

THE DEVELOPMENT OF A TECHNOLOGY  
TRANSFER PROGRAM FOR SMALL  
MANUFACTURERS IN A  
COMPETITIVE ENVIRONMENT

By

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**JULY, 2005**

“In The Name Of God, The Compassionate, The Merciful.”

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## **Chapter 1. Introduction**

US manufacturing is the engine that generates economic growth and prosperity. America's manufacturers provide good jobs, a better quality of life, and inventions that establish the nation's identity. Furthermore, American manufacturers improve US competitiveness while at the same time improve lives domestically and internationally. In essence, manufacturing is the backbone of the economy and the muscle behind the nation's security.

On a regional and rural perspective, small manufacturers comprise one of the most vital sectors of the US economy. Small manufacturers ensure and sustain the standard of living in numerous regional and rural communities of the US. According to the National Association of Manufacturers (2001), these small manufacturers account for about half of private-sector output, employ more than half of private-sector workers, and provide about three-fourths of net new jobs each year. Together with medium manufacturers, they comprise about 95 percent of all manufacturing firms and employ about half of all manufacturing employees, account for 37 percent of all manufacturing receipts (more than \$1 trillion a year), pay their workers 20 percent more than employees in other types of small business, and export increasingly more each year (the number of



small and medium manufacturers that export more than 10 percent of their sales tripled over the past decade).

Overall, small manufacturers play two vital roles in US industry. First, they provide a variety of products to large corporations, thus enabling these large companies to focus on their primary product lines. In fact, the extraordinary gains in efficiency, productivity, and profitability of US industry leaders in recent years were made possible by their ability to rely on a vigorous small manufacturer sector for a wide variety of specialized products. And second, small manufacturers act as incubators for creative innovations – from work processes to pioneering products. Their relatively small size and less cumbersome bureaucracies enable them to experiment with new ideas more readily than large corporations. In reality, a disproportionately high percentage of the most important breakthroughs in US industrial processes and products originated in small manufacturing environments (National Association of Manufacturers, 2001).

Although small manufacturers share many of the basic characteristics of small businesses in other sectors of US industry, their need for well-educated and trained employees is great. This is certainly the case since small manufacturers' work places are more technologically advanced than other companies, and thus they place a premium on education and training, and in many instances, retraining (National Association of Manufacturers, 2001). This results in better pay for their employees, which other small businesses cannot match. As a result, ancillary businesses profit greatly from this

additional income, which in turn bolsters the overall economic and social constructs of the surrounding communities (Bijker & Law, 1992).

Although US manufacturers engage in global competition with remarkable strengths, they also face unprecedented challenges – both cyclical and structural. According to the United States Department of Commerce (2004), the most recent recession in the business cycle, which first began in 2000, hit US manufacturers and their workers hardest. In the manufacturing sector alone, output fell 6 percent and employment fell by 2.6 million jobs, accounting for all of the net job losses from the fourth quarter of 2000 through the third quarter of 2003. However, as difficult as the recession has been, the manufacturing sector faces more significant structural challenges from the effects of rapidly changing technology and adjustments to a global economy. Specifically, trade barriers have decreased rapidly over the past decade; innovations in communications, computing, and distribution have accelerated the design, production, and delivery of goods; and improved production processes have spread rapidly throughout the world. Finally, private investment now flows largely unimpeded across national borders as investors seek the highest rates of return (United States - Department of Commerce, 2004).

Under these unprecedented challenges, US manufacturers continually face shrinking capital and market opportunities. Since manufactured goods make up the bulk of international trade, the competition is especially strong and robust. Taken together, the effects of technology and globalization accelerate the competitive pressures to lower

costs and increase productivity (United States - Department of Commerce, 2004). As a result, these challenges raise two important questions. First, for US industry and government, how best can they reinforce the manufacturing sector's strengths and at the same time maintain its competitive edge in an increasingly competitive global economy? And second, for US manufacturers themselves, especially, small manufacturers, who have limited resources more so than large manufacturers, what else can they do to improve or sustain any gained competitive edges and therefore remain a viable source of economic growth for the communities that depend upon them?

On the manufacturers side, there are many options to consider: cut costs, adopt lean manufacturing and lean accounting techniques, implement quality assurance programs that pursue zero defects in production, spur innovations in products, processes, and/or services, or implement robust and flexible technology transfer programs that increase competitive advantages. For small manufacturers, each of these options presents unique challenges and obstacles to establish and benefit from for the immediate future and for the long term. The last option in the above list is the focus of this research, especially since successful technology transfer could provide holistic, comprehensive solutions for any competitive environment.

For US industry in general and the government, creating and promoting the right technology transfer policy is key to perpetuating and fostering a competitive manufacturing sector. As part of the policy development process, determining whether past and current government actions help or hinder American manufacturers is a key

ingredient to ensure continual vigorous participation in the US and global markets. This is established by considering the following (United States - Department of Commerce, 2004):

1. What steps should government take to create the economic conditions that foster a healthy and competitive manufacturing sector and spur economic growth?
2. What are the best means of removing the impediments that government action has contributed to in the form of increased energy and healthcare costs and high or distortionary tax and regulatory compliance burdens that make it harder for US manufacturers to attract investment and compete?
3. How can government technology transfer policy foster an environment in which American manufacturers and their workers are the best trained in the world?
4. How can America ensure that success in the global marketplace is based on economic growth and strength, rather than on government intervention that creates artificial advantages, distortionary markets, and/or non-viable technology incubators?

## 1.1 State of the Manufacturing Industry in the US

Since 1997, the productivity of US factories has soared, rising at a 4.6% annual average rate. This is the fastest sustained rise in manufacturing productivity in at least 40 years, and well ahead of the 1960s glory days of US industrial prowess (Arndt & Aston, 2004). This productivity growth is the main contributor to US prosperity, both in tangible wealth and in standard of living. For example, every \$1 in manufactured goods generates an additional \$1.43 of economic activity, which is more than any other economic sector in the US. The average annual wage for an advanced manufacturing job in the US is \$52,430, which is significantly higher than wages paid in many other segments of the economy (United States - Department of Commerce, 2004). Plus, these jobs generally include health care and welfare benefits, which is an important facet for manufacturers to provide for their employees. Furthermore, every \$1 million in final sales of manufactured products, 64 percent of which is exported, supports eight jobs in the manufacturing sector and an additional six jobs in other sectors, such as services (United States - Department of Commerce, 2004).

Nationally, manufacturing contributes 22 percent to America's economic growth – (real GDP adjusted for inflation), which is more than any other sector of the US economy (United States - Department of Commerce, 2004). However, manufacturing's contribution to US prosperity is most visible in the enviable position of the US in Gross Domestic Product (GDP) per capita. In 2002, the US ranked 40 percent above the

average for the 15 countries in the European Community, 35 percent above Japan, and 20 percent above Canada on a GDP per capita basis (Popkin, 2003).

Regrettably, in recent years, the US factory sector has all but imploded. The US domestic factory output is still down 2% from its 2000 peak and at the same time, imported goods are up 8% (Arndt & Aston, 2004). Furthermore, 3 million factory jobs – one in every six – have been lost since the last peak in mid-2000. Although the manufacturing sector is expanding and hiring again, domestic manufacturers are not expected to recover the ground already lost to overseas competitors (National Association of Manufacturers, 2003; and Arndt & Aston, 2004).

According to Arndt and Aston (2004), this implosion is caused by the following circumstances:

1. Competition from low-wage offshore factories;
2. An excessively strong US dollar;
3. High corporate taxes;
4. The rising bill for employee and retiree benefits;
5. Declining investment and innovation expenditures.

Unfortunately, and most important, the fifth circumstance above created a vacuum in US manufacturing research and development capabilities, turning much of the manufacturing sector into a technological backwater. This distressing situation of

skimping on capital spending and innovation resulted in the stock of equipment and software used by manufacturers to increase by only 19% from 1995 to 2001 compared with an increase of 43% during the same period in the private sector. Furthermore, this distressing situation created an imbalance among the various manufacturing industries. In 2001, the manufacturing sector spent \$109 billion of their own funds on research and development; however, 67% of those funds were spent by the high technology, pharmaceutical, medical equipment, and automobile manufacturing industries, while the remaining industries devoted less than 2% of their domestic sales on research and development (Arndt & Aston, 2004). As a result, foreign rivals were able to catch up and compete vigorously and increase their market influence and share.

All in all, after 100 years of technological refinement in the US, it may be the case that all the innovation has been squeezed out of many industries and the innovative sources of productivity – (i.e., the use of technology to improve and enhance the inherent performance of the products) have been discovered, implemented, and utilized to the maximum. As a result, it is time to discover new technologies and transfer them successfully into the US manufacturing industry. Albeit, the US manufacturing sector should not be taken for granted. Many US small urban communities rely heavily on the manufacturing prowess of the US (Dobbs, 2004; Halstead, 2004; and Wallach & Woodall, 2004).

## 1.2 State of the Manufacturing Industry in the State of Oklahoma

Oklahoma manufacturers are an integral part of the state's overall economic well-being. They account for 20.4% of the state's private state payrolls (National Association of Manufacturers, 2001). Oklahoma's nearly 4,500 manufacturers currently employ approximately 175,000 and represent nearly a sixth of Oklahoma's gross state product (Oklahoma Alliance for Manufacturing Excellence, Inc., 2004). Overall, Oklahoma manufacturers employ approximately 30% of Oklahoma's employees (Taylor, 2004). Statewide, Oklahoma's manufacturing sector's contribution to real 1992 to 2000 gross state product growth was 21.7%, which ranked first among all the other sectors of the Oklahoma economy (National Association of Manufacturers, 2004).

Regrettably, Oklahoma's manufacturing sector is also facing critical challenges similar to the overall challenges faced by manufacturers across the US. During the recession cycle from July 2000 to October 2003, 28,700 factory jobs were lost, which equates to 1 out of every 6 Oklahoma factory jobs being lost (National Association of Manufacturers, 2004). However, since October 2003, Oklahoma has rebounded and regained back 90.2% of its lost jobs. Unfortunately, they are not the same jobs in the same communities (Dobbs, 2004; Halstead, 2004; and Wallach & Woodall, 2004). In 2001, Oklahoma's State GSP Real Growth Rate was a positive 1% and the Oklahoma State Manufacturing Real Growth Rate was a negative 8.5%. However, when the manufacturing growth rate is dropped from the overall State GSP Real Growth Rate, then the overall State GSP Real Growth Rate increases by a factor of three, to a positive 3%.



This adjusted rate, which excludes the manufacturing sector, was the fourth best in the nation in 2001, behind only Wyoming (3.5%), Idaho (4.3%), and Delaware (9.5%) (National Association of Manufacturers, 2004).

All things considered, manufacturing is central to Oklahoma's economic strength and future growth. Oklahoma's extensive technology transfer infrastructure, coupled with Oklahoma's pro-business environment, can strengthen the manufacturing sector and instill the necessary conditions for a full recovery. In other words, a strong manufacturing base is key to secure Oklahoma's future. And this securing process is critically dependent on decisive and corrective transfer measures.

### **1.3 Manufacturing Aid Initiatives**

In response to the implosion in the US manufacturing industry, US Secretary of Commerce Donald Evans launched the Manufacturing Initiative in March of 2003. The purpose of the initiative was two-fold. First, it called for a comprehensive review of issues affecting the competitiveness of the US manufacturing sector. And second, it required the development of a strategy, which incorporated remedies for the researched issues, to ensure that the government is doing all it can to create the conditions necessary to foster US competitiveness in manufacturing and stronger economic growth at home and abroad (United States - Department of Commerce, 2004).

As part of this comprehensive initiative, over 20 roundtable events were held and included manufacturers from various fields. The manufacturers attending the roundtables represented a broad mix of small, medium-sized, and large companies, as well as minority-owned and women-owned enterprises. The concerns expressed by the manufacturers during the roundtables fell within the following six categories (United States - Department of Commerce, 2004):

1. Focusing On Manufacturing and Its Competitiveness
2. Generating Stronger Economic Growth Domestically and Internationally
3. Reducing Costs That Erode Competitiveness
4. Reinforcing America's Technological Leadership
5. Ensuring A Highly Skilled and Educated Workforce
6. Insisting On A Level International Playing Field

In response to the above categories of concerns, the US Department of Commerce made several recommendations and called upon Congress, federal agencies, state and local governments, and the Department of Commerce itself to act accordingly. Correspondingly, this research study investigates and promotes manufacturing technology transfer, which is a part of the third recommendation by the Commerce Department. A summary of the six recommendations follows (United States - Department of Commerce, 2004):

- 1) Creating the Conditions for Economic Growth and Manufacturing  
Investment by:
  - a) Make Recent Tax Cuts Permanent
  - b) Reduce the Cost of Tax Complexity and Compliance
  - c) Make Permanent the Research and Experimentation Tax Credit
  - d) Expand Access to Lower Cost Capital
- 2) Lowering the Cost of Manufacturing in the United States by:
  - a) Conduct a Regulatory Review
  - b) Lower Health Care Costs
  - c) Modernize the US Legal System
  - d) Enact Energy Legislation
- 3) Investing in Innovation by:
  - a) Strengthen the US Patent System
  - b) Ensure an Appropriate Focus on Innovation and Productivity  
Enhancing Technologies
  - c) Support a Newly Coordinated Manufacturing Extension  
Partnership Program (MEP Program)
  - d) Promote Manufacturing Technology Transfer**
    - i) Ensure that the benefits of research and development are  
diffused broadly throughout the manufacturing sector,  
particularly to small and medium enterprises (SMEs).
  - e) Explore Unique Capabilities of National Labs and Universities
    - i) Establish cooperative research programs for the benefit of

small and medium enterprises (SMEs).

- 4) Strengthening Education, Retraining and Economic Diversification by:
  - a) Establish a High School and Technical Education Partnership Initiative
  - b) Analyze Specialized Training Needed to Succeed in the Manufacturing Environment of the Future
  - c) Establish Personal Re-employment Accounts
  - d) Coordinate Economic Adjustment for Manufacturing Communities
  - e) Transform Workforce Development Programs
- 5) Promoting Open Markets and a Level Playing Field by:
  - a) Encourage Economic Growth, and Open Trade and Capital Markets
  - b) Negotiate Trade Agreements that Benefit US Manufacturers
  - c) Enforce Trade Agreements and Combat Unfair Trade Practices
  - d) Reinforce Efforts to Promote the Sale of American Manufactures in Global Markets
- 6) Enhancing Government's Focus on Manufacturing Competitiveness by:
  - a) Establish a "President's Manufacturing Council"
  - b) Create an Assistant Secretary of Commerce for Manufacturing and Services
  - c) Form a New Office of Industry Analysis
  - d) Foster Intergovernmental Coordination

On the US Congressional side, the Senate of the United States during the 108<sup>th</sup> Congress addressed the implosion in the US manufacturing industry by proposing and debating three Senate bills and by debating one House bill. All four bills were referred to the appropriate Senate committees for further discussion and review. First, Senate Bill #1884 titled “Enhance Domestic Manufacturing and Worker Assistance Act of 2003” aims to extend and expand trade adjustment assistance to companies and communities negatively impacted by trade. This assistance by way of monetary allocations and time extensions is meant to assure a healthy American manufacturing sector.

The second Senate Bill #1886 titled “Manufacturing Assistance, Development, and Education in America Act” or the “MADE in America Act” aims to establish the National Office for the Development of Small Manufacturers, in order to increase the level of assistance available for manufacturers. This new national post will establish and coordinate new state-level grants to bolster a state’s secondary, vocational, and postsecondary school systems, working capital loans to revamp the technology base of small businesses, disaster loans and microloans to sustain a small business during difficult times, investment loans to create or retain manufacturing projects, and patent protection grants to assist small business concerns in seeking foreign patent protection. Hence, the new national office will appropriate monetary funds and human resources accordingly to accomplish its objectives.

The third Senate Bill #1977 titled “Small Manufacturers Assistance, Recovery, and Trade Act” or the “SMART Act” aims to establish an Assistant Secretary for

Manufacturing within the Department of Commerce, an Interagency Manufacturing Task Force, a Small Business Manufacturing Task Force, and an Assistant United States Trade Representative for Small Business in order to promote the US manufacturing industry. Specifically, all four entities above and together shall: develop new outreach and training programs for small manufacturers and small businesses in the manufacturing supply chain; develop manufacturing workshops; develop programs and services to strengthen small business vendors and suppliers that participate in the manufacturing supply chain; review and simplify the reporting requirements of the Small Business Development Centers, the Service Corps of Retired Executives, and the Women's Business Centers so that these organizations can maximize the time spent assisting their clients; provide district offices with adequate resources, including budget allocations for travel and materials used to conduct outreach and training activities; and assist in maintaining a trade distribution network using the regional and local offices. Furthermore, this Senate bill increases the loan amounts available for US exporters, establishes export financing programs, and refocuses and redesigns the export assistance centers. Finally, this Senate bill increases the maximum surety bond guarantee to the total work order or contract (monetary) amount.

The fourth bill, H.R. 3598, titled "Manufacturing Technology Competitiveness Act of 2004" aims to establish an interagency committee to coordinate Federal manufacturing research and development efforts in manufacturing, strengthen existing programs to assist manufacturing innovation and education, and expand outreach programs for small and medium-sized manufacturers. This bill addresses the implosion

in the US manufacturing industry by creating a collaborative manufacturing research pilot grant, a manufacturing fellowship program, and a standards education program. Also, the bill establishes the following: a standard by which underperforming manufacturing extension centers, which are part of the Manufacturing Extension Partnership program, can be placed on probation or closed altogether; the criteria of the new Competitive Grant Awards Program; and the new budget for the Teacher Science and Technology Enhancement Institute program. Finally, this bill increases the budget of two key government agencies. First the National Institute of Standards and Technology 's budget will increase from \$425,688,000 for fiscal year 2005 to \$492,764,000 for fiscal year 2008. And second, the budget of the Manufacturing Extension Partnership program will increase from \$110,000,000 for fiscal year 2005 to \$125,000,000 for fiscal year 2008.

#### **1.4 Definition of Terms**

Advances in technology are reshaping the workplace. The context of a competitive environment is being constantly redefined because of these technological advances. Therefore, manufacturers are constantly asked, even required, to adapt to this challenging dynamic environment to stay engaged and competitive themselves. This adaptation process produces new perspectives in how previous administrative and management processes are defined and incorporated into the workplace. As an example, as manufacturers attempt to keep pace with the competitive environment, their

management of technology methods change and evolve, especially technology transfer. This causes the introduction of new perspectives on old commonly used definitions of technology transfer processes.

These new perspectives regarding technology transfer resulted in establishing numerous definitions of technology transfer, as well as studies on the topic itself. Consequently, the term, technology transfer, is then defined to fit the context of each research agenda, and therefore it is a multi-dimensional term (Nashar, 1989). Researchers have defined at least 48 working technology transfer models, ranging from a holistic structure to a linear ideographic representation (Climent, 1991; Climent, 1993; Climent, et. al., 1995; Collins, 1998; Elstrott & Nagy, 1995; Hoff, 1997; Padmanabhan & Souder, 1994; and Seaton & Cordey-Hayes, 1993).

This dissertation research deals with the external and internal drivers associated with the transfer of technologies that are researched and developed due to the competitive environment. Based on this context, the following definitions are necessary to this study:

*Technology* – A body of knowledge, tools, techniques, and innovations derived from science and practical experience, that is used in the development, design, production, and application of products, processes, systems, and services (Pier, 1989).



*Technology Transfer* – The management of technology from the conceptual to functional stages utilizing engineering, science, and business administration disciplines to plan, coordinate, and deploy technological innovations as needed for manufacturers to develop organizational and/or industrial technology competencies and stabilities (Materna, 1980).

*Technology Transfer Dimension* – A fundamental type of technology transfer assistance delivered by a service provider to a small manufacturer. Typical technology transfer dimensions are technical assistance, research and development, business assistance, human resource management, and governmental compliance (Collins, 1998).

*Technology Transfer Attribute* – An inherent characteristic or quality in a technology transfer dimension, which is the primary mechanism for assistance to the small manufacturer. Examples of a technology transfer attribute are start-up incubators, technical support, new product development, and market studies (Collins, 1998).

*Technical Assistance* – A dimension of technology transfer, which provides manufacturers with assistance in engineering expertise, technical guidance, literature searches on requested topics, and serve as a liaison for cooperative technology deployment between the manufacturer and second parties (Collins, 1998; and Norton, 1995).

*Research and Development* – A technology transfer dimension in which information in the areas of pure and basic research is disseminated from the experimental lab or university setting to the manufacturer. This transfer could take the form of CRADA's - (Cooperative Research and Development Agreements) between the research laboratory and manufacturer (Bozeman & Papadakis, 1995; and Collins, 1998).

*Governmental Compliance* – Assistance in complying with EPA and OSHA regulations that is provided to small manufacturers in the form of training, on-site assessments, and obtaining permits. The primary areas of governmental compliance are related to the environment (EPA), workplace safety (OSHA), and labor (ODOL) (Collins, 1998; and McGovern, 1995).

*Business Assistance* – A dimension of technology transfer which offers start-up funding for new companies, new product development, financial assistance, and product market surveys to the small manufacturer. Without funding, many small manufacturers would be unable to deploy leading technologies to remain competitive (Clarke and Dobson, 1989; and Collins, 1998).

*Human Resource Management* – A dimension of technology transfer, which offers employee selection assistance, employee benefits, insurance, and worker's compensation training, and labor/management relations

assistance. This dimension provides critical employee-level assistance. With this assistance, a manufacturer can more readily deploy leading technologies to remain competitive (Collins, 1998; and Salvendy, 2001).

*Delivery System* – A system consisting of a state and/or federally funded agency establishing a program to assist businesses in Oklahoma. Program assistance may be in any technology transfer dimension, and is typically limited to only a few of the attributes of the dimension, such as technical support or literature search (Collins, 1998; and Oklahoma Alliance for Manufacturing Excellence, Inc., 1992).

*Cost Driver* – Any output measure that triggers costs and subsequently assists to relate technology transfer activities to resource costs in a way that makes cost control possible. Furthermore, cost drivers assist in understanding cost behavior, which then can be used to design an effective and efficient technology transfer program (Horngren, Sundem, & Stratton, 2002).

*Critical Mass* – The point at which enough individuals or entities have accepted an innovation so that the innovation's further rate of acceptance becomes self-sustaining. The Critical Mass defines, promotes, and drives a technology transfer program's details or specifics as to establish a stable base point for the future of a particular technology or related technologies (Rogers, 1995).

*Appropriate Technology* – This concept refers to the choices one makes between technological alternatives/choices. To make the choice sensibly, one must look at what one is trying to accomplish, what expertise and resources are available, and what unintended consequences may ensue. The U.S. Congress's Office of Technology Assessment characterizes Appropriate Technology as being small scale, energy efficient, environmentally sound, labor-intensive, and controlled by the local community. Furthermore, the Intermediate Technology Development Group, an organization that works toward the betterment of developing countries, adds that the technology in an Appropriate Technology program must be simple enough to be maintained by the people using it. In other words, this concept refers to the relatively efficient means in which a compatible technology is selected or transferred in context (Hazeltine & Bull, 1999; and Willoughby, 1990).

*Technology Choice* – This concept also refers to the choices one makes between technological alternatives/choices. However, unlike in an appropriate situation, a choice decision refers to the relatively effective means in which several compatible technologies are available for selection or transfer with or without context. In other words, a technology choice decision provides a quick fix that may not be the cheapest or generate the best long-term results (Willoughby, 1990).

*Technology Adoption* – This concept refers to the radical quick processes of transferring or accepting an innovation or a technology (Amendola & Gaffard, 1988; Gehani, 1998; and Lefebvre, Mason, & Khalil, 1998).

