25106
PLT_TYPH      -.10664       .40440       .03428       .02032      -.00587      -.05078      -.05604      -.01113
T_CO_HR        .07391       .17510      -.03135       .06125       .00348       .10018       .10203      -.18817
CO_TYP_H      -.05575       .33198       .05174       .07658       .14025       .13808       .02489      -.17578
             FACTOR  9
LEV12         -.00804
LEV34         -.01898
ENG12          .68167
IFR           -.16684
COMMLIC        .11465
CARRIER        .10323
AGE35          .05061
AGE45          .03585
SUMMER        -.02706
DAY            .11588
EAST          -.57552
HILL           .02600
FLAT          -.02579
TAKEOFF        .03532
FLY           -.04137
LANDING        .03466
WHEEL          .01704
T_PLT_HR      -.16124
PLT_TYPH      -.08709
T_CO_HR        .12270
CO_TYP_H       .15202
```

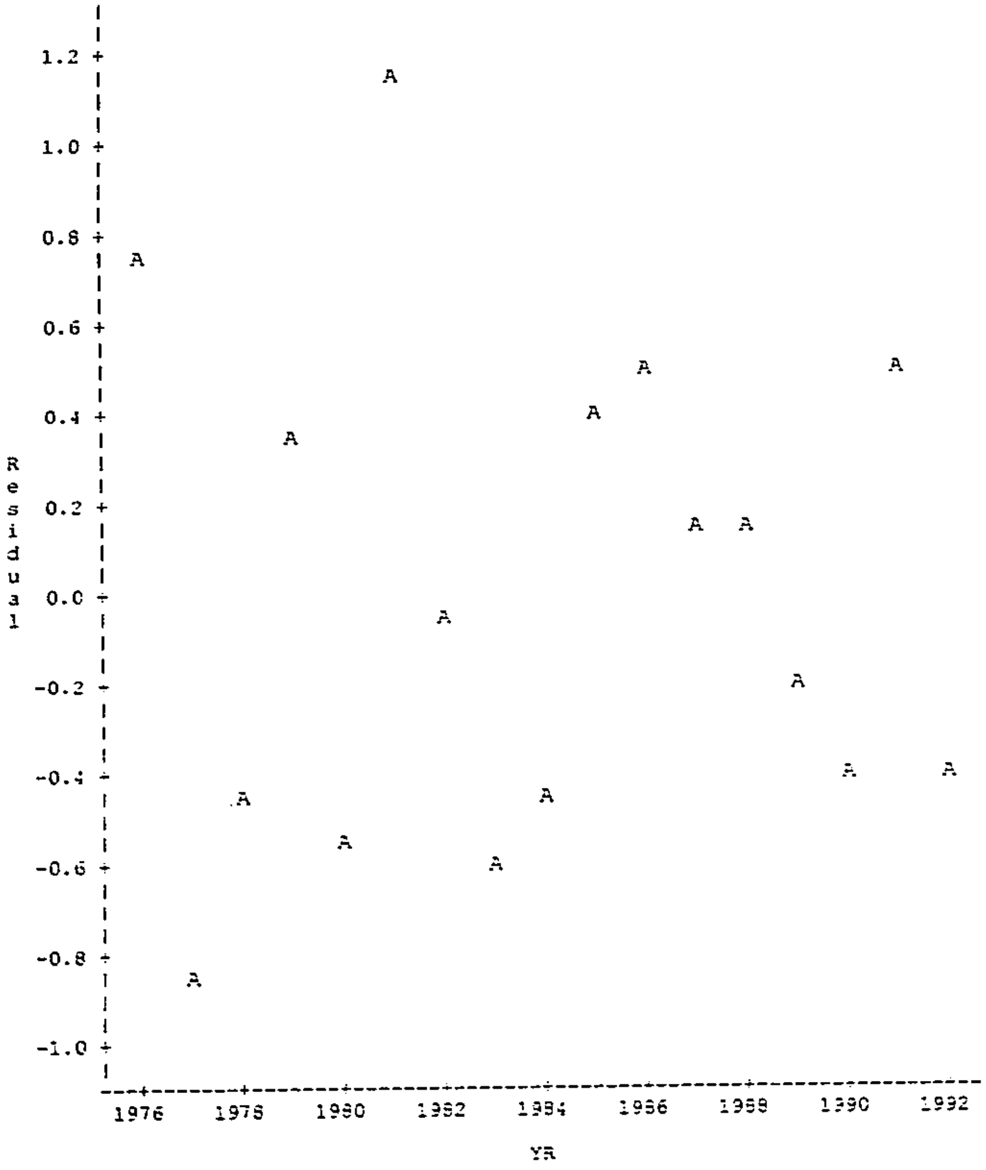
```
COVARIANCE MATRIX FOR ESTIMATED REGRESSION FACTOR SCORES:

