A Systems Engineering Approach for Implementation of a Corporate Growth Strategy

by

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Submitted to the Systems Design & Management Program
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering & Management
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January 2001

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Abstract

An experimental study was performed to create a structured decision making process, as it pertains to a corporate growth strategy. The thesis focuses on a segment of the growth strategy in the area of mergers and acquisitions. A multistage decision model was built using a set of axioms defined by a process flow of the acquisition steps. The decision model makes use of decision fault trees using experimental probabilities.

The model is capable of revealing decision paths which may be attractive, based on value but with unfavorable risk. The model can act as a risk management device for managers. Risk can be managed by choosing one path with favorable risk over another, or risk can be managed by the order in which the decisions are made. As more information is learned from acting on low risk decisions at first, new information will improve the probability previously riskier decisions. The learning from previous less risky decisions can provide the organization with base information for future decision making.

This thesis provides a case study for decision making of a corporate growth strategy at Pratt & Whitney Aircraft. The focus of the study is on Pratt & Whitney's Aftermarket Services organization which is currently undergoing massive growth. Included in this analysis is a study of the airline industry and a look at the drivers which are causing the Maintenance Overhaul and Repair market to consolidate into service providers who can provide 'One Stop Shopping' for their customers.

Acknowledgements

SDM has truly been a fantastic journey over the last two years. From the initiation in that cold January of 2000, where I came to meet so many truly special people who I have come to know, not only as classmates, but as friends. To this final document which culminates and brings to an end this journey. The content of this program has lived up to expectations. I walk away after these two years with valuable knowledge, which I will apply, for the rest of my life.

I want to offer special thanks to Professor Deborah Nightingale, my thesis advisor, for providing the guidance, which has resulted in a balanced approach to a very broad subject. Debbie's extensive experience in both academia and industry allows her to provide keen insights into an analysis such as this. I want to thank her for her candor, patience and enthusiasm.

Special thanks goes to Kevin Trammel, my supervisor, for his support of my endeavor over the past two years. Kevin's wealth of knowledge in the areas of strategic planning, organizational behavior, market dynamics, operations management, systems architecture and industry knowledge has been invaluable to me throughout this journey. Discussions with him on these subjects and other various philosophies have enhanced my learning experience. I thank him for his willingness to share his time and knowledge.

I would have never been able to partake in this tremendous opportunity if weren't for the support of my Director Warren Boley. I want to thank Warren for his support, his patience and mostly the wisdom he provided to me on the subject of leadership at the completion of this program.

Most significantly, I want to thank my family for their unending support and patience. My parents, John and Lorraine are always there for me and have provided me with moral support over the course of this journey. My wife Lori and my three children, Mary Kate, Maggie and John have endured the last two years with understanding, love and fortitude. I could not have completed this program if it were not for the support of my wonderful wife Lori.

After enduring the hardships of this program and finding the resolve to perceiver, I feel even closer to my lifetime hero, Benjamin Franklin, whose words of wisdom will stand the test of time, most notably, "Beer is living proof that God loves us and wants us to be happy."

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Chapter 1

Introduction and Statement of Problem

Pratt & Whitney has embarked on an aggressive growth strategy to double the size of its business within the next five years. As part of this plan, the after-market business at Pratt & Whitney will increase four times its current size. The strategic growth plan in the after-market division has a dual approach. The throughput of the current organization is expected to double and the remaining growth will be achieved through acquisitions and partnerships. This strategy has considerable inherent risk since large amounts of capital will be invested with the hope that the organization will mesh into a coordinated business which will flourish. The growth strategy will require Pratt & Whitney to reinvent how it currently conducts its business.

The risk inherent in the growth strategy must be successfully managed using the available resources. Decisions need to be as informed as possible so that risk is managed and the organization learns from the experiences as the strategy plays out. Using a structured systems engineering approach to decision making, corporate managers will be able to evaluate if a decision is consistent with the strategy and benchmark the results of previous decisions, thus allowing the organization the ability to learn.

A successful integration of an acquisition depends largely on informed timely decisions. The success of acquisitions has been correlated to the speed at which good decisions can be made[1]. This being the case, a tool which helps managers make speedy informed decisions would have tremendous value. The fundamental decisions which need to be

made quickly once the acquisition deal is complete are centered around organizational structure, reporting structure, human resource management, process methods, quality assurance, marketing management, financial and accounting management and integration of culture. Each acquisition integration will have a unique decision path, which best suits both organizations – acquisition to parent.

The thesis applies multistage decision analysis using conditional probabilities to help managers make informed and balanced decisions. A decision model is presented which incorporates a method to decompose abstract decisions into a series of factual questions which contain the meaning of the abstract decision. The decomposition is then evaluated in a binary sense; yes or no answers provide a solution. The model then converts the results from syntax to numeric and assigns probabilities. The decision analysis model then evaluates the probabilities and provides a numeric evaluation of a decision which managers can use to assess which direction to choose.

1.1 Thesis Scope

This thesis will analyze a segment of Pratt & Whitney's growth strategy in the area of expansion into the after-market division of the organization, Pratt & Whitney Aftermarket Services. The expansion is occurring from organic growth and growth through mergers and acquisitions. Pratt & Whitney expects to grow its PWAS division by four times its current size, two thirds of this growth will come from mergers and acquisitions and the other third will come from growth within the current organization. Pratt & Whitney has already begun acquiring companies and attempting to integrate them

[1] Business International, "Making Acquisitions Work", Geneva 17, Switzerland, 1988

into the organization. The results thus far have been varied - there is definitely room for improvement.

Specifically this thesis will investigate the merger and acquisition process at Pratt & Whitney. A structured approach to decision making will help evaluate the relative risks of certain decision paths, thus allowing management to judge which path best suits the organization.

1.2 Thesis Chapters Outline

In chapter one an introduction to the problem statement is provided along with a quick review of how the decision model presented in this thesis functions. The scope of the thesis is defined, explaining what segment of Pratt & Whitney's growth strategy is analyzed.

An overview of the airline industry is discussed in detail in chapter two. The trends and market forces, which are directly influential to Pratt & Whitney's growth strategy, are discussed. An analysis of the different airline maintenance market segments is explained. The needs of customers in these different segments are discussed along with the aircraft maintenance supplier relationships. A review of the new after-market business model called the Fixed Operator Maintenance Cost is compared and contrasted to the traditional model of variable operator maintenance cost.

A detailed overview of Pratt & Whitney, a division of United Technologies Corporation, is covered in chapter three. Along with Pratt & Whitney's capabilities and services, a

review of its organizational structure is presented. The evolution of Pratt & Whitney's organizational structure from a functional organization to a product focused Module Centers is chronicled.

The contents of Pratt & Whitney's growth plan is presented in chapter four. A review of the main constituents of the plan including customer focus, employee motivation, quality processes and products is explained.

In chapter five the research methodology used for this thesis is discussed, providing insight into how data was collected through interviews, literature and SDM course work.

The decision model technique created in this thesis is explained in detail in chapter six. The functionality and the steps necessary to operate the model are shown. A simulation is conducted, providing an example of how the model functions.

The findings and observations discovered from the experimental model simulation are discussed in chapter seven. An explanation of decision model possible outcomes, branch value relationships, level of integration and decision evaluation criteria are all covered.

Recommendations for managers using an acquisition growth strategy are provided in chapter eight. The remaining sections of the thesis include the bibliography and the appendices, which contain the results for the model simulation.

Chapter 2

Overview of the Commercial Airline Industry

The first commercial airline flight occurred in 1914[2], St. Petersburg to Tampa Florida aboard the Airboat Line, passengers paid $5 for the 18 mile flight. From these humble beginnings, commercial aviation in the US has grown into an industry, which represents over $120 billion in assets, transports over 650,000,000 passengers annually over a distance of 6 billion miles[3]. Social scientists say the world is becoming smaller and smaller as we move into the new millennium. It is air-travel, which is the driving force behind this phenomena.

Air-travel has transformed from a luxury for the privileged few, to a commodity within reach of many people. Compared to other modes of transportation air-travel is among the safest and most efficient. Globalization is a direct result of the expansion of the world's airline industry. Air-travel demand since 1965 has outpaced economic growth. During the next 20 years this trend is expected to continue. Technology advances such as video conferencing and the Internet have enhanced growth in air-travel. While this may seem counter intuitive, the explosion of information technology has fostered professional relationships around the globe which ultimately leads to an increase in travel.

[2] Morrison, Steven A., "*The Evolution of the Airline Industry*" Washington, D.C.: The Brookings Institution, 1995
[3] "Aviation & Aerospace Almanac", Westport, CT: Publications of Aviation Week, McGraw-Hill, 2000

Over the next 20 years the industry will purchase over 23,000 airplanes to support this growth and $3.1 trillion will be spent on aviation support services[4]. The world fleet today consists of a variety of different aircraft, with each model filling a specific market need. This diversification of aircraft allows today's airlines to offer more nonstop flights to more destinations with greater frequency. Matching the aircraft model's capability to the rout structure is a method to maximize profits. Today, airlines are able to customize their operations to the equipment. This is quite an accomplishment compared to the day when de Havilland Comet first took to the sky 50 years ago.

Currently the world air transport system is highly concentrated. The Official Airline Guide shows[5] that half the world's jetliner fleet is operated by just 17 of the largest airlines. Concentration is likely to increase with the presence of deregulation. Since 1978 after deregulation in the US, concentration has increased; favoring major airlines strategically located at "hub" airports. Today's top 10 US airlines supply 91 percent of the domestic Revenue Passenger Kilometers (RPK) compared to 67 percent prior to deregulation. Along with deregulation, the forces of privatization and globalization have fostered competition--driving airlines to operate at much higher levels of efficiency.

[4] "Current Market Outlook", Boeing Commercial Airplanes, 2001
[5] Airbus, "Global Market Forecast 1998 – 2017, page 9

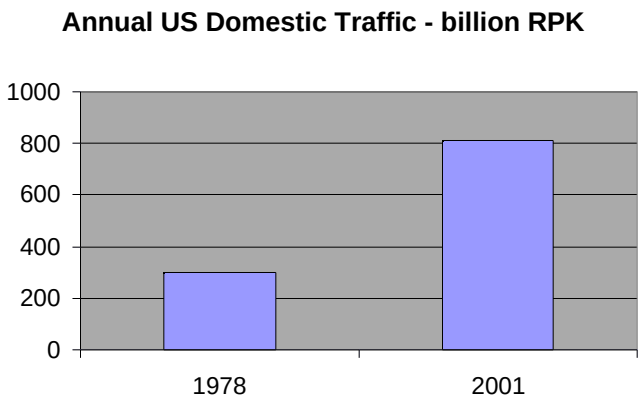


Figure 2-1: Growth of US Domestic Air Travel

As the US domestic air-travel market has matured, major US airlines have expanded into international markets as a source of continuing growth. Major US airlines have sought to repeat their domestic hub strategy on a global basis by entering into strategic alliances with foreign airlines. As shown in figure 2-2, just four of the major global alliances transport almost 60 percent of the world's passengers. Global alliances benefit airlines and customers alike by providing economies of scale.

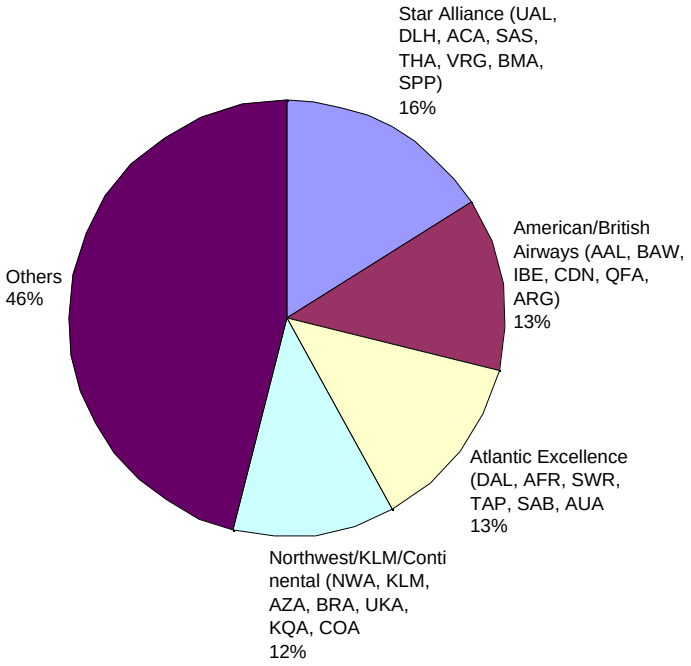


Figure 2-2: Airline Global Alliances

2.1 Industry Trend

Customers want low cost and convenience. Unfortunately, these two factors have an inverse relationship. A hubbed network route structure reduces costs by consolidating services, unfortunately the hubbed structure typically requires the customer to make a connecting flight to their destination. While travelers prefer direct flights to their destination, the fact is, the provision for such services is quite costly. With cost acting as the dominating factor in attracting customers, the hub structure will remain as the primary routing structure until costs can be matched in a point-to-point or fragmented route structure.

The hubbed model dramatically minimizes the route network as shown in figure 2-3. Using the relationship shown in the figure, the fragmented model has 30 routes verses the hubbed system which has only 10 routes for the same amount of cities. Costs are significantly reduced in the hubbed model, mainly because support services are centralized. In the US, the regional jet market, which provides non-stop flights, is growing. The ability of the regional jet market to compete, using a fragmented hub structure in the US, is mainly because of the existence of an abundance of airports throughout the country. This segment of the business in the US is expected to grow by 9 percent[6] in the next decade. The regional jet market is performing a dual substitution roll by taking the place of larger jets with unprofitable loads and replacing the propeller driven connector service aircraft.

For the emerging markets of intra-Asia, domestic China and domestic Asia, the hubbed model is expected to prevail since presence of airport infrastructure will dominate as the influencing factor. Airline alliances are using the hub strategy in the emerging global markets to ease the dependency on construction of new airports. The pressure placed on infrastructure has outpaced air-travel growth, even in recent years where huge amounts have been invested in new airports and expansions. Airlines are mitigating the problems of congestion by applying increasingly sophisticated revenue management systems. The Internet has allowed airlines to move massive amounts of information in real time, thus allowing the optimization dynamic modeling techniques. The result is significantly increased load factors. The strategic use of hubs, secondary hubs, and cooperation with rail on short routes has done much to maximize the utilization of current infrastructure.

[6] Boeing, "Current Market Outlook", 2001, page 7

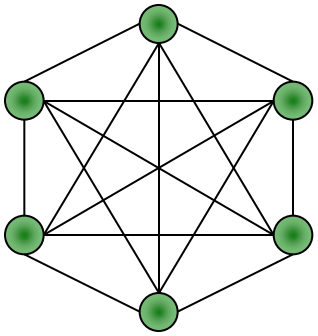
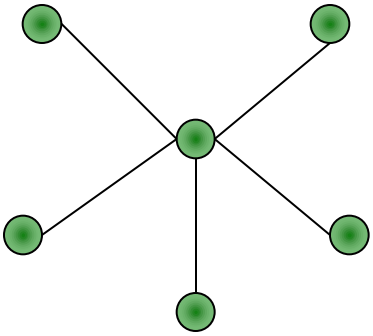
Network Type:	**Fragmented**	**Hubbed**
		
Number of cities:	n	n
Number of routes:	n (n-1) 6 (5) = 30	2 (n-1) 2 (5) = 10

Figure 2-3: Airport Models, Fragmented and Hubbed

2.2 Size of the Industry

The fleet of jetliners with at least 70 seats operated by the world's airlines is currently at 9700 aircraft. As shown in figure 2-4, aircraft are highly concentrated in three main regions: North America, Europe followed by Asia-Pacific. These regions correspond to the regions of greatest economic strength not necessarily with areas of greatest population.

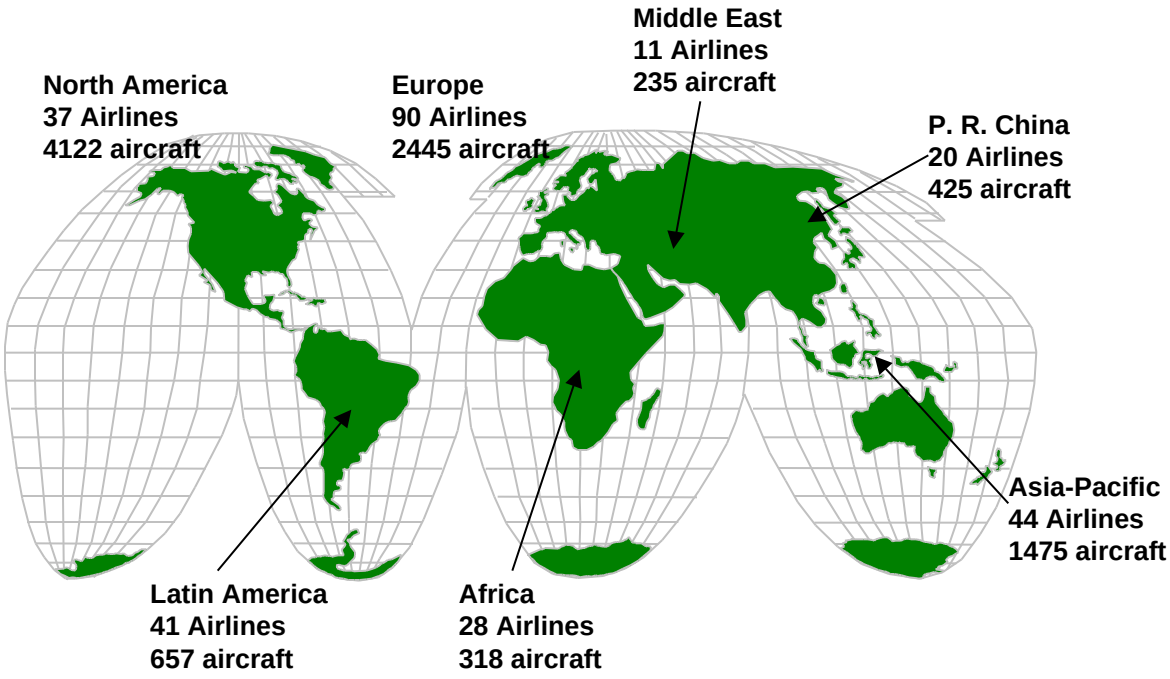


Figure 2-4: Distribution of the World's Jetliners

Industry analysts predict[7] that over the next 20 years, the world demand for new jetliners will increase to 32,955 passenger and cargo aircraft by 2020. This prediction is based on a 4.7% annual increase in revenue passenger-kilometers[8] (RPK).

[7] Airbus, "Global Market Forecast 1998 – 2017", page 4

[8] Revenue Passenger Kilometer (RPK) is a measure of the commercial airline industry's earning potential. RPK is calculated by multiplying the total sum of airline seats by the distance all the aircraft travel per year. There are currently about 1.8 million seats in the industry - this figure is expected to increase to 4.2 million in the next 20 years.

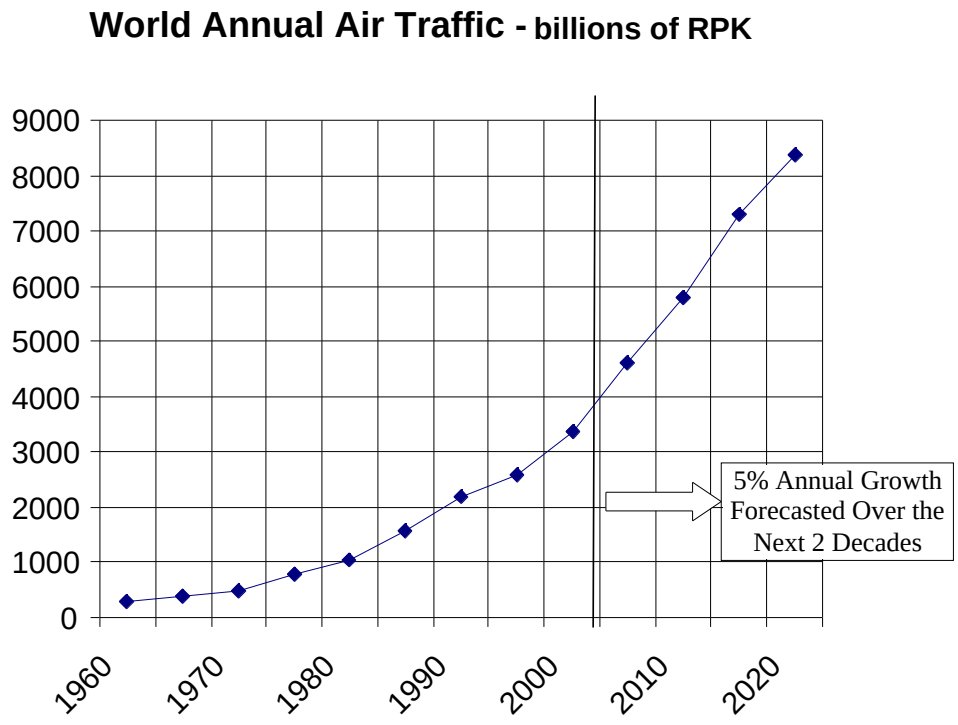


Figure 2-5: World Annual Air Traffic Growth Forecast

The airline industry is a cyclic business driven by economic conditions, but when RPK usage is plotted per decade, the trend has always been positive since the birth of the industry. Figure 2-5 shows this trend, and at a modest five-percent growth, in 20 years from now, there will be three times more air travelers than today. While some markets are at maturity and others are experiencing financial turmoil, air travel will continue to grow as the world's economy continues to grow. Air-travel is expected to outpace economic growth by approximately two percentage points on average over the next two decades[9]. This growth projection considers short-term economic cycles by averaging growth cycles peaks, producing a smooth long-term projection. Steady growth will be

[9] "*Current Market Outlook*", Boeing, page 7, 2001

supported by growing population, growing world trade, lower fares and service improvements such as more direct flights and increased frequency.