*Technology Adaptation* – This concept refers to the slow gradual processes of transferring or accepting an innovation or a technology (Gaynor, 1996).

*Small Manufacturer* – In order to maintain consistency with the small, medium, and large classifications of manufacturers used by the Oklahoma Alliance for Manufacturing Excellence, Inc., the definition of a small manufacturing firm is one that has between 1 and 250 employees. In 1989, 97% of all manufacturers had 250 employees or fewer. Moreover, about 85% of all Oklahoma manufacturers employ fewer than 50 persons (Collins, 1998; and Oklahoma Alliance for Manufacturing Excellence, Inc., 1992).

## **1.5 Background**

Manufacturing plays an important role in the daily life of the United States. Current US technology transfer policy decisions satisfy the short-term supply and demand technology criteria of manufacturers. However, to address long-term consequences of policy decisions, current technology development programs need

revision, especially the programs that incubate and transfer new technologies that sustain a manufacturer's competitive advantage in today's highly competitive environment (Green & Guinery, 1994; Hirsh, 1989; Hirsh, 1999; Manufacturing Institute, 2004; and Miller, 1996).

Several ongoing attempts in the US and in Oklahoma are being made to transfer technology to the manufacturer. Betz (1993) noted that past approaches in the United States attempted to push technologies to the manufacturer, and in some cases, even forced the manufacturer to adapt to the new technology. However, the current trend is for technology transfer to be more one-on-one oriented. Technology transfer specialists go directly to the small manufacturer and determine the companies' specific technology transfer needs (Collins, 1998; and Oklahoma Alliance for Manufacturing Excellence, Inc., 1992).

Several delivery systems currently exist within the US and Oklahoma to transfer appropriate technologies to small manufacturers (Oklahoma Department of Vocational and Technical Education, 1989). In some cases, these systems use federal funding to provide redundant technology transfer services to the manufacturer (Collins, 1998). Other states, such as Kansas (Bendis, 1996; KTEC Annual Report, 1996; and Sampson, 1996) and Georgia (Youtie, et. al., 1995a; and Youtie, et. al., 1995b), have dealt with the problem of overlapping services by performing needs assessment studies to determine how to best promote new technologies to small manufacturers, with optimal use of state and federal funding (Collins, 1998).

Although the results from other studies show some variability in what works, the general conclusion is that a delivery system must be flexible and adaptable, but structured enough to provide multiple services to the client. Also, the delivery system should have a broad-based infrastructure and linkages, robust enough to withstand the fluctuations in annual state and federal budgets, robust enough to withstand the socio-technical impacts of technology transfer programs themselves, and robust enough to withstand the threats and competitive environmental jolts inflicted by technological change, such as cyclical and structural economic/financial/business/political settings. These studies also show no preference as to whether the program is an industrial outreach or extension program. However, the common theme among successful technology transfer programs is that they consolidate for long-term maintainability, sustainability, and growth (Clarke and Dobson, 1991; Collins, 1998; and Osborne, 1989). Unfortunately, most of the time small manufacturers simply do not know about the federal agencies working within the state to promote and provide technology innovation and technology transfer assistance (Masten, Hartmann, & Safari, 1995). As a result, a consolidated robust structure of a single state-supported program for technology transfer would allow the small manufacturer more awareness and accessibility to the required information, assistance, or services.

In addition, the initial sets of transferred technologies that initiated the exceptional growth in the US manufacturing industry in the last two decades have reached the end of their useful life. To transition to another stable social and financial platform, where technology transfer programs still meet the supply and demand of current and future manufacturers, current policies and guidelines for developing new technology transfer

programs in a highly competitive, tight, global market need reassessment. This is extremely important for small manufacturers and their critical roles and services, since almost every community today, and the society in general, depends on a strong manufacturing base, good quality products, and an equitable standard of living (Amendola & Gaffard, 1988; Beije, 1998; Bijker & Law, 1992; Douglas & Wildavsky, 1982; Enholm & Malko, 1995; King & Anderson, 2002; Tidd, Bessant, & Pavitt, 1997; and Tye, 1991).

Consequently, as competitive pressures in the manufacturing industry increase, technology will play an even more significant role, and likewise constantly influence the technology transfer programs of the US. More specifically, as the US transitions to and favors technology adoption processes instead of technology adaptation processes and encourages technology choice programs instead of appropriate technology programs to immediately meet future manufacturing industry requirements for the short-term, flexibility and robustness in the new policies and guidelines, which established the new technology transfer programs geared for a competitive environment, will play a more vital role (Clarke and Dobson, 1991; Collins, 1998; and Osborne, 1989). This forced philosophical change into the manufacturing industry is questionably good for the short-term and is the result of: the US being the only superpower, the US being the leader in annual R&D expenditures, and the US being one of the leading consumers of manufactured goods and products. Finally, as US society further transitions from a manufacturing society to a consumer society, the consequences of neglecting appropriate technology programs will be more prevalent, especially when considering and resolving



competitive pressures for the long-term. Moreover, the increasing number of manufacturers adopting less matured technologies highlights this prevalence. Eventually, this adoption cycle increases the pressure to reduce costs at a faster rate than the consumer and financial markets can handle, which then negatively impacts US economic and financial infrastructures further. The end result being that there are a smaller number of small manufacturers operating in the US.

### **1.6 Unanswered Questions**

What are the desirable characteristics (dimensions and attributes) of a technology transfer program in a competitive environment, with application to the small manufacturers in Oklahoma? How should these dimensions and attributes be deployed, and what would be the organizational structure, approach, and process of the overall technology transfer program that would best satisfy the needs of the small manufacturer in a competitive environment?

### **1.7 Purpose of the Study**

This research study has three purposes. First, the study uses a research methodology for determining the desirable characteristics and approaches for transfer processes of a technology transfer program in a competitive environment. The

technology transfer program is based on the lessons learned from past transfer program paradigms and past research. Since the manufacturing industry's experience can represent a vital indicator of the US economy – reflecting both positive and negative indications for such a crucial part of society's experience with domestic and international competition - multiple criteria are used to make the technology transfer program developed here robust and generic that other states and countries can also use the model(s) to develop holistic technology transfer programs for their manufacturing industries.

The second purpose of this study is to validate the technology transfer program using Oklahoma as a test site. A qualitative survey was administered to small manufacturers to define and rank their technology transfer requirements and attitudes. New dimensions and values are established through the survey that would otherwise not have been considered, based on present models.

The third purpose of this study is to construct a conceptual model(s) of a holistic technology transfer program for Oklahoma under competitive pressure circumstances. The Oklahoma technology transfer program is developed based on the results from a survey of small manufacturers in Oklahoma. The organizational structure of the holistic technology transfer program is defined, along with the desirable characteristics and approaches.

## **1.8 Significance of the Study**

This research extends the body of knowledge concerned with technology transfer in a competitive environment and the much larger body of knowledge concerned with technology delivery systems. The model(s) and methodology developed in this research extend previous models and methodologies by considering acceptance attitudes and approaches and their effects on the technology transfer decision in the manufacturing industry and in a competitive environment overall. Earlier research was also extended by recognizing a continuum of outcome possibilities between adoption of a technology and adaptation of that technology. Also, this research extends earlier research by developing the characteristics of an appropriate technology program versus a technology choice program in the manufacturing industry and in a competitive environment overall.

## **1.9 Research Objectives**

To accomplish the purposes of this study, the following objectives are met:

1. Identify technology transfer characteristics (dimensions and attributes) presently being used, based on a literature review.
2. For Oklahoma manufacturers:
  - a. Identify what technology transfer characteristics small manufacturers view as important.

- b. Rank these characteristics according to importance.
  - c. Determine the technology transfer delivery system(s) small manufacturers are currently using.
  - d. Determine how manufacturers want to receive technology transfer.
3. Develop a conceptual model(s) of the organizational structure, approach, and process of Oklahoma's technology transfer program in a competitive environment based on the results of the survey and the literature review.

### **1.10 Research Plan and Design**

The methods for conducting descriptive survey research were the cornerstone of this study. Descriptive research is generally used when the researcher wants to obtain information, which is generalized to a whole class of units, or actors (Leedy, 1993). This type of research design is also used to gather insights regarding the phenomena of the moment, which is being investigated, and determine its accuracy and its underpinnings (Creswell, 2003; Kane & O'Reilly-De Brún, 2001; and Ragin, 1994). Key (1996) provides the following straightforward eight-step approach to descriptive survey research:

1. Statement of the problem;
2. Identification of information needed to solve the problem.
3. Selection or development of instruments for gathering the information.
4. Identification of target population and determination of sampling procedure.
5. Design of procedure for information collection.
6. Collection of information.
7. Analysis of information.
8. Generalizations and/or predictions.

In order for this study to satisfy the research objectives, an organized plan was developed utilizing Key's eight-step process for descriptive research. The first step was a statement of the problem. The second step involved a review of the literature on current technology transfer models and other relevant technology transfer research, and a review of current Oklahoma (in-state) delivery systems to determine which programs are being used by Oklahoma small manufacturers. A survey questionnaire was developed for the third step based on the information gathered in the literature review process. The fourth step identified the target population of small manufacturers for the survey questionnaire. The fifth and sixth steps involved the designing of a procedure for administering the survey and collecting the completed surveys. Finally, the last two steps in the eight-step approach to descriptive survey research are to analyze the collected data and to generalize and predict from the results.

### **1.11 Scope, Limitations, and Assumptions of the Study**

The focus of this research study was mainly on the external transfer of technology to the small manufacturer. Internal transfer (Rubenstein, 1989) and international transfer (Reisman, 1994; and Stobaugh & Wells, Jr., 1984) are beyond the scope of this research study. Although, small manufacturers can choose to use all three types of technology transfer – (internal, external, and international) for the deployment of technologies (Riggs, 1983), an exceptionally high percent of small manufacturers seek external assistance for technology transfer. According to Palminteria (1993), a small manufacturer’s lack of ability and experience and limited resources to develop and transfer new technologies internally – (i.e., within the organization) are the main reasons they opt for external technology transfer.

Also, this research study focused on Oklahoma small manufacturers. Therefore, manufacturers with more than 250 employees are not included in the survey. Moreover, large manufacturers, and to a limited exception medium manufacturers, tend to use internal technology transfer for new product development and research, and therefore these two groups are not as dependent on external technology transfer, and again, they are not included in this research study.

Collins (1998) identified ten Oklahoma (in-state) technology transfer delivery systems as having appropriate “attributes” according to the services they provide to small manufacturers. Accordingly, the performance of these ten delivery systems is not being

evaluated and used to establish the new models. Instead, the proposed models have been developed from the attributes of these delivery systems. More importantly, this research study does not intend to discredit the efficiency and effectiveness of existing delivery systems and industrial extension programs, but to set up a foundation for the transfer of technology to manufacturers in a competitive environment using an adequate, surveyed-benchmark approach. Additionally, there were other delivery systems in Oklahoma; however, they were not included in this research study simply due to the economic limitations of the research study. In return for this limitation however, this research study, along with Collins (1998), established a 7-year historical trend in how small manufacturers in Oklahoma use the ten already identified Oklahoma (in-state) technology transfer delivery systems, which is as important as the identified attributes of these ten in-state delivery systems and more important than trying to identify additional in-state delivery systems.

Lastly, issues relating to the social threat of technology transfer are also beyond the scope of this study (Cooper & Smith, 1992; Manuel, 1993; and Miller & Droge, 1986). An earlier National Science Foundation research study conducted by Mize and Warner, (Mize & Warner, 1981) provided insight into the social issues facing Oklahoma manufacturers when adopting technological innovation. Their research study focused on determining the appropriate technology base, and how science and technology could improve economic development in rural Southeastern Oklahoma region (Collins, 1998). Also, other socio-technical issues not considered in this research study are the effect of organizational change, organizational culture, and organizational management on the

process of incorporating and utilizing new technologies (Afuah, 2003; Burgelman, Christensen, & Wheelwright, 2004; Daft, 1995; Gaynor, 1996; Giddens, 2001; Green & Guinery, 1994; Jick, 1993; Katz, 2003; King & Anderson, 2002; Nelson & Quick, 1994; Radic, 1995; Rogers, 1995; Tidd, Bessant, & Pavitt, 1997; Tippet & Hamilton, 1992; Tushman & Anderson, 2004; Watkins, 1998; and Watts, 2001).

### **1.12 Summary**

Each time a small manufacturer considers a new technology for deployment, an important and critical implementation factor is the delivery system chosen by the small manufacturer. The main underlying reason for this decision process is to gain an advantage in today's highly competitive environment. Since a small manufacturer lacks in-depth transfer experience and has limited resources, there is little room for error with the deployment process. And therefore, choosing a suitable technology transfer program is critical for overall survival. It is certainly the case that a given technology has the potential to provide a competitive advantage, if the small manufacturer is able to transfer it successfully.

This research study uses multiple criteria to establish the foundational framework of a robust technology transfer program, which is able to meet the needs of Oklahoma small manufacturers in a competitive environment. Since small manufacturing companies continue to be at a profound disadvantage because their exposure to



technology transfer mechanisms has been one-dimensional (Osborne, 1989), this study allows Oklahoma manufacturers to become multi-dimensional. Many Oklahoma manufacturers are still not aware of the available technical assistance provided by the various delivery systems in their state (Collins, 1998).

According to Betz (1993), effective management of technology, especially technology transfer, increases competitiveness, develops technological strategies, and establishes core technical competencies, all of which are critical to the success of a small manufacturer in today's competitive environment. Accordingly, this research study also assesses and gauges the robustness of Oklahoma small manufacturers' management of technology efforts, especially their deployment efforts in a competitive environment.

In developing the conceptual models of the organizational structure, approach, and process of Oklahoma's technology transfer program in a competitive environment, the study first identified the successful technology transfer dimensions and attributes from the Oklahoma (in-state) delivery systems and others identified in the literature review. And second, the identified dimensions and attributes were categorized and presented to Oklahoma small manufacturers in the form of a survey questionnaire. The manufacturers then proceeded to rank these dimensions and attributes according to their level of importance. They were also encouraged to suggest other dimensions, attributes, and barriers not already presented in the survey questionnaire.

Overall, by enacting the developed conceptual model(s), America's (and specifically Oklahoma's) small manufacturers will remain a potent force in today's changing economy and markets. If the best array of technology transfer services to US manufacturers are not presented and set out in a timely manner, then there is a strong chance the US manufacturing base will shrink and manufacturing processes will shift to other global centers. Once this occurs, a decline in the US standards of living in the future is virtually assured. However, it is hoped that such model(s) will improve the competitiveness of small manufacturers, and manufacturers in general, and sustain and improve the economic condition of the state of Oklahoma and the US.

## **Chapter 2. Literature Review**

There are many benefits to society if technology transfer rates can be improved. Such problems as lagging productivity, inferior product quality, a negative balance of trade, and loss of traditional markets to foreign competitors can all be diminished with successful diffusion of technologies to private industry, especially the manufacturing industry (Weijo, 1987). The US government must be as diligent in encouraging technology transfer to the private sector as its major foreign competitors' governments have been (Greene & Miesing, 1984). Furthermore, as much as technology is recognized as an important factor in determining the trade performance and international competitiveness of a country (Guerrieri, 1992), the transfer aspect is also recognized as important (Hoff, 1997). As a result, achieving competitive success in a global market is depended on a strong, robust technology transfer program.

Global pressures and relentless advances in technology, coupled with societal demographic shifts have fostered this highly competitive working environment (National Association of Manufacturers, 2003). Altogether, these trends increase competition and create pressures which tend to destabilize economic indicators. For example, they may drive down inflationary targets, product costs, and import prices (Buchanan & Yoon, 1994; and Tye, 1991). Most importantly, this increased competition results in and

encourages technological changes and subsequently, the need for even faster technology transfer rates.

For example, the current global trend of deregulating the telecommunications industry, motor and rail transport, utilities, and financial markets has for the most part restrained prices of goods and services in these sectors, and perhaps simultaneously decreased the market power of their associated labor unions with respect to the wages that could be demanded (Hanke, 1987; Hirsh, 1999; and Ramanadham, 1993).

Furthermore, the technological changes (or advances), which permitted deregulation, can refer to a particular invention or the combined synergies of interrelated inventions. In both instances, the rate of adaptation for such inventions was greatly influenced by the complimentary nature of the technological changes brought upon by these inventions (Gaynor, 1996). In other words, the more compatible a technology is with a destabilized market or declining cost and price structure or pressure, the more likely the technology is adopted.

This interaction between accelerated technological changes and inventions creates significant new opportunities for value creation in the newly modified economic system (or destabilized market) for a specified time period. Paradoxically, the maturity rate and maturity level of these inventions and interrelated technological changes determine the market's stability and subsequent economic conditions and policies, including monetary, fiscal, structural, and technology transfer policies (Buchanan & Yoon, 1994; Gaynor, 1996; Ruttan, 2001; and Tye, 1991). In other words, deregulation, a structural economic

policy<sup>1</sup>, has the ability to encourage and sharpen incentives to work, save, invest, innovate, and transfer and to continue to influence and emphasize the underlying market mechanisms/forces, albeit in a stable mode for a short time period and predominately in an instable mode for longer time periods of the overall economic cycle (Braddon & Foster, 1996; and Green & Guinery, 1994).

Consequently, dealing with and harmonizing US and world manufacturing markets during the past three decades is a complex issue. This can be attributed to the accelerated rate of technological change and more so to the manner in which these changes and their underlying innovations affect manufacturing market sector practices (Hirsh, 1999). Recalling that these practices are the end results intended by the structural economic policies of the past three decades, a permanently induced instability could remain in the manufacturing market sector until the next innovation is introduced and transferred successfully. This instability can be countermanded if and only if the innovation is an improvement and is a publicly accepted technological change. For example, if an innovation brings about additional or increased efficiencies in manufacturing production processes, then the instability brought upon by the innovation is short lived and the public acceptance level is high for both the instability and the innovation (Gaynor, 1996; and Lewis, 1990).

The ability of the flexible and innovative businesses and work force of the US small manufacturers has enabled the US to take full advantage of emerging technologies

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<sup>1</sup> Structural Economic Policies include public policies, regulatory policies, deregulatory policies, and technology transfer policies (Ramanadham, 1993; Ruttan, 2001; and Tye, 1991).

to produce greater growth and higher asset values. Furthermore, current US policy has facilitated this process by containing inflation, by promoting competitiveness through technology transfer, and by promoting an open global trading system. Sustaining and strengthening such policies will be the goal for future Federal Reserve Boards, Congresses, and Administrations, which will in turn sustain and strengthen the record peacetime economic expansion of the US (Afuah, 2003; Hirsh, 1999; Katz, 2003; and Makansi, 2002).

Historically, previous innovations, such as the introduction of the dynamo or the gasoline-powered motor, needed considerable infrastructure investment before their full potential could be realized. For example, it was only when modern highways and gasoline service stations became widespread that the lower cost of motor vehicle transportation became apparent. Another example is the user-development of electricity over the past century. For instance, when electricity substituted for steam power in late 19<sup>th</sup> century, it was initially applied to production processes suited to steam. Gravity was used to move goods vertically in the steam environment. This scenario could not immediately change even with the advent of electric power. However, it was only when horizontal factories, designed for optimal use of electric power, began to dominate our industrial systems several years after electricity's initial introduction, that US productivity clearly accelerated (Deming, 2000; Green & Guinery, 1994; Hirsh, 1989; and Hirsh, 1999).

Currently, the same forces that have been reshaping the real economy have also been transforming the manufacturing industry. The most profound development lately has been the rapid growth of computer and telecommunications technologies. The advent of this technology has lowered the costs, reduced the risks, and broadened the scope of manufacturing services, making it increasingly possible for all the manufacturing supply-chain participants and the end-users to transact directly and efficiently, and for a wide variety of products to be tailored for very specific purposes (Hirsh, 1989; Hirsh, 1999; Miller, 1996; and Ruttan, 2001). Consequently, competitive pressures in the manufacturing industry are probably greater now than in the previous century.

Three major trends can explain these competitive pressures in the manufacturing industry and their profound influence on today's real economy. First, there is the increased dependence, reliability, and emphasis on education and ongoing training. It is difficult to overestimate the importance of education and ongoing training to the advancement of technology and product innovation in the manufacturing sector (Rogers, 1995). This is especially true for the user or customer of manufactured products. Past research indicates that users of manufactured products are typically very well educated. Moreover, users with a high level of education significantly increase their chances that they will use a manufactured product. Therefore, an increased emphasis on education and training is the first trend (Dorf, 2001; Hazeltine & Bull, 1999; and Rogers, 1995).

The second major trend is globalization. The continuous stream of technological changes and innovations and the advent of more sophisticated users/customers have accelerated this trend, which has profoundly reshaped manufacturing systems, as well as the real economy, for at least the past thirty years (Salvendy, 2001; and Tye, 1991). Now, both developments have expanded cross-border manufacturing holding, trading, and credit flows and, in response, both manufacturing firms and US and foreign entities have increased their cross-border manufacturing operations (Braddon & Foster, 1996; Green & Guinery, 1994; Guislain, 1997; and Khor & Lin, 2001). This once again resulted in greatly increased competition both at home, abroad, and at cross-border interactions.

The third major trend or development reshaping manufacturing markets is deregulation. The manufacturing sector is affected by the various past and present deregulation attempts in the telecommunications industry, motor and rail transport, utilities, and financial markets. This has been as much a reaction to technological change and globalization as an independent factor. Moreover, the continuing evolution of manufacturing markets and future innovations suggest that it will be literally impossible to maintain some of the remaining rules and regulations established for previous economic environments, especially for previous manufacturing market layouts and distributions (Guislain, 1997; Hanke, 1987; Ramanadham, 1993; Salvendy, 2001; and United States - Department of Commerce, 2004). While the ultimate structural economic policy goals of economic growth and stability will remain unchanged, market forces will



continue to make it impossible to sustain outdated restrictions in the face of increased technological changes and innovations (Braddon & Foster, 1996; Buchanan & Yoon, 1994; Gaynor, 1996; Green & Guinery, 1994; Salvendy, 2001; and Tye, 1991).

Assuming that economic growth is maintained or even increased in the real economy, especially in the manufacturing industry, this does not immediately indicate that a period of instability will not exist. To the contrary, instability is an inherent trait of structural economic policy (Hirsh, 1989). A good example of this is the turmoil that the US transportation services industry went through in the mid 1970s, with respect to interstate commerce and travel (Hanke, 1987).

In considering a rapidly evolving environment, the pace of legislative reform and revision to statutorily mandated regulations must also evolve and adapt. Nonetheless, there has been considerable re-codification of laws and regulations to make commerce and trading rules more consistent with market realities that have occurred in recent years (Smeloff & Asmus, 1997). For example, in the energy utility industry, which can greatly impact the manufacturing sector, the generating, transmitting, and distributing ceilings have been eliminated (or at least restructured), geographical restrictions have been virtually removed, many energy organizations do broadly-based energy contract underwriting and business dealing, environmental regulations have been eased, and finally those organizations with the resources and skills are encouraged and authorized to virtually match interstate competition across the continental US (Fox, 2003; and Hirsh, 1999). It seems clear that there is recognition by the US Congress that the basic

manufacturing framework has to be adjusted further to more consistently reflect market realities. However, this transitional process is not easy when the results of regulatory relief (i.e., deregulation) create both a new competitive landscape and new managerial and stability challenges, especially technology transfer challenges (Bryce, 2002; Fusaro & Miller, 2002; Miller, 1996; and Smeloff & Asmus, 1997).