              FACTOR  1   FACTOR  2   FACTOR  3   FACTOR  4   FACTOR  5   FACTOR  6   FACTOR  7   FACTOR  8   FACTOR  9

FACTOR  1      1.00000
FACTOR  2       .00000     1.00000
FACTOR  3       .00000      .00000     1.00000
FACTOR  4       .00000      .00000      .00000     1.00000
FACTOR  5       .00000      .00000      .00000      .00000     1.00000
FACTOR  6       .00000      .00000      .00000      .00000      .00000     1.00000
FACTOR  7       .00000      .00000      .00000      .00000      .00000      .00000     1.00000
FACTOR  8       .00000      .00000      .00000      .00000      .00000      .00000      .00000     1.00000
FACTOR  9       .00000      .00000      .00000      .00000      .00000      .00000      .00000      .00000     1.00000
```

ANNEX D
ADDITIONAL COMPUTER PRINTOUTS

2) REGRESSION ANALYSIS OUTPUT - ACCIDENT RATES

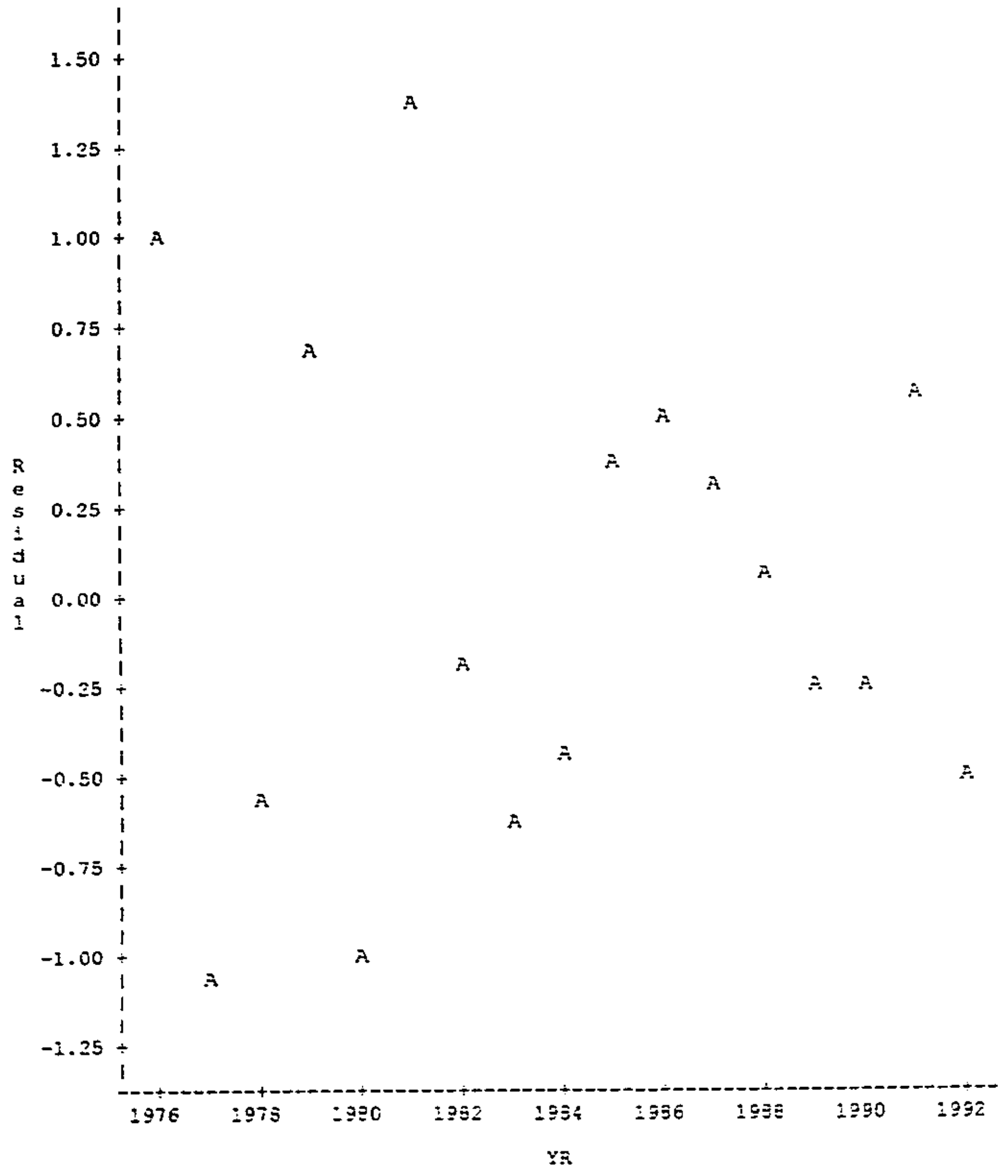
```
Model: MODEL1
Dependent Variable: ACC_DEPT

                              Analysis of Variance

                                 Sum of         Mean
        Source          DF      Squares       Square      F Value       Prob>F

        Model            6     20.04469      3.34078        7.018       0.0039
        Error           10      4.76037      0.47604
        C Total         16     24.80506

            Root MSE       0.68995     R-square       0.8081
            Dep Mean       8.43113     Adj R-sq       0.6929
            C.V.           8.18341


                              Parameter Estimates

                         Parameter      Standard    T for H0:
       Variable  DF       Estimate         Error   Parameter=0    Prob > |T|

       INTERCEP   1     530.830056  424.53609256         1.250        0.2396
       YR         1      -0.267930    0.21555711        -1.243        0.2422
       HRSFWN     1    0.000002468    0.00000250         0.988        0.3462
       JET        1       0.000885    0.01178633         0.075        0.9416
       CPL        1       0.000106    0.00022784         0.466        0.6512
       PASSKM     1   2.689615E-11    0.00000000         0.260        0.7999
       MOVE       1       0.000134    0.00087729         0.152        0.8820


Durbin-Watson D               2.332
(For Number of Obs.)             17
1st Order Autocorrelation    -0.238
```

Plot of RESID*YR. Legend: A = 1 obs, B = 2 obs, etc.



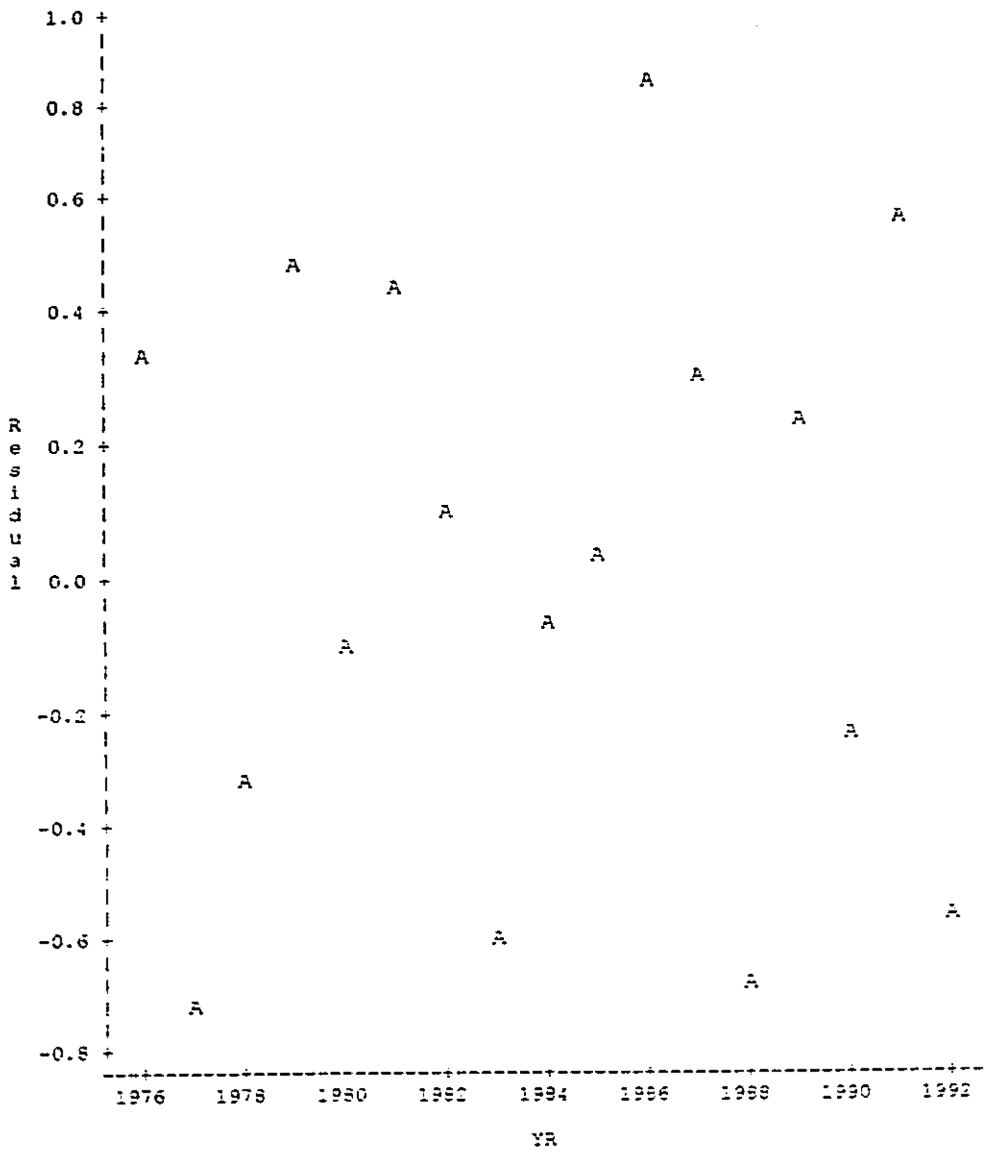
```
Model: MODEL1
Dependent Variable: ACC_HRS