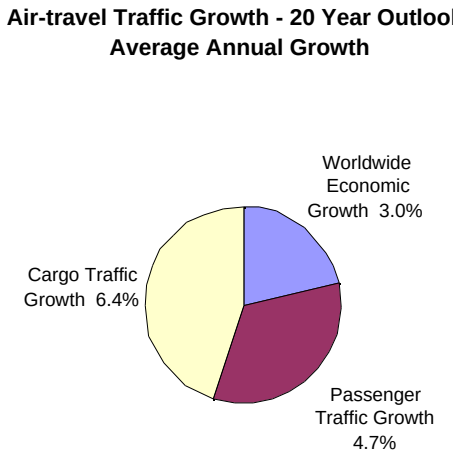


Figure 2-6: Air-Travel Traffic Growth Compared to World Economic Growth

The quantity of jumbo jets is expected to decline from 7% to 5% but the intermediate sized (twin aisle aircraft) fleet is expected to increase from 19% to 22%. The share of single aisle and regional jets will remain roughly the same at 73%[10].

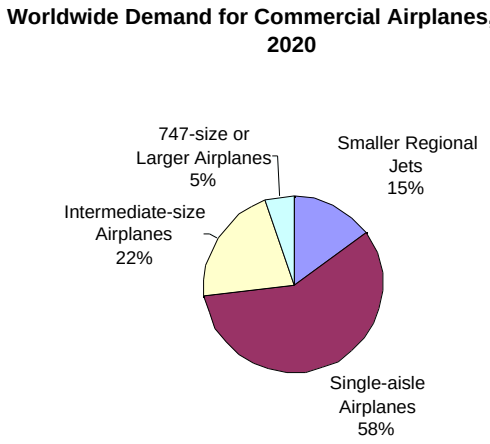


Figure 2-7: Worldwide Demand for Jetliners, Segmented by Aircraft Size

[10] Boeing, "Current Market Outlook", 2001, page 7

2.3 Comparative Technologies

Over the last three decades technology has continually reshaped the industry in a beneficial manner. Accidents have been reduced by ten-fold, aircraft noise has been reduced by a magnitude of 10 times, fuel consumption has been reduced by half and revenue yield has been chopped in half.

When comparing modes of transportation, the impact of noise is becoming a significant factor. Compared to a high-speed train, the zone of annoying noise (> 80 dBA) produced by a modern aircraft at takeoff and landing is much less. Since the noise produced by the high-speed train follows the entire distance traveled, the amount of people exposed to the sound is much greater than the aircraft. The huge physical barriers needed to contain noise from trains and roadways can be a larger impact on the environment than the noise itself. Compared to other modes of transportation, airlines pollute substantially less. Overall, airlines contribute less than 2% of these air pollutants: oxides of nitrogen, hydrocarbons and carbon monoxide. Road travel contributes over 50% and other modes of travel, such as boats or trains, contribute around 15% to the total world air pollution. The rest comes from non-travel industries.

2.4 Outlook for Commercial Air-Travel

The outlook for commercial air travel over the next two decades is positive. While the health of the industry follows the relative health of the world economy, which by all current accounts is in a downward trend, air travel is here to stay. Competition fostered by deregulation, privatization and globalization are driving airlines to operate at much

higher levels of efficiency. Airline strategies are increasingly becoming more focused on their core business – transporting people (or cargo in the case of freight transporters). The emphasis is on cost reduction from a complete life cycle perspective. This trend is causing airlines to seek service providers who can offer complete integrated solutions for operations, which are not part of their core business. These include a wide range of services, from aircraft and engine maintenance to food service and uniform providers. This change is resulting in a shift of work traditionally captive with the airline to outside providers. The worldwide demand for commercial aviation support services is expected to reach $3.1 trillion by 2020, figure 2-8 shows the distribution of this demand.

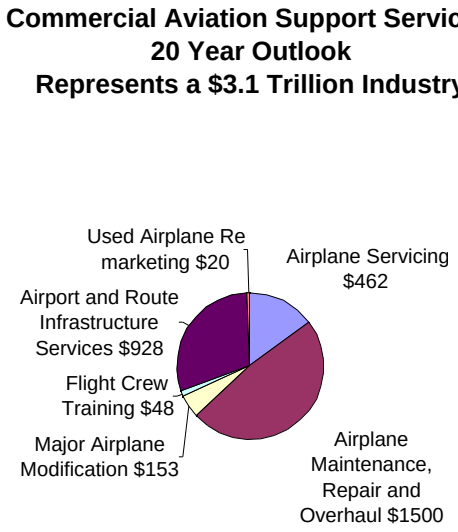


Figure 2-8: Demand for Commercial Aviation Services – 20 Year Outlook

The opportunity for service providers is tremendous. Growth in the service sector is expected to come from two areas, traditional industry growth of around 5% and growth

from 45% offshoot work from airlines – work which was traditionally captive by the airline[11].

Air-travel is a growing industry; the markets in domestic China and India, where over half the world's population exists, are largely untapped. Considering cost, convenience and overall environmental impact, air-travel competes successfully when compared to other modes of transportation. Air-travel is expected to be the preferred method of transportation as the world economy continues to grow.

The world Gross Domestic Product (GDP) is forecasted to grow by 3% over the next 20 years. The growth rate of GDP in developing economies will outpace mature economies. China is expected to have the fastest growth, at 6.1%, China's domestic market alone will require 1400 new airliners by 2020. For mature economies, GDP growth is expected to be between 2% and 3%. Growth in mature economies relies on productivity and efficiency gains in service industries and other consumer markets. Emerging economies are fueled by expanding labor forces, manufacturing and global trade. Following China, South America and Southwest Asia are the next fastest growing economies. As shown in figure 2-9, Revenue Passenger Kilometers (RPK) over the next 20 years will out pace GDP in all the world's regions. Air-traffic growth follows the expanding economy. International trade, lower fares and service improvements further drive growth in RPK. These factors increase the accessibility of air-travel to the mass populous.

[11] Proulx, J., "Ranking the Players", Aviation Week's Overhaul & Maintenance, Vol. VII, No. 5, pp. 32-42. Understanding of ratios of airline maintenance work performed in-house vs. work outsourced also came

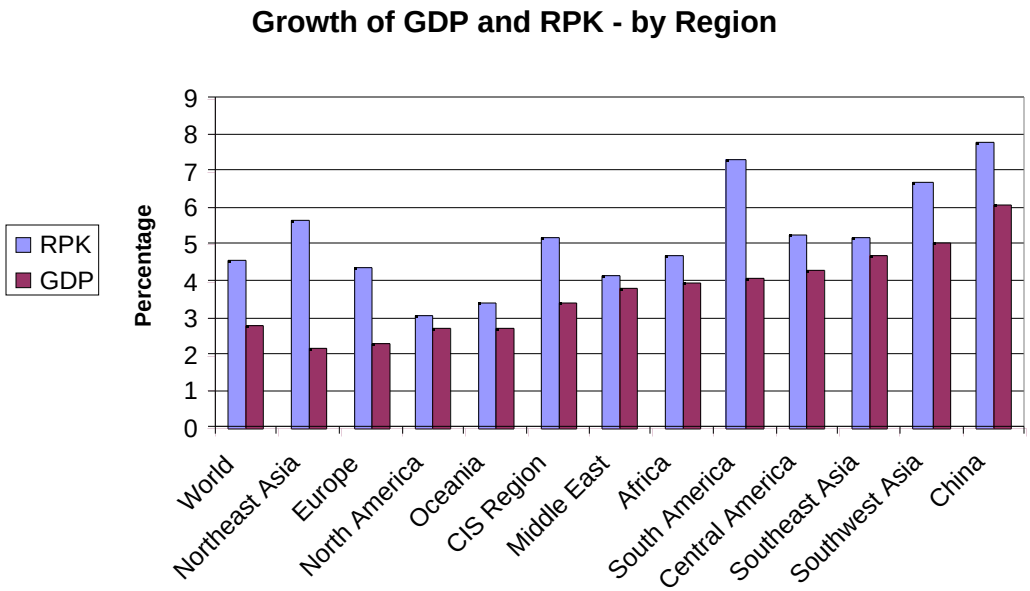


Figure 2-9: Growth of Gross Domestic Product Compared to Revenue Passenger Kilometers per World Region.

2.5 Airline Market Forces

As the world airline fleet increases so does the demand for after-market services. The market for airplane maintenance services is being shaped by the way various maintenance strategies are emerging. Airlines are focusing on total life cycle cost, not simply short-term costs. Airlines are looking to service providers to improve operational and economic efficiency. Airlines are reevaluating past practices of performing their own heavy maintenance. Today service providers are continuously expanding the scope of the services they provide; thereby meeting the demand of the airline, to reduce life cycle cost and improve efficiency. Engine maintenance services now include engine financing, engine leasing, fleet maintenance plans, maintenance material plans and fixed fee per

from discussions with industry experts, reference Chapter 5.2.

hour engine usage. Total fleet maintenance plans provide airlines with fixed cost maintenance structures, which allow for better planning. This way, the total supply chain is managed by partnership arrangements such as: joint ventures, third party agreements, and OEMs. Maintenance strategies are now becoming more integrated with the airline's usage profile. A maintenance strategy which is integrated with the airline's usage profile results in reduced airplane service disruption. Minimal airplane service disruption maximizes revenue through increased utilization.

Airlines continually evaluate their supplier base maximizing value by establishing a competitive environment. Much focus has been placed on utilization of existing inventories and inventory minimization. As the airline grows they must determine if growing their infrastructure to maintain greater numbers of aircraft is within the strategic growth plan. More and more operators are choosing not to invest in infrastructure, thus creating opportunities for third party service providers.

2.6 Airline Cost Structure

The main cost drivers for the airline are: fuel, aircraft maintenance, aircraft indirect operating cost, engine maintenance and other-costs not directly affecting maintenance service providers. The 'Other' category contains the costs of engine price, airframe price, flight crew, ground property and equipment, passenger indirect operating costs and general and administration costs. As shown in figure 2-10, maintenance providers

compete for the portion of the airline cost structure which makes up 15% of costs for engine and airframe maintenance. This 15% represents a $63 billion market[12].

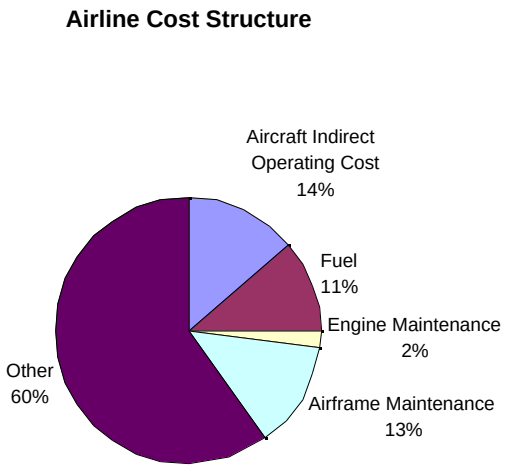


Figure 2-10: Airline Cost Structure, April 2001

2.7 Airline Maintenance Market Segments - Pratt & Whitney Analysis

P&W has recently conducted much research and analysis of current market conditions. Conclusions drawn from this analysis indicate airlines are segmented into three major groups. These segments include: fleet cost reducers, service expanders and maintenance outsourcers, including virtual airlines.

[12] Aviation Week & Space Technology, "Market Forces Reshaping MRO", April 2, 2001, page 87

2.7.1 Fleet Cost Reducers

Cost reducers represent airlines who have internal maintenance capability but have recently refocused their strategy on the core of their business, which is transportation of people or freight. Typically these are medium to large airlines who maintain relatively new fleets. American Airlines and Delta Airlines are examples of operators who fall into this category. Fleet cost reducers prefer to own their equipment and to operate it at the lowest possible cost. They will typically manage their maintenance operations as cost centers. While these operators typically have a captive overhaul shop, their refocus on core business activities makes them a possible customer for service providers. It is not likely cost reducers will expand internal maintenance capacity to match their growth, especially with the presence of external service providers who can provide maintenance operations at competitive cost or lower cost than the airline.

For Maintenance, Overhaul and Repair (MO&R) providers looking to expand their business, fleet cost reducers are potential customers who will seek their services.

2.7.2 Service Expanders

Airlines who perform their own maintenance and provide MO&R service to other airlines and third party shops are considered to be service expanders. These airlines typically are large, growing airlines focused on the airline business and related services. Their intent is to expand their business into many facets of the airline industry. Lufthansa and United Airlines can be considered service expanders. Service expanders provide a whole host of airline related services including: airline and engine maintenance and overhaul, engine

and airplane leasing, credit and banking services, material maintenance programs and total fleet maintenance programs.

Service expanders can be considered competitors for MO&R providers. MO&R providers seeking to expand their business through increased market share must learn to coexist with the service expander moguls. Coexistence through partnerships with airline service expanders and MO&R providers is occurring in some areas.

2.7.3 Maintenance Outsourcers and Virtual Airlines

Airline operators in this category have decided to outsource airplane and engine maintenance in its entirety. These airlines are completely focused on core capabilities of route structuring, seat utilization and brand name. The virtual airline will lease all equipment and outsource all maintenance. The virtual airline essentially does not own anything, as the business model is completely focused on transportation. British Airways and Continental Airlines can be considered maintenance outsourcers and Air Jamaica would be considered a virtual airline. Maintenance outsourcers and virtual airlines can be small or large airlines, they are typically well run, forward thinking organizations focused on profit maximization.

Airlines in this category actively seek the service of MO&R providers. They demand competitive cost and turn time, but favor “no worry” fully integrated maintenance solutions.

2.8 Airline and Aircraft Maintenance Supplier Relationship

As previously explained, airlines typically fall into one of three categories, the fleet cost reducer, the service expander and the maintenance outsourcers. Each of these three groups represents a different potential source of business for the maintenance service provider. The maintenance outsourcers is the largest group requiring service from MR&O providers. Currently 45% of the market for maintenance of engines and airplanes is captive by airlines.

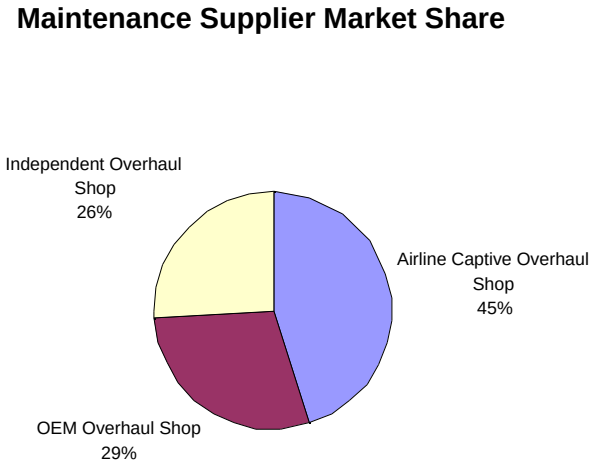


Figure 2-11: Airline Engine and Airplane Maintenance Supplier Market Share

The relationship with airlines and maintenance providers is tiered; the top most tier is the operator or airline, the next tier is the maintenance providers and lastly the parts repairers. The operator may or may not have internal maintenance capability. These operators will then deal with the next tier of maintenance providers which includes airline captive shops, Original Equipment Manufacturer (OEM) and independent shops. The

relationship with the operator will depend on whether the operator has internal capability or not. The arrows in figure 2-12 represent areas where a business relationship may exist, the arrows can also be thought of as material flow from the customer to the maintenance provider. The final tier represents piece part repairers; this group includes airline shops with internal piece part capability, OEM shops, independent shops and independent specialized shops. The market share held by these different parts repairers is shown in the figure. It should be noted that airline maintenance providers will outsource to OEMs and independent specialized shops. The airlines with internal maintenance capability typically will not use the services of independent shops since the airline already has this capability except for independent shops offering specialized services. Certain low usage specialized operations such as LASER welding may make greater economic sense to outsource. OEM overhaul shops as well as independent overhaul shops will also use specialized independent shops for the same reason.

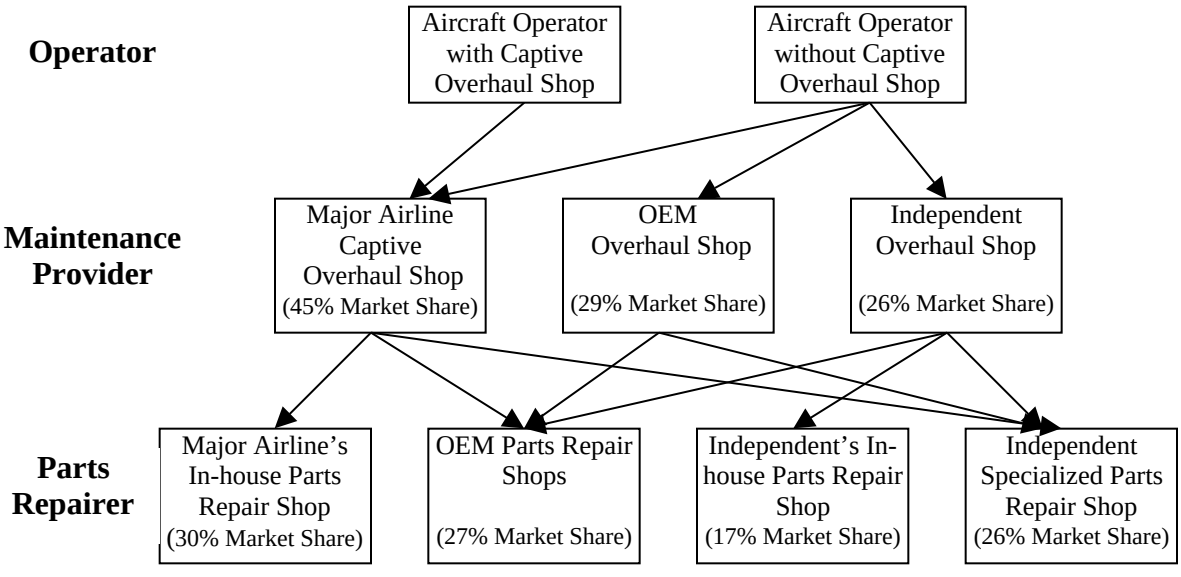


Figure 2-12: Airline and Maintenance Provider Relationships

2.9 Suppler Market Forces

The supplier base responds in conjunction to the economic conditions of the airlines. Suppliers must reduce their costs to maintain acceptable margins when providing airlines with reduced prices. The same cost pressures which are causing airlines to reduce their costs are driving them to offload work to third party suppliers which traditionally have been captive at the airline. The cost reduction drivers are in turn enhancing the volume of work going to non-airline service providers. Though much of the aviation services market is captive with the airline, a considerable amount of consolidation has occurred with third-party suppliers recently.

Economies of scale are the main driver of airplane maintenance markets. Huge initial capital costs must be matched by sufficient workflow to maximize equipment utilization. Most maintenance tasks require high cost skilled labor; high productivity must be maintained to keep costs under control. High productivity is dependent on sufficient volume of business. To achieve sufficient volume, maintenance providers typically consolidate their services, specializing in a certain specific skill sets. For example, shops specializing in major structural case repairs will typically not work on composite airframe parts. Service providers who offer a complete portfolio of services are made up of many joint venture specialty shops working in concert.

Globalization is a major force driving consolidation and joint venture activity; it is imperative service providers achieve global reach; after-market suppliers must be able to service their customers worldwide. After-market suppliers must be where their customers go; service providers who simplify an airline's logistics are more apt to receive

the contract over a service provider who does not have a global presence. These efforts result in increasing the overall scale of the after-market service provider's business. To achieve the workflow volume necessary for cost effectiveness service providers set up designated centers of excellence. The result of this strategy is to create an environment conducive not only to economies of scale but also process improvements from lean enterprise tools.

2.10 Bundling of Services – Fixed Cost Maintenance Business Model

Service providers offering fleet management plans can reduce an operator's cost-of-maintenance by fixing the airline's maintenance costs. The traditional business model provides services and parts on an as needed basis. The dynamics of this model results in suppliers trying to maximize profit by selling parts and labor at the highest price. The need for parts and service being sporadic results in a highly variable cost stream which is difficult to predict. A fixed cost fleet maintenance plan eliminates the variability and unpredictability from the airline's perspective. Figure 2-13 shows a typical 10 year outlook of maintenance costs under both the fixed cost model and variable model. Notice how the fixed cost model is predictable and acts as an annuity over the period. While in the early years the variable cost model is more favorable for the operator, in time the spikes in cost occur and predictability is shattered. The graph of the actual cost of the parts and services from the provider show that profitability can go to zero or be negative if the service provider can't meet their cost and reliability goals.