Change will ultimately occur because the competitive pressures set free by technology, globalization, and deregulation have inevitably blurred or eroded the traditional institutional differences and distinctions among manufacturing organizations in the supply-chain. It is sufficient to say for example that a strong case can be made that the evolution of energy technology alone has changed forever the energy industry's ability to place electricity generation, electricity transmission, and electricity distribution into neat packaged deals for manufacturers. Moreover, the manufacturing industry's ability to survive and prosper in the face of technological and structural changes by continuing to provide manufactured products to their customers at reduced or reasonable prices is yet to be documented. In retrospect, past evidence does clearly show that well-managed organizations in any industry survive, often maintaining or increasing market share (Buchanan & Yoon, 1994; Derthick & Quirk, 1985; Lefebvre, Mason, & Khalil, 1998; MacAvoy, 1992; Nuese, 1995; Quinzii, 1992; and Watkins, 1998). Now, technological changes have facilitated the entrance of new participants in the manufacturing industry and have demonstrated the ability to reduce product prices for consumers, yet the new balancing point in this industry has not been pinpointed or

reached. Overall, this balancing point will still need to be reached despite the continual emergence of new manufacturing products and services. In short, it is reasonable to assume that a well-managed manufacturing industry has nothing to fear from technology, globalization, or deregulation. However, if past consumer usage trends continue, they will create additional, and potentially more significant, manufacturing market pressures, which in turn will accelerate the adoption of current and future technology transfer efforts as a way to deflate and deal with these competitive pressures, more so than utilizing technological advances or globalization positions (Miller, 1996). It is quite likely that in future years it will be nearly impossible to distinguish where one type of manufacturing activity ends and another manufacturing activity begins. Nonetheless, it seems wise to move forward with caution in addressing the removal of the current legal barriers between commerce and trade, since the unrestricted association of commerce and trade would be a profound and irreversible structural change in the American economy, especially in American innovation and transfer efforts (Johnson, 1984; King & Anderson, 2002; Rogers, 1995; and Tidd, Bessant, & Pavitt, 1997).

If current research efforts lend confidence to how emerging technologies would affect the evolution of our economic and financial structures, then one can presumably develop today the regulations that would foster that evolution and eventual innovations and technology transfer programs. But as history suggests, confidence in how the real and financial economies will evolve is low. If the powers that be act too quickly, it runs the risk of locking in a set of inappropriate rules, which could adversely alter the

development of manufacturing market structures, especially small manufacturing market structures. Current efforts to foresee accurately the future implications of technologies (i.e., innovations) and market developments in the manufacturing industry, as in other industries, have not been particularly impressive (Bryce, 2002; Fox, 2003; and Fusaro & Miller, 2002). In fact, Rogers (1995) suggests that even after an innovation's technical feasibility has been clearly established, its ultimate effect on society is often highly unpredictable. There are two sources for this uncertainty (Afuah, 2003; Burgelman, Christensen, & Wheelwright, 2004; Christensen & Raynor, 2003; Green & Guinery, 1994; Katz, 2003; Rogers, 1995; and Tushman & Anderson, 2004). First, the range of applications for a new technology may not be immediately apparent. For example, Alexander Graham Bell initially viewed the telephone as solely a business instrument--merely an enhancement of the telegraph--for use in transmitting very specific messages, such as the terms of a contract. In fact, he offered to sell his telephone patent to Western Union for only \$100,000, but he was turned down. Likewise, Marconi initially overlooked the radio's value as a public broadcast medium, instead believing its principal application would be in the transmission of point-to-point messages, such as ship-to-ship, where communication by wire was infeasible.

A second source of technological uncertainty reflects the possibility that an innovation's full potential may be realized only after extensive improvements, or after complementary innovations in other fields of science and engineering. According to Charles Townes, a Nobel Prize winner for his work on the laser, the attorneys for Bell

Labs initially refused, in the late 1960s, to patent the laser because they believed it had no applications in the field of telecommunications. Only in the 1980s, after extensive improvements in fiber optics technology, did the laser's importance for telecommunications become apparent (Townes, 1999).

Likewise, it is not hard to find examples of such uncertainties within the energy services industry. The evolution of the over-the-counter electricity derivatives market over the past seven years has been nothing less than spectacular. But as the theoretical underpinnings of financial arbitrage were being published in the academic journals for the past 30 years, few observers could have predicted how the scholars' insights would eventually revolutionize global/domestic energy markets. Not only was additional theoretical and empirical research necessary, but also several generations of advances in computer and communications technologies were necessary to make these concepts computationally and structurally practicable (Bryce, 2002; Fox, 2003; and Fusaro & Miller, 2002).

All these examples, and several more, suggest that if the powers that be dramatically change the rules now about commerce and trade, neglecting the great uncertainty about future synergies between innovation and transfer forces, it may well end up doing more harm than good. Furthermore, as with all rule changes (e.g., deregulation) by a government, a situation may arise where it is impossible to correct the

errors promptly, if at all. In other words, modifications of fundamental structural economic policy rules, which may govern monetary, accounting, fiscal, and/or technology transfer issues, must proceed at a calculated pace in order to test the response of markets, including but not limited to the manufacturing markets, and the response of technological innovations and technology transfer to the altered rules (e.g., deregulation) in the years ahead.

At this point, predicting the future with due diligence and humility is highly relevant for how US industry supervision and management ought to evolve, especially with respect to the manufacturing industry and technology transfer. Only recently for example did regulators begin to understand that the supervision of an energy institution is, of necessity, a constantly evolving process reflecting the constantly changing energy services landscape (Bhattacharya, Bollen, & Daalder, 2001; and Wasserman, 1999). More and more, supervisory techniques and requirements attempt to harness both the new technologies (i.e., innovations) and energy market incentives to improve oversight while reducing regulatory burdens, most of which are becoming progressively obsolescent and counterproductive. Moreover, concerns about setting potentially inappropriate regulatory standards were an important factor in the decision by the energy agencies several decades ago; however, none of these energy agencies could have foreshadowed the technological advancements (energy and non-energy related) currently enjoyed by today's manufacturers and consumers (Hirsh, 1989; and Hirsh, 1999). Eventually, these agencies became convinced that the associated technologies and processes for measuring,

transferring, and managing energy risk were evolving so rapidly that any regulatory standard would quickly become outmoded or, worse, inhibit private market innovations and transfer. Largely for these reasons, the energy agencies ultimately chose to address the relationship between these energy risks and energy capital adequacy, especially energy research and development capital, through the supervisory process rather than through the writing of additional regulations. As a result, the deregulation movement started; however, soon after, this movement was transformed into a restructuring perspective and effort, which blurred the supervisory nature of existing regulations and temporarily undermined present energy financial markets. Moreover, this deregulation movement temporarily altered innovation and transfer efforts and temporarily destabilized energy markets, especially electricity markets (Hirsh, 1989; and Hirsh, 1999).

In summary, it is clear that both the real and the financial economies, especially manufacturing economies, have been, and will continue to be, changed dramatically by the forces of technological progress. Manufacturing firms will be under constant challenge to harness these forces to meet the ever-shifting competition. In such an environment, many existing rules and regulations will, if not modified, increasingly bind those manufacturing firms seeking to respond, let alone innovate and transfer successfully. Additionally, there is a profound need for legislators and manufacturing industry supervisors to adapt to the changing realities of today's highly competitive working environment, due to the combination of technological changes, deregulation, and globalization. However, the government still has an obligation to limit systemic risk

exposure. History continually reminds the public of the critical role that financial stability, especially manufacturing stability, plays in the stability of the real economy. Notwithstanding, manufacturing firms also have an obligation to their shareholders, their creditors, their consumers, and their community constituents to measure, transfer, and manage risk appropriately, especially those risks dealing with both innovation and technology transfer. In brief, the various government entities - (federal, state, and local) and the manufacturing industry both want the same things - manufacturing innovation, creative change, responsible risk-taking and transfer, and economic growth and stability. Manufacturing market forces will get us there successfully and will allow us to navigate successfully through today's competitive environment, perhaps not as quickly as some manufacturing firms and consumers may desire, but anything is attainable eventually (Glickman & Gough, 1990; Ilic, Galiana, & Fink, 1998; Insana, 2002; Jick, 1993; and Morgan & Henrion, 1990).

All in all, the literature available on technology transfer is plentiful and encompasses a wide-range of issues dealing with the diffusion of technology. However, successful diffusion to small manufactures is one issue of constant interest. Hence, the remainder of this chapter's nine sections addresses areas pertaining to technology transfer and small manufacturers. The first section discusses the historical background and overall implication of governmental policy for technology transfer. The second section gives a historical perspective of technology transfer in Oklahoma. Current technology transfer delivery systems in Oklahoma are reviewed in the third section to determine the dimensions and attributes that can be used in the development of a technology transfer



program. The fourth section reviews relevant technology transfer studies, again in order to determine the status of dimensions and attributes and to determine the requisite list of barriers in the development of a technology transfer program. The remaining sections discuss: 5) organizational structures of technology transfer approaches, 6) technical complexity of manufacturing operations, 7) technology transfer programs, 8) technology transfer processes, and 9) summary of a framework for a technology transfer program suitable for Oklahoma small manufacturers.

## **2.1 Governmental Policy for Technology Transfer**

Internationally, the US is a leader in discovering new technologies (Cutler, 1989). However, discovering new technologies is only the first step in the technology transfer process. Japan develops and commercializes these new discoveries at a faster rate than the US (Mansfield, 1988; and Moden, et. al., 1985). As examples of this difference, the ratio of mean innovation time for a new product is 25 percent less in Japan than in the US, and the mean innovation costs for new products are 50 percent more in the US than in the Japan. Nonetheless, the most noticeable difference between the two countries is the focus on research and development, marketing, and manufacturing strategy (Brown, 1992; and Schroeder, et. al., 1995). The US spends twice as much as Japan in research and development and marketing (Collins, 1998).

Baranson (1981), Lynn (1982), and Okimoto (1986) suggest that Japan's utilization of external technology transfer<sup>2</sup> more than internal technology transfer<sup>3</sup> explains the differences in the research and development and marketing expenditures. Moreover, Japan's reliance on innovativeness and entrepreneurship, which can be powerful engines for economic growth and expansion more so than standard classical price competition (Landau, 1992), allowed Japan to get ahead of the US. For example, the adoption of the most advanced product and process innovations, mostly imported from the US, contributed significantly to the rapid rise of the Japanese electronics industry in the global marketplace (Guerrieri, 1992). Furthermore, to explain this discrepancy, Landau (1992) cites several studies which show that the comparative performance of the US and Japanese labor productivity growth rates has been heavily influenced by the much higher (often doubled) rate of Japanese capital investment in a number of their industrial sectors, particularly the manufacturing sector. As a result, this high rate of investment fueled the rapid adoption by the Japanese of the latest available technologies - i.e., external technology transfers.

Overall, to alleviate competitive pressures, Weijo (1987) and Gillespie (1988) suggest that the US leverage and expand public science and technology activities with the private sector/industry - (i.e., technology transfer). This increased emphasis on new technologies and their effective deployment is particularly important to US small manufacturers, whose bases of competition are more likely to be product innovation,

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<sup>2</sup> For purposes of this study, external technology transfer utilizes technology transfer services outside the company to develop and deploy the technologies.

<sup>3</sup> For purposes of this study, internal technology transfer occurs when technologies are developed within the company.

advanced technology, and product quality (Burgelman, Christensen, & Wheelwright, 2004; Katz, 2003; and Whitney, et. al., 1988). Recognizing these likely competitive pressures, the US government implemented a series of technology policies to promote multiple levels of technology transfer, designed to ensure the vitality and continued growth of the manufacturing industry, especially the small manufacturers and their work force.

### **2.1.1 US Technology Policy**

Bozeman and Melkers (1993) noted that most large private sector organizations have well established in-house research and development departments. This competitive advantage allowed these organizations to discover new technologies and enhance current technologies without the need to go outside the organization for assistance. However, with this type of technology model, the new technology is often proprietary and expensive for other organizations to deploy (Cohen & Noll, 1991; Collins, 1998; and Ruttan, 2001).

Recognizing this problem, both US federal and state governments took a more active role in developing and disseminating new technologies to organizations in need. This new governmental role was accomplished by technology policy plans as early as the 1940's and by technology policy initiatives as early as the 1970's (Branscomb, 1992; and Ruttan, 2001). Overall, this role established a continuously evolving procedure for the

general public (entrepreneurs) and small manufacturers (too small to have full scale research and development departments) to gain access to new technologies and to obtain technical assistance when needed (Collins, 1998). Basically, the procedure contains three fundamental elements to enhance economic development, growth, and performance in private industry (Branscomb, 1992; and Ruttan, 2001). These elements are as follows (Collins, 1998):

*Supply-Side Activities* – This element is the pure research activity at the federal and state levels and focuses primarily on government missions and private sector innovation. The agencies most recognized in these areas are the government labs such as Lawrence Livermore, Oak Ridge, and Sandia at the federal level and the comprehensive research universities at the state level.

*Demand-Side Activities* – This element involves the cooperation on both the federal and state levels with respect to the transition of technologies to small and medium-sized manufacturers. The transition process equates to the availability, adaptation, and exploitation of these new technologies to the manufacturers. Another activity, which is part of this demand-side element, is motivating the manufacturers to invest in technologies, particularly the knowledge-based technologies of education, training, and retraining. Two examples of this type of technology transfer delivery system in Oklahoma are: the federally funded Cooperative Extension Service-Technology Transfer Program administered at the state level to promote new technologies; and the Small Business Development

Centers (SBDC's) that provide financial and start-up assistance to small manufacturers.

*Information and Facilities Infrastructure* – This element is the physical mechanism to facilitate the transfer of new technologies to small manufacturers. This mechanism translates to the human resources located at strategic sites throughout the state to assist small manufacturers to identify and implement the appropriate technologies. Two examples of this element are: the state-wide technology centers - the Vocational-Technical (Vo-Tech) system - that provide limited research and development expertise and networking opportunities to small manufacturers (Oklahoma Department of Vocational and Technical Education, 1989); and the state-wide Cooperative Extension Program that provides assistance to farmers across the state (Feller, 1993b).

### **2.1.2 US Technology Transfer Initiatives**

The federal government has enacted thirteen institutionally innovative initiatives in the last two decades to enhance commercial technology development and to more effectively transfer new technologies between federal research and development laboratories and private industry. The first prominent initiative was the Bayh-Dole Act of 1980 (Public Law 96-517), which stimulated commercial application of federal R&D patents. This initiative permitted universities, nonprofit firms, and small businesses to

own title to inventions from research funded by the federal government so they may license these inventions to industry for commercialization (Weijo, 1987). Research originally performed in the US was being commercialized more rapidly by foreign countries than by US firms (Ruttan, 2001).

The Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480) was the second initiative enacted to ensure that technology transfer be part of the objectives for the supply-side activities of federal research and development laboratories (Collins, 1998). The act mandated federal laboratories to take an active role in technical cooperation with industry by establishing at each laboratory an Office of Research and Technology Applications (ORTA). This is a requirement if the laboratory's annual budget is over \$20 million (Collins, 1998; and Ruttan, 2001). By 1988, more than 50 laboratories in the US were carrying out research, spending approximately \$20 billion (United States - Department of Commerce, 1993). Furthermore, the act created the opportunity for CRADA's (cooperative research and development agreements) to be established between the laboratories and manufacturers to jointly develop and commercialize new technologies (United States - Agriculture Research Service, 1993). CRADA agreements, which are overseen and facilitated by the Office of Research and Technology Applications, give small manufacturers access to research staff and a modern facility to conduct research particular to their core technical competencies (United States - General Accounting Office, 1994). Moreover, federal research and development agencies must devote one half of one percent of the agency's budget specifically to the deployment of new technologies to manufacturers (Collins, 1998).

The third initiative was the Small Business Innovation Development Act of 1982 (Public Law 97-219) which required federal agencies to provide special funds for small business R&D within the scope of their agency mission (Ruttan, 2001). Two years later, a fourth initiative was established, The National Cooperative Research Act of 1984 (Public Law 98-462), which relaxed antitrust enforcement for research joint ventures. Basically, the act encouraged firms to enter into joint precompetitive R&D ventures without fear of antitrust laws and eliminated the treble damages standard of antitrust laws in litigation arising there from (Ruttan, 2001).

The Federal Technology Transfer Act of 1986 (Public Law 99-502) was the fifth initiative and it amended the Stevenson-Wydler Act by providing additional incentives for promoting the deployment of new technologies. The Federal Technology Transfer Act also established the Federal Laboratory Consortium (FLC) for Technology Transfer, where research labs collectively conduct pure research on new technologies and identify and correct areas of redundant research (Collins, 1998; and Lee, 1990). The act empowered government-owned government-operated laboratories (GOGO's) to enter into cooperative R&D agreements (CRADA's) with either a university or an industry partner to conduct research towards the commercialization of a new technology. Overall, this act allowed federal laboratories, universities, and industry to work collectively in developing new technologies (Collins, 1998; and Ruttan, 2001).

The sixth initiative was a pair of Presidential Executive Orders signed into effect in 1987 (PEO # 12591 and PEO # 12618). Both executive orders further articulated the

issues of the Federal Technology Transfer Act to match with administrative purposes (Ruttan, 2001). In 1988, Congress passed a seventh initiative, The Omnibus Trade and Competitiveness Act (Public Law 100-418), which established Manufacturing Technology Centers (MTC's)/Manufacturing Extension Centers (MEC's) in 48 states. Also, under public law 100-418, the National Bureau of Standards was changed to the National Institute of Standards and Technology (NIST) and was designated as lead agency to establish and administer the Manufacturing Extension Programs (MEP's), which includes the MTC's/MEC's (Collins, 1998; and Ruttan, 2001).

The National Institute of Standards and Technology Act, created in 1989 (Public Law 100-519) was the eighth initiative and allowed the Department of Commerce to create a technology administration (Collins, 1998). The ninth initiative was the National Competitive Technology Transfer Act of 1989 (Public Law 101-189), which extended the CRADA authority to all government-owned contractor-operated federal labs (GOCO's). Moreover, this act enabled federal laboratories to enter into CRADA's specifically with universities and industry under the same requirements established in the Federal Technology Transfer Act of 1986 (Collins, 1998; and Ruttan, 2001).

The tenth initiative was the Intermodal Surface Transportation Efficiency Act of 1991 (Public Law 102-240). This act focused on technology transfer issues in the transportation industry and authorized the Department of Transportation to devote up to 50% of the cost of CRADA's to highway research and development (Collins, 1998). The eleventh initiative was the American Preeminence Act of 1991 (Public Law 102-245).



This act authorized federal laboratories to donate excess equipment to universities and nonprofit organizations (Collins, 1998). The twelfth initiative was the Small Business Technology Transfer (STTR) Program of 1992 (Public Law 102-564). This initiative established a three-year Small Business Technology Transfer (STTR) pilot program at federal research facilities and appointed the Small Business Administration as coordinator for the program (Collins, 1998). Lastly, the thirteenth prominent initiative enacted by the US federal government to enhance commercial technology development and to more effectively transfer new technologies between federal research and development laboratories and private industry was the Defense Authorization Act of 1993 (Public Law 103-160). This act directed the Advanced Research Projects Agency (ARPA) to promote dual-use technology via technology reinvestment (Ruttan, 2001).

All in all, these thirteen initiatives (12 legislative and one executive) in the last two decades demonstrate the US government's recognition of the importance of technology transfer, especially deploying technological information to manufacturers. Moreover, these thirteen initiatives demonstrate the US government's willingness and persistence to insure that all parties of the US economy, especially the small manufacturers, are able to take advantage of new technologies and establish competitive advantages to compete successfully in today's competitive global market place.

### **2.1.3 A Strategy for Promoting Technology Transfer to the Private Sector**

This subsection discusses three promotion strategies that policy makers can use to increase the effectiveness and efficiency of technology transfer programs. Weijo (1987) asserted that legislative changes are only one element in a solution to increase the effectiveness of technology transfer programs. The other, equally important element, is the development of a marketing strategy to promote government/private sector transfer of technology. Specifically, this strategy should emulate the technology transfer approach being used by private sector organizations, such as small manufacturers, to identify and develop new product ideas and to increase the competitive position of these organizations (Weijo, 1987).

The three strategies are depended on two main technology transfer approaches. First, the demand-pull approach to technological innovation works from an identified need in the marketplace toward the necessary technology that provides an effective and efficient solution to a customer's problem - i.e., a problem looking for a solution (Ruttan, 2001). Sales and marketing personnel are often the source of demand-pull ideas because of their intimate association with the customer. Identified needs flow from marketing to research and development where creative technologies are identified to solve customer problems (Weijo, 1987).

The second approach to technological innovation is technology-push. This approach works from an innovative technology toward identification of a need - i.e., a

solution looking for a problem (Gaynor, 1996; and Gehani, 1998). Since engineers and scientists have a solid understanding of innovative technologies, the research and development department generally is the primary source for technology-push ideas. These ideas then flow to other functional areas such as marketing or top management where further evaluation of each idea occurs (Weijo, 1987).

From a federal agency perspective, the demand-pull approach for introducing innovative technology into the private sector results in a passive method<sup>4</sup> toward technology transfer. In this first strategy for developing and promoting a technology transfer program, the demand-pull comes from private sector firms. Federal agencies do not attempt to thoroughly understand a customer's needs for a technological innovation. Instead, their goal is to make information accessible to private sector firms who are searching for solutions to a customer problem (Weijo, 1987).

On the other hand, the technology-push approach to technological innovation into private sector firms is the more active method<sup>5</sup> of technology transfer employed by federal agencies. This second strategy for developing and promoting a technology transfer program has two different audiences for technology-push opportunities, which can be viewed as another two strategies. In the first case (or second strategy overall), the target audience is the individuals employed in important roles (e.g., engineers and scientists), who incorporate new product development activities. This audience is the

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<sup>4</sup> The passive method of technology transfer refers to when the audience or customer must make the effort to seek information on a project. It is user-driven technology transfer (Weijo, 1987).

<sup>5</sup> The active method of technology transfer refers to when the transferring public agency is aggressively attempting to reach a designated target audience. It is source-driven technology transfer (Weijo, 1987).

appropriate audience for a transfer plan where a technology has application to a diverse set of industries, including the manufacturing industry (Weijo, 1987). An example is technology developed for the US Department of Energy's (DOE) thermal energy storage program. This technology has a variety of potential product and process applications in both the residential and commercial industry sectors. As a result, awareness of this technology must be transferred to engineers and scientists in many different industries, such as the manufacturing industry (Weijo, 1987).

With this role-directed technology transfer strategy, engineers and scientists in the private sector must make the conceptual leap to identify the products and processes that can be developed from a new technological innovation. They actively promote the ideas to other functional areas in an organization, which have input into new product ideas - e.g., marketing, manufacturing, and top management (Weijo, 1987).

The third promotion strategy that policy makers can use to increase the effectiveness and efficiency of technology transfer programs is again a technology-push strategy, however, the target audience is the innovator and early adopter organizations in specific industries. This audience is quite small, often involving fewer than 10 firms in a specific industry. An example of this path is using energy technologies being developed by DOE to target new heat pump technology for residential home application to the firms most likely to seriously adopt such technology (Weijo, 1987).

Overall, within the technology-push approach to technological innovation into private sector firms, the organization-directed strategy is a more active transfer strategy than the role-directed technology transfer strategy. The main reason being that it remains the responsibility of personnel at the government agencies to actively seek out the industries and the firms, such as small manufacturers, most likely to adopt a new technology. The engineers, scientists, and market researchers employed in national laboratories and other government agencies must make the conceptual leap to identify the products and processes that can be developed from a new technological innovation. Thus, government laboratories and agencies are the active promoter of ideas to the key functional areas in an organization, which have input into new product ideas – e.g., research and development, marketing, manufacturing, and top management (Gaynor, 1996; Gehani, 1998; and Weijo, 1987).