                           Analysis of Variance

                             Sum of         Mean
        Source          DF      Squares       Square      F Value       Prob>F

        Model            6     84.83602     14.13934       18.827       0.0001
        Error           10      7.51014      0.75101
        C Total         16     92.34617

            Root MSE       0.86661     R-square        0.9187
            Dep Mean      10.05465     Adj R-sq        0.8699
            C.V.           8.61901


                           Parameter Estimates

                          Parameter       Standard    T for H0:
      Variable  DF         Estimate          Error   Parameter=0     Prob > |T|

      INTERCEP   1      897.034988   973.32515599         0.922         0.3784
      YR         1       -0.453039     0.49336159        -0.918         0.3801
      DEPTS      1     0.000001643     0.00000392         0.420         0.6837
      JET        1        0.002869     0.01447609         0.198         0.8469
      CPL        1     0.000048269     0.00028296         0.171         0.8680
      PASSKM     1    5.822964E-11     0.00000000         0.342         0.7396
      MOVE       1        0.000951     0.00242721         0.392         0.7034


Durbin-Watson D               2.588
(For Number of Obs.)             17
1st Order Autocorrelation    -0.374
```

Plot of RESID*YR. Legend: A = 1 obs, B = 2 obs, etc.



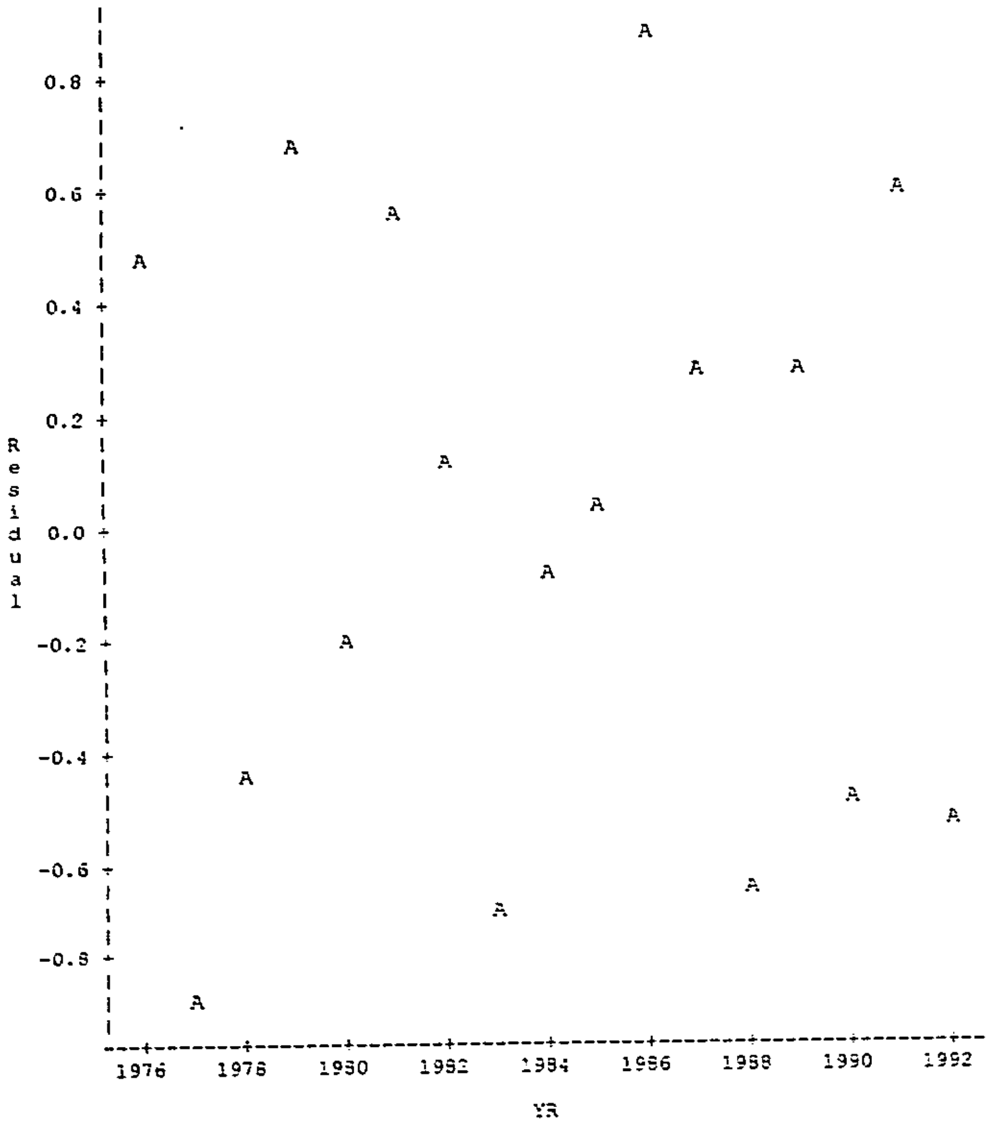
```
Model: MODEL1
Dependent Variable: FAT_DEPT

                           Analysis of Variance

                              Sum of         Mean
       Source          DF    Squares       Square       F Value       Prob>F

       Model            6    8.98301      1.49717         4.243       0.0220
       Error           10    3.52879      0.35298
       C Total         16   12.51180

           Root MSE       0.59404      R-square       0.7180
           Dep Mean       3.69710      Adj R-sq       0.5487
           C.V.          16.06762


                           Parameter Estimates

                     Parameter        Standard    T for H0:
     Variable  DF     Estimate           Error   Parameter=0     Prob > |T|

     INTERCEP   1    300.819809   365.51859969         0.823         0.4297
     YR         1     -0.152114     0.18559026        -0.820         0.4315
     HRSFWN     1   0.000001725     0.00000215         0.802         0.4410
     JET        1     -0.004496     0.01014779        -0.443         0.6671
     CPL        1   0.000072809     0.00019617         0.371         0.7183
     PASSKM     1  2.108277E-11     0.00000000         0.237         0.8174
     MOVE       1  -0.000055779     0.00075532        -0.074         0.9426