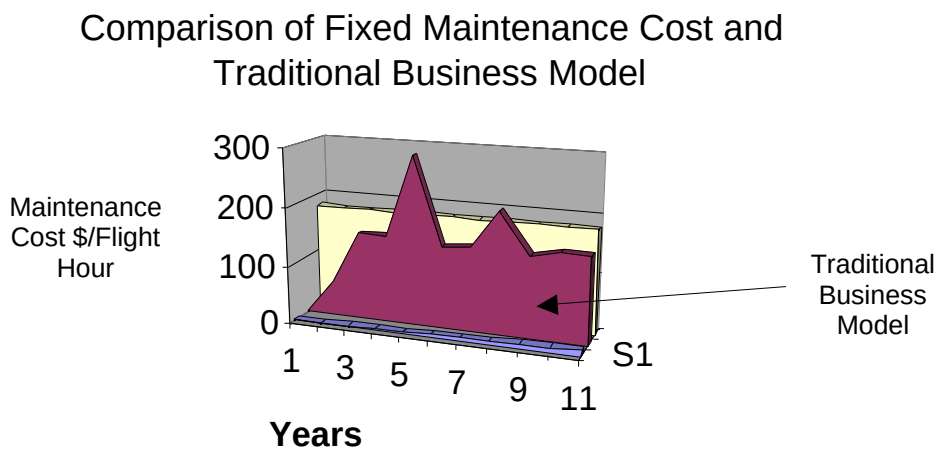


Figure 2-13: Comparison of Fixed Cost Maintenance and Traditional Business Model

The service provider must now reduce its costs and maximize efficiency to maximize profits in the fixed cost model. The new business dynamic is a significant shift from the traditional model. The fixed cost models allows airlines to better predict their overall operating costs and allows them to maintain focus on their core business of transportation. Service providers must incorporate lean principles within their operations to remain competitive. Under the fixed cost model the margin for spare parts collapses; the service provider is completely refocused on cost reduction and durability enhancement since they are now sharing the risk. Under the variable cost model, profit maximization occurs for the service provider when the operator's consumption of parts and services are maximized. The opposite is true with the fixed cost model; here the service provider's profits are maximized by reducing the consumption of parts and services. The fixed cost model is beneficial to the OEM and, as it turns out, healthier for the industry since it is typically lower cost to use new parts than to use aggressive repairs

which extensively rework parts and possibly lowering their service life in the process. Since the fixed cost model is more favorable with increased durability, the manufacturer is driven to provide increased durability and higher quality; improvements from a safety and reliability point of view.

2.10.1 Traditional After-market Business Model – Variable Operator Maintenance Cost

- Earnings driven by spare parts sales and margins
- Customer owns cost of maintenance
- Business Imperative: sell spare parts, overhauls and repairs

Customer Service Focus:

- Fleet-wide product support
- Prompt response to customer requests

Spares Management Focus:

- Fill the customer's spares forecast
- Manage inventory concessions

2.10.2 New Emerging After-market Business Model – Fixed Operator Maintenance Cost

- Earnings driven by reducing cost-of-maintenance
- Manufacturer owns Engine Flight Hour (EFH) based annuity, operator pays flat fee
- Manufacturer owns cost-of-maintenance
- Business Imperative: reduce consumption of spare parts, overhauls & repairs

Fleet Management Program Focus:

- Product support of specific engines at the customer
- Protect program Earnings Before Interest and Taxes (EBIT)

Material Management Program Focus:

- Forecast and fill the customer's material requirements
- Protect program EBIT

Airlines are demanding expanded fleet management services providing them with "no worries maintenance", "one stop shopping" and lower cost-of-ownership. Lower cost-of –ownership can be realized by: applying the fixed cost maintenance model, better planning through on-wing engine health monitoring, better engine build standards and workscope definition. Service providers are responding by bundling services and expanding their capability to become a "one stop shop". These dynamics are requiring service providers to maintain a global presence and act as a risk-sharing partner in the airline business. As a result the airline services industry is consolidating and is expected to converge into five to six large providers.

Pratt & Whitney's attempt to become one of these large service providers is causing the company to change from simply an Original Equipment Manufacturer (OEM) of engines, to a provider of complete services consistent with the lifecycle of the airplane. The lifecycle includes design of the engine, manufacture of the engine, installation of the engine airframe interface, engine and aircraft servicing and overhaul, technical and financial support. The radical change in scope from just an OEM to a full service provider more than simply expands the company's scope-- the whole manner in which it

conducts its business must change. Every step in the design process must include design for manufacturing, design for ease of manufacturing, design for ease of customer use, design for efficient overhaul and design for durability consistent with fleet or maintenance material support programs. Durability in this sense requires that engine components meet serviceable lives consistent with engine overhaul cycles.

Pratt & Whitney is rapidly expanding its business to achieve significant market position as a full service provider in the airline industry. Pratt & Whitney's current capabilities and organizational structure are discussed in detail in the next chapter.

Chapter 3

Pratt & Whitney Overview

Pratt & Whitney, a division of Connecticut based United Technologies Corporation, is a leader in the design, manufacture and support for commercial, military, general aviation, space propulsion and power generation gas turbine engines. Pratt & Whitney is a pioneer in flight and in technology. Today Pratt & Whitney engines power more than half of the world's commercial airline fleet, about 18,000 larger commercial and 33,000 Pratt & Whitney Canada engines. Every few seconds – more than 20,000 times a day – a Pratt & Whitney-powered airliner takes flight somewhere in the world. Pratt & Whitney military engines power the majority of the Airforce's aircraft, totaling nearly 11,000 engines. Pratt & Whitney truly has a presence world wide, with representatives in 76 cities in 47 nations.

Pratt & Whitney had sales of $7.36 billion in 2000. More than 600 airlines operate Pratt & Whitney large commercial engines in more than 150 countries. More than 7,400 regional airlines and other operators fly with engines made by Pratt & Whitney Canada. Twenty-seven armed forces operate aircraft powered by Pratt & Whitney and Pratt & Whitney Canada engines. A significant achievement from when it all started on a cold Christmas Eve day, December 1925 when Pratt & Whitney delivered its first Wasp engine – a 9 cylinder radial air-cooled piston engine to the US Navy. From that time, Pratt & Whitney has grown to about 30,000 employees operating its business units around the world.

3.1 Pratt & Whitney has five business units:

Location	Headquartered
Large Commercial Engines	East Hartford, CT
After-market Services	East Hartford, CT
Large Military Engines	East Hartford, CT
Space Propulsion Operations	West Palm Beach, FL
Pratt & Whitney Canada	Longueuil, Quebec

Engineering and manufacturing are conducted at six facilities: East Hartford Connecticut, Middletown, Connecticut, North Haven, Connecticut, North Berwick, Maine, Columbus, Georgia, and West Palm Beach, Florida. Engines are designed, developed, assembled, spare parts are produced and engines are validation tested at these six sites.

Pratt & Whitney Aftermarket Services division provides a full range of maintenance, overhaul, repair and replacement services to support both commercial and military customers. Pratt & Whitney has focused its core skill of jet engine technologies and manufacturing on: engine module overhaul, part repair, fleet and material management programs, new and serviceable materials management, and customer service to better serve its global customers. In an effort to become a full-service aircraft maintenance network, Pratt & Whitney is expanding its service offerings. The service network has added the manufacture and repair of composites and airframe components such as nacelles and thrust reversers.

3.2 Engine Overhaul and Part Repair Capabilities

Pratt & Whitney offers its customers comprehensive engine and module overhaul capabilities including all Pratt & Whitney engine models, International Aero Engine's (IAE) V2500 and General Electric's CFMI's and CFM56-3, -5 and –7. Pratt & Whitney also overhauls several military engines including the F100, the F119 and the F117. The company's growing global network of overhaul and repair facilities, now with over 26 locations, can perform all major commercial and military engine part refurbishment services, applying OEM processes and achieving competitive turn times. This network provides 24-hour, on-site support. The goal is to maximize the effective service life of customer parts by developing new technologies for faster, higher quality repairs. Pratt & Whitney offers customers the benefits of OEM quality standards and workmanship.

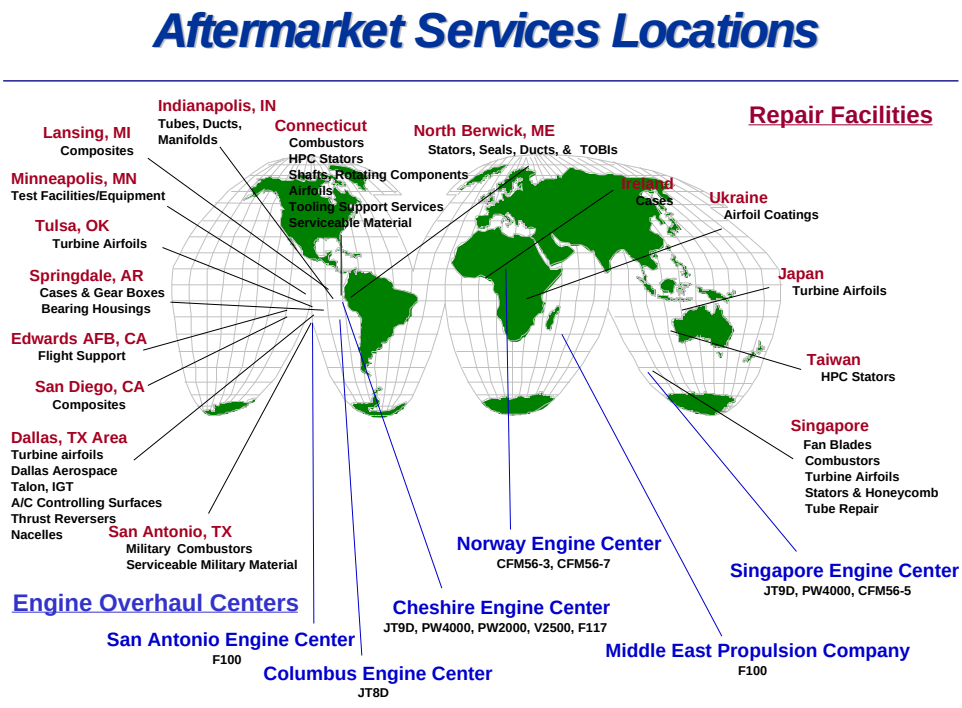


Figure 3.1: Pratt & Whitney Aftermarket Services Worldwide Locations

3.3 Materials Management and Logistics

Pratt & Whitney Aftermarket Services offers both new and used/serviceable parts. To lower ownership costs, the company maintains a large inventory of serviceable parts for all Pratt & Whitney models as well as General Electric's CFM56 and CF6 models.

3.4 Fleet and Material Management Programs

Pratt & Whitney provides custom-designed maintenance programs, including Fleet and Material Management Programs. Each program takes a comprehensive approach to engine maintenance both on and off-wing. Pratt & Whitney Aftermarket Services program managers work in partnership with customers to maximize reliability and time on-wing as well as reduce the total cost of ownership. Pratt & Whitney's customer-tailored fleet and material programs currently include long-term engine maintenance agreements with United Postal Service, US Airways, American Airlines, Delta Airlines, British Airways, America West, Japan Air Systems, the U.S. Air Force and other airlines.

3.5 Customer Services and Support

Pratt & Whitney provides emergency support, maintenance facility planning, training, technical publications, lease engines and engine tooling and support equipment with a worldwide customer service support network. Pratt & Whitney has a work force of representatives stationed at all its major customers throughout the world. The Pratt & Whitney representatives communicate daily with engineering and other groups back in the business units.

3.6 Pratt & Whitney Aftermarket Services Major Operations

Customer Service
Engine Overhaul
Global Part Repair
Composite Services
Fleet and Material Management Programs
New and Serviceable Materials
Aviation Services
Customer Services
Worldwide Customer Service Support Network

3.6.1 Engine Overhaul Facilities

San Antonio, TX USA	F100 family, F119
Columbus, GA USA	JT8D
Cheshire, CT USA	JT9D, PW2000, PW4000, F117, V2500
Singapore	JT9D, PW4000, CFM56-6
Norway	CFM56-3, -7
Saudi Arabia	F100 family

3.6.2 Part Repair Facilities

East Hartford, CT USA	Springdale, AR USA
East Windsor, CT USA	North Berwick, ME USA
North Haven, CT USA	Ireland
Rocky Hill, CT USA	Singapore
Claremore, OK USA	Taiwan
Dallas, TX USA	Kiev, Ukraine
San Antonio, TX USA	Japan

3.6.3 Composite Services

San Diego, CA USA	composites
Landing, MI USA	composites
Minneapolis, MN USA	test cell services
Tijuana Mexico	airframes, nacelles, and reversers

3.6.4 Material Management Services

Fleet and Material Management Programs	East Hartford, CT USA
New and Serviceable Materials & Logistics	East Hartford,CT & Dallas, TX USA
Aviation Services	East Hartford, CT USA

3.6.5 Primary Engines Overhauled

JT8D
JT9D
PW2000
PW4000
PW6000
V2500
F100 Family
F117
F119
CFM56-3, -5, -7

3.6.6 Primary Parts Repaired

JT3D	CFM56
JT8D	CF6
JT9D	RB211
PW100	Trent
PW2000	Tay
PW4000	Industrial Gas Turbine (IGT)
PT6	V2500

3.7 Engine Overhaul Process

The engine overhaul business consists of centers, which receive engines, disassemble, repair, reassemble, test and ship engines back to the customer. Pratt & Whitney currently has six such overhaul facilities. In conjunction with the overhaul centers, P&W has many facilities which conduct what is called 'piece part repair'. These facilities service the overhaul centers. The piece part repair companies center their operations around a family of parts. For example, a certain facility may focus primarily on major structural cases, this facility will have expertise in welding and machining of aerospace alloys and machines large enough to handle such hardware. Pratt & Whitney has 18 piece part repair facilities around the globe.

The jet engine overhaul market is characterized as a highly competitive market, driven mainly by turn time and secondly by cost. Quality in this game is expected-- any organization who slips up, resulting in an accident, may cease to exist quickly. Turn time tends to be the major driver in this industry, because the lost revenue from unserviceable aircraft is so large. A 747 sitting in the hanger represents around $800K lost revenue per day. Engine overhaul is conducted by three major segments: airlines who overhaul their engines and others, engine manufactures; and third party overhaul shops. The jet engine overhaul customer consists of airlines, leasing firms and government owned aircraft.

The customer in this industry basically wants a quality-overhauled engine, delivered quickly at a competitive price. The overhaul service provider who best meets these requirements wins, and as previously stated, turn time is the biggest driver. For example, a facility overhauling the P&W JT8D engine, which powers the largest installed base of

the world's commercial aircraft, must be able to provide an overhauled engine in less than 31 days costing no more than $600K for a heavy shop visit.

3.7.1 Basic Engine Overhaul Process

1. P&W's marketing department solicits customers promising competitive service. Marketing operates based on a previously defined corporate strategy. Upper management, using the support of P&W's financial organization, defines the strategy.
2. The overhaul service work scope and price is negotiated with the customer and a contract is drawn up. The work scope is a plan of overhaul, which meets the demands of the customer necessary to restore the engine back to serviceable condition at the lowest cost. The work scope contains a strategy, which based on experience produces an optimum of performance at low cost. The quality of the work scope significantly defines the overhaul center's competitive advantage.
3. The overhaul schedules and receives the engine.
4. Engine is disassembled, parts are cleaned and inspected.
5. Parts are marshaled to repair centers; scrap parts are replaced with new parts or serviceable used parts. Repair sources are chosen based on their ability to deliver a serviceable in time for assembly. The assembly time line defines how much time a repair source has to repair a part. This time is defined by when time the part was removed and when it has to be installed. The cost of the overhaul is largely influenced on the organization's ability to marshal parts in the most effective manner. For parts in which no repair exists the overhaul center will use the services of Repair Development Engineering. Repair Development is an organization within P&W's engineering organization, which produces an FAA (Federal Aviation Administration) approved technical data package. The technical data is then used by a repair source to repair the article in time for assembly.
6. The engine is then assembled and tested to ensure all systems are fully functioning. The quality of the overhaul is largely defined by what is called Exhaust Gas Temperature (EGT) margin. This parameter is evaluated by the Systems Performance Analysis engineering organization. The EGT margin monitors the overall health of the engine, as this temperature increases, it shows the engine is deteriorating. The overhaul contact will guarantee a certain level of EGT margin.
7. The engine is then installed into a transport rig and shipped back to the customer.

To minimize the impact to an operator, an overhaul provider must provide reliable service. Turn time reliability allows the customer to schedule maintenance in such a way to minimize costs and eliminate the need for excess aircraft to maintain routes.

3.8 Pratt & Whitney Organization Structure

Since Pratt & Whitney's beginnings in 1925 until approximately 1990, Pratt & Whitney was organized as a classic vertically integrated functional organization. As complexity in engine design was ever increasing, through the end of the piston era and into the jet age, there were very high demands on the organization requiring deep technical skill. From this need was born an organization which focused on the specific functions of engineering design, structural analysis, fluid dynamics, thermodynamics, material science and a host of supporting functions such as drafting, tool design, manufacturing process planning, document control and other general administrative functions. The structure was one of a truly classic craft industry, which relied on mentoring of the work force up through the functional chain of command. These organizations were successful in building deep skill in the functional areas but lacked sufficient focus on product needs as the technology matured. By the 1980's competition from General Electric and Rolls Royce intensified resulting in a series of organizational changes which sequentially decentralized the functional groups into a more product development focused organization.

Today Pratt & Whitney engine development is organized into Module Centers. Module Centers have full product ownership for the products they develop. The work force, including all disciplines, is co-located at the Module Center (MC). The MC support the product from raw material to customer delivery. The organizations contained in the Module Centers include: Human Resources, Environment Health and Safety, Facilities, Machine Services, Information Services, Finance, Quality, Continuous Improvement, Mechanical Design, Manufacturing Engineering, Procurement, Commodity Management,

Project Engineering, Secondary Flow Analytical Engineering, Heat Transfer Engineering, Aerodynamics and Structures Engineering.

The design of the new organization is crafted such that it is capable of supporting a complete lifecycle approach necessary to support the plan to grow from an OEM to a full service provider. The process of assembling all the required disciplines into a product-focused organization provides the necessary environment in which a total lifecycle concept can be fused into product design and manufacturing.

Pratt & Whitney has five Module Centers which are segmented by engine section.

Engine Center, Assembly and Test	Middletown, CT
Electronic & Mechanical Systems Module Center	East Hartford, CT
Compression System Module Center	Middletown, CT
Combustor, Augmentor & Nozzle Module Center	East Hartford, CT
Turbine Module Center	North Haven, CT

3.8.1 Organizational Evolution

In 1991 Pratt & Whitney adopted Integrated Product Development (IPD) and reorganized from functional groups into component focused product development organization. Component Integrated Product Teams (CIPT) were created. In this organizational design, working groups called Integrated Product Teams (IPT) contained members from each major discipline including: Design, Project, Structures, Analytical, Manufacturing, Purchasing and Product Support reported to the CIPTs. IPTs contained working level professionals and CIPTs were comprised of middle management. The shift to CIPT/IPTs was the first time Pratt & Whitney applied a matrix organizational design concept. At

first the work force struggled with new blurry reporting structure, but soon productivity gains were realized. From this point Pratt & Whitney made steps to further decentralize its functional organization, ultimately reaching the Module Centers. Table 3-1 shows the evolution and the impact of the various organizational changes over the last decade.

Table 3-1

Summary of P&W Organizational Changes, 1990 - 1999[13]

Organization	Centralized Activities	Distributed Activities	Focus	Mfg. Focus	Eng./Mfg. Integration	System Integration Activity
Functional (pre-1990)	Functional Groups	Engine Program Mgmt.	Functions / Disciplines	Mfg. Process	None	Informal Processes Lack Of System Focus
IPD (1991)	Parts Teams, Program Mgmt.	Functional Groups	Part Design	Mfg. Processes	Little. Lack of Mfg. Resources for IPT participation	Informal Processes. Lack of System Focus
Component Centers (1993)	Component Teams, Program Mgmt.	Functional Groups	Component Design	Parts Families	Little. Lack of Mfg. Resources for IPT participation	Introduce some formal Processes with System focus.
Product Centers (1995)	Component Teams, Program Mgmt.	Functional Groups	Component Design	Parts Families	Partial. Pockets of good Mfg. IPT participation	Introduce more System focused Processes
Systems Engineers (1995)	Component Teams, Program Mgmt. Functional Groups	Functional Groups	Component Design	Parts Families	Partial. Pockets of good Mfg. IPT participation	Formal Systems Engineering Process Developed
Module Centers (1999)	Program Mgmt. Functional Groups	Systems Integration Component Design & Mfg. of Modules	Design & Manufacture of Modules	Modules	Complete Co-location of Mfg. And Design Engineering	Moderate within Module, weak across Modules

[13] Mascoli, G., "A Systems Engineering Approach to Aero Engine Development in a Highly Distributed Engineering and Manufacturing Environment", Massachusetts Institute of Technology, SDM thesis, 1999, page 28.

During the evolution of the Engineering, Manufacturing and Procurement organizations, Pratt & Whitney Aftermarket Services (PWAS) was somewhat peripheral. At the time when the IPD concept was taking hold in 1990, PWAS was a small operation, focused mainly on warranty work. PWAS grew from a small organization in 1995 of 150 employees to 2000 employees by 2001. The organization was largely separate from the mainstream up until recently with the advent of the Module Centers. After the rapid expansion of the PWAS organization, and once the Module Centers were well established, PWAS was incorporated into Pratt & Whitney's mainstream organization as a major entity. As shown in figure 3-2 prior to 2000, PWAS was outside Pratt & Whitney Technical, now, as shown, PWAS reports directly to the Senior Vice President of Engineering.