All three strategies (the passive, the role-directed, and the organization-directed) can be used by government agencies to promote and transfer new technology to the private sector, especially small manufacturers since they operate with limited resources and capabilities. Table 1 presents Weijo's operational framework for the three strategies, which could be used by the various federal agencies to promote technology transfer to the private sector (Weijo, 1987). In essence, this framework could lay the foundation of a practical and competitive technology transfer program.

<u>Approach</u>	DEMAND-PULL		TECHNOLOGY-PUSH	
<u>Strategy</u>	Passive		Role-Directed	Organization-Directed
<u>Purpose</u>	To make information accessible to those individuals and organizations searching for solutions to customer / society problems		To actively promote awareness of new technology to individuals occupying boundary-spanning roles in organizations	To actively promote the adoption of new product or process concepts to innovator firms in an industry
<b><i>Factors influencing selection:</i></b>				
<i>Stage of R&amp;D Development</i>	Early	Middle	Middle	Late
<i>Nature of Innovation</i>	Ideas or physical goods	Ideas or physical goods	Ideas or physical goods	Physical goods
<i>Available Financial Resources</i>	Limited	Moderate	Moderate	Extensive
<i>National Priority</i>	Long-term	Moderate-Term	Moderate-Term	Near-term
<i>Security Concerns</i>	No	Yes	Yes	Yes
<i>Willing to Invest in Assessment Studies</i>	No	Yes	Yes	Yes
<i>Willing to Invest in Concept Studies</i>	No	No	No	Yes
<i>Number and Characteristics of Firms in an Industry</i>	Diffuse	Diffuse	Diffuse	Focused
<i>Distribution Channel Design</i>	Pull	Pull	Pull	Push
<b><i>Technology Transfer Strategy:</i></b>				
	Technical Databases	Professional journals and conference presentations targeted to certain disciplines	Professional journals and conference presentations targeted to certain disciplines	Personal Contacts
	NTIS	Trade publications and conference presentations targeted to certain industry groups or national associations	Trade publications and conference presentations targeted to certain industry groups or national associations	Transfer of R&D Personnel
	Professional Journals			Onsite Visits
	Trade Publications	Technology Fairs	Technology Fairs	Joint Ventures
	Conferences and Workshops	Industry Teams	Industry Teams	Demonstration Projects
				Tax Incentives

**Table 1. Strategies for Promoting Technology Transfer to the Private Sector**

## **2.2 Historical Perspective of Technology Transfer in Oklahoma**

This section of the literature review details Oklahoma's experience with technology transfer programs. Although there are many state programs in Oklahoma, only the predominant technology transfer programs are discussed. One of the first well-known programs created within the last 20 years is the Oklahoma Cooperative Extension Service. This program provides assistance to Oklahoma farmers and ranchers. Another well established program is the Industrial Technology Research and Development program, which focuses on diffusing appropriate technologies to industry in Southeastern Oklahoma. One of the more recent programs is the Oklahoma Alliance for Manufacturing Excellence, Inc. This was the first statewide attempt to transfer technology to industry through a brokering system. And finally, one of the more duplicated programs nationally is the vocational and technical system in Oklahoma - i.e., the Oklahoma Vocational and Technical system (Vo-Tech). This program like its sister programs nationally provides statewide Vo-Tech centers for vocational and technical training to industry employees (Collins, 1998).

### **2.2.1 Oklahoma Cooperative Extension Service**

Technology transfer programs in Oklahoma date back to the early 1900's; the Smith-Lever Act of 1914 built a foundation for the Oklahoma Cooperative Extension Service (Fite, 1988). This program, frequently referred to in this study as the Ag Model,

provides assistance and service to the agricultural sectors in the state (Collins, 1998; and Oklahoma Cooperative Extension Service, 1996). This Ag Model epitomizes a long-term partnership between federal, state, and county governments. McFall and McKelvey (1989) state that this program has endured many trying times in US history especially because of its ability to evolve with the changing times and still adhere to its mission, which is to provide statewide assistance in four major areas: agriculture, home economics, 4-H youth development, and rural development.

There are three other extension programs, all created in 1957, which complement the land grant institution based cooperative extension service (Fite, 1988). The business, education, and engineering extension programs provide statewide assistance to manufacturers in the form of training sessions, workshops, and seminars. However, each of these three programs operates independent of the others, and each is headquartered out of their respective colleges at Oklahoma State University (Collins, 1998).

### **2.2.2 Industrial Technology Research and Development (REI)**

In the last 20 years, Oklahoma has seen a gradual rise in the number of technology transfer opportunities afforded to small manufacturers across the state. This positive situation is due to the increased effort to improve technology transfer services dating back to the late 1970's and 1980's. One of the programs created during that era was the Industrial Technology Research and Development Foundation (ITRAD) (Mize &

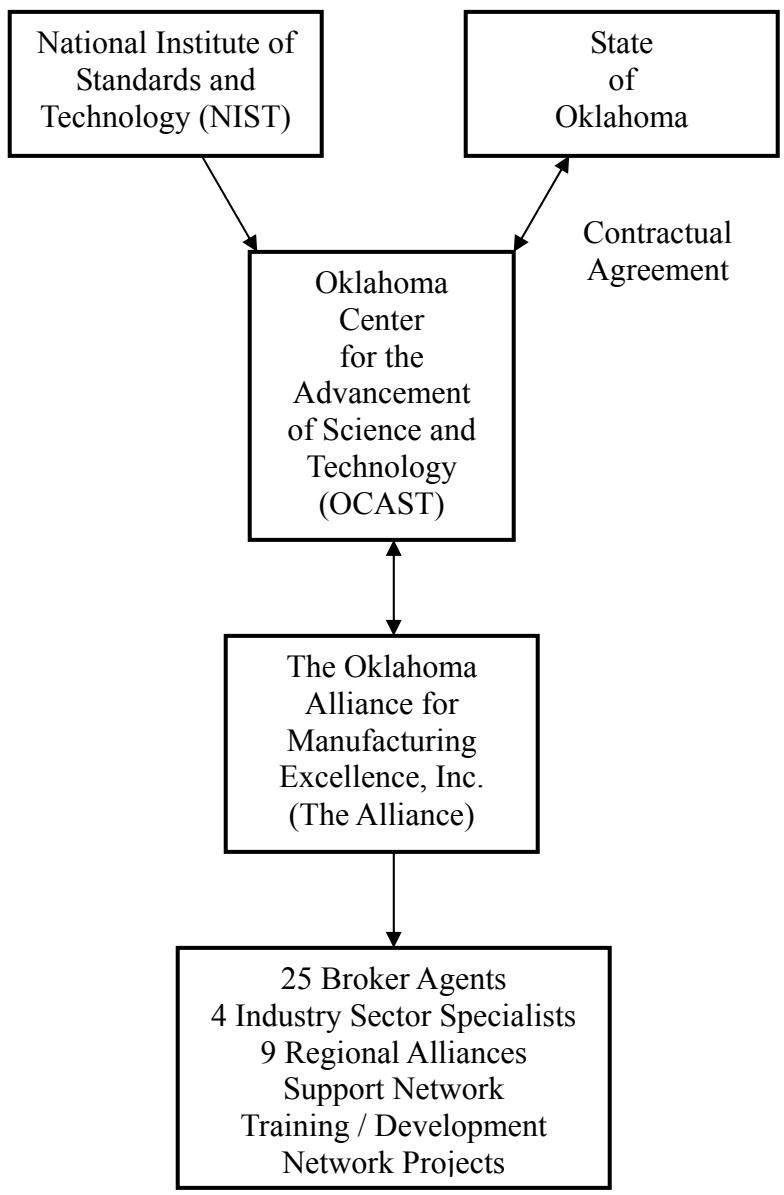


Warner, 1981). This program, however, has gone through several mergers with other non-profit organizations and is currently called Rural Enterprises, Inc. (REI). Over the years, the Rural Enterprises, Inc. program has provided such services as industrial incubators, technology transfer, and financial assistance to small manufacturers in the Southeastern portion of Oklahoma (Collins, 1998; and Smith, 1993).

### **2.2.3 Oklahoma Alliance for Manufacturing Excellence, Inc.**

In 1987, the Omnibus Economic Development Act created the Oklahoma Center for the Advancement of Science and Technology (OCAST). OCAST is the agency for appropriating federal and state funds to service-providing organizations, such as research universities, centers of excellence, industrial extension, and innovative manufacturers (Collins, 1998; and OCAST, 1996, September). By 2004, OCAST had distributed approximately \$104.8 million in cumulative investment in Oklahoma for research, development, and technology transfer and had leveraged private and federal funds equal to \$1.35 billion for the same purpose, which is a leverage ratio of 12.87 (OCAST, 2004). OCAST is the funding and contractual administrator for the Oklahoma Alliance for Manufacturing Excellence, Inc. (The Alliance). Figure 1 shows OCAST's role within The Alliance (Collins, 1998).

OCAST's presence in Oklahoma contributed significantly to creating The Alliance, a 501 (c) (3) non-profit organization, which means it can receive funding from



**Figure 1. OCAST and The Alliance Relationship Diagram**

both public and private sources. In November 1991, a group of economic development specialists organized a task force to determine the best strategy for developing an industrial extension plan for Oklahoma (Oklahoma Alliance for Manufacturing Excellence, Inc., 1992). The task force's members discovered that a critical characteristic for success is to know what the customers, in this case the small manufacturers, wanted in the form of technology transfer.

As a result, the "Alliance" model was crafted capitalizing on the thoughts and ideas of the small manufacturers across the state. Now instead of pushing a technology transfer program onto manufacturers, the new paradigm was to create a pull technology transfer program, where information and services were filtered down to the manufacturing firms as they were requested (Collins, 1998). This new technology transfer paradigm for the state of Oklahoma used broker/agents, who interacted one-on-one with small manufacturing firms. This broker/agents scenario facilitated the creation of 30 manufacturing councils across the state, with plans to develop more councils (Goldsmith, 1996; and Oklahoma Alliance for Manufacturing Excellence, Inc., 1995). These councils hold regular monthly meetings, attended mostly by small manufacturers. In addition, in order to facilitate and optimize the input from the small manufacturers, these monthly meetings are located in areas where there is a high concentration of small manufacturers. Consequently, the majority of the councils' membership over the last decade has been mainly small manufacturers (Oklahoma Alliance for Manufacturing Excellence, Inc., 2004).

The Alliance, which is part of the national Manufacturing Extension Partnership (MEP) program, has assisted Oklahoma manufacturers in several ways. First, in terms of the overall number of manufacturers helped, The Alliance has assisted 2597 manufacturers in the past eight years. Second, it has saved manufacturers \$90.7 million in labor, energy, and overhead costs in the past 4 years. Third, with help from The Alliance, Oklahoma manufactured product sales were \$130.8 million in 2004. This was a 23.2 percent increase over the previous 3 years' combined total sales of \$434.2 million, for a total of \$565 million. And finally, in 2004, The Alliance helped to create and retain 894 Oklahoma manufacturing jobs with a salary impact of \$45.1 million (Oklahoma Alliance for Manufacturing Excellence, Inc., 2004). For these reasons, The Alliance receives excellent ratings from the National Institute of Standards and Technology and is among the top third most effective MEP centers nationwide.

#### **2.2.4 Oklahoma Vo-Tech System**

The Oklahoma Vocational and Technical System (Vo-Tech) consists of close to 50 schools, all of which provide training to youths and adults through a wide range of curricula. These schools are distributed across the state. No other agency in Oklahoma has a network of education and training facilities of this magnitude. Originally, the Vo-Tech system concentrated on trades programs such as air conditioning and heating, auto body, carpentry, drafting, masonry, and welding. However, recently, the Vo-Tech system has continued to excel in the instruction of vocational trades to high school and adult

students at the same time adding technical and business services to assist small manufacturers (Collins, 1998).

As a result, Oklahoma small businesses have benefited from the services offered by the Vo-Tech system. Moreover, small business incubators located at these Vo-Tech schools allow small manufacturers to have lower-cost facilities to commercialize their new products or processes. Manufacturing equipment can be leased by the small manufacturer from the Vo-Tech to curb the high initial capital investment required for purchasing new equipment at startup. Furthermore, the Vo-Tech system has offered training on the operation of equipment and machinery by using in-house instructors or equipment factory representatives. Finally, the Vo-Tech system has also provided a skilled labor pool of students who have received training from the various Vo-Tech programs (Collins, 1998).

### **2.3 Current Technology Transfer Delivery Systems in Oklahoma**

In Oklahoma, there are currently ten delivery systems as the primary contributors of technology transfer. Each delivery system is classified according to its match with the three US Technology Policy elements: supply-side activities, demand-side activities, or information and facilities infrastructure. Further, five primary technology transfer dimensions provide another level of stratification to the technology transfer delivery systems for Oklahoma. These five dimensions are business assistance, governmental

compliance, technical assistance, research and development, and human resource management. These five dimensions are further explained in the following paragraphs. Figure 2 shows the technology transfer relationship chart for the delivery systems in Oklahoma (Collins, 1998).

### Business Assistance

This technology transfer dimension provides business assistance to small manufacturing companies. By far, this sub-category is the most popular, particularly with new small manufacturers needing start-up assistance (Collins, 1998). Some of the primary services frequently provided to small manufacturers are: organizational strategy development (Masten, Hartmann, & Safari, 1995; and Werther, Berman, & Vasconcellos, 1994), strategic technology management systems (Bursic & Cleland, 1991), short-term and long-term financial procurement and management planning (Dixon & John, 1989), marketing (Daft, 1995; and Solomon & Stuart, 2003), and low cost facilities.

Three business assistance programs are selected for review for this study. They are: the Small Business Development Center (SBDC), the Oklahoma Alliance for Manufacturing Excellence, Inc. (The Alliance), and the Oklahoma Vocational and Technical System (Vo-Tech). SBDC's assist small manufacturers with marketing strategies and business plans. The Alliance provides direct contact with manufacturing clients through their Broker/Agent system. And

<b>Technology Transfer Model</b>	<b>US Technology Policy Elements</b>	<b>Levels of Assistance</b>
The Alliance	1. Demand-Side 2. Infrastructure	1. Business
Department of Environmental Quality (DOEQ)	1. Demand-Side	1. Govt. Comp.
OSU Engineering Extension Program (OSU)	1. Supply-Side 2. Infrastructure	1. Govt. Comp. 2. Technical 3. R & D
Oklahoma Center for Integrated Design and Manufacturing (OCIDM)	1. Demand-Side 2. Supply-Side	1. Technical 2. R & D
Oklahoma Department of Labor (ODOL)	1. Demand-Side	1. Govt. Comp. 2. HRM
Rural Enterprises, Incorporated (REI)	1. Demand-Side	1. Business 2. Technical
Small Business Development Center (SBDC)	1. Demand-Side	1. Business 2. HRM
State University System (SUS)	1. Supply-Side 2. Infrastructure	1. Technical 2. R & D
Cooperative Extension Service Technology Transfer Program (CES-TTP)	1. Demand-Side 2. Supply-Side 3. Infrastructure	1. Govt. Comp. 2. Technical 3. R & D
Oklahoma Vocational and Technical System (VO-TECH)	1. Demand-Side 2. Infrastructure	1. Business 2. Technical 3. HRM

**Levels of Assistance:** (Primary Level of Assistance Provided by the Delivery System)

**Business** = Business Assistance

**Govt. Comp.** = Governmental Compliance

**Technical** = Technical Assistance

**R & D** = Research and Development

**HRM** = Human Resource Management

**Figure 2. Technology Transfer Relationship Chart for Selected Models in Oklahoma**

finally, the Vo-Tech program provides the valuable incubator system, which is a useful resource to new start up companies (Collins, 1998; Culp, 1996; and Lumpkin & Ireland, 1988).

### Governmental Compliance

Compliance with government regulations concerning the environment is a recent purpose for technology transfer programs. According to McGovern (1995), regulatory compliance is a major concern today for small manufacturing companies, more so than ever before. Compliance is a survival concern for most small manufacturers, and the primary request for information is how to comply at the least possible cost (Collins, 1998). The three selected programs to be reviewed are: Oklahoma State University Engineering Extension Program (OSU), the Oklahoma Department of Labor - Consultation Service (ODOL), and the Department of Environmental Quality - Customer Service (DOEQ).

### Technical Assistance

In this sub-category, there are two recognized programs in the state of Oklahoma: the Cooperative Extension Service Technology Transfer Program (CES-TTP), and the Oklahoma Center for Integrated Design and Manufacturing (OCIDM). Both programs are small in scale, with only one to three staff members for each program (Norton, 1995).



## Research and Development

Two programs are considered in this technology transfer dimension, which involves the research and development phase of technology transfer. They are the State University System (SUS) and the Federal Laboratory Consortium (FLC) (Carr, 1992a; and Carr, 1992b). The University of Oklahoma, Oklahoma State University, and The University of Tulsa each have research facilities. However, Oklahoma State University, the land grant institution for the state of Oklahoma, has multiple off-site research facilities and experiment stations. On-site, at the main campus in Stillwater, Oklahoma, Oklahoma State University has two multi-million dollar research facilities: the Advanced Technology Research Center and the Oklahoma Food and Agricultural Products Research and Technology Center. Currently, Oklahoma State University - Tulsa Campus in Tulsa, Oklahoma is in the process of approving the construction of its own multi-million dollar Advanced Technology Research Center.

The Federal Laboratory Consortia (FLC's) promotes cooperative research and development agreements (CRADA's) (Radosevich & Lombana, 1993) between their research facilities and manufacturers to develop and commercialize new technologies (Souder & Padmanabhan, 1989). The CRADA's serve another purpose for the FLC, which is to use available space and expertise at their research facilities (Carr, 1995). Interestingly, unlike in the prior decade, recent increases in government defense contracts spending have created

opportunities for the federal laboratories to offer time and service to manufacturers in an attempt to move from a pure and basic research role to a role as developers of applied technologies (Babcock, 1991; and World Watch Institute, 2003).

### Human Resource Management

In this final sub-category of technology transfer dimensions, there are three recognized programs in the state of Oklahoma: the Oklahoma Department of Labor - Consultation Service (ODOL), the Small Business Development Center (SBDC), and the Oklahoma Vocational and Technical System (Vo-Tech). These three programs provide various degrees of employee selection assistance, employee benefits, insurance, and worker's compensation training, and labor/management relations assistance (Collins, 1998). Also, these three programs improve the organizational effectiveness of small manufacturers, especially in the competitive fields (or pressures) of recruiting, performance appraisal, training, and compensation (Jackson & Schuler, 1995; and Salvendy, 2001).

Overall, this section of the chapter has examined the main technology transfer programs in Oklahoma, which is the test site for this study. Further, each technology transfer program in Oklahoma has been analyzed and classified according to its fit into one or more of the three elements in the US Technology Policy as depicted in Figure 2 on

page 72. The technology transfer delivery systems in Oklahoma have also been examined and benchmarked for desirable dimensions. This study will focus next on past pertinent research efforts, which evaluated technology transfer programs.

## **2.4 Relevant Technology Transfer Studies**

In this part of the study, other state technology transfer programs are examined to determine the desirable attributes, dimensions, organizational structures, barriers, and characteristics of a technology transfer program. Accordingly, the works of Osborne, Clarke, Dobson, Hoff, and Collins are evaluated and summarized.

### **2.4.1 Osborne's Work**

In November 1989, David Osborne published a comprehensive analysis of state technology programs across the United States (Osborne, 1989). Osborne estimated that between 1986 and 1987 the US spent \$400-\$700 million on technology transfer programs. He also speculated that there were approximately 300 programs by the late 1980's (Atkinson, 1988).

Concern regarding the lack of focus on the successful characteristics of technology transfer programs was beginning to take shape in the technology transfer

community (Tornatzky & Fleischer, 1990). Also, technology policy makers began to realize it was time to learn from the experiences of the last decade, since the enactment of the Federal Technology Transfer Act. Tornatzky argued that programs should start an evaluation process to develop a way to determine the characteristics of successful technology programs (Tornatzky, 1988).

Osborne (1989) identified four major problems facing state technology programs:

1. A research base that is too small to stimulate the commercial development of new technologies in the regional economy.
2. Inadequate transfer of technological advances from research institutions, such as universities, to local corporations.
3. Insufficient support for new enterprise development as a means to commercialize new technologies.
4. Insufficient deployment of new process technologies by existing manufacturers.

Osborne suggested multiple detailed strategies to address the specific problem in each area. Presented next is a summary of the strategies from the report that directly relate to the proposed state technology transfer program. First, for problem #1, Osborne's strategy # 3 was to establish university research parks. Since 1980, over 150 university research parks have been established. A study by Battelle Columbus Laboratories regarding the success of such parks, found that of the first 27 university research parks created, only six were winners, 16 were losers, and five reported mixed success (Battelle

Columbus Laboratories, 1982). The study speculated that the ratios of winners to losers would hold true for the remaining university research parks. The study also concluded that the major reason for the failures was the inability to fill the research facilities, which translated to financial instability.

Second, for problem # 2, Osborne suggested a strategy that creates a broker/agent facilitator, which would bring together manufacturers, service providers, and other resources. As an example, the Ben Franklin partnerships in Pennsylvania and the Edison Technology Centers in Ohio have used this broker/agent model to network academic researchers, manufacturers, venture capitalists, management assistance specialists, and others to provide technology transfer services to manufacturing firms. Interestingly, Oklahoma's The Alliance has used the same model to serve as a link between appropriate service providers and manufacturing clients.

Third, to address problem # 3, Osborne suggested four strategies. Strategy # 1 was to make sure that an adequate supply of risk capital was available for manufacturers. Strategy # 2 supported the use of low-cost facilities as incubators for new start-up companies. Strategy # 3 identified the need for small manufacturers to develop a solid business plan. And finally, Osborne's Strategy # 4 recommended creating support networks for high technology start-up companies.

Finally, for problem # 4, Osborne provided the most relevant information by addressing industrial extension programs. He identified four basic categories of

industrial extension programs: passive programs, broker programs, active programs, and comprehensive programs. A passive program is one that simply responds to requests from manufacturing firms through a database search, similar to a technology transfer strategy in a demand-pull approach mentioned by Weijo, (1987). Second, a broker program takes the technology process a bit further by referring the clients to other service providers, who can perform the technology transfer service. Osborne referred to a study conducted in 1985 by Andrew Wyckoff of the US Office of Technology Assessment and Louis Tornatzky of the Michigan Industrial Technology Institute (currently with the Select University Technologies, Inc. - SUTI) that found these passive and broker programs were not in high demand (Wyckoff & Tornatzky, 1988).

In addition, the research findings of Wyckoff and Tornatzky were not supported by empirical data; however there appeared to be sufficient evidence that the passive and broker programs simply did not offer enough value-added assistance to the manufacturers. Furthermore, the researchers found that almost all small manufacturers lacked the time or money to initiate a project, meet with the service provider, and follow through with a project, not to mention the ability to pay for the provided services.

The third category identified by Osborne, active programs, were distinguishable in that a technology transfer specialist or a program specialist had one-on-one contact with the small manufacturer (Wu, 1994). Specifically, the specialist met with the management team, analyzed particular needs, assisted in determining a solution to the problem, and assisted, when necessary, in installing new equipment. All in all, Wyckoff and Tornatzky's

work indicated that active programs were far more effective than the passive and broker programs. In fact, manufacturers were more willing to invest in the services of the specialist. However, there is a critical precaution regarding the specialist when considering this type of program. The specialist needs to be more industry-oriented and less academic-oriented. Wyckoff and Tornatzky suggested that the best technology transfer specialists are the ones with industry experience, since they are able to give more hands-on assistance to manufacturers.