Durbin-Watson D               2.371
(For Number of Obs.)             17
1st Order Autocorrelation    -0.248
```

Plot of RESID*YR. Legend: A = 1 obs, B = 2 obs, etc.



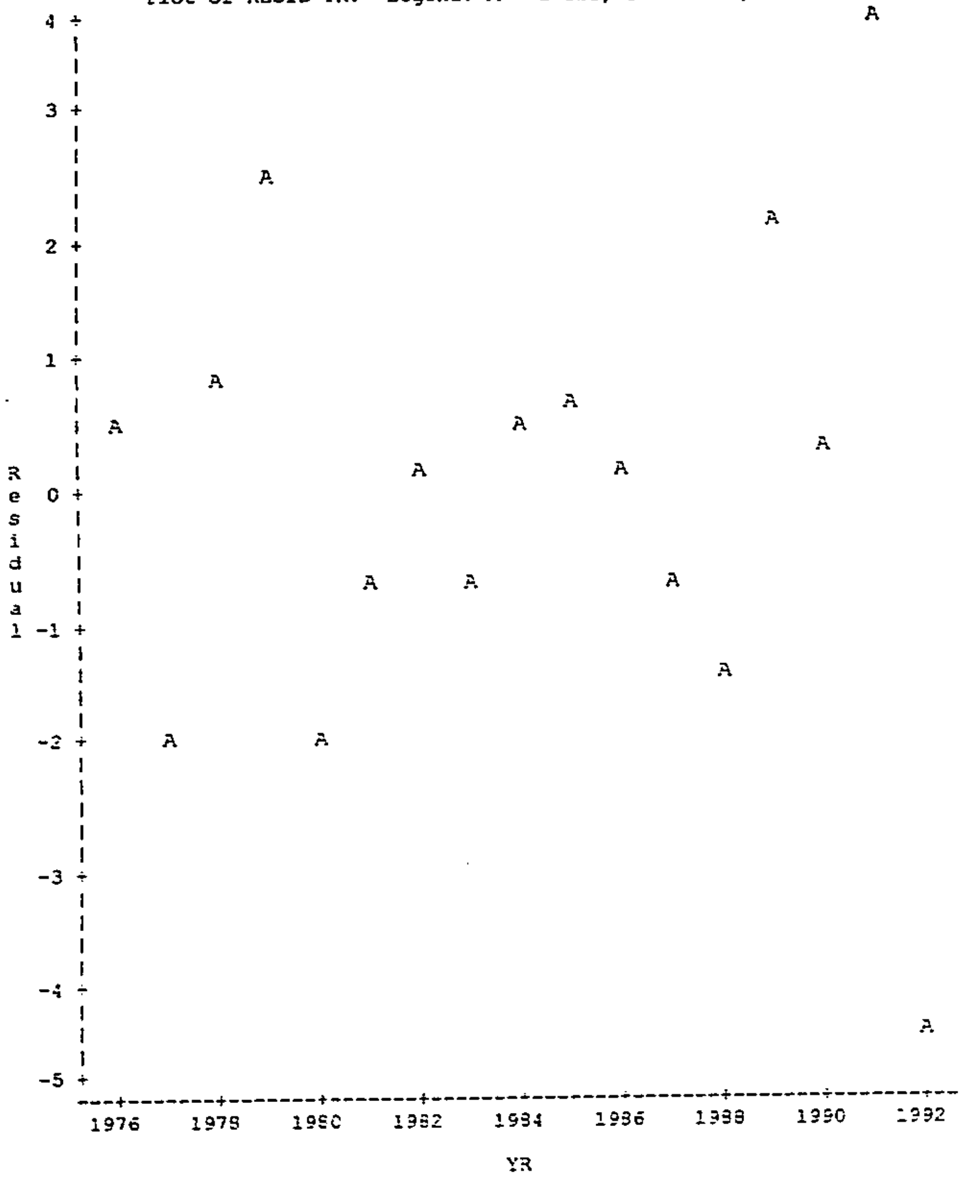
```
Model: MODEL1
Dependent Variable: FAT_HRS

                         Analysis of Variance

                              Sum of         Mean
    Source          DF       Squares       Square       F Value       Prob>F

    Model            6      27.85667      4.64278         9.653       0.0011
    Error           10       4.80982      0.48098
    C Total         16      32.66649

        Root MSE       0.69353     R-square       0.8528
        Dep Mean       4.43388     Adj R-sq       0.7644
        C.V.          15.64157


                         Parameter Estimates

                     Parameter       Standard    T for H0:
   Variable  DF       Estimate          Error   Parameter=0     Prob > |T|

   INTERCEP   1     283.450100   778.92990574         0.364         0.7235
   YR         1      -0.143268     0.39482602        -0.363         0.7243
   DEPTS      1    0.000001936     0.00000313         0.618         0.5506
   JET        1      -0.005668     0.01158469        -0.489         0.6352
   CPL        1    0.000065785     0.00022644         0.291         0.7774
   PASSKM     1   1.789483E-11     0.00000000         0.131         0.8962
   MOVE       1      -0.000150     0.00194244        -0.077         0.9400


Durbin-Watson D              2.456
(For Number of Obs.)            17
1st Order Autocorrelation   -0.282
```

Plot of RESID*YR. Legend: A = 1 obs, B = 2 obs, etc.



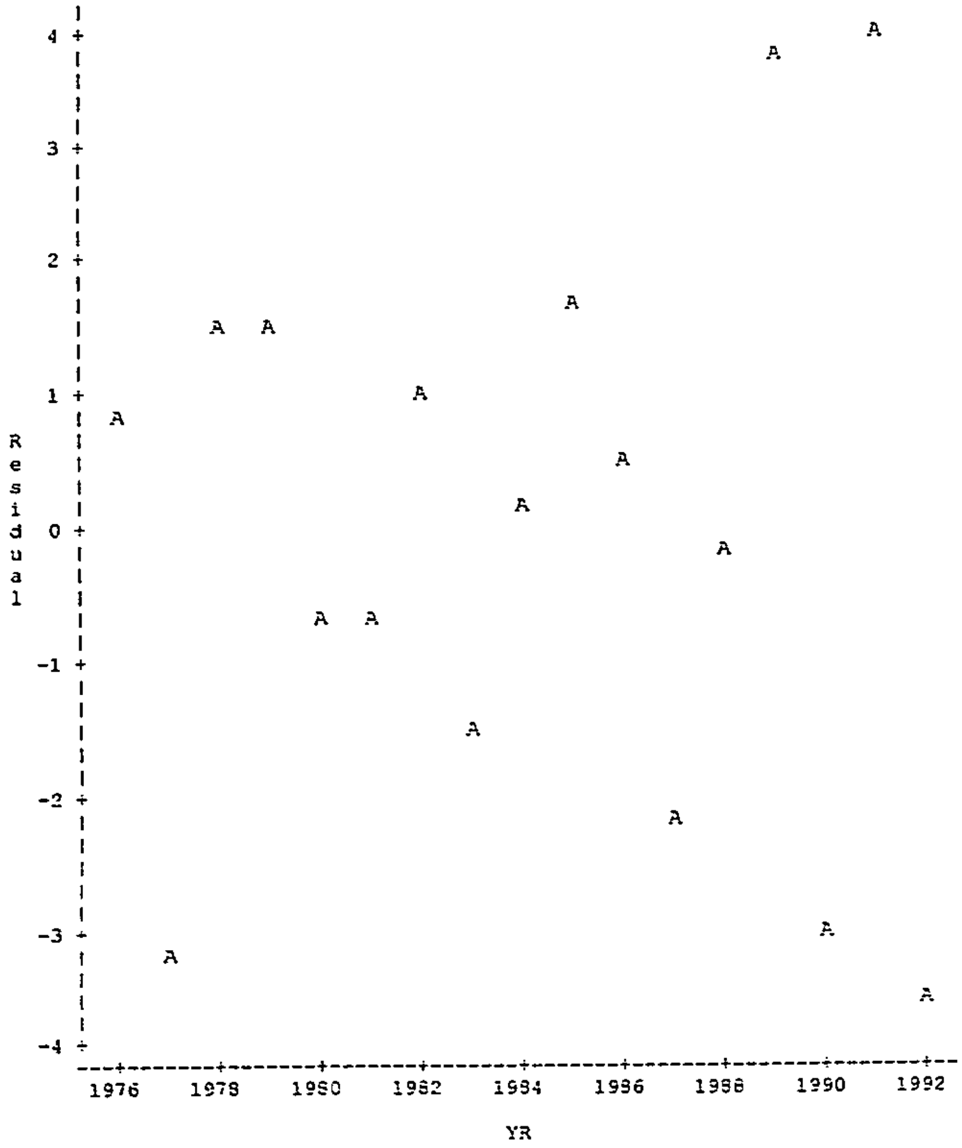
```
Model: MODEL1
Dependent Variable: VIC_DEPT