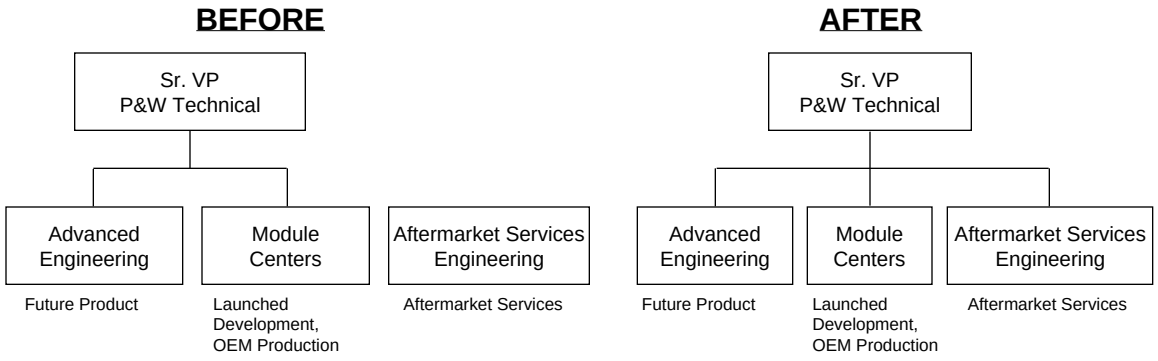


Figure 3-2: Pratt & Whitney Organizational Evolution, PWAS Division

Chapter 4

Pratt & Whitney's Growth Plan

During the last year, Pratt & Whitney has defined a five-year strategic plan focused on 'delighting customers'. This plan has some characteristics not seen in previous ones. Company leadership engaged and worked with the upper part of middle management in creating a collective vision. This involvement of all the divisions, including Engine Services, was seen as a new approach.

Pratt & Whitney leadership identified alignment across all divisions and groups as a goal. It became a challenging decomposition problem, with each subsequent layer attempting to align their objectives with those specified by their supervisors. The hope was to engage all 30000 Pratt & Whitney employees by allowing everyone to iteratively negotiate their personal objectives with their groups and supervisors. This allowed the strategic plan to become a living document, as employees were tasked with defining their priorities in a way that is consistent with the company wide vision. Pratt & Whitney's president, Louis Chenevert's alignment plan will create strength through unity. Unity will simplify systems and maximize knowledge transfer, allowing all the divisions to benefit from excellence being created throughout the entire organization. This goal is expressed throughout the company as,

"Be One Company"

The growth plan has five overarching goals which run common across all business units within the company. Each business unit will define the actions necessary to achieve the

over arching goals. The supporting actions for the PWAS division are shown below along with the overarching goals.

1. **Be one Company**

- Eliminate waste caused by bureaucracy
- Learn from other organizations

2. **Customer Focus**

- Achieve 5.5 on Customer Score Card
- Achieve 95% on-time delivery
- Reduce supplier related costs by 50%

3. **Employee Motivation**

- Provide worldwide career opportunities
- 100% Compliance on completing employee development plan
- Recruit and develop the finest team of people in the industry

4. **Quality Processes & Products**

- Every Business Unit must achieve one level improvement in Pratt & Whitney's quality program called Achieving Competitive Excellence (ACE)
- Reduce quality escapes by 50%
- Implement common processes
- Flawlessly execute restructuring plan

5. **Financial Performance**

· Achieve Growth plan according to plan

· Capture maximum value from acquisitions

· Execute value capture of acquisitions in first six months of existence

4.1 Customer Focus

PWAS has a goal of achieving a Customer approval rating of 5.5 out of 7. P&W's Customer Technical Support organization administrates the customer approval rating by use of a Score Card. Customers rate P&W quarterly on many different aspects of the service P&W provides. Each organization which interfaces with the customer is rated individually; these organizations include: Customer Technical Support, On-site Services, Spare Part Sales, Repair Development, Tooling Development, Technical Publications and P&W Engine Services. Although this satisfaction goal is subjective, the surveys represent a critical learning tool in PWES' ability to understand and meet customers' needs. In addition to normal communication channels, surveys provide a more formal mechanism for measuring what Engine Services Division is doing well and poorly. It also helps P&W benchmark its performance against its competitors.

As a result, PWES has communicated the following guideline throughout the organization in an effort to begin to improve customer relationships:

'Do what you say you're going to do!'

This theme strives to improve credibility and to build a foundation from which PWES can develop a culture of responsiveness and commitment to improvement.

Two metrics that are believed to contribute to customer satisfaction are quality and turn time improvement. Quality goals have been defined in terms of 50% reduction in escapes. Turn time goals are focused less on actual time required and more on decreasing variability in the process. This target is expressed as 'achieve 100% on time deliveries'.

PWES aims to support Pratt & Whitney's strategic goals for customer satisfaction by fostering a culture of meeting commitments and driving towards specific improvements in both quality escapes and on time deliveries. The strength of this approach is that while the requirements are specific and clear, they allow the constituent parts of the organization to define for themselves *how* they are going to do it.

4.2 Employee Motivation

Internal Pratt & Whitney employee surveys conducted over the past several years have begun to map out the concerns and feelings of these key stakeholders inside the company. Survey results identified decreasing employee morale and attributed this trend in part to concerns regarding empowerment and to questions regarding the vision of upper management.

Unlike customer satisfaction, less progress has been made in identifying mechanisms for improving customer morale. As a division, PWES has committed to the following approach:

- Base line an employee scorecard that will provide a direction for improvement.
- Promote the variety of worldwide employment options available in PWES.

There is a clear need to take the same structured approach towards internal stakeholders as towards external stakeholders. The strategic plan itself could be a first step in establishing a trust with employees. More data will be acquired prior to defining the appropriate metrics for measuring employee motivation.

4.3 Quality Processes and Products

Pratt & Whitney's quality and process improvement program is called ACE. ACE stands for Achieving Competitive Excellence.

The definition of this program is:

> The application of a set of tools to achieve a level of quality and productivity to produce products and services that will surpass our customers' expectations.

The mission statement for ACE is:

> Achieve a level of quality and productivity improvements that will enable us to produce products and services that will delight our customers.

The quote, "ACE is our operating system" is stated in P&W's Strategic Road Map. The fundamental concept is to apply a host of process and quality improvement tools, which create measurable results. The measurable results are reported in the monthly metrics within the enterprise.

Some of the tools of ACE are:

- TPM, Total Productive Maintenance & 6S
- Process Management/Process Certification/Standard Work
- QCPC Quality Clinic Process Charts
- RRCA Relentless Root Cause Analysis
- MP Mistake Proofing
- EH&S Environmental Health & Safety

Each level of the enterprise from corporate down to the work groups uses these tools to generate process and quality improvements. The tools are generic but the application is specific to the organization.

There are three levels of achieving ACE: bronze, silver and gold. Each level is an increasing level of proficiency and performance gain.

The enterprise level metric requires each organization within P&W to achieve one level of ACE improvement each year. The ACE program is directly linked to the strategic plan of the enterprise. The tools are designed to improve P&W's performance with Customer Focus, Employee Motivation, Quality Processes & Products, and Financial Performance.

4.4 Financial Performance

P&W conducts monthly reviews comparing its financial performance with the strategic plan. Earnings Before Taxes and Interest (EBIT) is evaluated actual to plan for each of

the different organizations within the enterprise. The monthly report contains trending metrics to help compare how P&W is doing relative to the industry.

Each year corporate defines the top-level growth targets from which the detailed plans are formulated. Once the plans are in place the initiatives for each organization is defined. The financial performance of the organization is then measured on how well they perform relative to plan.

Management teams responsible for growth through acquisitions are measured on how quickly they can assimilate new businesses into the enterprise. This financial metric is evaluated based on both monetary performance and speed.

4.5 Industry Drivers Generating Pratt & Whitney's Need for Mergers & Acquisitions

In fulfillment of the growth the strategy Pratt & Whitney needs to position itself as a large service provider capable of providing customers "One Stop Shopping". To reach this level of customer service, control of the supply chain is necessary. The level of control must be at least as much as your competitors in order to remain in the game. Supply chain control is necessary because some of the services a full service provider provides will actually lose money, but it allows access to other more profitable areas of the business, such as piece part repair on parts which require sophisticated processes and specialized equipment. Engine overhaul typically is a low margin business, but it provides access to the part stream. It is this access to the material stream which drives the enterprise into the overhaul business. The overhaul center controls the flow of parts;

the captive material is sent to parts repair facilities which specialize in repair operations pertinent to a specific class of parts as discussed in chapter 3 (Engine Overhaul Process). Part repair requiring specialized equipment and skill is a higher margin business compared to overhaul, thus the income generated typically comes from parts.

Since control of the supply chain is critical for success, the maintenance supplier must be fully capable of providing all the services the supply chain demands. Supply chain control requires the maintenance provider to have a complete portfolio of services including overhaul, repair, specialized repair, test, validation, and material management. These forces are what are causing service providers to grow in size. The need to be big is resulting in consolidation of medium players and small players.

Chapter 5

Research Methodology

5.1 Research Overview

The focus of this thesis is directed towards Pratt & Whitney's growth strategy in the Aftermarket Services division. Growth from mergers and acquisitions depends on successful integration of the new organization into the parent. The research conducted focuses on integration of organizational structure, human resource management, quality assurance, process methods, marketing, financial management and culture. Managers need to be able to quickly access the impacts which integration will inevitably cause to these organizational structure and human resource areas. Effective leadership in an environment of flux depends on informed decisions and the ability to evaluate risk.

To understand how to improve the process in which Pratt & Whitney is using to achieve this growth an understanding of the airline industry was necessary. A thorough review was conducted considering the current state of the commercial airline industry, the future state of the industry along with the market driving forces which shape the industry. The author's experience in the areas of the after-market business and Pratt & Whitney organizational structure provided a basis on knowledge on how to proceed. The decision modeling technique defined in this thesis was derived from course work performed in the SDM program. The overall research process compiled information gathered from three main sources. These three sources are discussed in the following sections of this chapter.

Sources of Information:

5.2 Data Collection through interviews with industry experts

5.3 Literature search

5.4 Extraction and application of pertinent information and tools from SDM program

5.2 Data Collection through Interviews with Industry Experts

As a part of the research I conducted for this thesis, I interviewed several industry experts who have provided me with a tremendous amount of insight and pertinent data. I was able to interview people who had actually put together acquisition deals at Pratt & Whitney. This provided much insight into how and why acquisitions were made, along with how various integrations were carried out over the last 10 years. These perspectives allowed me to evaluate where Pratt & Whitney is relative to its peers in the aerospace industry. The wealth of information gained from these interviews allowed me to conduct the research for this thesis and create a decision modeling technique with a balanced and grounded approach.

The following individuals were interviewed:

Mark Biagetti

Director, Pratt & Whitney Strategic Planning, Pratt & Whitney Aftermarket Services

Edmund DiSanto

Director, Business Development

Glenn Gruber

Director, Pratt & Whitney Strategic Planning, Commercial Engines

Alan Moodie

Director, Business Development Pratt & Whitney Aftermarket Services

Deborah Nightingale

Professor Aeronautics & Astronautics and Engineering Systems Department, Massachusetts Institute of Technology

Dev Rudra

Senior Engineer, Industry Analyst

Kevin Trammel

General Manager of Pratt & Whitney's Repair Development Organization.

5.3 Literature Search

The literary material for this research was obtained from 5 main sources.

1. MIT's Libraries provided a wealth of information in the form of up-to-date texts, industry reference manuals and periodicals. These materials are listed in the Bibliography.
2. Aviation Week's, Overhaul and Maintenance magazine, McGraw Hill, provided current airline industry data and industry trends along with current events.

3. The library at Pratt & Whitney's Strategic Planning office provided a tremendous amount of airline industry data, which was most useful for the analysis of the airline industry conducted for this thesis.
4. The Internet provided current data on companies competing for MR&O market share.
5. Materials from SDM courses, these materials are discussed in the next section, 5.4 Application of Relevant SDM Course Work.

5.4 Application of Relevant SDM Course Work

The Decision analysis model created in this thesis applied decision analysis tools obtained from Engineering Risk Benefit Analysis[14]. Construction of the model also applied Professor Shoji Shiba's Language Processing (LP) method and the WV model[15]. The LP method in combination with the WV model allows abstract concepts to be decomposed into factual statements. Understanding and handling complexity using Systems Engineering Process from Systems Engineering[16] were applied to the analysis of Pratt & Whitney's growth strategy. Systems Engineering also offered techniques for understanding risk and methods to manage risk of complex systems. Pertinent findings from MIT course books[17], lecture notes, case studies and academic research at MIT's Lean Aerospace Initiative were used to create this thesis. The course material provided

[14] Engineering Risk Benefit Analysis, course number ESD.72, is offered as a part of the SDM program in the spring semester. Multistage Decision Models are found in the notes provided and the Video Course Manual, Drake, A., W., 1986

[15] Shiba, Shoji, Walden, D., "Four Practical Revolutions In Management, Systems for Creating Unique Organizational Capability ", Productivity Press, Portland Oregon, 2001, note: WV is not an acronym, WV represents the process flow through the model.

[16] Systems Engineering, course number ESD.33J, is offered as a part of the SDM program in the summer semester. Complexity section I & II and Systems Engineering Process I – IV are covered in Volume I, chapters 3 – 8 of Systems Engineering course manuals.

[17] Souces include; Reinertsen, D., G., "Managing the Design Factory", The Free Press, New York, NY, 1997, page 78. Ancona, Kochan, Scully, Van Maanen, Westney, "Organizational Behaviour & Processes", South-Western College Publishing, 1999, M-2 The Strategic Design Lens, pages 10 – 25.

in Technology Strategy[18] provided tools for understanding the product development cycle and organizational dynamics between functional and product focus organizations. The manuals provided in Systems Engineering provided a wealth of tools including Process Flow Analysis and Complexity Management. The handouts provided in Engineering Risk Benefit Analysis gave instruction on how to conduct decision analysis. Integrating the Lean Enterprise provided methodology for Lean Transformation of the Enterprise[19].

[18] Technology Strategy, course number 15.984, is offered as an elective in the SDM program. Teece, D. J., "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy', Ballinger Publishing, Cambridge Mass, 1987

[19] Integrating the Lean Enterprise, course number 16.852/ESD.61J, is offered as an elective as part of the SDM program. Mize, J., H., "Fundamentals of Enterprise Integration", class hand out, November 2000

Chapter 6

Decision Modeling

6.1 Overview

This thesis will define a decision methodology for integrating mergers and acquisitions into the organization so value can be maximized. Decision analysis will be used as a tool to define a structured path to best integrate a particular acquisition. The decision path for each individual integration varies based on the conditions specific to the acquisition. The decision analysis technique will evaluate the risk of the decisions along a path; this process will allow managers to evaluate the risk verses the gain of a certain decision path.

The decision model is constructed by completing a series of seven steps, the first of which requires the definition of a series of fundamental decisions. These decisions are critical to the overall success of the acquisition's integration into the parent. While these decisions maybe uniquely crafted to address specifics of the acquisition understudy, there are eight fundamental decision categories which are universal and act as a guide. These categories are discussed in section 6.2.

The next step in creation of the model requires a decomposition of the fundamental decisions into factual statements. The factual statements are designed to contain the complete meaning of the fundamental decision. In the simulation presented in this thesis, the fundamental decisions were decomposed into eight factual statements, which embody the meaning of the fundamental decisions.

Steps three through six take the requirements defined from the fundamental decisions and the decomposition and compare them to the actual conditions at the acquisition. This comparison is evaluated numerically and is used to create the multistage decision tree.

The final step in the process is to evaluate the results of the decision tree and define a decision path. The remainder of this chapter will discuss in detail how the model functions. To help understand the functionality of the decision modeling technique, a simulation is provided using 10 fundamental decisions crafted to match conditions that were observed during an integration process that occurred at Pratt & Whitney. Further interpretation of the model results are analyzed and presented in the next chapter.

6.2 Fundamental Decision categories

The following fundamental decision categories represent critical human resource and process issues, which must by handled correctly and swiftly for successful integration. These categories are universal to most all integrations[20].

Organizational Structure
Reporting Structure
Human Resource Management
Process Methods
Quality Assurance
Marketing Management
Financial and Accounting Management
Integration of Culture

[20] Business International, " Making Acquisitions Work", Geneva 17, Switzerland, 1988, pages 27 - 93

The fundamental decisions act as major trendsetters, unlike decisions, such as: Which corporate travel charge card should the new acquisition use? Fundamental decisions will direct the organization down a certain critical path. An example of a fundamental decision derived from the fundamental categories and used in the simulation is as follows:

> "Do we keep the acquisition's current management or do we replace with P&W management?"

This decision is critical to the outcome of the integration. In order for the model to provide management with information on which direction to choose, the decision in its current form must be decomposed into factual statements. The decomposition in factual statements will allow this abstraction to be evaluated numerically.

6.2.1 Decomposition Technique - The Language Process Method and the WV Model

The Language Processing (LP) method and the WV model, both inventions of Professor Shoji Shiba[21], provide a method to handle abstract concepts, allowing them to be decomposed into factual statements which embody the intent of the abstract concept. The WV model provides a frame work where the user begins in the abstract then goes down to the factual level, then climbs back to a more informed abstract level. The user follows this up and down path for six cycles and progressively moves towards solution definition. The LP method is a technique where the user is trained to break abstract statements into

factual components. Both the WV model and the LP method are explained in greater detail later in this chapter, reference 6.4.2.1 & 6.4.2.2

The WV model and the LP method are tools which remove inference and ambiguity from the evaluation process. Complexity is handled by converting inference and ambiguity into a break down of factual questions that can be answered directly. Use of these tools allows a conversion of the abstract into the factual realm, which then can be analyzed numerically in a decision model.

After applying the decomposition methods the abstract fundamental decisions will be comprised of several binary (yes or no) questions. Once the statements are 'digitized' then the results can be evaluated into a decision model. Using decision tree analysis with assigned probabilities to measure levels of uncertainty, the model is able to compare the benefit of two possible out comes. This analytical evaluation allows managers to decide which direction to go, thus defining the decision path.

A structured Systems Engineering approach to decision making, using Engineering Risk Benefit Analysis and abstraction conversion methods, will allow corporate managers to evaluate if a decision is consistent with the strategy and benchmark the results of previous decisions, thus allowing the organization the ability to learn from these experiences. As this knowledge base builds, Pratt & Whitney will have increased its skill in capturing value of the businesses it acquires and partners with.

[21] Shiba, S., Walden, D., "Four Practical Revolutions in Management, Systems for Creating Unique Organizational Capability", Productivity Press, Portland, Oregon, 2001. Pages 75 and 209, note WV is not

6.3 Steps Required to Perform the Decision Model

The decision model presented in this thesis requires the completion of seven steps, which will then result in a decision path. The seven steps are as follows:

Step 1 Define the fundamental decisions which are necessary for a successful integration of an acquisition using the following fundamental decision categories: Organizational Structure, Reporting Structure, Human Resource Management, Process Methods, Quality Assurance, Marketing Management, Financial and Accounting Management and Integration of Culture.

Step 2 Using the Language Processing Method and the WV model, break each fundamental decision into a series of fact based questions. The questions must be able to be answered by yes or no and contain only a single element of the abstract fundamental decision.

Step 3 Now compare the acquisition's capability against the elemental questions and determine a score.

Step 4 Determine the time, cost and resources necessary to implement each element to support the fundamental decision.

Step 5 Assign the decision tree branch probabilities.

Step 6 Assign the decision tree branch values.

Step 7 Evaluate the results of the decision tree for each fundamental question analyzed, this will then reveal the decision path.

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an acronym, it is called 'WV' because as it is graphically show it tends to look like the letters WV.

6.4 Decision Model Simulation and Detailed Explanation

This section will discuss in detail how the model is set up and how it functions. Examples from the simulation performed in this thesis are used to facilitate understanding of how each of the seven steps operate.

6.4.1 Step One

> Define the fundamental decisions which are necessary for a successful integration of an acquisition.

Step one of the model: "define fundamental decisions which are necessary for a successful integration of an acquisition", requires a brainstorming session from experts within in the corporation and possibly a consultant. The fundamental categories act as a sound guide to help shape the content of the fundamental acquisition decisions[22]. The fundamental decisions used in this simulation were the result of research performed at Pratt & Whitney. Experts within the company with experience in acquisition integration, strategic planning and business development were consulted[23]. The following 10 fundamental decisions are a result of this research and consultation.

[22] The fundamental categories were derived from research performed at Pratt & Whitney and literary research, most notably, Business International, "Making Acquisitions Work", Geneva 17, Switzerland, 1988 and Smith, W., K., "Handbook of Strategic Growth Through Mergers and Acquisitions", Touche Ross & Co., 1985

[23] See section 5.2 for list of Pratt & Whitney experts consulted.

Table 6-1

Fundamental Acquisition Decisions

1	Do we keep acquisition's current management or do we replace with P&W management?
2	Do we reorganize the acquisition's organizational structure or implement P&W's IPD?
3	Do we use the acquisition's method of regulatory validation or require use of P&W's FAA Designated Engineering Representatives (DER)?
4	Do we use the acquisition's Materials and Process Engineering (MPE) organization to validate engineering source approval, or use P&W's MPE organization?
5	Do we use the acquisition's Continuous Improvement (CI) system or require use of P&W's ACE program?
6	Do we replace the acquisition's marketing department with P&W's marketing department?
7	Do we replace the acquisition's financial and accounting department with P&W's financial and accounting department?
8	Do we replace the acquisition's human resources department with P&W's human resources department?
9	Do we maintain the acquisition's brand name with the addition of P&W or completely change to P&W?
10	Do we integrate the culture or keep culture separate?

6.4.2 Step Two

> Using the Language Processing Method and the WV model, break each fundamental decision into a series of fact based questions.