The fourth industrial extension program category identified by Osborne was the comprehensive program model. Although active programs were more adequate than the passive and broker programs in providing the appropriate technology assistance to manufacturers, they still were not comprehensive enough to be effective. The comprehensive program model provided all types of assistance to a manufacturer. For instance, an engineering specialist analyzed the technical issues of design, production, inventories, and new product development with the client. Additionally, a business specialist provided training, labor-relations, and grant approval assistance to the client. According to Osborne, the comprehensive models were far superior to the other models due to the wide array of services offered to the clients. In his words (Osborne, 1989):

Most technology-related programs have only one dimension: They fund research, they create incubators, they provide seed capital, or they help manufacturers adopt new production technologies. But, economic development is not a one-dimensional process. Firms do not have single needs. Development is a process in which many different elements -- capital, technology, labor, management, information, and so on -- come together in a mix that allows

entrepreneurship to flourish and companies to grow. Getting the mix right is as important as providing one or two of the elements that are missing. Programs that focus on the entire mix -- programs that are comprehensive in nature -- are often the most effective.

In Osborne's study, the final chapter discusses the lessons learned from the state technology transfer programs across the country. Ironically, when looking at the experiences of state technology transfer programs, the issue was not whether research parks work best or broker/agent programs give the most individual contact with clients, but rather the major issue was the condition of the state's economy (Collins, 1998). In other words, the state's economic position and manufacturing competitive advantage determined which program would be utilized the most. Thus, a competitive environment can inadvertently establish utilization trends in the technology transfer programs arena. Identifying the areas for improvement in the state's economy and how the government's intervention (federal, state, and local) can make the most impact in improving economic growth are the relevant lessons to benchmark, which can directly initiate and lead to the benchmarking of a manufacturer's competitive environment. In his study, Osborne grouped the lessons learned into three categories: policy, design, and political lessons.

Feller (1993) asserts that there is still much to be learned from technology policy. His assertions are still applicable even in today's competitive environment. Likewise, Osborne's study discussed in detail several critical elements in policy lessons, which again are still applicable today. The lessons are (Collins, 1998):



1. Assess the economic conditions in the state, and know what is happening at the regional, industry, and institution levels.
2. Audit the economy of the state. The states with the best technology programs tend to have developed and implemented strategies for understanding their state economies.
3. Foster growth and development in the manufacturing sector rather than establishing new programs. Stimulating the growth of the economy through technological innovation in the state should be the foremost objective.
4. Fund programs based on the outcomes and not inputs. Programs need to establish metrics of measurable performance (Brown, et. al., 1995; Chapman, 1994; Chapman, 1995; Crutcher& Fieselman, 1994; Feller & Roessner, 1995; Schroer, et. al., 1995; Shapira & Youtie, 1995; Shapira, Youtie, & Roessner, 1996; Tornatzky, et. al., 1995; Torvatn, 1994; and United States - General Accounting Office, 1996). Osborne did not elaborate on the types of metrics that should be measured in state technology programs. But the Technology Transfer Society's conference in 1996 held in Santa Fe, New Mexico was devoted to establishing metrics - what works and what does not work (Bendis, 1996; Jones, 1996; Melkers, 1996; and Tornatzky, 1996).

Design lessons for state technology programs are fairly complicated. A “boiler-plate” methodology does not exist for all state technology programs (Feller, 1988). The

main reason for this difficulty is that a successful technology program depends upon knowing the level of economic development within the particular state. Osborne's main suggestions to assess this economic status involve determining the capabilities of manufacturers to deploy new technologies, evaluating the university research base, and auditing the existing education systems. Osborne suggested other elements, which should be considered when designing a state technology program:

1. Make the programs comprehensive. The program should seek to have the right mixture of all the needed services. Pennsylvania's Ben Franklin Partnership is an example of a comprehensive program (Haluska, 1996).
2. Develop state programs around the manufacturing needs of the state. If the objective is to promote economic growth, the program should be funded around the priorities of manufacturing and not academic agendas. Research agendas should be problem and market oriented as defined by industry (Johnson, 1984).
3. Have one-on-one interaction with all stakeholders, including academia, manufacturers, government, and other service providers (Kelly, 1994).
4. Evaluate the programs, even in the design process. Properly designed programs had measurable performance parameters to meet (Feller & Anderson, 1994; and Shea, 1995).
5. Encourage local/regional ownership of programs. A decentralized

program should address the individual economic development needs for each region of the state. Osborne's study indicated that most states had widely diverse regional economies (Beije, 1998).

6. Design programs on an appropriate scale. In the study, Osborne says (Johnson, 1984):

Many economic development programs were far too small to have anything more than a marginal impact, particularly industrial extension programs, risk capital funds, and management assistance programs. On the other hand, some technology programs have been created from scratch with sums in the neighborhood of \$100 million, far too large an amount for the initial years.

Lastly, in the study, Osborne maintained that an understanding of the political environment is crucial to establishing a successful state technology program. Osborne presented a set of lessons to be learned regarding politics and state technology programs, which were:

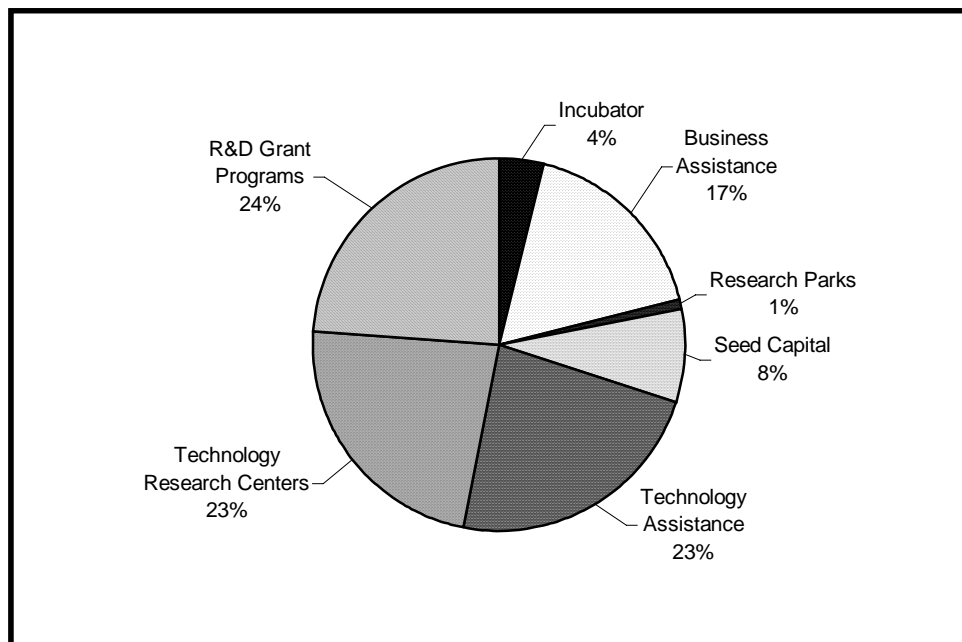
1. Create a strategic vision people can understand (Jennings, 1995).
2. Develop broad based support. The best approach to this situation is to craft a bipartisan strategic plan and lobby the support of the most influential constituents in industry, politics, and academia (Cagan & Vogel, 2002; and Keller & Berry, 2003).
3. Encourage local ownership of the program. This is the best strategy for long-term sustainability and growth of the state technology program (Beije, 1998).

4. De-politicize the funding of the program if at all possible. Legislators have been perceived as having short-term goals, in line with their terms of office (Johnson, 1984).
5. Maintain balance in state technology programs to account for the social factors affecting technological change (Teich, 1986). A comprehensive program provides adequate assistance for the social impacts workers experience with technological change in their workplace (Daft, 1995; Douglas & Wildavsky, 1982; Giddens, 2001; and Rifkin, 2004).

#### **2.4.2 Clarke and Dobson's Work**

Two studies conducted in 1989 and 1991 respectively by Marianne Clarke and Eric Dobson for the National Governor's Association identified and evaluated state industrial extension programs. First, the 1989 study focused primarily on determining the established network of US organizations which provided technology transfer services to manufacturing firms (Clarke and Dobson, 1989). For the study, surveys were sent out to an appointed coordinator in each state. The coordinators then distributed the surveys to programs within their state that dealt with business assistance, technical assistance, research and development, etc. The results of the 178 surveys received from 44 of the 50 states provided the following observations:

1. The state extension delivery systems were very decentralized, providing direct one-on-one assistance to clients. Some programs used the broker model, which serves larger groups of clients, while other programs used the one-on-one-follow-through, direct-assistance model, which provided more in-depth assistance but to fewer clients. Decisions with respect to model choice were based on each model's capability to provide the greatest economic growth for the respective region.
2. Universities were the most popular location for state technology programs. In fact, universities administered over 50 percent of the programs in the survey.
3. A high percentage of clients were small, from five to 50 employees, while another 23 percent of the clients were medium sized - 250 to 500 employees. Interestingly, small clients typically requested existing technologies for their facilities rather than developing new technologies.
4. The surveyed state technology programs provided a diverse set of business services to clients, covering multiple dimensions of technology transfer. Moreover, all the programs were multi-dimensional in structure and in financial support. Figure 3 depicts the funding percentage by program orientation for 1988.



**Figure 3. Funding Percentage by Program Orientation**

5. Of the 13 state extension programs surveyed, all shared the following fundamental characteristics:
  - a. Each used the client-initiated problem-identification approach (demand-pull) instead of the technology-push approach.
  - b. Each recognized they cannot be effective providing one-dimensional services to a client. Frequently, a client who requested technical assistance also needed assistance in training and marketing of a new product.
  - c. Each offered on-site service to clients, a valuable component in the state extension program.
  - d. Each recognized that the state extension specialists simply did

not have the expertise to solve all the problems presented by the manufacturers. As a solution, the extension specialist accessed a network of faculty, researchers, private industry, and other specialists in different areas.

- e. Each offered a formal training program component in the state extension program dependent upon the services offered to the client.

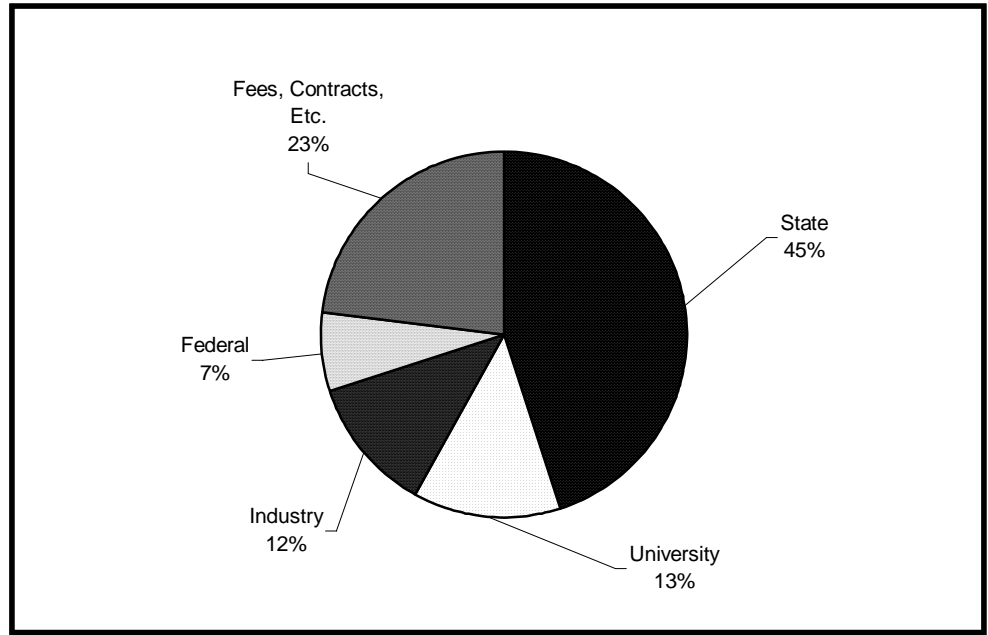
As for the second study by Clarke and Dobson (1991), it focused primarily on the characteristics of the state technology extension programs. This second study's results were based on responses from 42 programs operating in 28 states. Approximately 90 percent of the programs in the second study were established after 1980 and emulated the agricultural extension model, presented and analyzed in Cooper (1994) and Feller (1993b), as their prevailing model.

According to Clarke and Dobson, there are two types of organizational structures for the state technology transfer programs: university-based or locally-based. Their survey results indicated an equal preference between the university-based or locally-based. As far as the university-based programs, a major university in the state, notably a land grant institution, most commonly administered the programs. Georgia Tech's Industrial Extension Service, Maryland's Technology Extension Service, and Iowa's Center for Industrial Research and Service are all outstanding examples of the university-based program in the US. Each of these programs has been in existence for over 30

years, was located at a major university, and had regional offices with technical, business, and support staff.

On the other hand, locally-based programs were for the most part administered by multiple service providers and were state supported. According to Clarke and Dobson, a high percentage of these programs were less than 20 years old, had a central office at a non-university location, and did not have regional offices across the state.

In terms of funding sources, Clarke and Dobson’s research did not differentiate between the university-based and the locally-based programs. However, they did identify the source of funding in their study. Figure 4 provides a breakdown of the funding by source of funds.



**Figure 4. Funding by Source of Funds**



As far as a breakdown of the clients analyzed by Clarke and Dobson's study, small manufacturers represented over 60 percent of the total referrals. Medium and large firms accounted for 32 percent and 5 percent respectively. According to Clarke and Dobson, the structure of the program directly affected the types (or sizes) of clients served and how many were served on a yearly basis. The one-on-one program assisted fewer clients, while the brokering programs assisted more clients.

Lastly, in their study, Clarke and Dobson concluded their efforts by discussing some of their lessons learned from the state extension programs. The researchers also provided several relevant lessons that were applicable to the proposed hybrid models. Their more important lessons were:

1. Direct on-site services continue to play an important role in reaching manufacturers.
2. Most programs do not charge for the services of the manufacturing extension specialist (United States - General Accounting Office, 1996a). However, a few of the programs charge a fee for service, and a few others attempt to recover costs. Overall, all of the programs stated that the fee-for-service concern played an important part in whether the manufacturer used the program's service or not (Masten & Hartmann, 1993). Also, almost all the manufacturers, with the exception of the large firms, mentioned they were unable to pay a sizable fee for services offered. However, most of the state programs

pointed out that a small fee might be acceptable by the small and medium manufacturers. All in all, almost half of the surveyed programs did not charge a fee, while others used a structured fee system (21%), cost recovery (15%), seminars and workshops only (9%), or matching fees (9%).

In summary, Clarke and Dobson's two comprehensive research studies provide important and significant information regarding state technology transfer programs, the various types of state programs, how they are funded, and their most common delivery mechanism. Specifically, Clarke and Dobson's suggestions addressed some of the fundamental concerns raised in Section 1.6 of this study - Unanswered Questions.

### **2.4.3 Hoff's Work**

In 1997, Kristen Hoff developed a technology adoption continuum that incorporated risk factors. The continuum recognizes technology adoption/rejection decision outcomes. In her study, she identified nine technology risk factors and four firm characteristics as potentially having major effects on the technology adoption/rejection decisions of manufacturing firms. The set of nine risk factors are: incompatibility, discontinuity, non-trialability, indivisibility, incommunicability, time to implementation, time to realization, difficulty of modification, and irreversibility. The four firm

characteristics are: firm size, technical expertise, technical progressiveness<sup>6</sup>, and satisfaction with past experiences.

Her study looked at the technology transfer decisions of the wood products industry of the South Central United States, specifically Arkansas, Louisiana, Mississippi, Oklahoma, and Texas. Her continuum considered six different technologies<sup>7</sup> and their deployment potential at wood products manufacturers. A multinomial logit model captured the manufacturers' adoption and rejection attitudes.

Her results confirmed several previous technology transfer propositions. First, with regard to the incompatibility risk factor<sup>8</sup>, her research confirmed that the higher the perceived incompatibility of a technology, the higher the adoption resistance. This confirms prior propositions that compatibility may adversely affect rejection behavior (Ram, 1987) and that compatibility positively affects adoption behavior (Rogers, 1995). Her study was the first time that support had been found for both propositions. Because of this finding, there is a need for technology developers to provide on-site training with the purchase/acquisition of technology, to improve efforts to convey the technology's advantages to gain support from upper management, and to increase (when possible) the options available with a technology that make it easier to fit into a particular manufacturing line. Furthermore, this finding extends beyond the range of adoption and

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<sup>6</sup> Technical progressiveness referred to two distinctive efforts by a firm: (1) a firm's attitude towards developing technical expertise and allowing for experimentation, and (2) a firm's number of trade shows attended in the last year.

<sup>7</sup> The six different technologies are: thin saw kerf technology, CNC machining, water-based finishes, self-managed/cross functional work teams, statistical process control, and pc-based production control.

<sup>8</sup> Hoff's incompatibility factor was a combination of three sub-factors: how much support upper management gave to the adoption of the technology; how much training was required to implement the technology; and how well a technology fits into current production systems.

nonadoption decisions to adoption, leaning towards adoption, neutrality, leaning towards rejection, and rejection decisions when manufacturers consider a particular technology (Hoff, 1997).

The second set of technology transfer propositions that were confirmed relates to the difficulty of modification risk factor. Her research showed that firms that perceive a technology to be difficult to modify for their manufacturing system were more likely to reject the technology than firms that perceived the technology to be less difficult to modify. Moreover, firms that perceived a technology to be less difficult to modify for their manufacturing system were more likely to adopt the technology than firms that perceived the technology to be more difficult. These results confirmed Ram's (1987) previously untested proposition that increased amenability to modification reduces the probability of rejection. However, Hoff's study also indicated that increased amenability to modification increases the probability of adoption. Altogether, these indications also confirmed Robertson and Gatignon's (1986) and Gatignon and Robertson's (1989) propositions that the more standardized the technology, the more rapid the adoption and diffusion of that technology would be in a competitive environment (Hoff, 1997). Again, due to this finding, there is a need for technology developers to provide technologies that are more easily modified to fit into different manufacturing systems. For example, developers of thin blade saws could create adjustable fittings so the blades could be fitted onto a variety of arbors (Hoff, 1997).

Overall, Hoff's work suggests that marketing, commercialization, and technology transfer efforts should address the risk factors on the adoption continuum as a whole, especially incompatibility and difficulty of modification. Furthermore, a technology transfer program's infrastructure should emphasize these efforts for successful deployment, especially at small manufacturers. The director of such a program should seek to transfer technologies inclusive of the adoption continuum. This involves: seeking to transfer a technology through individuals who can understand the customer's current manufacturing system and the newly developed technology; performing a needs assessment of the manufacturer, and translating this assessment and communicating it back to the individuals in the innovating organization who developed, designed, and produced the technology (Hoff, 1997). This three-step process could ensure the development of a robust and flexible state technology transfer program.

Hoff's work also suggests that determining a firm's position on the adoption continuum is a crucial first step, more so than determining the risk factors that could increase or decrease a firm's adoption resistance. According to Hoff, technology transfer agents, such as sales people, extension agents, etc., can be utilized to assess a firm's current position along the continuum quickly and accurately. Such a first step ensures that the appropriate risk factors are addressed to allow for successful transfer of the technology to the potentially adopting firm. Essentially, the goal of manufacturers is not to adopt technology just to adopt technology nor to reject technology just to reject technology (Hoff, 1997). But rather, the goal of manufacturers in the technology adoption/rejection decision is to adopt the right technologies for their firm using the most

efficient and effective means. These means include the different technology transfer decisions, processes, and approaches to accommodate a firm's needs and competitive advantages.

#### **2.4.4 Collins's Work**

In 1998, Terry Collins presented an approach for developing a comprehensive state technology transfer program for small manufacturers. His research effort suggested five options for technology transfer dimensions that can be used to develop a state technology transfer program. The dimensions were: business assistance, governmental compliance, research and development, technical assistance, and human resource management. Essentially, the success of a program depended upon the comprehensive nature of the program and the locality of the program.

His study looked at the technology transfer decisions of small manufacturers in the state of Oklahoma. Using a survey questionnaire, Collins' study established a preliminary comprehensive view on the constructs of a state technology transfer program. Critical factors such as technology transfer dimensions, technology transfer attributes, and organizational design and structure, provided a comprehensive view for technology transfer program development, from the ground up. His model allows a technology transfer specialist to select successful attributes that would match the needs of manufacturers at the regional and state-wide levels.

Another aspect of his research study determined the overall attitude of Oklahoma small manufacturers towards the available technology delivery systems in the state (Figure 2, page 72). His results indicated that approximately 75 percent of the surveyed manufacturers were not aware of these delivery systems, except for the Vo-Tech and the University Systems, which were more recognized than the other programs because they have an established network of locations across the state (Collins, 1998). However, since Collins' study was the first to inspect this aspect, it was not possible to establish a historical trend of utilization by the manufacturers.

Overall, his results indicated the following with respect to each technology transfer dimension. For technical assistance, the respondents mentioned assistance with manufacturing technologies as their most important need. For research and development, the respondents mentioned existing products, company strategy, new product development, and confidentiality as most important. As far as the governmental compliance dimension, the respondents mentioned non-compliance, governmental compliance assistance, and OSHA safety and loss as most important. For business assistance, the respondents mentioned market study as most important. Finally, for the human resource management dimension, the respondents mentioned employee benefits, insurance, and workers' compensation training as most important.