                          Analysis of Variance

                              Sum of         Mean
        Source          DF    Squares       Square      F Value       Prob>F

        Model            6    51.07200      8.51200       1.379       0.3112
        Error           10    61.74616      6.17462
        C Total         16   112.81816

            Root MSE       2.48488     R-square       0.4527
            Dep Mean       6.29356     Adj R-sq       0.1243
            C.V.          39.48285


                          Parameter Estimates

                        Parameter      Standard    T for H0:
      Variable  DF       Estimate         Error   Parameter=0    Prob > |T|

      INTERCEP   1   -3001.768617  1528.9788012       -1.963        0.0780
      YR         1       1.523248    0.77633140        1.962        0.0782
      HRSFWN     1    0.000013649    0.00000899        1.518        0.1600
      JET        1      -0.043733    0.04244859       -1.030        0.3272
      CPL        1      -0.000171    0.00082057       -0.209        0.8388
      PASSKM     1   -6.75319E-10    0.00000000       -1.815        0.0996
      MOVE       1      -0.000108    0.00315955       -0.034        0.9733


Durbin-Watson D              2.417
(For Number of Obs.)            17
1st Order Autocorrelation   -0.381
```

Plot of RESID*YR. Legend: A = 1 obs, B = 2 obs, etc.



```
Model: MODEL1
Dependent Variable: VIC_HRS

                              Analysis of Variance

                                 Sum of         Mean
        Source          DF      Squares       Square      F Value       Prob>F

        Model            6    103.78780     17.29797        2.167       0.1338
        Error           10     79.81469      7.98147
        C Total         16    183.60250

            Root MSE       2.82515     R-square       0.5653
            Dep Mean       7.51066     Adj R-sq       0.3045
            C.V.          37.61521


                              Parameter Estimates

                         Parameter       Standard    T for H0:
       Variable  DF       Estimate          Error   Parameter=0    Prob > |T|

       INTERCEP   1   -5465.263129   3173.0379841        -1.722        0.1157
       YR         1       2.771693     1.60835775         1.723        0.1156
       DEPTS      1    0.000018573     0.00001277         1.455        0.1764
       JET        1      -0.052058     0.04719203        -1.103        0.2958
       CPL        1   -0.000094283     0.00092244        -0.102        0.9206
       PASSKM     1    -9.4341E-10     0.00000000        -1.699        0.1202
       MOVE       1      -0.006013     0.00791269        -0.760        0.4648


Durbin-Watson D              3.008
(For Number of Obs.)            17
1st Order Autocorrelation   -0.588
```

Plot of RESID*YR. Legend: A = 1 obs, B = 2 obs, etc.



ANNEX D
ADDITIONAL COMPUTER PRINTOUTS

3) REGRESION ANALYSIS OUTPUT - EFFECT OF DEREGULATION

```
Model: MODEL1
Dependent Variable: ACCLN

                           Analysis of Variance

                                Sum of         Mean
        Source          DF     Squares       Square      F Value       Prob>F

        Model            2     0.76454      0.38227       14.645       0.0004
        Error           14     0.36545      0.02610
        C Total         16     1.12999

            Root MSE        0.16157     R-square        0.6766
            Dep Mean        5.48733     Adj R-sq        0.6304
            C.V.            2.94433

                           Parameter Estimates

                          Parameter       Standard    T for H0:
      Variable  DF         Estimate          Error   Parameter=0    Prob > |T|

      INTERCEP   1       135.526807    25.88915248         5.235        0.0001
      YR         1        -0.065601     0.01306541        -5.021        0.0002
      TIME_DER   1         0.000193     0.00007059         2.734        0.0162

Durbin-Watson D               0.990
(For Number of Obs.)             17
1st Order Autocorrelation     0.475
```

```
Model: MODEL2
Dependent Variable: ACC_DEPT

                         Analysis of Variance

                          Sum of         Mean
Source          DF       Squares       Square      F Value       Prob>F

Model            2       0.21264      0.10632       11.946       0.0009
Error           14       0.12460      0.00890
C Total         16       0.33724

    Root MSE        0.09434     R-square       0.6305
    Dep Mean        2.12191     Adj R-sq       0.5777
    C.V.            4.44603

                         Parameter Estimates

                     Parameter       Standard     T for H0:
Variable  DF          Estimate          Error   Parameter=0    Prob > |T|

INTERCEP   1         61.814650    15.11714706         4.089        0.0011
YR         1         -0.030104     0.00762913        -3.946        0.0015
TIME_DER   1       0.000055808     0.00004122         1.354        0.1972


Durbin-Watson D              1.322
(For Number of Obs.)            17
1st Order Autocorrelation    0.303
```

```
Model: MODEL3
Dependent Variable: ACC_HRS

                              Analysis of Variance

                                 Sum of         Mean
        Source          DF      Squares       Square      F Value       Prob>F

        Model            2      0.69134      0.34567       31.201       0.0001
        Error           14      0.15511      0.01108
        C Total         16      0.84645

            Root MSE       0.10526      R-square       0.8168
            Dep Mean       2.28251      Adj R-sq       0.7906
            C.V.           4.61146

                              Parameter Estimates

                      Parameter       Standard    T for H0:
      Variable  DF     Estimate          Error   Parameter=0    Prob > |T|

      INTERCEP   1   109.459573    16.86633331         6.490        0.0001
      YR         1    -0.054050     0.00851189        -6.350        0.0001
      TIME_DER   1  0.000098610     0.00004599         2.144        0.0501

Durbin-Watson D             1.467
(For Number of Obs.)           17
1st Order Autocorrelation   0.247
```

```
Model: MODEL4
Dependent Variable: FATLN

                           Analysis of Variance

                              Sum of         Mean
        Source        DF     Squares       Square      F Value       Prob>F

        Model          2     1.21421      0.60711       10.080       0.0019
        Error         14     0.84324      0.06023
        C Total       16     2.05745

            Root MSE       0.24542     R-square       0.5902
            Dep Mean       4.64385     Adj R-sq       0.5316
            C.V.           5.28486