The requirement to decompose the high level, abstract fundamental decisions into elemental questions is necessary, so the capability of the acquisition to carry out the acquisition strategy can be assessed numerically in the decision tree. The LP method and WV model provide a framework to perform the decomposition.

6.4.2.1 WV Model

The WV model[24] separates abstract level of thought from factual knowledge, which relies on level of experience. The WV model starts with a high level thought but then drives the user down to the factual level. At this lower level the user collects data, then moves progressively up to the more abstract level. This movement between the abstract and the factual realm, results in a combination of intuition and fact-based knowledge to reach solution, not inference. The method discourages the temptation to jump into solution definition without a complete understanding of the problem. The structure of the model is shown graphically in figure 6-1.

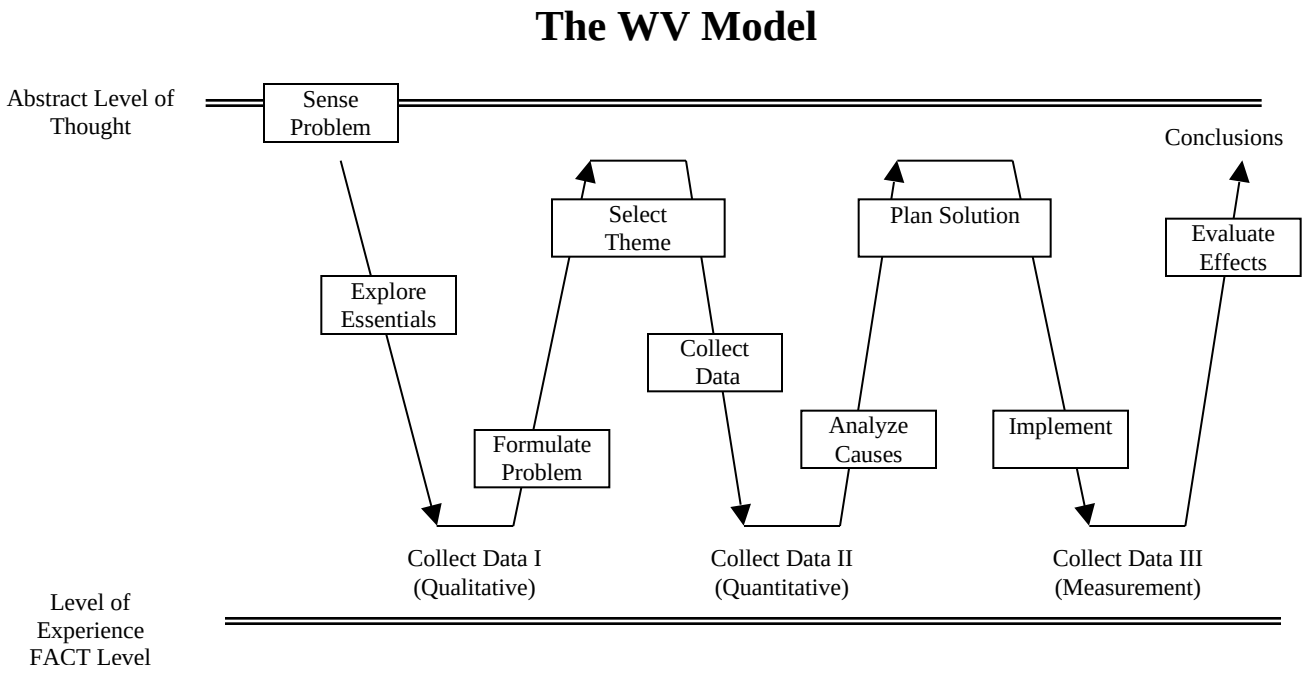


Figure 6-1: The WV Model, Movement from the Abstract to the Factual

[24] Shiba, S., Walden, D., "Four Practical Revolutions in Management", Productivity Press, Portland Oregon, 2001, pages 75 – 82.

The interplay between the abstract and the factual is shown in the figure, as the user moves horizontally from left to right, problem solution is achieved by collecting data and then building on that information. This cycle is performed two more times before arriving at the solution method. Notice how the six cycles of moving from the abstract to the factual draw out a W and V – hence the WV model.

6.4.2.2 Language Processing Method

The language Processing method[25] is a technique where the user crafts factual statements, which contain the meaning of an abstract statement. The technique defines the meaning of what is being said by marching down the 'ladder' of abstraction[26]. As the user proceeds down on the ladder of abstraction the meaning becomes less abstract. It is at the lower levels of abstraction were inference is eliminated. Removing ambiguity is necessary for conveying exact meaning. A graphical representation of the ladder of abstraction is shown in figure 6-2, notice how as the user proceeds up each rung of the ladder, the level of abstraction increases. Our cow goes from the specific animal up to a level of abstraction which is completely disconnected from the animal.

[25] Shiba, S., Walden, D., "Four Practical Revolutions in Management", Productivity Press, Portland, Oregon, 2001, pages 203 - 213

[26] Shiba, S., Walden, D., "Four Practical Revolutions in Management, Systems for Creating Unique Organizational Capability", Productivity Press, Portland, Oregon, 2001, page 209

Ladder of Abstraction

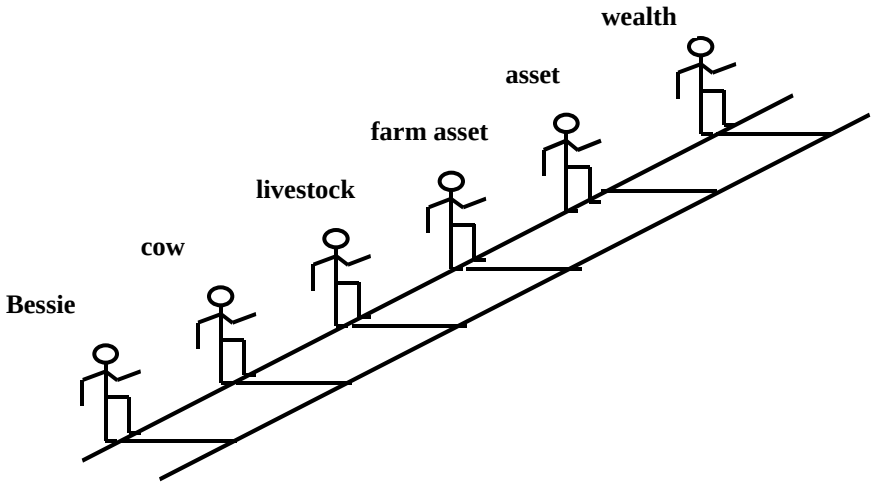


Figure 6-2

The decision model requires that the fundamental acquisition decisions, which are abstract, are to be decomposed into a series of factual statements which contains all the meaning of the abstract decision.

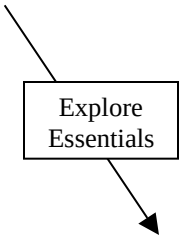
6.4.2.3 Simulation of the Decomposition Process

The decomposition process is best performed by a multidisciplined team. The team needs the following skill sets to be effective: knowledge of prior integrations, knowledge of the actual conditions at the acquisition, knowledge of human resource issues, engineering process, financial process, contract and legal, knowledge of corporate strategy and knowledge on how the decomposition process works using the WV model and the LP method. Once the team is in place, and all the data on the current conditions

at the acquisition has been collected, the process of decomposing the fundamental questions into factual statements can begin.

The first step is to go from the abstract level of the fundamental question and follow down the first leg of the WV model into the factual realm. The following is the result of this step for this simulation, refer to figure 6-1 to see the steps in the WV model.

Abstract — Do we keep the acquisition's management or do we replace it with P&W management?



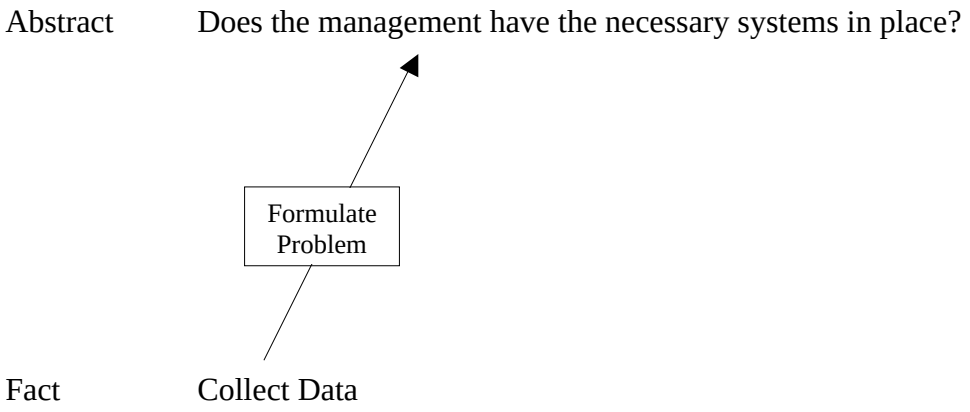
Fact — Does the management have a budget plan in place?

Is the budget plan tracking to plan?

Does the management have a growth plan in place?

Is the monthly income tracking to plan?

At the fact level, the LP method is used to create questions which embody the meaning of the abstract but can be answered by only a single fact. The next step requires the team to follow the WV model back up to the abstract and select a theme as was shown in figure 6-1. Shown below is the theme selected after collecting data from the answers of the factual questions generated in the first leg of the WV model.



The team goes through the process of the WV model, going up and down from abstract to fact as shown in figure 6-1. The factual questions must all meet the requirements of the LP method, by allowing only a single fact per question and enough questions to embody the full meaning of the abstract fundamental question. Once all the factual questions are created, the team has succeeded in completing the decomposition. The decomposition must be performed for each fundamental acquisition question. The result of the decomposition process for the first acquisition integration decision used in the model simulation is shown in table 6-2. The decomposition results of the remaining nine fundamental acquisition questions conducted in the simulation are shown in appendix A.

Table 6-2

Elemental Decomposition of the Abstract Fundamental Decision

	Required Element Question, (Fact Level)
1	Is management using cellular manufacturing?
2	Is there a Systems Engineering Organization in place?
3	Is there a Continuous Improvement Organization?
4	Does Management require an employee development plan?
5	Does Management have a growth plan in place?
6	Is the organizations monthly income tracking to plan?
7	does the management have a budget plan in place?
8	Is the budget plan tracking to plan?

Notice how each question can be answered with a yes or no question, this allows the model to interpret the information in a binary sense. In this simulation only eight questions were used to describe the meaning of the fundamental acquisition integration question. In a true application there could be several more elements needed to fully capture the intent of the fundamental decision.

6.4.3 Step Three

> Now compare the acquisition's capability against the elemental questions and determine a score.

In this step the requirement is to evaluate the elemental questions which were generated from step 2. Each element is evaluated and either a yes or no is inputed into a table. A 'yes' answer indicates that the acquisition is fully capable of carrying out the required element of the fundamental question. A 'no' indicates the acquisition does not currently have this capability. The number of 'yes' answers provided determines a score. The score is normalized such that a perfect score is 1. The score becomes the probability that the acquisition is capable of delivering the desired outcome. Hypothetically, if the score is 1, it indicates that the acquisition has all the elements currently in place, meaning there is a very high probability that the acquisition is capable of meeting the requirement of the fundamental acquisition decision. From a management point of view, this would mean that no action should be taken, the acquisition is capable, so for this fundamental decision it would be not be advantageous to make changes right away. The table below shows the score in the simulation for decision 1.

Table 6-3

Decision: 1. Do we keep acquisition's current management or do we replace with P&W management?

		Answer		
	Required Element Question, (Fact Level)	Yes	No	Score
1	Is management using cellular manufacturing?	1		0.125
2	Is there a Systems Engineering Organization in place?		1	0
3	Is there a Continuous Improvement Organization?	1		0.125
4	Does Management require an employee development plan?	1		0.125
5	Does Management have a growth plan in place?	1		0.125
6	Is the organizations monthly income tracking to plan?		1	0
7	does the management have a budget plan in place?	1		0.125
8	Is the budget plan tracking to plan?	1		0.125
		Branch Probabilities		0.75

The score column in the table takes the 'yes' answers then normalizes the value based on the number of elements. The score is then calculated by summing the 'yes' answers. The score becomes the branch probability for the decision analysis tree.

$$Score = \sum (yes / \# of elements)$$

$$Branch\ \Pr obability = Score$$

6.4.4 Step Four

> Determine the time, cost and resources necessary to implement each element to support the fundamental decision.

The requirement for this step is to determine what the time, cost or resources are required to put each element in place. This process places a value on each of the elements. The decision model will use this established value to compare possible outcomes. Management can decide which path to follow based on the cost in time dollars or resources. A decision can also be evaluated based on its overall impact on the organization, positive or negative. This method was applied to decision ten, *Do we integrate the culture or keep culture separate*? For this decision, each element (reference

Appendix A) was evaluated based on whether it would have a positive or a negative impact on the organization.

In the simulation conducted in this thesis, each of the ten fundamental decisions were evaluated by a single measurement criteria--either time, cost or impact. In a true application, the decision model would consider all three measures: cost, time and resources. The table below shows the value placed on the elements in the simulation for fundamental decision number 1.

Table 6-4

Decision: 1. Do we keep acquisition's current management or do we replace with P&W management?

		Answer			
	Required Element Question, (Fact Level)	Yes	No	Score	Time Required to Implement Element (years)
1	Is management using cellular manufacturing?	1		0.125	1.0
2	Is there a Systems Engineering Organization in place?		1	0	1.0
3	Is there a Continuous Improvement Organization?	1		0.125	1.0
4	Does Management require an employee development plan?	1		0.125	0.2
5	Does Management have a growth plan in place?	1		0.125	0.5
6	Is the organizations monthly income tracking to plan?		1	0	0.5
7	does the management have a budget plan in place?	1		0.125	0.5
8	Is the budget plan tracking to plan?	1		0.125	0.5

The time required to put each element in place is shown in the far right column in table 6-4. For each missing element, elements which have a ‘no’ answer, the decision model will book keep this time. The times to implement an element are based on available resources, which considers working tasks in parallel. This allows the time to be summed in a linear fashion. The decision model will compare the time it takes to get the acquisition up-to-speed against what it would take to completely revamp the acquisition with a Pratt & Whitney policy or organization.

6.4.5 Step Five

Assign the decision tree branch probabilities.

Decision tree analysis begins with a major decision called a terminal decision node. In this simulation, the terminal decision node corresponds to the fundamental acquisition integration decision. The terminal decision is shown on the left-most side branches of the decision tree in figure 6-3. The next node is called a chance node; this is where the value of the terminal decision node branch value is calculated using the conditional probabilities assigned to the branches to the right of the chance node. In a multistage decision tree analysis, the user works from right to left to compute the expectations.

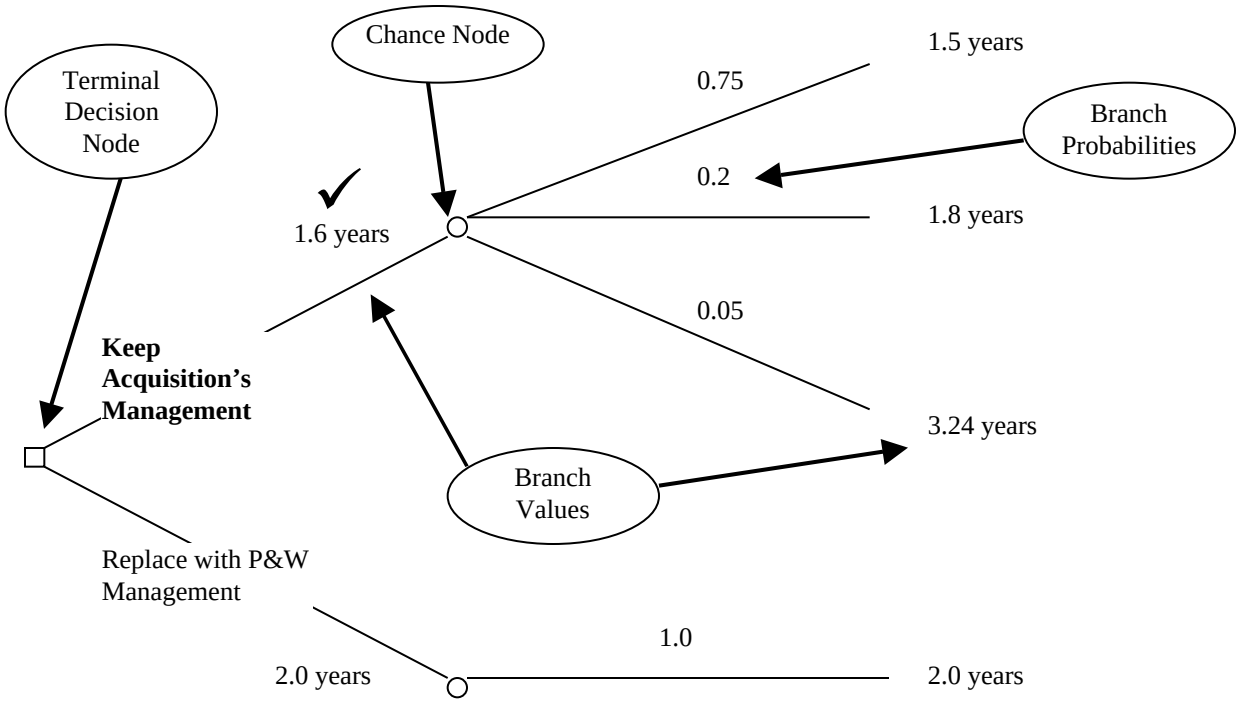


Figure 6-3: Anatomy of a Multi-stage Decision Model

As part of the actions in step 3, the normalized score was determined from the answers of the elemental questions. The value of the score is determined to be the upper rightmost branch probability, or the likelihood that this outcome will come true. The score in this simulation is 0.75, as shown in figure 6-3. The score acts as the level of certainty that the acquisition will carry out the elements of the decision. In decision tree analysis the total branch probability must equal 1[27]. The other two branches represent the relative uncertainty. This decision model is constructed using two levels of uncertainty. These two tiers of uncertainty provide a system sensitivity, which will allow the manager to evaluate the inherent risk. These branch probabilities are based on the amount of confidence that the acquisition will meet the requirements of the elements from step 3. This model sets the other two branches at 80% and 20% of the uncertainty.

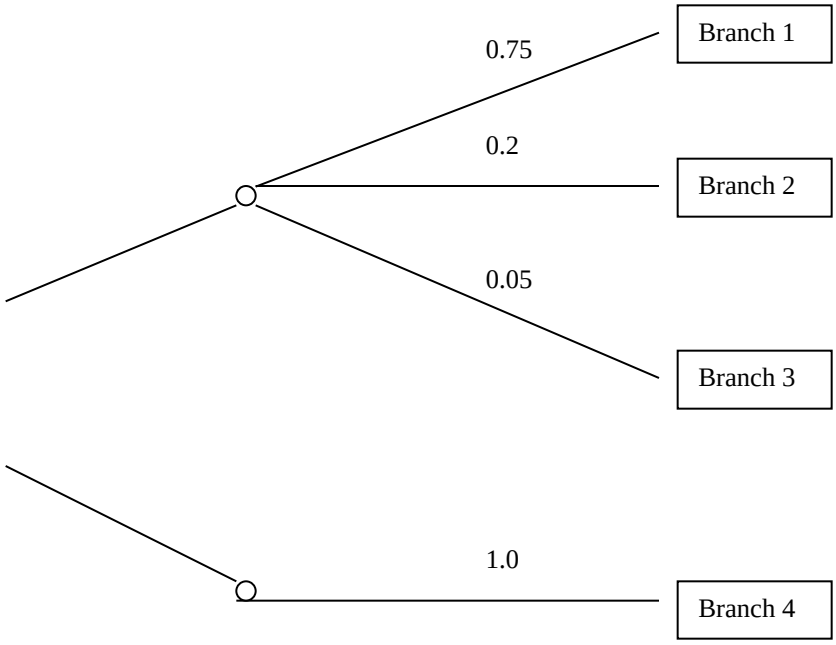


Figure 6-4: Branch Probabilities

[27] Apostolakis, G., "Decision Analysis", Video course manual, Massachusetts Institute of Technology, Cambridge, MA, 1986, page 1.4

Calculation of Branch Probabilities

Branch 1: branch 1 = score (from step 3)

Interpretation: Refer to the Step 3 explanation.

Branch 2: uncertainty = (1- score)
(1-score) x (0.80) = branch 2 probability

Interpretation: Of the uncertainty that exists, there is an 80% chance they will not falter.

Branch 3: uncertainty = (1-score)
(1-score) x (0.20) = branch 3 probability

Interpretation: Of the uncertainty that exists, there is only a 20% chance the acquisition will falter.

Branch 4: Probability = 1

Interpretation: Since it is known what Pratt & Whitney is capable of, then theoretically there is no uncertainty.

6.4.6 Step Six

Assign the decision tree branch values.

The branch tree values like the decision elements discussed in *Step Four*, in section 6.4.4, are measures of costs in terms of time resources, dollars or qualitative points. Note: branch value equations are shown directly after figure 6-5 in this section. Branch value 1, as shown in figure 6-5 is a result of the summation of the elements from Step Four, Branch values 2 & 3 show the increases which occur as a result of the uncertainty. Branch values 5 and 6 are shown in figure 6-5, these are the terminal decision node branch values. Managers compare these values to make a decision on which path to choose. The decision model calculates the branch values at the terminal decision node by multiplying the conditional probabilities times the right hand branch values. As shown in

figure 6-5, the terminal decision node branch value is calculated by summing branch value 1 times its probability, branch value 2 times its probability and branch value 3 by its probability. The result is a weighted value, which considers the cost and probable outcome of the terminal decision branch.