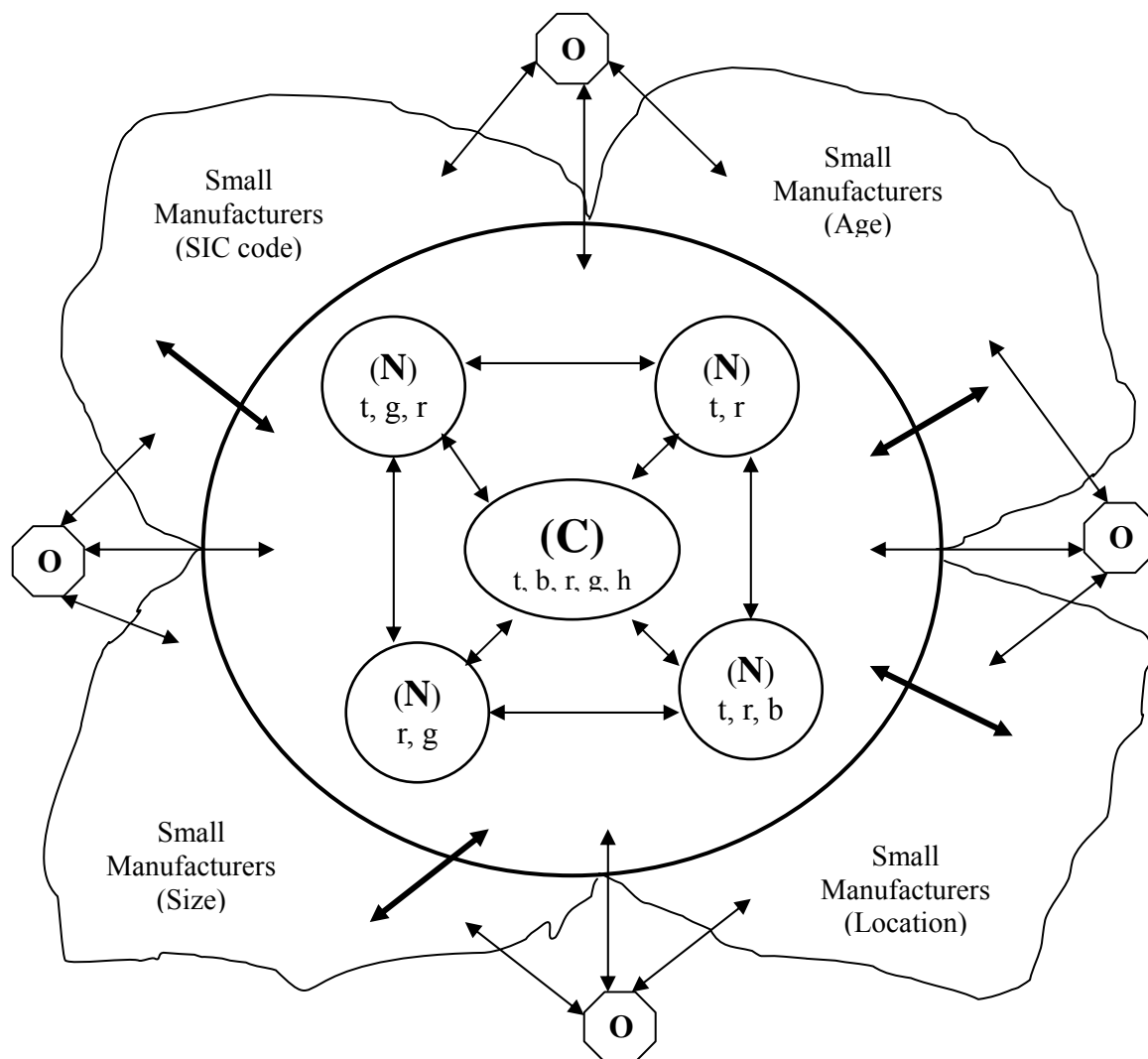
His study also suggested the following general insights into technology transfer services, all of which supported previous research studies by Osborne, Clarke and Dobson, Feller, and Cooper:

1. Over half of the small manufacturers indicated that they would not be willing to pay for technology transfer services. This finding supported the research of Osborne (1989) with respect to financing technology transfer services.
2. The number of hours away from the business to attend a technology transfer meeting was not an issue to the small manufacturers. The manufacturers were equally split between three choices: 4 hours, 4-8 hours, and greater than 8 hours. In fact, some manufacturers in his study mentioned that they would even be willing to stay however long it takes to get the appropriate technology transfer training.
3. The multiple classification of variance analysis revealed the following: the two-way interaction of the AGE and SIZE variable relationship was significant for the technical assistance dimension, the one-way interaction of the SIC variable was significant for the governmental compliance dimension, the one-way interaction of the AGE variable was significant for the business assistance dimension, the one-way interaction of the SIZE variable was significant for the research and development dimension, the one-way interaction of the SIC variable was significant for the human resource management dimension, the one-way interaction of the AGE variable was significant for the organizational structure variable, and the one-way interaction of the AGE variable was significant for the company location variable (Metropolitan and Rural).



4. The multiple classification of variance analysis also revealed that the SIC and SIZE variables were not significant for the company location variable (Metropolitan and Rural). There was a diversified mixture of all types of industries and sizes of small manufacturing companies represented across all 77 counties of the state of Oklahoma.
5. Larger, younger firms rated the technical assistance dimension higher than smaller, older manufacturing companies.
6. Manufacturing firms classified in the 22XX, 23XX, 26XX, and 35XX SIC codes rated the governmental compliance dimension higher than did manufacturers in the 36XX and 37XX SIC codes.
7. Younger or lesser-established manufacturers had a higher need for the business assistance dimension and the attributes of loan processing, venture capital assistance, etc.
8. Manufacturers employing between 76 and 250 rated the research and development dimension much higher than did manufacturers with 25 or fewer employees.
9. Manufacturing firms classified in the 20XX and 37XX SIC codes rated the human resource management dimension higher than did manufacturers in the 35XX and 36XX SIC codes.
10. Newer manufacturing firms found organizational structure more important to their business than a more established, older manufacturing company.

Finally, his results indicated the following with respect to the organizational structure of Oklahoma's technology transfer program. Oklahoma small manufacturers need their technology transfer program to provide multiple dimensions and attributes and request this assistance to be delivered in the form of a single source comprehensive state technology program. Collins proposed a modified university-based comprehensive structure to accommodate the needs of the small manufacturers. First, the program should consider the SIC code, age, location, and size of the manufacturer as it delivers specialized services. Second, a university would still remain as the core with multiple nodes (regional offices) strategically located through out the state; however, the location of the regional offices would be selected based on the infrastructure (US Technology Policy Element) of existing state facilities, such as the state Vocational Technical centers, a district office of the Oklahoma Cooperative Extension Service, or a technology commercialization assessment center. This allows the small manufacturer to be closer to the state-wide program's facilities, thus permitting better linkage and fit of the transfer and utilization of technologies to the small manufacturer (Collins, 1998). Specifically, regarding the location of such centers, manufacturers indicated they were not willing to drive more than 50 miles. This limitation would allow for a 4-8 hours technology transfer meeting. A representation of this modified university-based comprehensive structure for a state technology transfer program is provided in Figure 5.



Comprehensive Structure University - Core (C)  
 Regional Offices - Nodes (N)  
 Outside Resources (O)  
 Technical Assistance (t)  
 Business Assistance (b)  
 Research and Development (r)  
 Governmental Compliance (g)  
 Human Resource Management (h)

**Figure 5. Organizational Structure for a State Technology Program in Oklahoma**

## **2.5 Organizational Structures of Technology Transfer Approaches**

One of the objectives of this study is to determine the most desirable organizational structure for a state technology transfer program that will satisfy the technological needs of small manufacturers, both regionally and statewide, in a competitive environment. To accomplish this, past research on organizational strategy and design and on technology transfer mechanisms was reviewed. This process did reveal a set of traditional and transformational models that can be used.

### **2.5.1 Organizational Strategy and Design Literature**

A review of Afuah (2003), Daft (1995), Miles (1989), Nelson and Quick (1994), and Schermerhorn (1996) reveals that there are four basic types of organizational structures: functional, divisional, matrix, and network. These four structures were analyzed to determine how they would fit in a state technology transfer model. First, the functional structure focuses on one particular area of specialization in the organization. Accordingly, if this option was adopted, the state technology transfer program would be a uni-dimensional program and provide only one type of assistance, such as business assistance, technical assistance, research and development, governmental compliance, etc. The one advantage of this type of structured program is the high level of technical support available to small manufacturers to solve problems using its highly specialized technical staff.

The second identified organizational structure was the divisional structure. This option groups together a program's human and material resources to work together either on similar products, in the same geographical region or with the same customer base. However, this type of structure was not used by any of the identified state technology transfer programs.

The third basic type of organizational structure identified was the matrix arrangement. This configuration uses a combination of the divisional and functional structures, where resource teams belong to multiple work groups. The resources of the technology transfer program are assembled into teams from the various program's groups, such as from the functional, divisional, product, and/or project departments, for new product development, long and short term projects, securing capital funding, securing venture capital, etc. Currently, two prominent comprehensive state technology transfer programs use the matrix organizational structure: Georgia and Maryland.

The fourth type of organizational structure is the network configuration. In this arrangement, a state program has one central core location with an established network of external support mechanisms and services. When the central core location needs a specific type of assistance, the central core location would contact its network of external resources and work directly with them to meet the manufacturer's request. The Oklahoma Alliance for Manufacturing Excellence, Inc. is an excellent example of the network organizational structure. The Alliance uses a network of broker agents representing the entire state to work as liaisons with the small manufacturer. These

broker agents, once contacted, would select the appropriate resources and methods suitable for meeting the technology transfer needs of the small manufacturer.

Lastly, upon further review of the organizational strategy and design literature, another type of organizational structure was identified. This transformational model or “Metamodel” is more complex than the previous four basic types because it uses a macro approach to the creation, maintenance, and structure of an organization. Furthermore, this model has two distinctive dimensions: structural and contextual. The structural dimension, which describes the internal characteristics of an organization, refers to eight key internal structural areas of a state technology transfer program: formalization, specialization, standardization, hierarchy of authority, complexity, centralization, professionalism, and personnel ratios. On the other hand, the contextual dimension, which characterizes the whole organization, refers to six key contextual areas of a state technology transfer program: size, organizational technology (or technical complexity), environment, goals and strategy, culture, and integration (Banner & Gagne, 1994; Daft, 1995; Goold & Campbell, 2002; and Nelson & Quick, 1994). Hence, the “Metamodel” macro approach integrates all 14 areas into the design of a state technology transfer program.

Overall, these fourteen structural and contextual key dimensions of an organization are interdependent. For example, large organization size, a routine technology, and a stable environment all tend to create a state program that has greater formalization, specialization, and centralization (Daft, 1995). Essentially, these

dimensions offer a basis for the measurement and analysis of a program's characteristics that a casual observer cannot see at first glance. Although their impact on a state technology transfer program is significant, their impact on the transfer processes is equally significant, if not more.

For this study, two dimensions are of particular interest. The first is the complexity structural dimension. The "Metamodel" presents three levels for this dimension within an organizational structure (Daft, 1995): vertical differentiation, horizontal differentiation, and spatial dispersion. Vertical differentiation is the number of levels in the hierarchy within the organization, such as the state technology transfer program director, associate directors for each technology transfer dimension, and the specialists within each dimension of the technology transfer program. Horizontal differentiation, on the other hand, is the individual technology transfer dimensions - (i.e., business assistance, technical assistance, research and development, governmental compliance, and human resource management) that are linked horizontally across the state technology transfer program to provide assistance to the small manufacturer. And finally, the last complexity structural dimension level within an organizational structure is spatial dispersion, which refers to the off-site regional satellite offices of the state technology transfer program.

The second dimension is of particular interest to this study because it relates mainly to the technological status of the receiving entity, which is in this study the small manufacturer. This dimension, a contextual dimension, is usually referred to in the

literature as either organizational technology or technical complexity of the organization. Essentially, this dimension assesses the nature of the manufacturing systems or subsystems within the organization, which include the actions and techniques used to change organizational inputs into outputs.

The stream of research on this dimension is interested in how organizations shape and are, in turn, shaped by technological change. This literature sheds considerable light on how organizational architectures, capabilities, and senior teams affect both a firm's ability to shape technological change and to compete effectively in today's competitive environment when technologies change (Tushman & Anderson, 2004). Additional discussion on this important contextual dimension is contained in Section 2.6 of this study.

### **2.5.2 Technology Transfer Literature**

With regard to the technology transfer literature, only a few studies talked about the organizational structures of the various state and federally funded technology transfer programs (Clarke and Dobson, 1991; Collins, 1998; Osborne, 1989; Smilor & Gibson, 1991; and Waugaman, 1990). The Smilor and Gibson study concentrated on the structure of R&D consortiums and new organizational forms for research and development. Their results indicated that four variables play a key role in the development of a program: communication, distance, technological equivocality, and motivation. This role is



important for technology transfer between R&D consortium programs as well as within R&D consortium programs.

Similarly, Waugaman's research efforts focused on German University-Industry technology transfer activities, with respect to the overall system of higher education. His study compared the organizational structure of Germany's higher education systems to the United State's university technology programs. A noteworthy outcome from his research is that there are fundamental and structural differences in how the university-based programs were structured and financed between the two countries.

As for the next three groups of researchers, they contributed the most relevant information on technology transfer organizational structures in the US. First, Osborn's efforts, as discussed earlier, identified four categories of organizational structure: passive, broker, active, and comprehensive. These four categories represented a state technology transfer program's organizational structure as well as the technology delivery methods to the manufacturers. Second, Clarke and Dobson's work, as discussed earlier, revealed two distinct types of state technology transfer programs: university-based and locally-based. Moreover, each type of program uniquely deploys technologies to small manufacturers. The advantage of the recommended university-based program was three-fold: it offered direct access to university resources; provided graduate students to assist in the research and development activities; and made available the university's stable funding sources. Lastly, Collins' study, as discussed earlier, promulgated the need to modify the university-based model to include specialized services for manufacturers. Specifically, his model

suggested that a manufacturer's age, location, size, and SIC code could be included in the model's infrastructure and design to render specialized services efficiently and effectively. This modified university-based model accommodates more small manufacturers. Essentially, this model allows for better interaction between the state program and the manufacturers, and thus increase the likelihood of successful technology transfer.

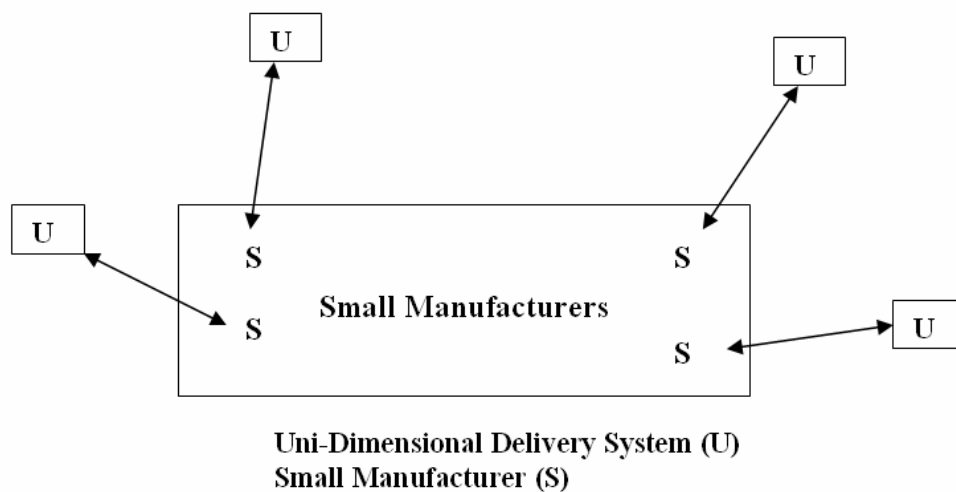
In general, the increasing competitive pressures in today's global market, starting from the 1980's to the present, has heightened the interest in providing robust and successful federal and state technology transfer programs. Recognizing and implementing the appropriate organizational structure of such programs is a critical step in that direction, which is to remain competitive and to retain a viable manufacturing base. For example, starting from the mid-1980's, Pennsylvania, Indiana, and New York adopted a more locally-based technology transfer delivery system to provide support to their local manufacturers. Likewise, Ohio and Virginia used their well-established community college system (a localized structure) to administer technology transfer within their borders. New Jersey chose to provide technology transfer services through its industry-specific technical assistance outreach centers, which are strategically located across the state. Although the New Jersey programs are university-based, they are administered by a private, non-profit organization and they are not situated at land grant institutions. And finally, Oklahoma's The Alliance, established in the early 1990's, is a good example of the state's efforts to aid small manufacturers in today's competitive environment. As mentioned earlier, The Alliance is a locally-based broker-network

structure, which provides a multitude of services to the small manufacturers located across the state.

### **2.5.3 Organizational Structures for Technology Transfer Programs**

The above literature identified three basic types of organizational structures as important models for a state technology transfer program: the uni-dimensional structure, the locally-based network structure, and the university-based comprehensive (holistic) structure. The uni-dimensional model represents a state program with one central location within the state and it has no regional or local offices. A program with such a model provides assistance in only one technology transfer dimension. The functional characteristics of this structure are limited in the sense that this arrangement lacks efficiency in communication and coordination (Afuah, 2003; Miles, 1989; and Schermerhorn, 1996). Small manufacturers would contact the uni-dimensional program and work directly within that program's delivery system. However, there is no interaction between the different uni-dimensional programs' delivery systems. A representation of this type of program is provided in Figure 6.

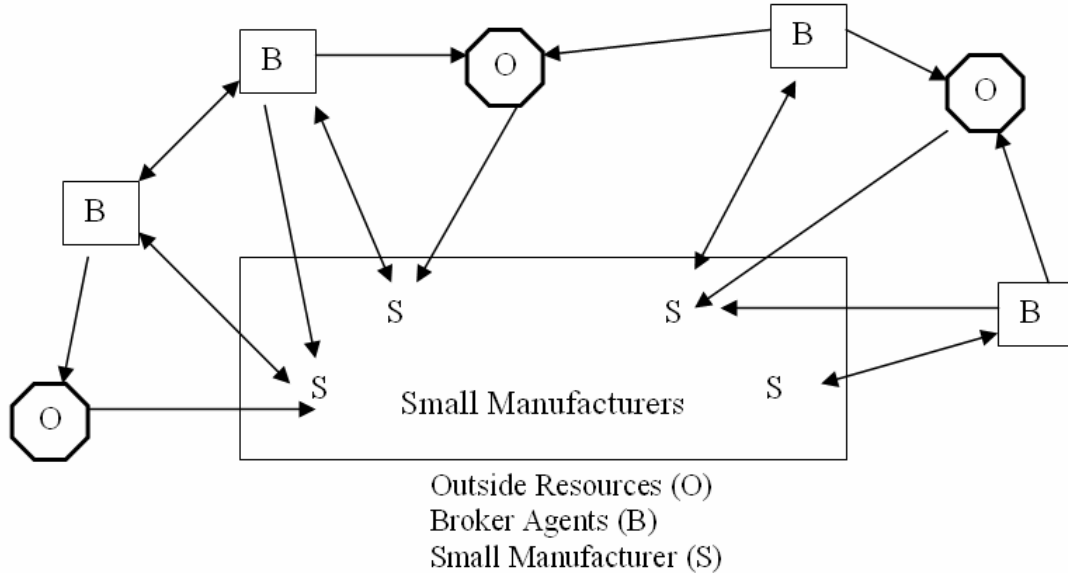
The second structure is the locally-based network model, which is based on a brokered system representation. In this program, the broker agents are located strategically across the state to maximize their assistance to small manufacturers. These agents are part of a larger brokering network, and each broker then serves a particular



**Figure 6. The Uni-Dimensional Structure**

region or territory. Unlike in the uni-dimensional arrangement, the functional characteristics of this structure are not limited. The broker agents do attempt to maintain efficiency in their communication and coordination activities, especially with outside resources not easily accessible to the small manufacturers in their region or territory (Afuah, 2003; Miles, 1989; and Schermerhorn, 1996). For example, if a broker agent does not have the expertise needed to solve a particular problem, they can access the rest of the network within the state for feedback and assistance. A representation of this type of program is provided in Figure 7.

Finally, the third basic type of organizational structure for a state technology transfer program is the university-based comprehensive (holistic) structure. This model type is a mixture of a matrix and network organization so small manufacturers can take advantage of one-on-one assistance capability and experienced teams of specialists.

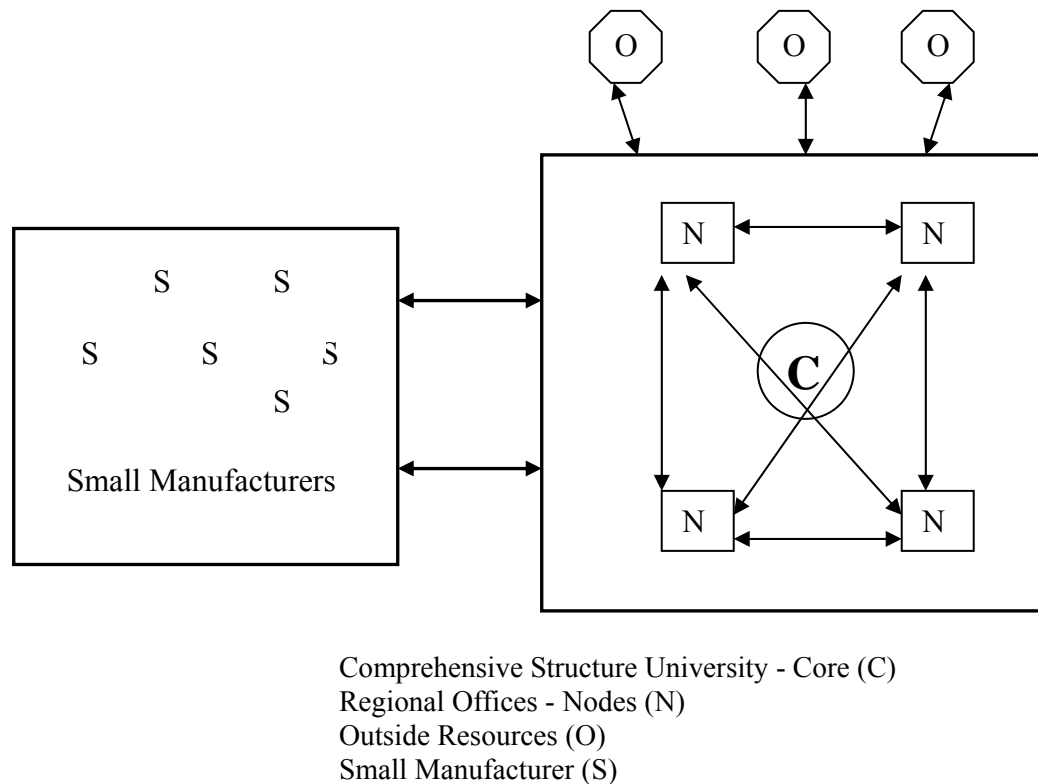


**Figure 7. Locally-Based Network Structure**

Furthermore, regional satellite offices are located strategically across the state in proportion to the specific needs of small manufacturers. The functional characteristics of this structure are vast in the sense that this arrangement does not impede communication and coordination efforts in meeting the needs of small manufacturers (Afuah, 2003; Cooke & Mayes, 1996; Gaynor, 1996; Stevenson, 2002; and Tushman & Anderson, 2004).

This model type is an open system with the university at the core of the structure. This allows either pass-through interaction at the core or direct interaction between the regional nodes. Also this arrangement allows for a decentralized management philosophy with each node making independent decisions. If a challenge arises, such as a new product or process, then teams are formed within the structure using any active node, and

the node closest to the small manufacturer manages the project. In addition, outside resources, such as consultants, experts, federal research and development laboratories, equipment manufacturers, and suppliers are utilized as needed. A representation of this type of program is provided in Figure 8.



**Figure 8. University-Based Comprehensive Structure**

## 2.6 Technical Complexity of Manufacturing Operations

It is certainly the case that the competitive environment influences organization design. Considering that form usually follows function, the form of the organization's

structure should be tailored to fit the needs of the manufacturing technology to remain competitive (Feller, 1993b). For technology transfer programs to be successful in a competitive environment, they need to consider an organization's structure and its organizational-level technologies and production technology status (Daft, 1995). Specifically, a technology transfer program should accommodate the technical complexity of an organization's operations, especially the associated manufacturing operations and manufacturing technologies, which include traditional manufacturing processes and new computer-based manufacturing systems.

A study conducted in 1958 by Joan Woodward, a British industrial sociologist, evaluated the organizational infrastructure of manufacturing firms. This study was the first and most influential study reflecting on manufacturing technology and its affect on an organization. In the study, one hundred British manufacturing firms were surveyed to determine their structural characteristics, their dimensions of management styles, and their type of manufacturing process. One of the most significant outcomes of her study was the development of a scale for the technical complexity of the manufacturing processes at the firms. This technical complexity represents the extent of mechanization of the manufacturing processes (Daft, 1995; and Woodward, 1958). High technical complexity meant machines perform most of the work, while low technical complexity meant workers play a larger role in the production processes.

Woodward's scale of technical complexity originally had ten categories; however, today the ten categories are consolidated into three basic technology groups (Daft, 1995). The three groups are as follows:

1. Group 1 - Small-Batch and Unit Production. Manufacturers in this group tend to be job shop operations that manufacture and assemble small orders to meet specific needs of customers. Custom work is the norm in this group of manufacturers and their small-batch production facilities rely heavily on the human operator. Therefore, the production process is not highly mechanized. An example of this type of work is made-to-order manufactured products, such as specialized construction equipment, custom electronic equipment, and custom clothing.
  