                           Parameter Estimates

                     Parameter      Standard    T for H0:
      Variable  DF    Estimate         Error   Parameter=0    Prob > |T|

      INTERCEP   1  145.693667   39.32617982         3.705        0.0024
      YR         1   -0.071131    0.01984664        -3.584        0.0030
      TIME_DER   1    0.000126    0.00010723         1.178        0.2583


Durbin-Watson D              1.320
(For Number of Obs.)            17
1st Order Autocorrelation    0.268
```

```
Model: MODEL5
Dependent Variable: FAT_DEPT

                            Analysis of Variance

                               Sum of         Mean
        Source          DF    Squares       Square      F Value       Prob>F

        Model            2    0.56573      0.28287        8.329       0.0041
        Error           14    0.47547      0.03396
        C Total         16    1.04121

            Root MSE       0.18429     R-square       0.5433
            Dep Mean       1.27843     Adj R-sq       0.4781
            C.V.          14.41528

                            Parameter Estimates

                        Parameter       Standard    T for H0:
      Variable  DF       Estimate          Error   Parameter=0    Prob > |T|

      INTERCEP   1      71.981509    29.53038399         2.438        0.0287
      YR         1      -0.035633     0.01490302        -2.391        0.0314
      TIME_DER   1  -0.000010820     0.00008052        -0.134        0.8950

Durbin-Watson D             1.646
(For Number of Obs.)           17
1st Order Autocorrelation   0.071
```

```
Model: MODEL6
Dependent Variable: FAT_HRS

                         Analysis of Variance

                                Sum of         Mean
        Source          DF     Squares       Square      F Value       Prob>F

        Model            2     1.23504      0.61752       16.564       0.0002
        Error           14     0.52194      0.03729
        C Total         16     1.75698

            Root MSE       0.19308     R-square       0.7029
            Dep Mean       1.43902     Adj R-sq       0.6605
            C.V.          13.41770

                         Parameter Estimates

                     Parameter        Standard    T for H0:
      Variable  DF    Estimate           Error   Parameter=0    Prob > |T|

      INTERCEP   1  119.626432     30.93967319         3.866        0.0017
      YR         1   -0.059580      0.01561425        -3.816        0.0019
      TIME_DER   1  0.000031982     0.00008436         0.379        0.7103


Durbin-Watson D              1.642
(For Number of Obs.)            17
1st Order Autocorrelation    0.092
```

```
Model: MODEL7
Dependent Variable: VICLN

                              Analysis of Variance

                                 Sum of         Mean
        Source          DF      Squares       Square      F Value       Prob>F

        Model            2      0.89429      0.44715        2.699       0.1020
        Error           14      2.31698      0.16564
        C Total         16      3.21327

            Root MSE       0.40699     R-square       0.2783
            Dep Mean       5.13403     Adj R-sq       0.1752
            C.V.           7.92730

                              Parameter Estimates

                        Parameter       Standard    T for H0:
      Variable  DF       Estimate          Error   Parameter=0    Prob > |T|

      INTERCEP   1     150.265715    65.21600033        2.304        0.0371
      YR         1      -0.073222     0.03291239       -2.225        0.0431
      TIME_DER   1       0.000240     0.00017782        1.349        0.1989

Durbin-Watson D              2.647
(For Number of Obs.)            17
1st Order Autocorrelation   -0.373
```

```
Model: MODEL8
Dependent Variable: VIC_DEPT

                              Analysis of Variance

                                 Sum of         Mean
        Source          DF      Squares       Square      F Value       Prob>F

        Model            2      0.26545      0.13272        0.924       0.4199
        Error           14      2.01109      0.14365
        C Total         16      2.27654

            Root MSE        0.37901     R-square       0.1166
            Dep Mean        1.76861     Adj R-sq      -0.0096
            C.V.           21.42988

                              Parameter Estimates

                         Parameter       Standard    T for H0:
      Variable  DF        Estimate          Error   Parameter=0    Prob > |T|

      INTERCEP   1       76.553558    60.73260251         1.261        0.2281
      YR         1       -0.037724     0.03064977        -1.231        0.2387
      TIME_DER   1        0.000103     0.00016560         0.620        0.5453