For each fundamental acquisition question, the results of the branch values at the terminal decision node provide the manager with information that will help decide which path to choose.

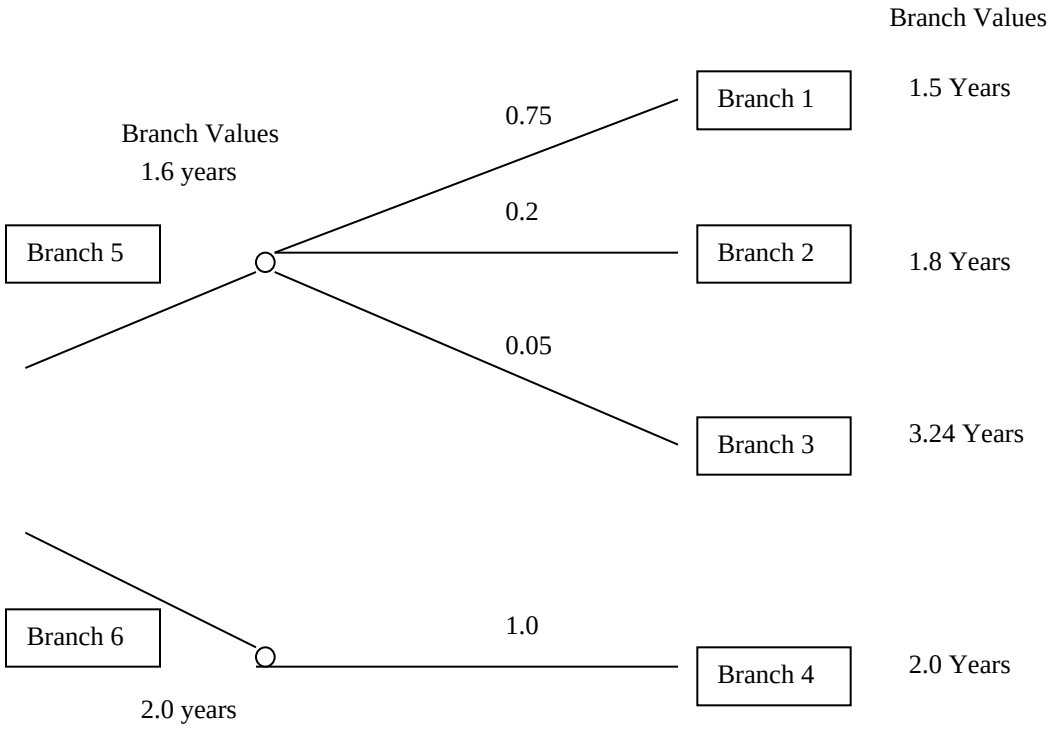


Figure 6-5: Branch Values

Calculation of Branch Values

Branch 1: value = summation of elements which the acquisition is not currently capable of

Branch 2: value = (summation of the elements which the acquisition is not currently capable of) x (80% chance the uncertainty will come true)

(sum of elements) x (1.20)

Branch 3: value = (summation of the elements which the acquisition is not currently capable of) x (20% chance the uncertainty will come true)

(sum of elements) x (1.80)

Branch 4: value = this value is known since it has been done before by P&W, so theoretically the value is known.

Branch 5: value = sum of the (conditional probabilities x value)

(P1 x value1) + (P2 x value2) + (P3 x value3)

Branch 6: value = P4 x value

6.4.7 Step Seven

Evaluate the results of the decision tree for each fundamental question analyzed; this will then reveal the decision path.

Once the decision tree is built and the probabilities and the values are established the terminal node decision node can be made by evaluation of the results as shown by the computed values on the terminal decision node branches.

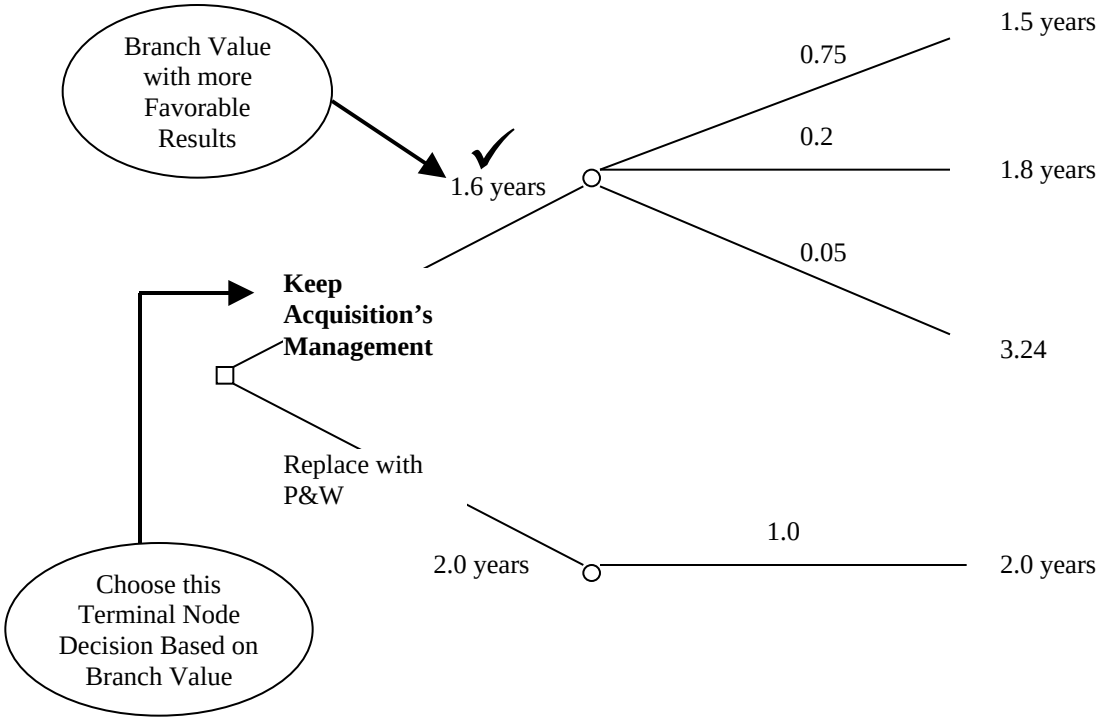


Figure 6-6 Choosing Terminal Node Decision

By inspection the manager can decide which way to go by evaluating the terminal decision node result. For example, it is better to keep the acquisition's management in place if it only takes 1.6 years for the acquisition's management to meet requirements, compared to 2 years for Pratt & Whitney to install a new management team. Interpretation of results from the decision model are discussed in detail in the following chapter.

Chapter 7

Findings

7.1 Overview

A simulation of the decision modeling technique presented in this thesis was conducted using the fundamental acquisition decisions covered in chapter 6.4. The seven steps[28] of the modeling technique were performed for each of the ten fundamental acquisition decisions. The raw data from each of the decision data tables and decision analysis trees are shown in Appendix A. The results of the simulation will be discussed in detail in the following section.

7.2 Decision Model Possible Outcomes

For each of the ten fundamental acquisition questions there are one of two possible outcomes. The results of the decision model will direct the user to either use the acquisition's current system or change it to a Pratt & Whitney system. The possible outcomes are depicted in table 7-1 as 1A or 1P. The first digit refers to the decision number, 'A' indicates the decision will keep the acquisition's system in place and 'P' indicates the acquisition's system will be replaced with a Pratt & Whitney system. The decision outcomes selected are shown by the outcomes which have been encircled in bold as shown in table 7-1.

Table 7-1: Possible Outcomes of the Fundamental Acquisition Decisions

		Possible Outcomes	
		Acquisition	Pratt & Whitney
1	Do we keep acquisition's current management or do we replace with P&W management?	1 A	1 P
2	Do we reorganize the acquisition's organizational structure or implement P&W's IPD?	2 A	2 P
3	Do we use the acquisition's method of regulatory validation or require use of P&W's FAA Designated Engineering Representatives (DER)?	3 A	3 P
4	Do we use the acquisition's Materials and Process Engineering (MPE) organization to validate engineering source approval, or use P&W's MPE organization?	4 A	4 P
5	Do we use the acquisition's Continuous Improvement (CI) system or require use of P&W's ACE program?	5 A	5 P
6	Do we replace the acquisition's marketing department with P&W's marketing department?	6 A	6 P
7	Do we replace the acquisition's financial and accounting department with P&W's financial and accounting department?	7 A	7 P
8	Do we replace the acquisition's human resources department with P&W's human resources department?	8 A	8 P
9	Do we maintain the acquisition's brand name with the addition of P&W or completely change to P&W?	9 A	9 P
10	Do we integrate the culture or keep culture separate?	10 A	10 P

[28] The seven steps necessary to conduct the decision model presented in this thesis are discussed in detail in chapter 6.

7.3 Model Results

The results of the model are summarized in table 7-2. The table includes the terminal node branch values from the decision analysis trees. The decision outcomes are listed after evaluation of the branch values. The decisions chosen correlate to a higher branch value. Also included in the post decision analysis evaluation of the data is the relationship of the terminal decision node values, the status of integration and what criteria was used to evaluate the terminal decision. In the case of this simulation the evaluation criteria used was time, cost or impact.

Table 7-2: Simulation Results Summary Table

Decision Analysis Results Summary Table

Decision Number	Question	Decision Result from Decision Analysis	Branch Values		Relationship	Pro-integration		Evaluation Criteria
			Acquisition	P&W		Yes	No	
1	Do we keep acquisition's current management or do we replace with P&W management?	Keep acquisition's management	1.6	2.0	Weak		1	Time
2	Do we reorganize the acquisition's organizational structure or implement P&W's IPD?	Implement P&W's IPD	4.4	1.0	Strong	1		Time
3	Do we use the acquisition's method of regulatory validation or require use of P&W's FAA Designated Engineering Representatives (DER)?	Use P&W's DER	1.1	0.5	Strong	1		Time
4	Do we use the acquisition's Materials and Process Engineering (MPE) organization to validate engineering source approval, or use P&W's MPE organization?	Use P&W's MPE	699.7	500.0	Medium	1		Cost
5	Do we use the acquisition's Continuous Improvement (CI) system or require use of P&W's ACE program?	Use P&W's Ace program	3.0	2.0	Medium	1		Time
6	Do we replace the acquisition's marketing department with P&W's marketing department?	Keep acquisition's Marketing Department	0.5	1.0	Strong		1	Time
7	Do we replace the acquisition's financial and accounting department with P&W's financial and accounting department?	Use P&W's Financial and Accounting Department	3.1	1.0	Strong	1		Time
8	Do we replace the acquisition's human resources department with P&W's human resources department?	Use P&W's HR department	1.7	1.5	Weak	1		Time
9	Do we maintain the acquisition's brand name with the addition of P&W or completely change to P&W?	Maintain acquisition's brand name	5023.2	3500.0	Medium		1	Cost
10	Do we integrate the culture or keep culture separate?	Maintain acquisition's culture.	4.8	5.0	Weak		1	Impact
						6	4	

7.3.1 Branch Value Relationships

Qualitative evaluations of the relative strength of the branch value relationships are conducted by observing the magnitude of the branch values for each decision. The results of this review are shown in table 7-2 in the column labeled 'Relationship'. The relationship--strong, medium or weak-- refers to a comparison of the outcome of the branch values at the terminal decision node. The interpretation of the relationships are as follows.

Relationship:

Strong When the branch values are separated by a large amount as in decision 2, (refer to table 7-1) it is clear the decision should be made in favor of the branch with a large value. In the case of a strong relationship, the model predicts the cost of choosing the decision with the high value will be small. When the relationship is strong there is high probability that the direction chosen will result in success. In this case the manager is confident in the direction and the risk is low. The corollary is also true, if the manager chooses not to heed to the model's prediction, there is a high risk that the costs to the organization will be high.

Medium A medium relationship means the branch values at the terminal decision node are different but not nearly of the magnitude as demonstrated by a *strong* relationship. In this case the model predicts that the cost of either decision outcome is similar and the clarity on which way to go is not as apparent. In the simulation presented, decisions four, five and nine turned out to be *medium*.

Weak When the relationship is *weak*, the model is indicating that the cost of either outcome is about the same. The clarity on which way to go is much less, and the success of either direction is about the same. Risk is low

since the cost of both possible outcomes is virtually the same. Decisions one, eight and ten of the simulation turned out to have a weak relationship.

7.3.2 Level of Integration as Shown by the Model

The outcome of each decision is evaluated as to whether it is pro-integration or not. At each terminal node the decision to be made either favors staying with the current system in place at the acquisition or changing to a Pratt & Whitney system. If the decision favors keeping the acquisition's system in place, then this is considered to be anti-integration. When a change to a Pratt & Whitney system is decided then this results in a pro-integration decision. The results of the simulation yielded six pro-integration decisions to four anti-integration decisions. The result of the model, as shown in table 7-2, indicates that partial integration is the best fit for success for this particular integration. This result reveals that blanket decisions from management on levels of integration may not be in the best interest for success from an enterprise perspective. The model provides the level of integration which best fits the organization based on actual conditions of a specific acquisition.

7.3.3 Decision Evaluation Criteria

As explained in Chapter 6.4.4 Step Four, the evaluation criteria for each element of the fundamental acquisition decision maybe in the form of monetary cost, time to implement, consumption of resources and relative impact, positive or negative. In an actual decision model as explained in Chapter 6.4.4, all the measures would be considered for evaluation. The evaluation criteria for the simulation was carefully chosen so that the most important measurement criteria was represented. As shown in table 7-2, time was used as the

evaluation criteria for seven out of ten of the decisions. Timeliness is paramount with these seven decisions. The success of mergers and acquisitions are in many ways dependent on the actions of the post-merger/acquisition management[29]. Critical to success is the immediate aftermath when decisions on organizational structure and human resources must be made. Managers must be well informed and able to evaluate the risks of such decisions and just as important as the quality of the information, the decision must be quick.

The decisions which were dependent on monetary impact are critical for the success but did not require an immediate resolution. Decision four dealt with validations of processes involving the use of specialized equipment, which was available in part at the acquisition and in entirety at Pratt & Whitney. In this case it can be seen that the means to complete certain tasks were available, but they were distributed. The decision was to consolidate operations at Pratt & Whitney, an important decision, but not one requiring immediate action.

Successful integration of mergers and acquisitions includes proper consideration for corporate culture. Measuring effects of culture quantitatively is difficult but a binary approach using two categories, positive verses negative impact can yield satisfactory results. This technique was applied to decision ten; *Do we integrate the culture or keep separate*? As shown in table 7-2, the impact of keeping the acquisition's culture intact verses changing the culture over to Pratt & Whitney's culture, favored the change to Pratt & Whitney. The relationship was weak however, which means it would not have an

[29] Business International, "Making Acquisitions Work", Geneva 17, Switzerland, 1988, page 4

adverse affect to the success of the acquisition integration if the acquisition's culture were left intact. The impact evaluation technique in this case revealed that the acquisition's culture was compatible with Pratt & Whitney's.

7.4 Decision Path

The fundamental result of the decision model is the decision path. The decision path allows the manager to make quick well-informed decisions, which are critical to the success of the integration. Considering that with ten decisions with two possible outcomes per decision as many as 184,756 different combinations for the decision path exists[30], the model succeeds in evaluating the decisions and defines a path of greatest probability for success. The decision path for the simulation is shown in figure 7-1, the figure also graphically depicts decisions which support more or less integration.

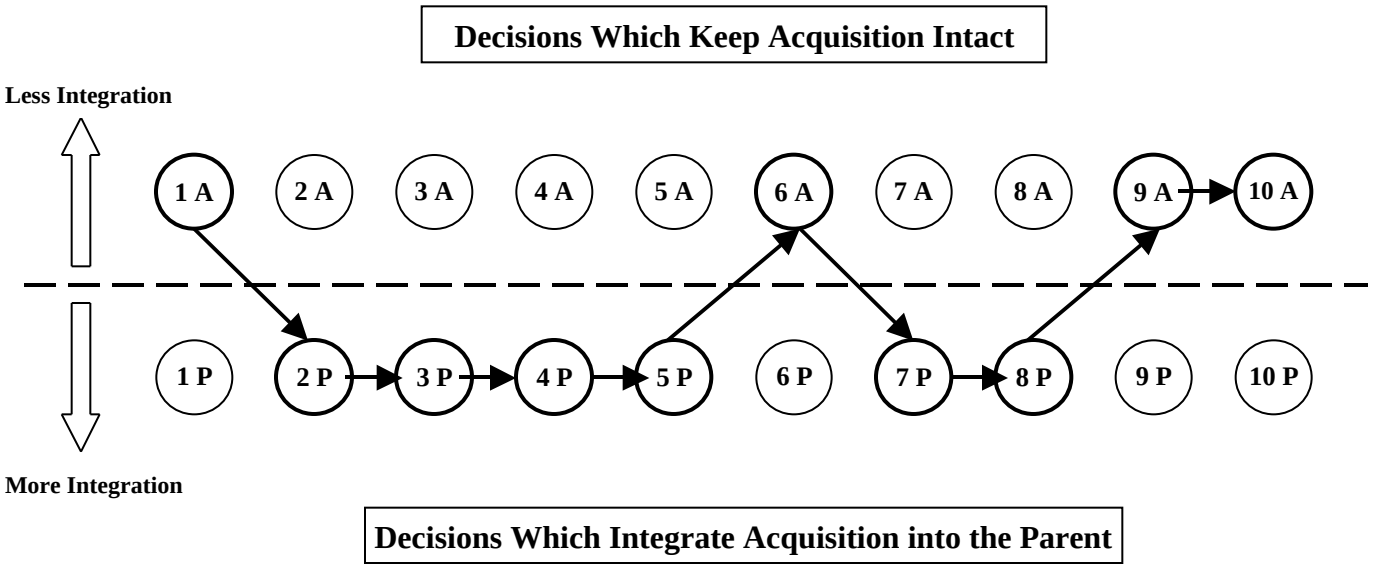


Figure 7-1: Decision Path Defined by the Decision Model Simulation

7.5 Decision Path Interdependencies

Once the fundamental decision path is completed, the integration team must understand if any interdependencies exist. The team conducts a review and determines if the decision being analyzed has a direct effect on any of the other decisions. The interdependencies from the decision model simulation are shown in table 7-3.

Table 7-3: Decision Path Interdependencies

Decision Number	Result from Decision Analysis	Interdependencies
1	Keep acquisition's management	7, 8
2	Implement P&W's IDP	1, 10
3	Use P&W's DER	10
4	Use P&W's Materials Process Engineering	
5	Use P&W's ACE program	1, 10
6	Keep acquisition's Marketing department	1, 2, 9, 10
7	Use P&W's Financial and Accounting dpt.	1, 10
8	Use P&W's HR department	1, 10
9	Maintain acquisition's brand name	6
10	Maintain acquisition's culture	2, 7, 8

As can be seen from Table 7-3, the decision to keep the acquisition's management results in interdependency with decision 7 and 8. This means the acquisition's management must be able to work with Pratt & Whitney's financial department and human resources

[30] This figure is calculated as follows: Combinations = n!/(r! x (n!-r!)), where n = 20 = number of possible outcomes and r = 10 number of decisions.

organization to be successful. The interdependency exercise reveals that keeping the acquisition's marketing department in place generates four interdependencies: management, Pratt & Whitney's IDP organization, acquisition's brand name and culture. It shows that the success of marketing and the acquisition as a whole depends on four critical aspects of the integration. Clearly if marketing and management are not aligned problems will result. Success also depends on marketing embracing Pratt & Whitney's IPD process. The interdependency with acquisition brand name and culture result from the fact that the acquisition's marketing department has allegiance to the brand and with the familiar culture. Marketing's client base is built on the acquisition's brand name; therefore, if the acquisition's brand name were eliminated, so would marketing's allegiance and possibly most of the client base.

Managers must be aware of the interdependencies when formulating the decision path. Interdependencies reveal critical areas, as shown by the simulation: management, culture and surprisingly, marketing are areas critical to a successful integration. The awareness of the interdependencies will alert management to problem areas as the integration process proceeds. The awareness will allow midcourse corrections to occur alleviating any disasters.

Chapter 8

Recommendations

Successful integration of mergers and acquisitions requires good decisions and swift action. Good decisions are dependent on good information. A tool which provides managers with sound information would allow swift action and much improved success with integration of mergers and acquisitions.

The decision model presented in this thesis provides a structured method which raises the decision process well above a superficial evaluation of the conditions as perceived by a single individual. The model dissects the abstract into elemental components and evaluates the acquisition's ability to carryout what a group of experts, the acquisition team, defines is necessary for success. The model provides managers with a numerical evaluation, which allows them to definitively determine a decision path.

The work conducted in this thesis shows that the decision modeling technique is capable of managing inference and ambiguity in the decision process. The decision model is able to evaluate the probability for success for the decisions selected. A complete decision path can be decided rather quickly using the model, giving managers the power of quick well-informed decisions. The model uses the full strength of the organization by assembling a team of experts from the core of the organization, not singularly focused peripheral groups.

Recommendation 1

Companies relying on mergers and acquisitions as a part of their growth strategy should assemble an acquisition team who become expert in the use of the model presented. The team must be multidisciplined and have the following major skill sets: knowledge of prior integrations, knowledge of the actual conditions at the acquisition, knowledge of human resource issues, engineering process, financial process, competitive industry knowledge, contract and legal, knowledge of corporate strategy and knowledge on how the decomposition process works using the WV model and the LP method.