2. Group 2 - Large-Batch and Mass Production. This group of manufacturers tends to have manufacturing processes characterized by long production runs of standardized parts. Since it is a large-batch production operation and customers do not have special needs, the output often goes into inventory from which orders are filled. Examples of this group include most assembly lines, such as for automobiles or trailer homes.
  
3. Group 3 - Continuous Process Production. In this group, the manufacturer's entire process is mechanized. There is no starting and stopping. Therefore, this represents mechanization and standardization one step beyond those in an assembly line, as in Group 2. In this category, automated machines control the continuous process, and



outcomes are highly predictable. Examples of this group include chemical plants, oil refineries, liquor producers, and nuclear power plants.

Altogether, the three technical complexity groups highly influence the design of a state technology transfer program's infrastructure. By identifying the technical complexity of an organization, especially small manufacturers, a technology transfer program can more easily identify and assess the technology needs of the organization and deploy the technology accordingly. This perspective can compensate for the small manufacturer's lack of ability and experience and limited resources to develop and transfer new technologies internally – (i.e., within the organization) (Daft, 1995; Nelson & Quick, 1994; Palminteri, 1993; Salvendy, 2001; Woodward, 1958; and Woodward, 1965). In other words, identifying the technical complexity of an organization can lead to successful external technology transfer.

Currently, there are small manufacturers in the state of Oklahoma that fit into all three categories. Therefore, from a design and functional standpoint, determining the technical complexity of a small manufacturer is an important factor to consider in establishing a state technology transfer program for the state of Oklahoma. This is especially critical for small manufacturers in today's highly competitive environment. Specifically, identifying the technical complexity offers yet another view of technology and its relationship to organizational design within a manufacturing setting. This additional view is based on the concept of technological interdependence and on the pattern of an organization's work flows, especially the manufacturing operation flows.

As far as the concept of technological interdependence, Nelson and Quick (1994) define it as the degree of interrelatedness of the organization's various technological elements, such as human resources, machines, materials, information, finances, facilities, and technical experience. All of these elements are considered inputs of the organization as it strives to convert them into outputs, which are the products and services that the organization offers to the external environment. Consequently, as the technological interdependence in an organization increases, an organization's complexity - (technical complexity, design, and/or structure) also increases. This increase has a profound effect on the technology transfer decisions at the organization level as well as on a state program level. This increase requires more managerial coordination than market coordination at both levels (Burgelman, Christensen, & Wheelwright, 2004). Most notable is the situation where a small manufacturer needs more advanced technologies to meet demands, which then requires greater technological interdependence. This challenging situation translates to different technology transfer decisions, processes, and approaches to accommodate the small manufacturer's needs and competitive advantages.

Overall, determining the relationship between technology and structure is a critical factor when designing a state technology transfer program. The technology needs of each group – (1 - Small-Batch and Unit Production; 2 - Large-Batch and Mass Production; or 3 - Continuous Process Production) are different and thus demand a flexible and robust state technology transfer program. This could be obtained and maintained by having different and accommodating missions for the various departments in the state program/s. The remaining two sections of this chapter will discuss these options.

## 2.7 Technology Transfer Programs

The overall evaluation of technology transfer programs to aid in solving societal problems customarily involves considering the relationship between potential technical performance and the required investment of resources. Although such performance-versus-cost relationships are clearly useful for choosing between alternative technologies, they do not by themselves determine how much technology can justifiably be purchased and deployed (Betz, McGowan, & Wigand, 1984). This latter determination requires knowledge of the relationship between social benefits and justified social cost. Thus, the two relationships - (performance versus cost and social benefits versus justified social cost) – may then be used jointly to determine the optimum investment of societal resources in a transferred technological approach to a societal need. It is most certainly the case that transferred-information processing (cognition), personality, social factors, economic factors, and cultural factors interact to determine individual and societal responses to technology transfer issues and policies, especially the policies created in response to a competitive situation, such as today's manufacturing environment (Bijker & Law, 1992; Gupta, 2001; and Theodoulou, 2002).

Since technological growth and development is rapidly turning-over, technology transfer programs need to be dynamic, resilient, and holistic in nature. Since technology itself is neither economically and culturally neutral (it never has been and never will be) (Willoughby, 1990), there are social interference factors and environmental preconditions and postconditions to address. Essentially, decisions relating to technology transfer

approaches need to be accommodating and inclusive of the given environment, both from the business environment and firm's viewpoints and circumstances (Betz, McGowan, & Wigand, 1984; Douglas & Wildavsky, 1982; Hazeltine & Bull, 2003; and Lewis, 1990).

Considering that manufacturing is an essential part of society, developing the right technology transfer program is critical to maintain society's manufacturing base. Furthermore, a technology transfer program's mission determines its critical role, especially in a competitive environment, and a firm's decisions determine its technology transfer management processes. One of the objectives of this study is capturing a picture of the right program given the needs of the small manufacturers and capturing a picture of the applicable choices and decisions of the small manufacturers given the attitudes of the small manufacturers (Dorf, 2001).

For state technology transfer programs, the two choices available to capture the important items mentioned above are an appropriate technology program and a technology choice program. These two types of programs can play important roles in today's "fully competitive" market<sup>9</sup> (Agmon & Von Glinow, 1991; and O'Sullivan & Sheffrin, 2003). They can alleviate the competitive pressures experienced by US

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<sup>9</sup> According to O'Sullivan and Sheffrin (2003), a perfectly competitive market is a market with a very large number of firms, each of which produces the same standardized product and takes the market price as given, since the market is so small that it does not affect the market price of the good it produces. This market reflects complete and equal information, and everyone possesses perfect information. Therefore, technology can be transferred separately from other products, processes, people, or organizations, which means there is no unique problem with technology transfer. However, today's manufacturing environment is highly competitive. Today's market is a fully competitive market. There is international trade for all goods and services, including technology, which cannot be traded separately from other products, processes, people, or organizations. This fully competitive market reflects incomplete and unequal information, and everyone does not possess perfect information. Therefore, there is a unique problem in trading with technology (or technology transfer) (Agmon & Von Glinow, 1991).

manufacturers. They can also reduce the difficulties associated with technology transfer decision making related to both technology selection and technology delivery system selection (Chen, 1996).

In an appropriate technology transfer program, the technology is understood to be appropriate. This appropriateness is reflected in the technology being tailored to fit the psychosocial and biophysical contexts prevailing in a particular location and period (Willoughby, 1990). In other words, the technology in an appropriate technology transfer program matches both the user and the need in complexity and scale in the given circumstances (Hazeltine & Bull, 1999). In such a program, the technology is given to prepared workers, and because of this preparation, the workers achieve quality results easily and efficiently.

The appropriate technology in an appropriate technology transfer program is inherently small scale and does not easily attract attention. Its benefits can be overlooked even though the many small improvements it produces add up to more than that of a few large-scale, highly visible successes. In general, an appropriate technology program offers: goods and services on a long-term sustained basis, an avenue for manufacturing independence, and gradual transition and flexibility in manufacturing operations (Hazeltine & Bull, 1999). Moreover, the goods and services meet previously described needs for the material necessities of the manufacturer. Also, the independence and gradual transition components encourage attitudes effective in supporting confidence and responsibility in the manufacturing operations and in the manufacturing industry as a

whole. These two components also foster preservation of the manufacturing base and of the manufacturing identity and culture of small manufacturers (Hazeltine & Bull, 2003).

In a competitive environment, a small manufacturer can benefit from an appropriate technology transfer program because the small manufacturer is assured that a full range of factors, such as Hoff's factors on the technology adoption continuum (Hoff, 1997), are researched and analyzed, prior to making technology recommendations and technology transfer decisions. Also, by using an appropriate technology, a small manufacturer is not required to make unnecessary time and financial commitments to benefit from the technology. For example, there is no need to hire consultants or well-trained specialists to assist with the deployment processes. Another benefit is the non-disruptive nature of the appropriate technology. The manufacturing culture and operations can be slowly (efficiently) adapted to accommodate the technology. Lastly, appropriate technology fosters cooperation, frugality, and satisfaction in the workplace, which translates into a stronger and more cohesive workforce and manufacturing operations overall (Hazeltine & Bull, 1999).

The criteria for deciding if a technology is appropriate can be formalized into the following three guiding questions (Hazeltine & Bull, 1999):

1. Does the technology provide the goods and services it must at a reasonable cost, including long-term costs?

2. Does the technology have desirable influence on the manufacturing environment now and will it in the future?
3. Does the technology promote a healthy lifestyle for the worker?

Developing an appropriate technology state technology transfer program involves formulating answers to the above guiding questions. Hazeltine and Bull (2003) suggest the following six-step approach:

1. *Clearly identify the problems of the small manufacturer.* Applied research methods can be used to identify, select, and develop appropriate technology.
2. *Clearly identify the nature and purpose of the appropriate technology prior to deployment.* The transfer specialist, development scientist, policymaker, manufacturing engineer, plant manager, and plant engineer must all have and share a common definition of the nature and purpose of the considered appropriate technology.
3. *Clearly meet the needs of the small manufacturer.* The considered appropriate technology needs to recognize the circumstances and situations of a small manufacturer and the surrounding intended and unintended community consequences.
4. *Perform a technological assessment.* To document the progress of the transfer, a technological assessment is necessary. This assessment is aided by establishing an industrial technological information bank, with possible

regional and sectoral locations and by establishing a national center for the exchange of technological information, notably for sharing research findings relevant to small manufacturers. This could enable a survey of appropriate technologies available and an assessment of their respective merits, leading to technological choices.

5. *Transfer of technologies.* All states should cooperate in evolving a national code of conduct for the transfer of technology, corresponding in particular to the special needs of small manufacturers. Also, this code could include a worker oriented-technology transfer development standard.
6. *Information and adaptation.* Developed small manufacturers could assist other small manufacturers by facilitating access to relevant information, to other suited technologies, and to new uses of existing technologies. This should be permitted with favorable terms and conditions, especially to adapt the technologies to the small manufacturer's local needs.

All in all, an appropriate technology state technology transfer program can be regarded as a system's view for designing a state technology transfer delivery mechanism (Bijker & Law, 1992; and Jervis, 1997). Such a system's view addresses the following key infrastructures of concern to an appropriate technology state technology transfer program (Agmon & Von Glinow, 1991; Chen, 1996; Cohen & Noll, 1991; and Lewis, 1990):



- Catastrophic / beneficial potential of the transferred technology
- Controllability of the transferred technology
- Adaptability of the transferred technology
- Acceptance / threat potential of the transferred technology
- Familiarity of the transferred technology
- Equity concerns of the transferred technology
- Technical level / knowledge level potential of the transferred technology
- Perception / attitude concerns of the transferred technology

Absent the necessary time, energy, and resources to fully research and develop appropriate technology options, the second choice for a state technology transfer program is a technology choice program. This second option could still provide the required technologies given the needs of the small manufacturers; however, such technology solutions provide quick fixes and may not be the cheapest or generate the best long-term results (Willoughby, 1990). Unlike in an appropriate technology program situation, technology choice programs do not clearly attempt to answer definitively the questions - Appropriate to whom? Appropriate to what? And appropriate where? - (Betz, McGowan, & Wigand, 1984).

Essentially, choice technologies could be viewed as transitional or intermediary technologies, and in doing so, choice programs provide technological choices so that manufacturers can answer for themselves within their limited time frame what is appropriate from a range of alternatives (Betz, McGowan, & Wigand, 1984; and

Willoughby, 1990). In other words, choice programs do capture a picture of the applicable choices and decisions of the small manufacturers given the attitudes of the small manufacturers, but the picture is uncertain, especially for the long-term.

Generally, technology is deemed stabilizing if and only if the heterogeneous relations in which it is implicated (or transferred into), and of which it forms a part (the manufacturing setting), are themselves stabilized (Bijker & Law, 1992). In other words, if a transferred technology is stabilizing (i.e., successful deployment), then this is because the network of relations in which it is involved, together with the various strategies that drive and give shape to the network, reach some kind of accommodation<sup>10</sup> (Bijker & Law, 1992). However, unlike in an appropriate technology program situation where an accommodation is frequently reached, in a technology choice situation, an accommodation is reached occasionally. When an accommodation is reached, it implies that a critical mass was achieved. Specifically, this critical mass indicates that there was enough understanding and momentum in the transfer processes to successfully move a small manufacturer from the rejection to the adoption side of Hoff's technology adoption continuum (Hoff, 1997).

Technologies in a technology choice program generally have the following features (Betz, McGowan, & Wigand, 1984; Katz, 2003; and Lambright, 1979):

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<sup>10</sup> An accommodation is defined as a meeting of the minds between the transferor and the transferee, and this can be expressed in or through a variety of forms, shapes, or media - such as words, technologies, physical actions, and organizational arrangements (Bijker & Law, 1992).

1. It is not necessarily small scale. Thus, it is possible the technology: may not be replicated (or duplicated) throughout the manufacturing operations, may not be located near its market and its source of raw materials, and may not provide employment where the workers live.
2. On some occasions, it may involve low capital costs. Therefore, it can be set up within a small manufacturer's capacity for saving for investment in other productive enterprises, and if needed, the new manufacturing plant or facility for the technology is not beyond the ability and capability of the small business owner, especially to acquire the necessary capital.
3. It is labor intensive (or capital saving) so that it conserves scarce capital and creates additional jobs. However, this is true for the short-term only.
4. It uses simple techniques so that they are within the capacity of the workers, given their educational experiences, to master and develop for themselves.
5. It relies on local resources as far as possible so that the manufacturer's natural capabilities are developed further.
6. Its initial investment expenses have a multiplier effect on local employment.
7. On some occasions, it may allow manufacturers to escape financial and physical dependence, thus avoiding interruptions in the manufacturing operations.
8. It is profitable, and it may create a surplus for the manufacturer, which can be the manufacturer's source of future income and investment. This can

be an incentive for the manufacturer to undertake the investment in the first place. However, again, it may not be the cheapest or generate the best long-term results.

9. On some occasions, it may not be possible to define all the related cost drivers and risk factors. However, the deployment process could still continue, which means the deployment is a work-in-progress. There is no preset or predetermined learning curve for the technology.

The design parameters of technology choice programs usually do not factor in all the technical, economic, physical, human, cultural, social, environmental, public, intellectual, and political intended and unintended consequences, or a combination these consequences (Willoughby, 1990). Furthermore, within the field of technology-practice, technology transfer specialists harmoniously integrate all three mutually interdependent dimensions of technology management - socio-political (or Organizational), ethical-personal (or Cultural), and technical-empirical (or Technical), when planning, designing, and implementing an appropriate technology transfer program and especially when it is time for decision-making with respect to a technological deployment or several technological deployments. However, in technology choice transfer circumstances, the specialists might consider and integrate one dimension or two dimensions, but rarely consider and integrate all three dimensions (Pacey, 1983).

Technology choice transfer programs' activities effectively occur with or without "complete" context. Also, such activities lack an amount of dynamism as compared to

appropriate technology transfer program's activities (Willoughby, 1990). The goal of technology choice transfer programs is to achieve as best and as close as possible a good technological fit within small manufacturers' settings to effectively resolve their transfer concerns, problems, and requests, and therefore remain competitive (Reisman, 1994; Rubenstein, 1989; and Stobaugh & Wells, Jr., 1984).

In summary, the primary strategy of an appropriate technology state technology transfer program is to efficiently achieve a good fit between technologies and the contexts in which they are intended to operate. Such a program can choose from the available or not yet developed alternative or mainstream technologies. Furthermore, this program is well equipped to handle a variety of problems encountered by small manufactures, including but not limited to the areas of technology, society, and environment, separately or collectively. And the purpose of this program is geared for the long-term. Although, the technology transfer specialist/advisor cannot foresee into the future, the specialist/advisor can at least lay out the technology options and their associated features and possible consequences with more confidence.

On the other hand, the primary focus of a technology choice state technology transfer program is to efficiently assess the needs of small manufactures. Such questions as - what the manufacturer is trying to accomplish, what expertise and resources are available, and what unintended consequences may ensue – are answered in the quickest time possible to minimize downtime and to retain the manufacture's competitive advantages. Under this program, the technology transfer specialist/advisor provides

applicable technology solutions with the premise that they are temporary, short-term solutions for the given situations. Technology product design criteria, such as effectiveness, reliability, maintainability, reparability, and availability are not completely ascertained and available to pass on to the manufacturers. Such a program can also choose from the available or not yet developed alternative or mainstream technologies, and even appropriate technologies. However, in that unique situation, the appropriateness aspect is not fully realized by the manufacturer because the manufacturer selected adoption methodologies for deployment. This is discussed in greater detail in the following section.

## **2.8 Technology Transfer Processes**

An organization chooses to transfer technologies in one of two ways. The organization can either choose technology transfer adaptation processes or technology transfer adoption processes. Both options present advantages and disadvantages, especially when considered in combination with the state technology transfer program options discussed previously (Appropriate Technology and Technology Choice).

Moving technology from the research lab through production, marketing, and sales to the customer in a timely profitable manner has proven to be a difficult challenge even for the best managed US firms (Gibson & Smilor, 1991). The challenges of technology transfer are even magnified when crossing organization boundaries (Williams

& Gibson, 1990). For a small manufacturer operating in a highly competitive environment, this magnification increase is even greater. Basically, the manufacturer has an important decision to make after an applicable technology is found. To retain the competitive advantages, the manufacturer must confront the organizational boundaries outside the organization and the functional and managerial boundaries within the organization. This confrontation or challenge is unavoidable, and the small manufacturer must decide how to the best approach the situation quickly.

This situation at some point deals with the obstacles and barriers to the transfer process. Technology transfer is often a chaotic, disorderly process involving groups and individuals outside and within the organization who may hold different views about the value and potential use of the technology (Gibson & Smilor, 1991). Therefore, promptly reaching a compromise among these different views is a top priority for the small manufacturer. Moreover, knowing that a technological solution exists and that the manufacturing operation, including may be the overall survival of the organization, depends on successful diffusion, the manufacturer must decide the rate or pace with which this compromise is reached, which also affects the solution's transfer rate or pace. This decision has far reaching implications for the small manufacturer, both from a time as well as financial point of view.

The manufacturer's first option could be to adapt the technology. This refers to the slow gradual transfer processes and decisions with which the manufacturer accepts a technology (Gaynor, 1996). Successful technology transfer using this option depends on

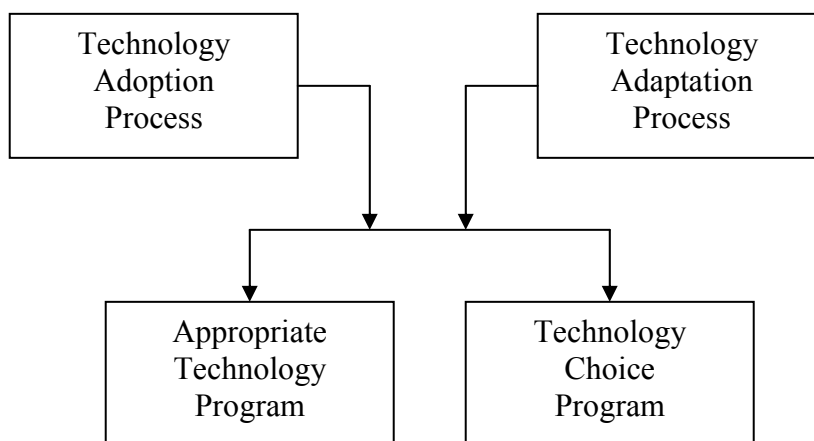
the manufacturer's attitude, patience level, capability, and resources to confront and resolve any and all encountered obstacles and barriers. If the manufacturer chooses this very detailed methodological option, then the technology is more likely to be successfully transferred on time and within budget.

The second option available to the manufacturer is to adopt the technology. This option refers to the radical quick transfer processes and decisions with which the manufacturer accepts a technology (Amendola & Gaffard, 1988; Gehani, 1998; and Lefebvre, Mason, & Khalil, 1998). The transfer rate using this option is fast, often faster than a small manufacturer likes; however, the small manufacturer's competitive advantages may be at risk. Therefore, adoption of the technology is the necessary response to remain competitive, despite the fact that adoption is not the most efficient and effective way to transfer the technology.

As mentioned earlier, when adaptation or adoption processes are considered in combination with either an appropriate technology or a technology choice state technology transfer program options, there are eight possible outcomes relating to the overall time and cost aspects of technology transfer delivery systems. These outcomes depend greatly on the decision-making processes and on the circumstances of the small manufacturer. Moreover, small manufacturers in today's competitive environment need to make favorable decisions relative to their technology transfer needs, considering the organizational boundaries outside their organization and considering the functional and managerial boundaries within their organization. A representation of the possible



technology transfer decision paths is provided in Figure 9, and a representation of the possible technology transfer decision path outcomes is provided in Table 2.



**Figure 9. Possible Technology Transfer Decision Paths**

	Appropriate Technology		Technology Choice	
	<i>T. Adoption</i>	<i>T. Adaptation</i>	<i>T. Adoption</i>	<i>T. Adaptation</i>
Cost overruns likely to exist?	No	No	Yes	No
Time overruns likely to exist?	Yes	No	Yes	Yes
Technology Transfer Decision Path Outcome?	Less Optimal	Most Optimal	Least Optimal	Less Optimal

**Table 2. Possible Technology Transfer Decision Path Outcomes**

## 2.9 Summary

Manufacturing is an integral part of today's economy. Societies and communities depend on a strong competitive manufacturing base. For manufacturers, especially small manufacturers, to retain their competitive advantages, federal, state, and local technology policy acts and initiatives need to continue promoting technology transfer activities and delivery systems. Historically, the US has demonstrated excellent leadership in promoting manufacturing and advancing technology transfer. However, change is an inevitable part of any system. How the role players (US government, small business owners, technology transfer programs, and technology transfer change agents) adapt to and evolve with today's competitive environment determines the new manufacturing base and society's economic and social well being.

Manufacturing's innovation process provides enormous benefits for the entire US economy, such as: grows the economy, invents the future, generates productivity increases, provides more rewarding employment, and pays the taxes (Popkin, 2003). However, as the US manufacturing industry grows and matures, it relies more and more on emerging technologies to keep up with manufacturing's new and more competitive global playing arena. This arena is presenting serious challenges to the long-term viability of the US manufacturing base and the innovation processes that underlie it. Some of these challenges are: loss of jobs, loss of export potential, loss of skilled workers, decreasing investments, and rising costs (Popkin, 2003).

The solution now and in the future is robust and flexible technology transfer programs. Such programs could establish a technological critical mass that enables US small manufacturers to retain their market share, and in some instances increase it (Geisler, 1997). Establishing such programs also allow US small manufacturers to stop spending time, money, and energy on the latest technology craze (Chambers & Kouvelis, 2003). Furthermore, these programs can infuse the necessary information and technology into the small manufacturer's organizational infrastructure to remain competitive. Predominantly, small manufacturers that learn from their own experience and problem-solving efforts with technology transfer delivery systems have a tremendous advantage over others that chase the latest technology. Sometimes smaller focused investments in worker knowledge and skills can generate long-term rewards more than today's newest machines (Chambers & Kouvelis, 2003; and Jeremy, 1991). Essentially, robust and flexible technology transfer programs can assist small manufacturers to develop long-term strategies built around their organizational capabilities and functional and managerial boundaries as opposed to a stream of reactionary technology investments and technology transfer investments. This enables small manufacturers to achieve successful technology transfer in a competitive environment.