Durbin-Watson D              2.953
(For Number of Obs.)            17
1st Order Autocorrelation   -0.526
```

GLOSSARY OF SELECTED TERMS

Accident - an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:

a) a person is fatally or seriously injured as a result of:

- being in the aircraft, or
- direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
- direct exposure to jet blast,

except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways, hiding outside the areas normally available to the passengers and crew; or

b) the aircraft sustains damage or structural failure which:

- adversely affects the structural strength, performance or flight characteristics of the aircraft, and
- would normally require major repair or replacement of the affected component,

except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage to propellers, wing tips, antennas, tires, brakes, fairing, small dents or puncture holes in the aircraft skin; or

c) the aircraft is missing or is completely inaccessible.

Aerial Experiment Association (AEA) - an association established by Dr. Alexander Graham Bell, in Halifax, in 1907 for the purpose of constructing a flying machine driven through the air by its own power and carrying a man.

Aircraft-kilometer (or Aircraft-mile) - represents the distance traveled by an aircraft. It is obtained by totaling the number of kilometers (or miles) flown by each aircraft.

Aircraft movement - a take-off, a landing, or a simulated approach by an aircraft.

Air Traffic Control unit (ATC unit) - an area control center established to provide air traffic control service to IFR flights and controlled VFR flights; a terminal control unit established to provide air traffic control service to IFR flights and controlled VFR flights operating within a terminal control area; an airport control tower unit established to provide air traffic control service to airport traffic.

Air Transport Board (ATB) - independent regulatory body, set up by the government in 1944 and superseded by the Air Transport Committee of the CTC in 1967. Its role was to regulate the economic aspects of commercial aviation by allocating routes, monitoring industry competition and investigating complaints on routes and tariffs charged by airlines.

Air Transport Commission (ATC) - member committee of the National Transportation Agency responsible for regulating air transportation in the country.

Airworthiness Requirements (ARs) - standards which have to be met by an aircraft manufacturer ranging from fatigue life of the structure and the loads which must be simulated on test apparatus, to stability and safe performance.

Aviation Occurrence - any accident or incident associated with the operation of an aircraft; or any situation or condition that is believed to induce an accident or incident if left unattended.

Aviation Statistics Center (ASC) - a satellite unit of Transportation Division of Statistics Canada, dedicated to collecting and distributing economic aviation related data.

Bilateral air agreement - an agreement or treaty between two nations contracting for reciprocal international air service between the two nations, such service to be operated by designated carriers of each nation. The agreement may include provisions for the type of aircraft used, intermediate stops en route, aircraft safety, taxation-free fuel, and arbitration procedures.

Canadian Automated Air Traffic System (CAATS) - a federally sponsored project aimed at improving the present air traffic technology.

Canadian Aviation Safety Board (CASB) - a body in the administration of civil aviation which was created by the 1984 Canadian Aviation Safety Act, and was replaced by the TSB in 1990.

Canadian Transport Commission (CTC) - federal government body created by the 1967 National Transportation Act and superseded in 1988 by the National Transportation Agency.

Certificate of Airworthiness (C of A) - a conditional certificate of fitness for flight issued in respect of a particular aircraft every year after mechanical inspection of the machine by a certified mechanic and a test flight by a specially certified pilot.

Certificate of Registration - a certificate issued to the owner of an aircraft with respect to the registration and registration markings for that aircraft.

Charter service - service offered for transport of passengers or cargo, in which one or more charters obtain the exclusive use of an aircraft for one or more trips. The charter services are referred to Classes 4 (domestic) and 9-4 (int'l) licence.

City-pair - a presentation of statistical data which is used to show the volumes of traffic flown between two specific cities. The two cities are those between which travel is authorized by a ticket or part of a ticket. They can represent direction, flow or origin and destination.

Civil aviation - general term describing all non-military aircraft.

Civil Aviation Authority (CAA) - British counterpart of TSB.

Class of service - refers to the licence authority under which a carrier is authorized to provide service, as specified by the National Transportation Agency. These classes are defined as follows:

(1) The following classes of air services that are permitted to be operated under domestic licenses referred to in subsection 72(2) of the Act are established, namely:

Class 1 - Scheduled domestic service, being a service that is required to provide transportation and that serves points in accordance with a service schedule at a toll pre unit of traffic;

Class 2 - Regular Specific Point domestic service, being a service that is required to provide transportation to the extent to which facilities are available and that serves points in accordance with a service schedule at a toll per unit of traffic;

Class 3 - Specific Point domestic service, being a service that, consistent with traffic requirements and operating conditions, offers transportation and serves points at a toll per unit of traffic;

Class 4 - Charter domestic service, being service that offers transportation on reasonable demand at a toll for the charter of an entire aircraft with aircrew; and

Class 4G - General domestic service, being a service that does not belong to any of the classes described above.

(2) The following classes of air services that are permitted to be operated under non-scheduled international licenses are established, namely:

Class 9-3 - Unit Toll non-scheduled international service, being a service that, consistent with traffic requirements and operating conditions, offers transportation and serves points at a toll per unit of traffic;

Class 9-4 - Charter non-scheduled international service, being a service that offers transportation on reasonable demand at a toll for the charter of an entire aircraft with crew; and

Class 9-4R - restricted Charter non-scheduled international service, being a service that

(i) is operated by a non-Canadian air carrier,

(ii) offers transportation on reasonable demand at a toll for the charter of an entire aircraft with crew, and

(iii) is restricted to operation of international charter flights other than:

(A) fourth freedom ABC's, ABC/ITC's and ITC's, and

(B) third freedom and fourth freedom flights governed by the provisions of an international agreement, convention or arrangement to which Canada and the non-Canadian air carrier's state are both parties.

(3) The air carrier holding a licence permitting an air service of a class established by subsection (1) or (2) to be operated and that licence are allocated to the same class as that air service.

Clear air turbulence (CAT) - turbulence encountered in air where no clouds appear.

Cockpit resource management (CRM) - a new approach to flight crew training program, requiring the coordination and workload management needed to successfully fly the high-technology cockpit. These lessons emphasize not hardware and systems, but crew coordination demanded by automation.

Commercial aviation - encompasses the activities of all major airlines and large commercial ventures which specialize in the transport of passengers or goods for profit; including scheduled and charter operations. These activities are defined as Level I to III air carriers.

Controlled flight into terrain (CFIT) - occurrence of an accident involving controlled flight into terrain; this can be a result of poor visibility, flight instrument's malfunction or pilot disorientation. In light of numerous studies pointing to the increased occurrence of these kinds of occurrences in recent years, ICAO has assigned high priority to the development of a safety program to prevent them by requesting the installation and use of ground proximity warning system (GPWS).

Deplanement - traffic (passenger, cargo and mail) which lands and disembarks at an airport in Canada. In includes interline and intraline transfers, and traffic stopping over, as well as traffic terminating at an airport.

Destination - the last point in the itinerary and the last point at which the passenger is to deplane at the completion of the journey.

Domestic - refers to traffic beginning and terminating in the provinces and territories of Canada, and to traffic flown between city-pairs in Canada.

Enplanement - traffic which embarks and takes-off from an airport in Canada. It is different from passenger departure in that a passenger is counted as one enplanement regardless of the number of times the plane takes-off and lands with that passenger on board; this means that for flights with intermediate stops enplanements and passenger-departures are not equal.

Fatal accident - aviation accident that resulted in at least one fatality.

Federal Aviation Administration (FAA) - American counterpart to the Canadian NTA and parts of TC.

Five freedoms - traffic rights relating to international air transportation that one country receives from the other when a bilateral air agreement is made. All five freedoms are not necessarily granted in every agreement. They are, in order: (1) to fly across another's territory without landing, (2) to land for non-traffic purposes, (3) to put down passengers, mail and cargo taken on in the territory of the State whose nationality the aircraft possesses, (4) to take on passengers, mail and cargo destined for the territory of the State whose nationality the aircraft possesses, and (5) to take on passengers, mail and cargo destined for the territory of any other contracting State and to put down passengers, mail and cargo coming from any such territory.

Fixed-wing aircraft - aircraft having wings fixed to the airplane fuselage and outspread in flight, that is non-rotating wings.

Flying operation expenses - expenses incurred directly in the in-flight operation of aircraft or in the holding of aircraft and aircraft personnel in readiness for assignment to an in-flight status. Landing fees are also included in this account.

Foreign air carriers - airlines with headquarters outside Canada.