Recommendation 2

The company should use a structured approach to the integration process. The model presented in this thesis provides a solid foundation on how to proceed. Reliance on rules of 'thumb' and 'gut feel' is not a reasonable approach when so much is at stake. In today's business world, complexity is at a level where single individuals or peripheral groups are incapable of completely comprehending the full scope of what is necessary to conduct a decision path. A structured approach maximizes the resourcefulness of the enterprise and quickly sorts out risky decision paths.

Recommendation 3

Integrate the acquisition only to a level that makes sense. The simulation of the decision model conducted in this thesis resulted in a level of integration, which supported full integration by only six out of the ten fundamental acquisition questions. In this case it was clear that a greater or lesser amount of integration would be damaging to the success of the integration. The model is capable of defining a level of integration which is

harmonious to both the acquisition and the parent. Fundamentally it is best to match the level of integration with the actual conditions at the acquisition.

Recommendation 4

Conduct a review process to evaluate the success of the integration. This process is critical so that any midcourse corrections can be made. The integration process should have some fluidity and not be bound by rigid rules and processes, which could undermine success. External market and economic changes or incorrect data all can influence the decision path. The evaluation conducted in the review process will provide the basis for the organization to learn from previous decisions. The continuous learning will strengthen future decision models, ensuring greater success in acquisition integration.

Bibliography

Ancona, Kochan, Scully, Van Maanen, Westney, *Organizational Behavior & Processes*, Cincinnati, OH: South-Western College Publishing, 1999

Beer, M., *Organization Change and Development*, Santa Monica, CA: Goodyear Publishing, 1998

Boppe, C., "Systems Engineering", Course Manual, Cambridge, MA: Massachusetts Institute of Technology, Summer 2000

Drake, A. and Keeny, R., "Decision Analysis" Video Course Manual, Cambridge, MA: Massachusetts Institute of Technology, 1986

Glynn, S. and Pelland, T., "Information Flow & Knowledge Capture Lessons for Distributed Integrated Product Teams", MIT MS Thesis, 2000

Haspeslaugh, P.C. and Jemison, D.B. *Managing Acquisitions*, New York: The Free Press, 1991

Henderson, R, "Special DLL Seminar in Management: Technology Strategy" Course Manual, Cambridge, MA: Massachusetts Institute of Technology, Spring 2001

Kingsley-Jones, M., and Duffy, P, "World Airliner Census", Flight International, No. 4802, Vol. 160, pp. 40-69

Kramer, R.J., "The Post-Merger Organization Handbook", The Conference Board, Inc., 1991

Lampl, R., (Executive Editor), *Aviation & Aerospace Almanac 2000*, New York: Aviation Week/McGraw-Hill Companies, 2000

Mascoli, G., "A Systems Engineering Approach to Aero Engine Development in a Highly Distributed Engineering and Manufacturing Environment", MIT MS Thesis, 1999

Morrison, S. and Winston, C., *The Evolution of the Airline Industry*, Washington, DC: The Brookings Institution, 1995

Nightingale, D., "Integrating the Lean Enterprise", Course Manual, Cambridge, MA: Massachusetts Institute of Technology, Fall 2000

Phillips, E. and Taverna, T., "Market Forces Reshaping MRO", Aviation Week & Space Technology, April 2, 2001, pp. 86-92

Pritchett, P., *After the Merger*, New York: McGraw-Hill, 1997

Pritchett, P., *Making Mergers Work*, Homewood, IL: Dow Jones-Irwin, 1987

Proulx, J., “Ranking the Players”, Aviation Week’s Overhaul & Maintenance, Vol. VII, No. 5, pp.32-42

Reinertsen, D. *Managing the Design Factory*, New York, NY: The Free Press, 1997

Shiba, S and Walden, D, *Four Practical Revolutions in Management*, Portland, OR: Productivity Press, 2001

Smith, W. *Handbook of Strategic Growth Through Mergers and Acquisitions*, Englewood Cliffs, NJ: Prentice Hall, Inc., 1985

Yunker, J., *Integrating Acquisitions*, New York: Praeger Publications, 1983

Anonymous, “Airline Cost Index, Second Quarter 2001” Air Transit Association, Office of Economics, 2001

Anonymous, “Current Market Outlook 2001”, Boeing Commercial Airplanes, 2001

Anonymous, “Global Market Forecast 1998-2017”, Airbus Industries, April 1998

Anonymous, *Making Acquisitions Work*, Geneva, Switzerland: Business International, 1988

Appendices

Appendix A

This appendix contains the results of the decision models for the ten fundamental acquisition questions analyzed in the simulation.

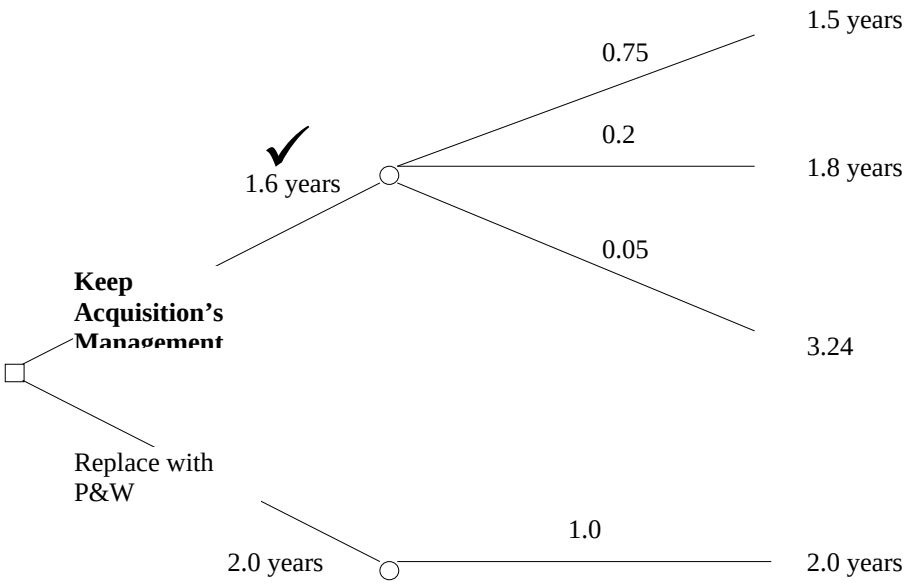
Decision Analysis Data Table

Decision: 1. Do we keep acquisition's current management or do we replace with P&W management?

		Answer				Branch 1	Branch 2	Branch 3
	Required Element Question, (Fact Level)	Yes	No	Score	Time Required to Implement Element (years)	Implement Missing Elements (years)	80% Time with Uncertainty Extension	20% Time with Uncertainty Extension
1	Is management using cellular manufacturing?	1		0.125	1.0	0.0		
2	Is there a Systems Engineering Organization in place?		1	0	1.0	1.0		
3	Is there a Continuous Improvement Organization?	1		0.125	1.0	0.0		
4	Does Management require an employee development plan?	1		0.125	0.2	0.0		
5	Does Management have a growth plan in place?	1		0.125	0.5	0.0		
6	Is the organizations monthly income tracking to plan?		1	0	0.5	0.5		
7	does the management have a budget plan in place?	1		0.125	0.5	0.0		
8	Is the budget plan tracking to plan?	1		0.125	0.5	0.0		
					Branch Implementation Times (years)	1.5	1.8	3.24
	Branch Probabilities			0.75		0.75	0.2	0.05 =

Summary Table

Branch	Probability	Implementation Time
1	0.75	1.5
2	0.2	1.8
3	0.05	3.24
	Branch Value	1.6
4	1.0	2.0
	P&W Branch Value	2



Appendix A - continued

Decision: 2. Do we reorganize the acquisition's organizational structure or implement P&W's IPD?

		Answer					Branch 1	Branch 2	Branch 3
	Required Element Question, (Fact Level)	Yes	No	Score	Time Required to Implement Element (years)	Implement Missing Elements (years)		80% Time with Uncertainty Extension	20% Time with Uncertainty Extension
1	Do the Design and Structural Engineering teams report to the same project manager?		1	0	0.5	0.5			
2	Is there a manufacturing team member on the product development team ?		1	0	0.2	0.2			
3	Is manufacturing represented at the Configuration Control Board.	1		0.125	0.2	0.0			
4	Is there a product technical support team member on the product development team?		1	0	0.2	0.2			
5	Is there a technical integration organization in place?		1	0	1.0	1.0			
6	Are the members of the product development team co-located?		1	0	1.0	1.0			
7	Does the product development team conduct design reviews with technical integration org?	1		0.125	0.5	0.0			
8	Does the product development team review field problems?		1	0	0.5	0.5			
					4.1				
					Branch Implementation Times (years)		3.4	4.08	7.344
		Branch Probabilities		0.25			0.25	0.6	0.15 = 1.0

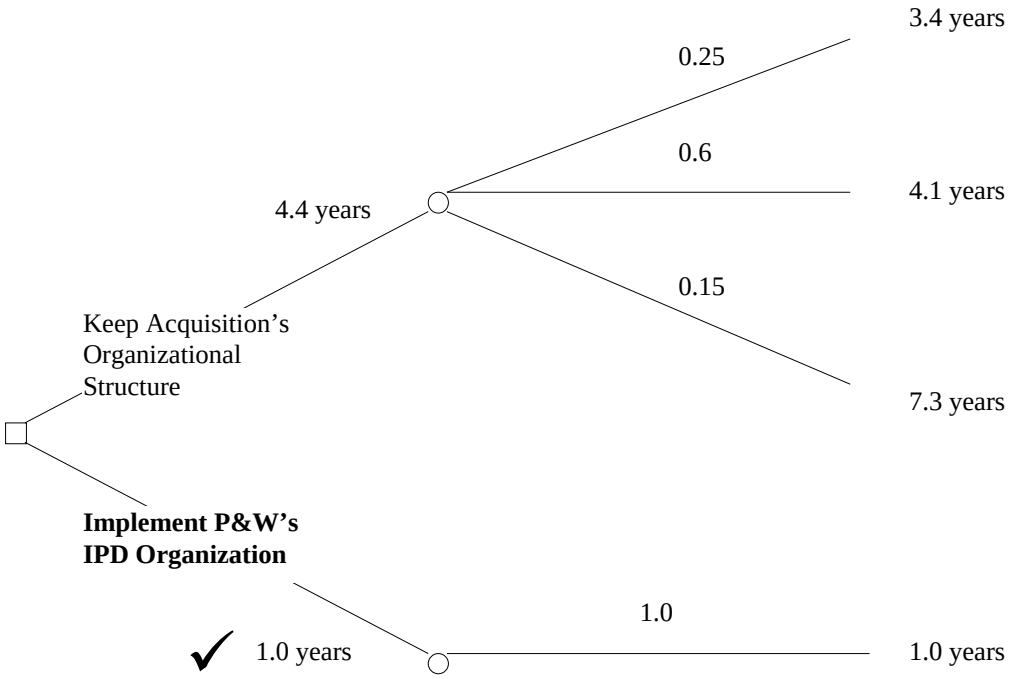
Summary Table

Branch	Probability	Implementation Time (years)
1	0.25	3.4
2	0.6	4.08
3	0.15	7.344

Branch Value 4.4

4	1.0	1.0

P&W Branch Value 1



Appendix A - continued

Decision: 3. Do we use the acquisition's method of regulatory validation or require use of P&W's FAA Designated Engineering Representatives (DER)?

		Answer			Branch 1	Branch 2	Branch 3
	Required Element Question, (Fact Level)	Yes	No	Score	Time Required to Implement Element (years)	Implement Missing Elements (years)	80% Time with Uncertainty Extension	20% Time with Uncertainty Extension
1	Is the independent DER the acquisition using have FAR 133 qualification?	1		0.125	2.0	0.0		
2	Does the ACO in Burlington Mass, have record of the independent DER?	1		0.125	0.5	0.0		
3	Will the European Regulatory Agency (RA) accept technical data packages from their DER?	1		0.125	1.0	0.0		
4	Will the Pacific region RA, the JAA accept technical data packages from their DER?		1	0	0.5	0.5		
5	Will United Airlines accept signoffs from the acquisition's independent DER?	1		0.125	1.0	0.0		
6	Will Japan Airlines accept signoffs from the acquisition's independent DER?		1	0	0.5	0.5		
7	Does the ACO in the independent DER's region require the same yearly review?	1		0.125	0.5	0.0		
8	Is the turn time of technical data packages on average less than 2 days	1		0.125	0.5	0.0		
					6.5			
					Branch Implementation Times (years)	1.0	1.2	2.16
	Branch Probabilities			0.75		0.75	0.2	0.05 = 1.0

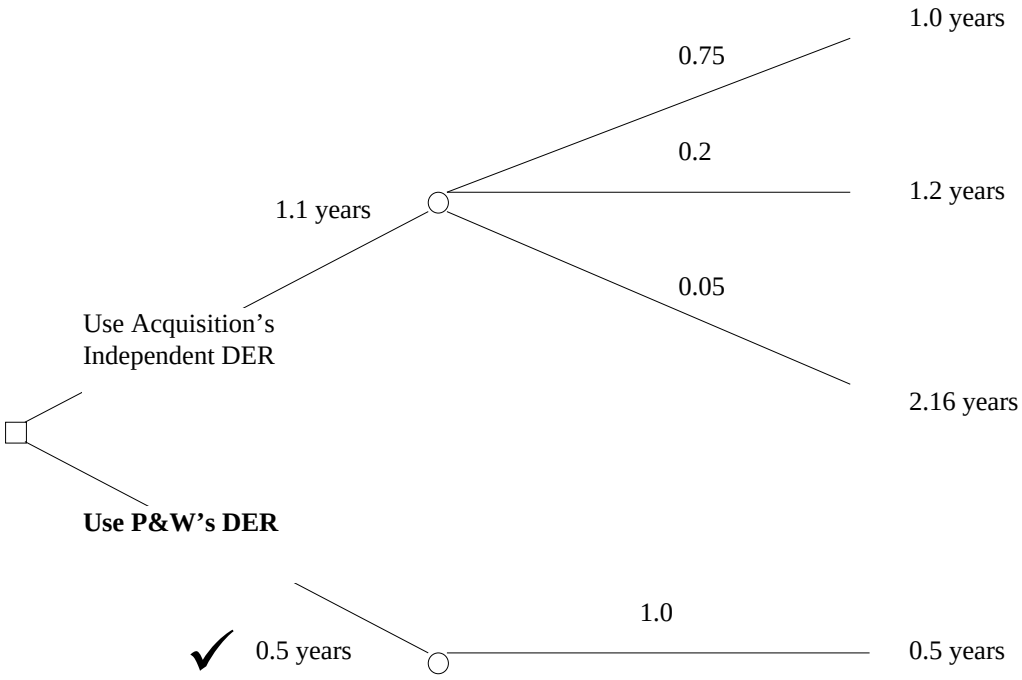
Summary Table

Branch	Probability	Implementation Time (years)
1	0.75	1.0
2	0.2	1.2
3	0.05	2.16

Branch Value 1.1

4	1.0	0.5

P&W Branch Value 0.5



Appendix A - continued

Decision: 4. Do we use the acquisition's Materials and Process Engineering (MPE) organization to validate engineering source approval, or use P&W's MPE organization?

		Answer				Branch 1	Branch 2 80%	Branch 3 20%
	Required Element Question, (Fact Level)	Yes	No	Score	Cost Required to Implement Element (dollars, thousands)	Cost to Implement Missing Elements (dollars, thousands)	Cost with Uncertainty Extension	Cost with Uncertainty Extension
1	Does the acquisition have a dedicated costing engineer?		1	0	100.0	100.0		
2	Is the acquisition's welding engineer certified by the ASME?	1		0.125	50.0	0.0		
3	Are the repair qualifications filled with the local ACO?	1		0.125	50.0	0.0		
4	Does the acquisition have X-ray defraction capability?		1	0	500.0	500.0		
5	Is the acquisition's materials lab certified by the ACO?	1		0.125	50.0	0.0		
6	Does the acquisition's lab have capability to perform metalography?	1		0.125	80.0	0.0		
7	Does the acquisition's lab have capability to perform Vicker's diamond hardness?		1	0	10.0	10.0		
8	Is the turn time for source approval on average less than 60 days	1		0.125	200.0	0.0		
					1040.0			
					Branch Implementation Cost (dollars, thousands)	610.0	732	1317.6
	Branch Probabilities			0.625		0.625	0.3	0.075 = 1.0

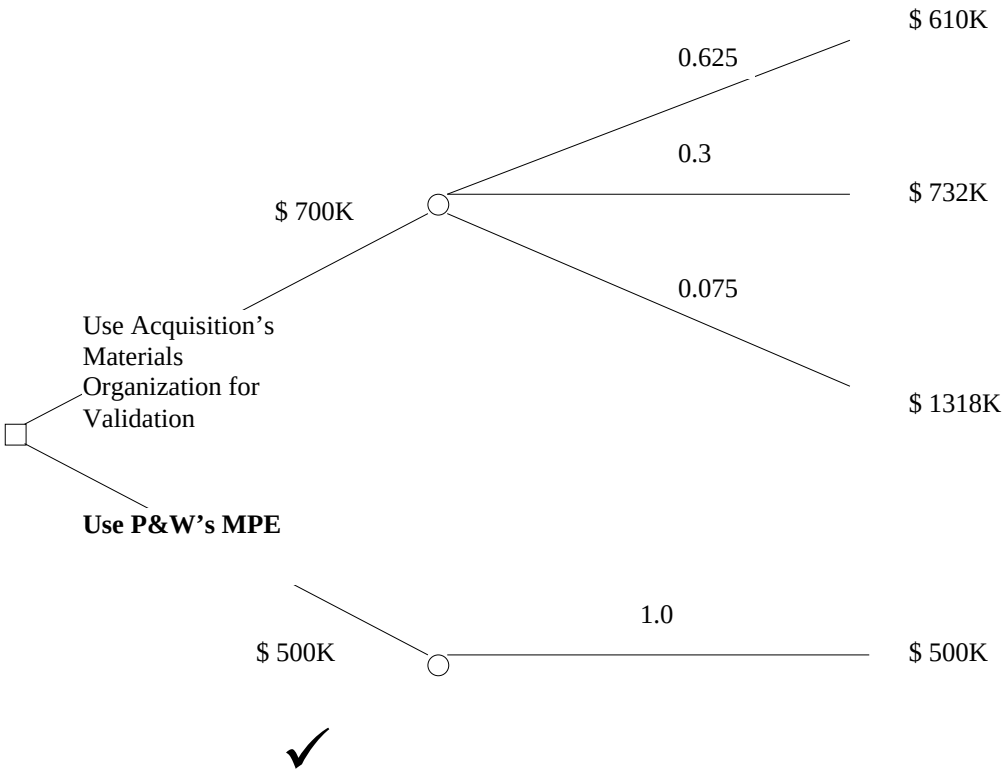
Summary Table

Branch	Probability	Implementation Cost (dollars, thousands)
1	0.625	610.0
2	0.3	732
3	0.075	1317.6

Branch Value 699.7

4	1.0	500.0

P&W Branch Value 500



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Appendix A - continued

Decision: 5. Do we use the acquisition's Continuous Improvement (CI) system or require use of P&W's ACE program?

	Required Element Question, (Fact Level)	Answer Yes	Answer No	Score	Time Required to Implement Element (years)	Branch 1 Implement Missing Elements (years)	Branch 2 80% Time with Uncertainty Extension	Branch 3 20% Time with Uncertainty Extension
1	Does the acquisition have a Total Productive Maintenance Program (TPM)?		1	0	0.5	0.5		
2	Does the acquisition have a 6S Program in place?		1	0	0.5	0.5		
3	Does the acquisition have a management process certification program in place?		1	0	0.5	0.5		
4	Does the acquisition have a shop process certification program in place?	1		0.125	1.0	0.0		
5	Does the acquisition have a Standard Work (SW) program in place?	1		0.125	2.0	0.0		
6	Does the acquisition have a Quality Clinic Process Chart (QCPC) program in place?		1	0	1.0	1.0		
7	Does the acquisition have a Relentless Root Cause Analysis (RRCA) program in place?	1		0.125	0.5	0.0		
8	Does the acquisition have a Mistake Proofing (MP) program in place?	1		0.125	0.5	0.0		
					6.5			
					Branch Implementation Times (years)	2.5	3	5.4
	Branch Probabilities			0.5		0.5	0.4	0.1 = 1.0

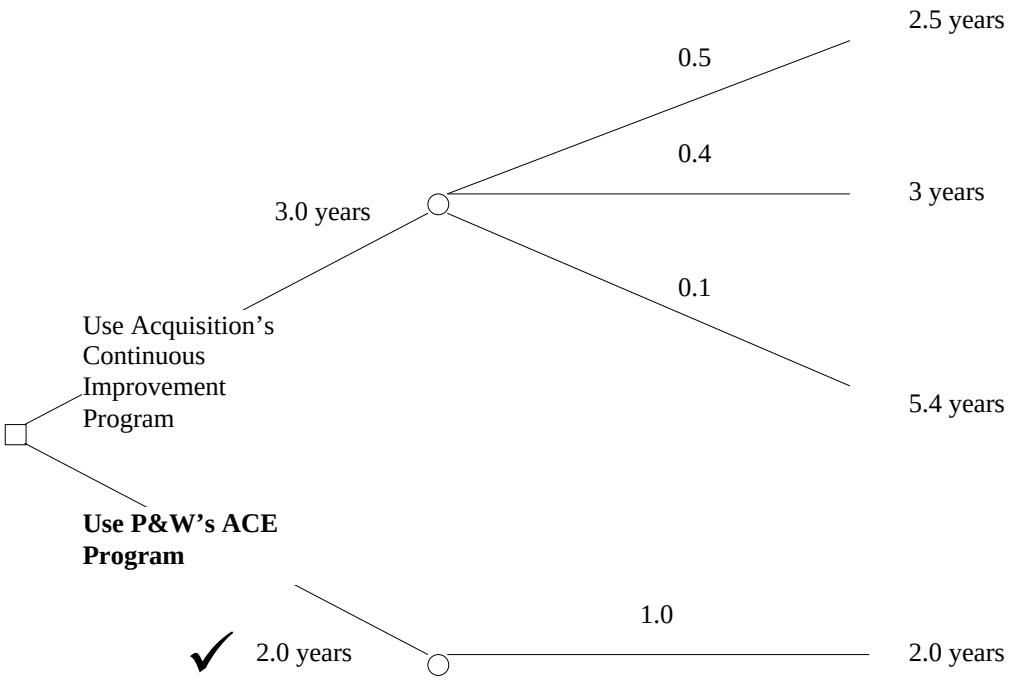
Summary Table

Branch	Probability	Implementation Time (years)
1	0.5	2.5
2	0.4	3
3	0.1	5.4

Branch Value 3.0

4	1.0	2.0

P&W Branch Value 2



Appendix A - continued

Decision: 6. Do we replace the acquisition's marketing department with P&W's marketing department?