General aviation - that portion of civil aviation which encompasses all facets of aviation except scheduled air services and non-scheduled air transport operations for remuneration or hire and military aviation. These activities include: private flying by individuals, groups or business firms, and specialty flying such as sightseeing, flight training, aerial photography and survey, or other types of flying which does not involve the transport of passengers or goods from one place to another, solely not for hire or compensation. This group also includes government-owned aircraft and commercial air carriers whose activities are limited to Levels IV to VI.

Goods tonne-kilometre (or tonne-mile) - represents the carriage of one tonne of goods over one kilometer (or one mile). Tonne-kilometer (or tonne-mile) figures are obtained by totaling the number of kilometers (or miles) flown with each tonne of goods.

Hague Protocol - this protocol modified the Warsaw Convention by increasing the liability limits. The Hague Protocol was adopted in the Hague on September 28, 1955 and entered into force on August 1, 1963.

Hub and spoke network - association of major airlines with smaller feeder carriers as a result of the 1988 air transport deregulation. In these new network families, the major airline is usually committed to fly announced long-haul routes, whereas the smaller carriers fly shorter distances.

Incident - an occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operations.

International - refers to traffic originating or terminating in Canada destined to or originated from foreign countries. International traffic is subdivided into Transborder (to or from a United States) and other international (to or from points in other countries).

International Air Transportation Association (IATA) - previously called International Air Traffic Association, established to make air travel more convenient and more acceptable to customers, as well as protect and promote the commercial and economic aspects of air carriers.

International Civil Aviation Organization (ICAO) - a specialized agency of the United Nations whose objective is to develop the principles and techniques of international air navigation and to foster planning and development of international civil air transport.

International Convention for Air Navigation (ICAN) - international organization of 1919 and the forerunner of ICAO.

Itinerant movement - at airports with control towers and/or flight service stations refers to a movement in which an aircraft proceeds to or arrives from another location; or where aircraft leaves the circuit but returns without landing at another airport.

Jet stream - a migrating stream of high speed winds present at high altitudes.

Level definitions - use for purposes of statistical reporting. Canadian air carriers are classified into six reporting levels (seven prior to 1988) as defined by Statistics Canada and the National Transportation Agency:

Level I - includes every Canadian air carrier not classified in report Level II-VI that, in each of the two calendar years immediately preceding the report year, transported at least 1,000,000 revenue passengers or at least 200,000 tons of revenue goods.

Level II - includes every Canadian air carrier not classified in report Level I or III-VI that, in each of the two calendar years immediately preceding the report year, transported at least 50,000 revenue passengers or more, but fewer than 1,000,000 revenue passengers, or 10,000 tons of revenue goods or more but less than 200, 000 tons of revenue goods.

Level III - includes every Canadian air carrier not classified in report Level I, II or IV-VI that, in each of the two calendar years immediately preceding the report year, transported at least 5,000 revenue passengers or more, but fewer than 50,000 revenue passengers, or 1,000 tons of revenue goods or more but less than 10,000 tons revenue goods.

Level IV - includes every Canadian air carrier not classified in report Level I-III, V or VI that, in each of the two calendar years immediately preceding the report year, realized annual gross revenues of $250,000 or more for the air services for which the carrier held licence.

Level V - includes every Canadian air carrier not classified in report Level I-IV or VI that, in each of the two calendar years immediately preceding the report year, realized annual gross revenues of less than $250,000 for the air services for which the air carries held a licence.

Level VI - includes every Canadian air carrier that, in the report year, operated the air service for which the air carrier held a licence for the sole purpose of serving the needs of a lodge operation.

Line oriented flight training (LOFT) - method of pilot training by use of a sophisticated simulator programmed to initiate scenarios requiring the crew to coordinate their efforts in order to complete the mission safely. This method is mostly applied during the Cockpit Resource Management (CRM) programs.

Local carrier - any Canadian airline of Levels II, III and IV that operates classes 2, 3, 9-2 or 9-3 licenses.

Major airline - in this publication, refers to a Level I air carrier.

Microwave Landing System (MLS) - a global standard for the guidance of aircraft landing in bad weather and other conditions of limited visibility.

National Transportation Agency (NTA) - federal agency which assumed responsibility for the regulation of Canadian transportation in January, 1988, thus replacing CTC. The goal of NTA is to support the implementation of the national transportation policy through the economic regulation of carriers and modes of transportation that come under federal jurisdiction. Its activities include dispute resolution, licensing carriers and regulation of international tariffs and transportation facilities.

Operating expenses - expenses incurred in the performance of air transportation. It includes direct aircraft operating expenses as well as ground and indirect operating expenses.

Operating revenues - revenues form the performance of air transportation and related non-flying services. It includes: (1) transport revenue from all classes of traffic, and (2) non-transport revenue consisting of payments under the National Transportation Act where applicable, and the net amount of revenue less related expenses from services incidental to air transportation.

Origin - the first air departure point in a passenger's itinerary (the point where a passenger first boards a carrier at the beginning of the journey).

Passenger - a person who pays a fare and receives air transportation is counted as one revenue passenger. Persons paying 25% or less of the normal applicable fares are not included.

Passenger-departures - traffic which embarks and takes-off from an airport in Canada. It is different from enplanement in that a passenger is counted every time the plane takes-off and lands with that passenger on board.

Passenger-kilometer (or Passenger-mile) - represents the carriage of one passenger for one kilometer (or one mile). It is obtained by totaling the number of kilometers (or miles) flown by each passenger.

Passenger load factor - a measure of passenger capacity utilization derived by expressing revenue passenger- kilometers as a percentage of available seat-kilometers.

Phases of flight - stages of airplane operation: initial roll, take off, initial climb, climb, cruise, descent, approach, flare/touchdown and parking and taxiing of the aircraft. 80 to 90 percent of aircraft accidents occur during the take off, initial climb and landing phases of flight.

Power plant - the source of propulsion such as piston engines, turbo-propellers, jet engines and helicopters.

Primary accident cause - that original event which initiated the course of events leading to an accident or incident. Although most accidents are the result of a number of interrelated factors, usually one can determine the single original point in time and event that triggered the mishap.

Private aircraft - aircraft used solely for private purposes, not for-hire and compensation. Owners include individuals, groups and business firms.

Radar Modernization Project (RAMP) - Transport Canada's 10-year, multi-million dollar Radar Modernization Project to completely replace the antiquated primary and secondary radar and display systems for air traffic control. The project began in the beginning of 1981 and was scheduled to be completed in the early 1990's.

Regional carrier - any Canadian airline designated by Transport Canada as a 'regional carrier'.

Rotary-wing aircraft - Helicopters and autogyros.

Scheduled service - air transportation of persons, cargo and mail at a toll per unit service performed under Classes 1, 2, 3, 8, 9-2 or 9-3 licenses as issued by the National Transportation Agency.

Southern and northern sectors - dividing line separating the southern and northern domestic sectors as determined by the National Transportation Act of 1987. Carriers are subject to two distinct regulatory regimes based on location of the points they serve. The south which contains 95% of Canada's population is almost completely deregulated, whereas in the north more stringent regulatory principles govern air transport.

Tonne-kilometer - represents the carriage of one tonne of goods or passengers for one kilometer. The number of tonne-kilometers is the sum of the kilometers flown with each tonne of goods or passengers.

Trans-Canada Air Lines - first Canadian national carrier, established in 1937 and renamed Air Canada in 1964 (eventually privatized in 1988).

Transport Canada (TC) - established in 1936 and initially called Department of Transport. This federal government department provides and operates domestic airway facilities, a national air terminal system, and regulatory services required for aviation safety.

Transportation Safety Board (TSB) - an independent body in the administration of civil aviation which was created by the 1990 Canadian Transportation Accident Investigation and Safety Act and is responsible for investigating aviation accidents, reporting its findings and recommending improvements in order to advance safety in all modes of transportation in Canada.

Weight group - the classification of weight classes in groups for statistical purposes. The weight groups correspond to the following:

1. For fixed-wing aircraft, the maximum authorized take-off weight on wheels:

Group A: less than 1,950 kg
Group B: 1,950 to 3,402 kg
Group C: 3,403 to 8,165 kg
Group D: 8,166 to 15,876 kg
Group E: 15,877 to 34,019 kg
Group F: 34,020 to 68,039 kg
Group G: 68,040 to 158,757 kg
Group H: greater than 158,757 kg

2. For rotary-wing aircraft, the maximum authorized take-off weight on wheels:

Group A: less than 2,000 kg
Group B: 2,000 to 3,402 kg
Group C: 3,403 to 8,165 kg
Group D: 8,166 to 15,876 kg.

Windshear - a change, either vertically or horizontally, in wind speed and/or direction in a short distance resulting in a tearing or shearing effect.