	Required Element Question, (Fact Level)	Answer Yes	Answer No	Score	Time Required to Implement Element (years)	Branch 1 Implement Missing Elements (years)	Branch 2 80% Time with Uncertainty Extension	Branch 3 20% Time with Uncertainty Extension
1	Does the acquisition cover the geographic region?	1		0.125	0.5	0.0		
2	Does the acquisition conduct business with United Airlines?	1		0.125	0.5	0.0		
3	Does the acquisition conduct business with British Air?	1		0.125	0.5	0.0		
4	Does the acquisition conduct business with Japan Airlines?	1		0.125	1.0	0.0		
5	Does the acquisition conduct business with China Airlines?	1		0.125	2.0	0.0		
6	Does the acquisition conduct business with Air India?	1		0.125	1.0	0.0		
7	Does the acquisition produce a sales contract on average less than 30 days?	1		0.125	0.5	0.0		
8	Does the acquisition have regional sales managers in place?		1	0	0.5	0.5		
					6.5			
					Branch Implementation Times (years)	0.5	0.6	1.08
	Branch Probabilities			0.875		0.875	0.1	0.025 = 1.0

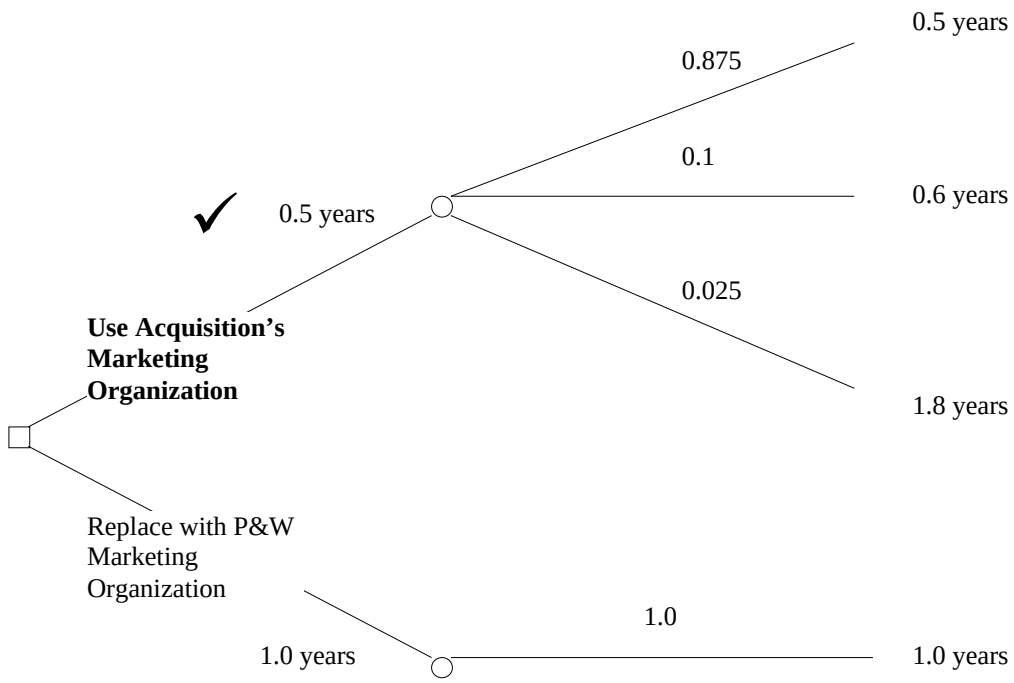
Summary Table

Branch	Probability	Implementation Time (years)
1	0.875	0.5
2	0.1	0.6
3	0.025	1.08

Branch Value 0.5

4	1.0	1.0

P&W Branch Value 1



Appendix A - continued

Decision: 7. Do we replace the acquisition's financial and accounting department with P&W's financial and accounting department?

	Required Element Question, (Fact Level)	Answer Yes	Answer No	Score	Time Required to Implement Element (years)	Branch 1 Implement Missing Elements (years)	Branch 2 80% Time with Uncertainty Extension	Branch 3 20% Time with Uncertainty Extension
1	Does the acquisition have audited annual financial reports for the last 10 years?	1		0.125	0.5	0.0		
2	Does the acquisition have projected financial statements for the next 5 years?		1	0	0.5	0.5		
3	Does the accounting principles used by the acquisition evaluate assets the same as P&W?		1	0	0.5	0.5		
4	Does the acquisition report the same trend ratio analysis as P&W?		1	0	0.5	0.5		
5	Does the acquisition handle aging of account receivable in the same manner as P&W?		1	0	0.5	0.5		
6	Does the acquisition report quarterly earnings in the same manner as P&W?	1		0.125	0.5	0.0		
7	Does the acquisition calculate depreciation in the same manner as P&W?	1		0.125	0.5	0.0		
8	Does the acquisition calculate liabilities in the same manner as P&W?		1	0	0.5	0.5		
					4.0			
					Branch Implementation Times (years)	2.5	3	5.4
	Branch Probabilities			0.375		0.375	0.5	0.125 = 1.0

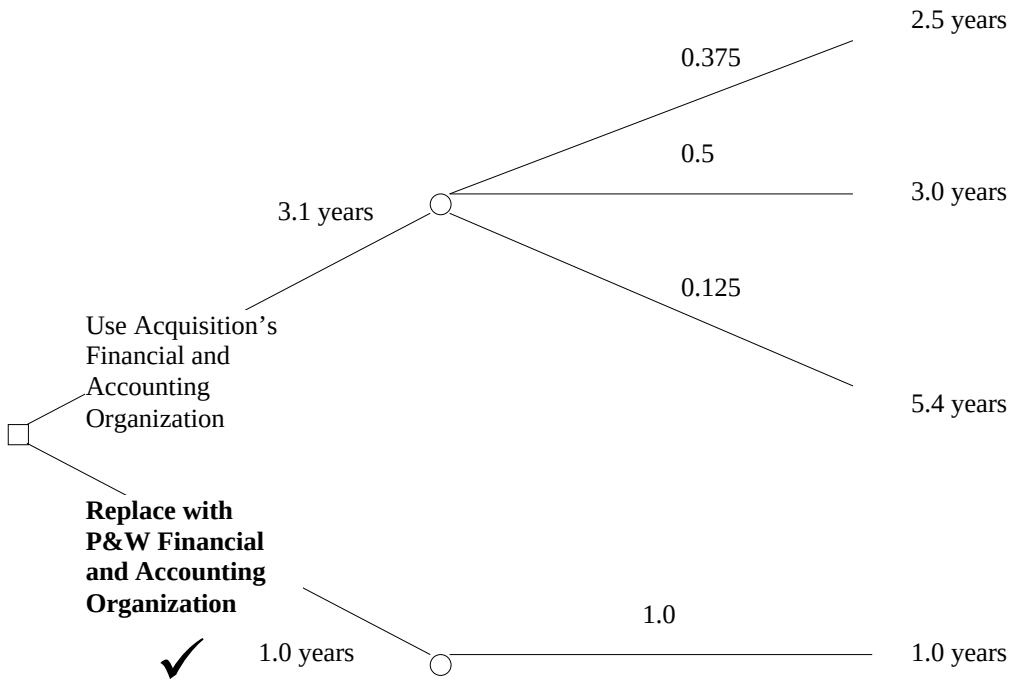
Summary Table

Branch	Probability	Implementation Time (years)
1	0.375	2.5
2	0.5	3
3	0.125	5.4

Branch Value 3.1

4	1.0	1.0

P&W Branch Value 1



Appendix A - continued

Decision: 8. Do we replace the acquisition's human resources department with P&W's human resources department?

	Required Element Question, (Fact Level)	Answer Yes	Answer No	Score	Time Required to Implement Element (years)	Branch 1 Implement Missing Elements (years)	Branch 2 80% Time with Uncertainty Extension	Branch 3 20% Time with Uncertainty Extension
1	Does the acquisition have a pension plan for employees?	1		0.125	1.0	0.0		
2	Does the acquisition have 2% per year pension growth after 15 years?		1	0	0.5	0.5		
3	Does the acquisition have pay grades?	1		0.125	0.5	0.0		
4	Are the acquisition's pay grades out of compliance with P&W policy?		1	0	0.5	0.5		
5	Does the acquisition provide educational assistance to their work force P&W?		1	0	0.5	0.5		
6	Does the acquisition have a leadership development program?	1		0.125	1.0	0.0		
7	Does the acquisition have a plan in place to correct diversity non-compliance?	1		0.125	0.5	0.0		
8	Does the acquisition have a special award system in place ?	1		0.125	0.5	0.0		
					5.0			
					Branch Implementation Times (years)	1.5	1.8	3.24
	Branch Probabilities			0.625		0.625	0.3	0.075 = 1.0

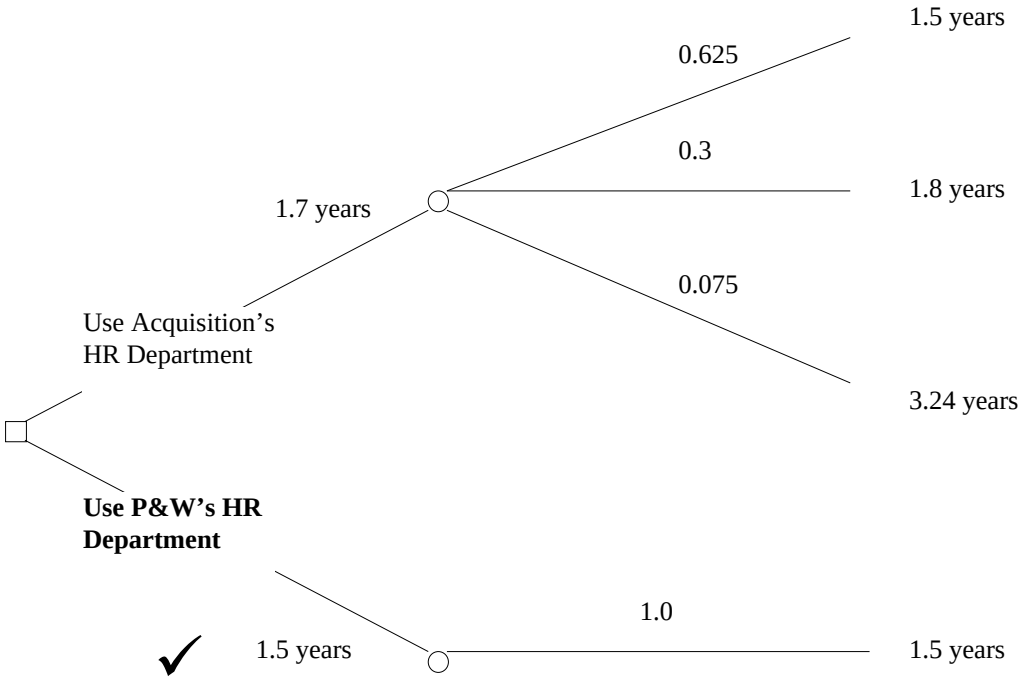
Summary Table

Branch	Probability	Implementation Time (years)
1	0.625	1.5
2	0.3	1.8
3	0.075	3.24

Branch Value 1.7

4	1.0	1.5

P&W Branch Value 1.5



Appendix A - continued

Decision: 9. Do we maintain the acquisition's brand name with the addition of P&W or completely change to P&W?

		Answer					Branch 1	Branch 2 80%	Branch 3 20%
	Required Element Question, (Fact Level)	Yes	No	Score	Cost Required to Implement Element (dollars, thousands)	Cost to Implement Missing Elements (dollars, thousands)		Cost with Uncertainty Extension	Cost with Uncertainty Extension
1	Has United Airlines signed next year's contract?		1	0	2500.0	2500.0			
2	Has British Air signed next year's contract?		1	0	600.0	600.0			
3	Has Japan Airlines signed next year's contract?	1		0.125	1000.0	0.0			
4	Has China Air signed next year's contract?		1	0	500.0	500.0			
5	Has Air India signed next year's contract?	1		0.125	400.0	0.0			
6	Has Air Canada signed next year's contract?	1		0.125	900.0	0.0			
7	Has UPS signed next year's contract?		1	0	600.0	600.0			
8	Has Delta Airlines signed next year's contract?	1		0.125	1200.0	0.0			
					7700.0				
					Branch Implementation Cost (dollars, thousands)		4200.0	5040	9072
	Branch Probabilities			0.5			0.5	0.4	0.1 = 1.0

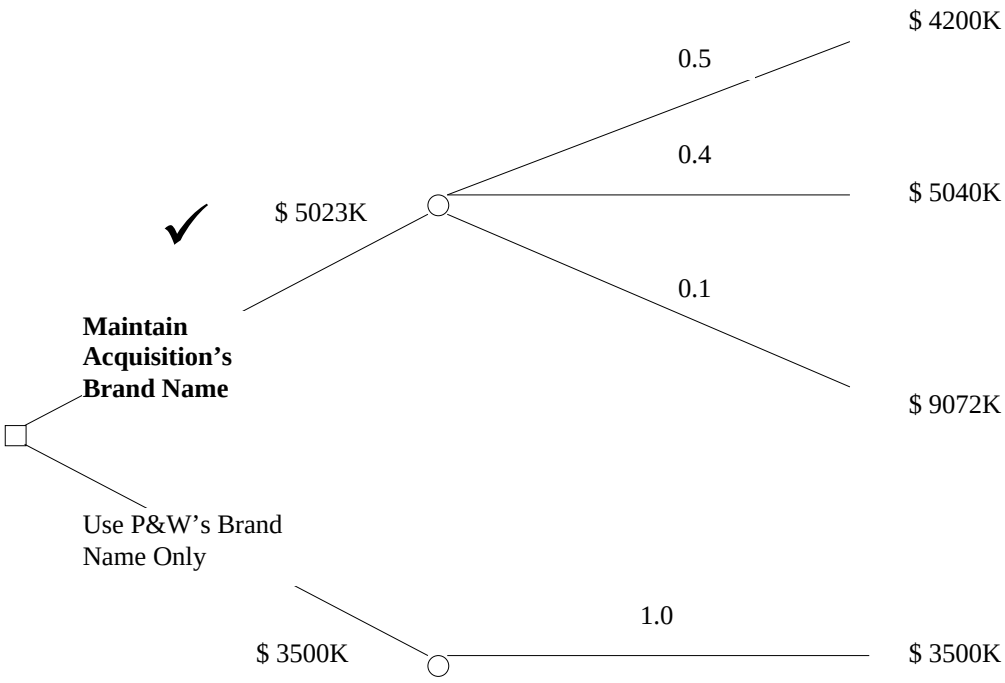
Summary Table

Branch	Probability	Implementation Cost (dollars, thousands)
1	0.5	4200.0
2	0.4	5040
3	0.1	9072

Branch Value 5023.2

4	1.0	3500.0

P&W Branch Value 3500



Appendix A - continued

Decision: 10. Do we integrate the culture or keep culture separate?

	Required Element Question, (Fact Level)	Answer Yes	Answer No	Score	Impact from Integrating Culture	Branch 1 Negative Impact from Integrating Culture	Branch 2 80% Impact with Uncertainty Extension	Branch 3 20% Impact with Uncertainty Extension
1	Does the acquisition have less than 6 layers of management?	1		0.125	1.0	0.0		
2	Does the acquisition have a corporate climbing frame?		1	0	1.0	1.0		
3	Does the acquisition require 4 year college degree to work in professional grade level?		1	0	1.0	1.0		
4	Does the acquisition have a defined growth strategy?		1	0	1.0	1.0		
5	Does the acquisition have a dress code?		1	0	1.0	1.0		
6	Did the acquisition have to report to a cooperate entity?	1		0.125	1.0	0.0		
7	Is the acquisition located in the USA?	1		0.125	1.0	0.0		
8	Does the acquisition have greater than 135 employees?	1		0.125	1.0	0.0		
					8.0			
					Negative Integration Impact	4.0	4.8	8.64
	Branch Probabilities			0.5		0.5	0.4	0.1 = 1.0

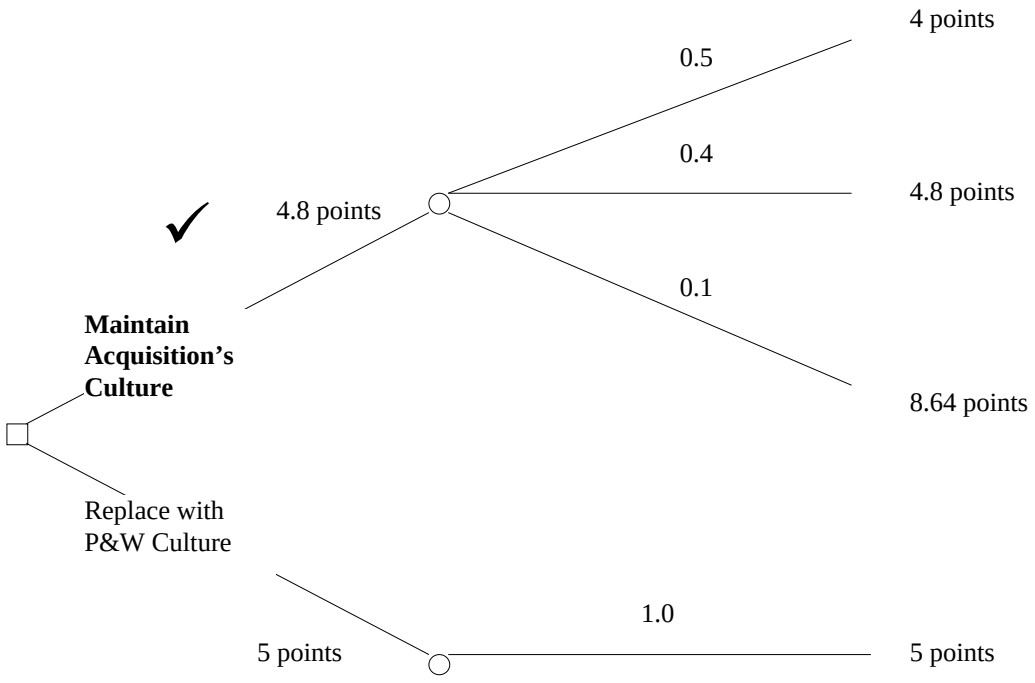
Summary Table

Branch	Probability	Negative Integration Impact
1	0.5	4.0
2	0.4	4.8
3	0.1	8.64

Branch Value 4.8

4	1.0	5.0

P&W Branch Value 5



Appendix B

Appendix B contains the decision analysis results summary table.

Decision Analysis Results Summary Table

Decision Number	Question	Decision Result from Decision Analysis	Branch Values		Relationship	Pro-integration		Evaluation Criteria
			Acquisition	P&W		Yes	No	
1	Do we keep acquisition's current management or do we replace with P&W management?	Keep acquisition's management	1.6	2.0	Weak		1	Time
2	Do we reorganize the acquisition's organizational structure or implement P&W's IPD?	Implement P&W's IPD	4.4	1.0	Strong	1		Time
3	Do we use the acquisition's method of regulatory validation or require use of P&W's FAA Designated Engineering Representatives (DER)?	Use P&W's DER	1.1	0.5	Strong	1		Time
4	Do we use the acquisition's Materials and Process Engineering (MPE) organization to validate engineering source approval, or use P&W's MPE organization?	Use P&W's MPE	699.7	500.0	Medium	1		Cost
5	Do we use the acquisition's Continuous Improvement (CI) system or require use of P&W's ACE program?	Use P&W's Ace program	3.0	2.0	Medium	1		Time
6	Do we replace the acquisition's marketing department with P&W's marketing department?	Keep acquisition's Marketing Department	0.5	1.0	Strong		1	Time
7	Do we replace the acquisition's financial and accounting department with P&W's financial and accounting department?	Use P&W's Financial and Accounting Department	3.1	1.0	Strong	1		Time
8	Do we replace the acquisition's human resources department with P&W's human resources department?	Use P&W's HR department	1.7	1.5	Weak	1		Time
9	Do we maintain the acquisition's brand name with the addition of P&W or completely change to P&W?	Maintain acquisition's brand name	5023.2	3500.0	Medium		1	Cost
10	Do we integrate the culture or keep culture separate?	Maintain acquisition's culture.	4.8	5.0	Weak		1	Impact
						6	4	