This chapter has reviewed existing governmental and state technology transfer policies and programs and applicable models for technology transfer programs and processes. The research by Clarke, Collins, Dobson, Hoff, and Osborn established the critical factors for a successful technology transfer program, while the research of Cooper, Feller, Ruttan, and Weijo presented frameworks for a state technology transfer

program. Moreover, research conducted by Bull, Dorf, Hazeltine, and Willoughby identified the essential elements of appropriate technology and technology choice state technology transfer programs. Also, Woodward's study reviewed the effects of technology complexity in manufacturing operations on manufacturing technology transfer activities. Finally, the work of Gaynor, Gibson, and Smilor reviewed the effects of adaptation processes on technology transfer decisions, while the work of Amendola, Gaffard, and Gehani reviewed the effects of adoption processes on technology transfer decisions.

Based on these research efforts, the following key elements of a state technology transfer program are identified:

1. Provides all the technology transfer services small manufacturers need.  
These services should be comprehensive in structure and design;
2. Located at a university-based site with decentralized, strategically located, regional offices and a headquarters located at the state capital for administrative and coordination purposes;
3. Built on a well-established technology transfer adoption continuum;
4. Built on established technology transfer dimensions of business assistance, technical assistance, research and development, governmental compliance, and human resource management;
5. Developed and integrated around the manufacturing needs of the state;
6. Integrated around the economic, political, and social conditions of the state;

7. Promotes one-on-one interaction between the technology transfer agents and the small manufacturers;
8. Provides focused appropriate and choice technology transfer delivery systems to the small manufacturers, which are under compelling competitive pressures;
9. Built on demand-pull and technology-push technology transfer approaches;
10. Considers the technical complexity of the small manufacturers;
11. Provides technology transfer services at reasonable cost; however, the collected fees are meant to recover the cost of the services and are not meant to generate revenue;
12. Contains both demand-side and supply-side technology policy elements;
13. Provides technology transfer services using focused and detailed adaptation and adoption technology transfer processes geared to small manufacturers;
14. Contains robust and flexible information and facilities infrastructure technology policy element.

### **Chapter 3. Research Methods and Design**

This chapter presents the procedures that were used to develop and administer a mailed questionnaire to small manufacturers in Oklahoma. The main focus of this questionnaire is to ask for information to determine the small manufacturers' attitudes towards their beliefs and needs for technology transfer in a competitive environment. This determination process allows the researcher to answer the unanswered questions stated in Chapter 1 within the framework established by the 14 key elements of a state technology transfer program identified in Chapter 2. The unanswered questions are:

1. What are the desirable characteristics (dimensions and attributes) of a technology transfer program in a competitive environment, with application to the small manufacturers in Oklahoma?
2. How should these dimensions and attributes be deployed, and what would be the organizational structure, approach, and process of the overall technology transfer program that would best satisfy the needs of the small manufacturer in a competitive environment?

Next, this chapter discusses the nominal group discussion (NGD) sessions held with a sample of manufacturers in Oklahoma to determine their top ten competitive

pressures. Afterwards, a brief discussion of the survey's population is presented along with the schedule for the mailing of the survey questionnaire. Also, this chapter correlates survey questions with the research questions to ensure that the research objectives were satisfied. Finally, this chapter discusses survey pretest procedures and response rate issues.

### **3.1 Nominal Group Discussion (NGD) Procedure**

Prior to mailing the survey, the researcher attended a manufacturing council meeting held by The Alliance, during which questions regarding industry competitive pressures were discussed in a group atmosphere, as suggested by and outlined in Delbecq, Van de Ven, and Gustafson (1975). This initial meeting resulted in a list of 24 competitive pressures currently faced by manufacturers in Oklahoma. Due to the limited time available during the meeting for further deliberations, subsequent discussions were held via email between the researcher and the represented manufacturers.

After the first round of email deliberations, which took place in July 2004, nine additional competitive pressures were added, for a total of 33 competitive pressures. Subsequently, the researcher requested from the participating manufacturers a list of their top ten competitive pressures (rank ordering was not required). After one week, the compiled list of the ten most important competitive pressures was then emailed back to the manufacturers for ranking from 1 to 10, with 1 being the most important competitive

pressure for their business and 10 being the least important competitive pressure for their business. For ranking purposes, Delbecq, Van de Ven, and Gustafson (1975) suggested that the most important pressure receive 10 points and the least important pressure receive one point. The competitive pressure receiving the most number of points would be ranked first and the competitive pressure receiving the least number of points would be ranked tenth. Likewise, the remaining positions from two to nine would be filled accordingly.

The final ranked list of the 10 most important competitive pressures is as follows:

1. Qualified Employees – **(QE)**
2. Worker’s Compensation – **(WC)**
3. Training & Retraining – **(TR)**
4. Raw Material Pricing - Steel – **(RMPS)**
5. Labor Cost Management – **(LCM)**
6. Marketing – **(MRKT)**
7. New Product Development – **(NPD)**
8. Human Resources – **(HR)**
9. Supply-Chain Management – **(SCM)**
10. Electricity/Energy Deregulation – **(EED)**

This list was used in the survey questionnaire to further delineate how Oklahoma’s small manufacturers would like to receive technology transfer assistance to alleviate these competitive pressures.



### 3.2 NGD's Survey Instrument Implications

Prior research concerning small manufacturers (Collins, 1998) concluded that small manufacturers would like to receive technology transfer via a university-based comprehensive structure, as depicted previously in Figures 5 and 8 on pages 100 and 111 respectively. This structure is more than capable in offering solutions to the competitive pressures of small manufacturers. However, the turn around time in such comprehensive structures can be lengthy, and today's highly competitive environment requires faster turn-around times. Moreover, the top ten competitive pressures covers a wide-spectrum of areas from manufacturing operations to the business requirements of small manufacturers. Therefore, a state technology transfer program should accommodate this additional complexity factor.

As result, the survey questionnaire attempted to shed additional light on this aspect by specifically asking the small manufacturers how they want to receive technology transfer assistance to resolve each competitive pressure. The presented options were: the uni-dimensional structure, the locally-based network structure, and the university-based comprehensive (holistic) structure. Each of these three structures, as previously discussed in Chapter 2, provides certain advantages with respect to alleviating competitive pressures. Furthermore, the resources of small manufacturers are conserved when their state technology transfer program considers this relationship. This is especially important when small manufacturers participate directly in the transfer decision-making process. And in this case, small manufacturers are indicating their technology transfer structure preferences to resolve their competitive pressures.

### 3.3 Survey Methodology

The target population for the study was Oklahoma small manufacturing companies, with small defined as 250 employees or less. These companies were identified by the Standard Industrial Classification (SIC) code (Oklahoma Department of Commerce, 1996). However, not all of the SIC codes identified industries that manufacture products and/or goods. As a result, the population of the study identified as small manufacturing companies was limited to the following SIC codes:

<b><u>SIC Code</u></b>	<b><u>Classification Description</u></b>
20	Food and Kindred Products
22	Textile Mill Products
23	Apparel and Textile Products made from Fabrics
26	Paper and Allied Products
34	Fabricated Metal Products, except. Machinery and Transportation
35	Machinery, except Electrical
36	Electrical and Electronic Machinery, Equipment, and Supplies
37	Transportation Equipment

A list of the companies classified as small manufacturers was obtained from The Alliance. This list contained 493 companies as of June 2004. The decision was made to send out the survey to all 493 companies on the list. The purpose was to get as much feedback as possible from as many small manufacturers as possible. This allows for a

more detailed picture of the competitive pressures currently faced by Oklahoma small manufacturers and their technology transfer needs in this competitive environment. Also, this decision avoids any potential gaps in information that may occur with surveying only a selected sample of the small manufacturers in Oklahoma.

### **3.4 Survey Instrument**

A mail-out survey questionnaire was developed based on the work of Bourque and Fielder (1995), Collins (1998), Hoff (1997), and Leedy (1993). Furthermore, observations regarding survey methodologies presented in Bordens and Abbott (2002) and Warde (2003) were also included in the design of the survey questionnaire. The questionnaire itself was reviewed by academicians and was also pre-tested using a group of small manufacturers. Their feedback and comments were incorporated to improve the survey's overall clarity and design. Specifically, their constructive criticisms focused on the use of academic terminology, on question structure and wording, and on the questions' intrusiveness, detail, and length. The six pre-test sessions averaged approximately 20 minutes each and addressed issues of construct and content validity commonly faced when administering mail surveys. Finally, the questionnaire was also approved by the Oklahoma State University Institutional Review Board prior to mailing - (a copy of the approval form is found in Appendix A). In addition, a copy of the survey cover letter and the approved survey questionnaire are provided in Appendices B and C respectively.

The expected response rate for this study was 15 percent, which is the average response rate for mail surveys (Malhotra, 1993). Therefore, when the overall response rate is not 15 percent or several mail-outs are used to reach this threshold, non-response bias becomes a concern and requires special considerations. This is a critical drawback to using mail surveys for data collection.

The questions or set of questions on the survey were carefully developed to address the unanswered questions in this study. To simplify the analysis process, the unanswered questions are divided into six questions or six research questions (RQ). Furthermore, the six research questions and their corresponding survey questions attempted to provide information on characteristics and perception differences that were believed to differentiate among the technology transfer decisions of small manufacturers under competitive pressures and working in a highly competitive environment. The following is the six research questions matched with the set of questions from the survey. The notation to match with the survey is as follows: the survey section number, the survey question number, and the survey question in italics (Section #, Q#, Q-italics). A correlation discussion of the survey instrument follows:

**RQ 1.** What were the critical dimensions of a technology transfer system in a competitive environment?

The literature review identified five critical dimensions of technology transfer systems: technical assistance, business assistance,

research and development, governmental compliance, and human resource management assistance. The following survey questions determined which dimensions small manufacturers were currently using or had used in the past.

*Section 1.0, Q7 - My company is currently involved with technology transfer in one or more of the following areas. (Please check ALL that apply): 1) Technical Assistance, 2) Research and Development, 3) Governmental Compliance, 4) Business Assistance, 5) Human Resource Management Assistance, and 6) None.* This question establishes a small manufacturer's specific and current need for the technology transfer dimensions.

*Section 2.0, Q1 - How important have the following areas of technology transfer been to your company as you strive to resolve your competitive pressures?* This question asked the respondent to indicate any technology transfer dimension used in the past.

*Section 2.0, Q2 - Which technology transfer agencies have been of importance in meeting the technology transfer needs for your company as you strive to resolve your competitive pressures?* This question identified which 10 technology transfer delivery systems had been used by the small manufacturers.

**RQ 2.** What technology transfer attributes do Oklahoma small manufacturers identify as important to their company in a competitive environment?

*Section 3.0, Q1 - Rate the following technical support techniques based on your company's current technology transfer needs as you strive to resolve your competitive pressures. This question addressed the technical assistance attributes.*

*Section 3.0, Q2 - Rate the level of importance the following types of assistance have been to your company as you strive to resolve your competitive pressures. This question identified 10 of the major types of technical assistance commonly requested by small manufacturers.*

Each of the next four questions from Section 4 of the survey addressed the technology transfer dimension of research and development and its related attributes.

*Section 4.0, Q1 - How important is research and development as part of your company's strategy as you strive to resolve your competitive pressures?*

*Section 4.0, Q2 - In which of the following areas would research and development be most beneficial for your company as you strive to resolve your competitive pressures?*

*Section 4.0, Q3 - Do you believe a cooperative research agreement between your company and a research facility would be beneficial when developing a new product or process as you strive to resolve your competitive pressures?*

*Section 4.0, Q4 - How important is in-house research to protect confidentiality for new products as you strive to resolve your competitive pressures?*

Each of the next four questions from Sections 5, 6, and 7 of the survey addressed the technology transfer dimensions of governmental compliance, business assistance, and human resource management assistance and their related attributes.

*Section 5.0, Q1 - How important are these types of governmental assistance to your company as you strive to resolve your competitive pressures?* The attributes for this question were OSHA Safety and Loss Control, Hazardous Chemical Assistance Program, Governmental Compliance Assistance, Equal Employment

Opportunity Assistance, and Trade Mark/Patent Application and Registry.

*Section 6.0, Q1 - How important are the following areas of business assistance to your company as you strive to resolve your competitive pressures?* The attributes for this question were all related to the management and financial aspects of operating a business. Thus, the attributes of the business assistance dimension were Financial Consulting, Loan Processing Assistance, Marketing Study Assistance and Support, Patenting Process Assistance, and Venture Capital Assistance.

*Section 6.0, Q2 - How important would temporary low cost facilities be to the startup of your company or new product as you strive to resolve your competitive pressures?* Prior research indicated that small manufacturers operating in a highly competitive environment could benefit greatly from using incubator system facilities, a main attribute of the business assistance dimension, as a way to reduce costs and remain competitive.



*Section 7.0, Q1 - How important are the following areas of Human Resource Management assistance to your company as you strive to resolve your competitive pressures?* The attributes of the human resource management assistance dimension were Employee Selection Assistance, Employee Benefits, Insurance, and Worker's Compensation Training, and Labor/Management Relations Assistance. Considering that the top three competitive pressures currently faced by Oklahoma small manufacturers are all related to the human resource management assistance dimension, any eventual state technology transfer program must exhibit expertise in this dimension and its related attributes. This is consistent with prior research studies. If Oklahoma small manufacturers are to remain competitive, any eventual program must consider and implement this dimension and its related attributes.

**RQ 3.** What would be the organizational structure of a technology transfer program that would best satisfy the needs of the small manufacturer in a competitive environment - i.e., university-based comprehensive (holistic), locally-based network, or uni-dimensional?

*Section 5.0, Q2 - How important would governmental assistance be if services were provided without the threat of receiving a citation for out of compliance violations as you strive to resolve*

*your competitive pressures?* Some delivery systems provided governmental compliance in a non-threatening approach. This approach affected the overall organizational structure of the technology transfer program.

*Section 8.0, Q1 - How important would a single source, statewide technology transfer agency be to you as you strive to resolve your competitive pressures?* Such an agency would provide technical assistance, research and development, governmental compliance, business assistance, and human resource management assistance within one unit. This question determined the overall attitude towards a single technology transfer program providing all the required technology transfer assistance.

*Section 8.0, Q2 - How important are the following three approaches of technology transfer to your company as you strive to resolve your competitive pressures?* **Approach 1** - One agency where you can get all of the technology transfer assistance you need, **Approach 2** - Different agencies which provide only one specific type of assistance, and **Approach 3** - A system where you contact one person who will arrange meetings with other technology transfer agencies. The first approach is the university-based comprehensive (*holistic*) program structure; the second

approach is the uni-dimensional (*fragmented*) program structure; and the third approach is the locally-based (*broker agent*) network program structure.

*Section 8.0, Q3 - Please indicate which approach from the three approaches outlined in the previous question would be most beneficial to resolve each of the following **top ten ranked** important competitive pressures currently faced by Oklahoma manufacturers - (Please check **ONLY ONE** for each pressure).*

This question interrelates the three structural program approaches to the top ten ranked important competitive pressures mentioned earlier. As a result, this question determines the need of small manufacturer with respect to the structure of the state technology transfer program, considering their competitive pressures.

*Section 9.0, Q1 - How many miles would you be willing to travel to a technology transfer meeting that discusses ways to resolve competitive pressures? This question clarifies the need for regional offices or off-site locations for meetings with small manufacturers to receive technology transfer assistance. Thus, this question identifies regional boundaries for Oklahoma's state-wide technology transfer program.*

*Section 9.0, Q2 - How many hours could you be away from work to attend a technology transfer meeting? Again, this question also identifies the need for regional offices or off-site locations for technology transfer meetings with small manufactures.*

**RQ 4.** What should be the underlying emphases of a state technology transfer program to meet future manufacturing industry requirements?

*Section 1.0, Q5 - Approximately how many **engineers** (by degree) does your company employ? This question determines the technical ability of small manufacturers and their potential to deploy technology with more success, especially in a competitive environment.*

*Section 1.0, Q9 - How would you characterize the technical complexity of your manufacturing operations? (Please check the **ONE** that best describes your manufacturing operations):*  
*Customized work and relies heavily on the human operator -- (Small-batch & unit production), Long production runs of standardized parts w/ no customized work -- (Large-batch & mass production), or Entire process is mechanized and outcomes are predictable -- (Continuous process production).* This question

clarifies the technology needs of small manufacturers according to the technical complexity in their manufacturing operations.

*Section 9.0, Q3 - Approximately how many **trade shows or conventions** has a representative from your company attended in the past three years?* This question determines what small manufacturers are willing to do to improve their competitive advantages. By being introduced to current or new technologies at trade shows or conventions, small manufacturers can: increase market share, find new markets, reduce costs (efficiency), and increase through-puts (lean manufacturing and lean accounting). Also, this question helps to determine the overall mission (demand-pull or technology-push) of the state technology transfer program based on the attendance frequency and activity of small manufacturers at the trade shows or conventions. A high number of attendances for a small manufacturer indicates a demand-pull situation, while a low number of attendances for a small manufacturer indicates a technology-push situation (Gaynor, 1996; Gehani, 1998; Ruttan, 2001; and Weijo, 1987).

*Section 9.0, Q4 - In general, how would you describe your company's **past experiences** with new technology? (Please check **ONLY one item**): Very dissatisfied, Dissatisfied, Neutral, Satisfied,*

*Very satisfied, and Not applicable.* This question indicates the relative past experience of small manufacturers with new technology and its deployment process.

*Section 9.0, Q5 - Please check the items listed below which you consider barriers to new technology at your company as you strive to resolve your competitive pressures - (Please check **ALL** that apply): Work force skills, Lack of readily available information on the technology, Financing, Lack of understanding and training with the technologies, Facility limitations, Lack of support by upper management, Management skills, Lack of a proven track/performance record with the technology, Unknown benefits, Transfer and Implementation difficulties, Technology appropriateness, Satisfaction with existing technologies, Major concern regarding change, Minor concern regarding change, None of the above, and Other: Please specify.* This question establishes the foundational pillars of a state technology transfer program relative to the technology adoption continuum, which recognizes technology adoption/rejection decision outcomes (Hoff, 1997).

*Section 9.0, Q6 - What has been your **primary source of training / transfer assistance** with past technologies? (Please check **ONLY** one item): Vendors, College, Vo-Tech Classes, Industry*

*Associations, None/Not Applicable, Union Training, In-House Expertise, and Other: Please specify.* This question identifies where a small manufacturer received training and transfer assistance with past technologies.

*Section 9.0, Q7 - What do you believe should be your **primary source of training / transfer assistance** for future new technologies? (Please check **ONLY** one item): Vendors, College, Vo-Tech Classes, Industry Associations, None/Not Applicable, Union Training, In-House Expertise, and Other: Please specify.* This question identifies where a small manufacturer wants to go to receive training and transfer assistance with future new technologies.

*Section 9.0, Q8 - Would your company be willing to provide financial support for technology transfer services that would aid you in resolving your competitive pressures? Yes or No. If yes, what percent of the total cost for technology transfer assistance would you be willing to pay if the average cost of a technology transfer project is \$1,000? (Please check **ONLY** one item): 0–5, 6–10, 11–15, 16–20, 21–25, 26–50, 51–75, 76–89, and 90–100 Percent.* This question addresses monetary and financial impacts, which is a major concern in the deployment of technology transfer.

In a competitive environment, small manufacturers are hesitant to pay for technology transfer services. Thus this question measures the small manufacturer's attitudes towards paying a fee for technology transfer assistance.

*Section 9.0, Q9 - What would the major issues be if you were able to design a state-wide technology transfer program tailored to the small manufacturers in Oklahoma as they strive to resolve their competitive pressures? (Please check **ALL** that apply):*

*Comprehensive technology transfer program, Timeliness of assistance, Confidentiality of information, Availability of technologies, Cost to the small manufacturer for services, and Others: Please specify.* This question identifies possible departments or concentration areas within the state technology transfer program crucial for successful technology deployment.

*Section 9.0, Q10 - What type of state-wide technology transfer program would best support your company's technology transfer needs: an Appropriate Technology Program - (provides a preferred long-term solution but may not generate the quickest short-term results) or a Technology Choice Program - (provides a quick fix that may not be the cheapest or generate the best long-term results)?* This question determines the overall technology transfer



approach of the state technology transfer program to meet future manufacturing industry requirements, based on the preferences of small manufacturers. Both technology approaches can offer possible technology solutions to alleviate competitive pressures faced by small manufacturers. However, each approach is unique and its technology solutions are based according to the attitudes and viewpoints of each individual small manufacturer.

*Section 9.0, Q11 - How important is it to your company to develop expertise on existing and subsequent manufacturing/production technologies to meet company goals, especially the goal to resolve your company's competitive pressures?* This question determines the level of commitment of small manufacturers to successfully deploy technologies to alleviate their competitive pressures.

*Section 9.0, Q12 - How important is it to your company to make plant/office space available for experimentation with new technology to support company goals, especially the goal to resolve your company's competitive pressures?* The question also determines the level of commitment of small manufacturers to successfully deploy technologies to alleviate their competitive pressures.

*Section 9.0, Q13 - Do you currently have any technology transfer needs that will require assistance? If so, please explain.* This question assesses the current technology transfer needs of small manufacturers to establish a starting point for the state technology transfer program. Also, receiving this feedback is critical to providing immediate assistance to small manufacturers as they confront their competitive pressures.

*Section 9.0, Q14 - Would you be willing to participate in another more in-depth survey in the near future that focuses on technology transfer programs and their related cost drivers and risk factors? Yes or No.* This question further determines the level of commitment and interest of small manufacturers to continue developing a state technology transfer program as they confront their competitive pressures. Fifty technology transfer cost drivers and risk factors were identified as pertinent to successful technology transfer. If a state technology transfer program recognizes and emphasizes and encourages tracking and accounting of these fifty drivers and factors as it interacts with manufacturers, then the probability of developing a sustainable, robust, and flexible state technology transfer program is increased. However, this aspect was not included in this initial study and its survey questionnaire.

**RQ 5.** What is the small manufacturer's preferred technology transfer deployment process with respect to a technology or innovation to accept, adopt, and/or transfer it – i.e., a technology adoption process or a technology adaptation process?

*Section 1.0, Q10 - How would you characterize your company's technology transfer attitudes and policies when considering a new technology or innovation to accept, adopt, and/or transfer it to meet external and/or internal competitive pressures on your company? (Please check the **ONE** that best describes your company's philosophy with respect to technology transfer): Prefer radical quick processes of transferring or accepting an innovation -- (Technology Adoption) or Prefer slow gradual processes of transferring or accepting an innovation -- (Technology Adaptation).*

**RQ 6.** What are the demographics of small manufacturers in the state, and how do these demographics, combined with the attitudes and preferences of small manufacturers, affect technology transfer needs under competitive pressures?

The following survey questions determined background information regarding the small manufacturers, such as age, size, location,

SIC code, primary utilized technology, and the respondent's position or title.

*Section 1.0, Q1 - My job title is?* This question identifies who is completing the survey as well as the positions of top managers working in the small manufacturing enterprises.

*Section 1.0, Q2 - The primary technology which is used to manufacture the products of your company is? (Example: Woodworking, Metal Fabrication, etc.).* This question identifies the technology being used in the manufacturing environment and gives an indication of the products being developed or produced at the company.

*Section 1.0, Q3 - My company manufactures products in the following industries: (Please check ALL that apply): Food and Kindred Products (SIC Code 20), Fabricated Metal Products (SIC Code 34), Machinery, except Electrical (SIC Code 35), Electrical and Electronic Machinery, Equipment, & Supplies (SIC Code 36), Transportation Equipment (SIC Code 37), and Other: Please Specify.* This question gives an indication of the company's manufacturing operations and an additional indication of the company's manufactured products.

*Section 1.0, Q4 - The number of full-time employees in my company are: 1-25, 26-50, 51-75, 76-100, or 101-250? This question gives an indication of the size of the small manufacturers and their manufacturing operations.*

*Section 1.0, Q6 - My company is located in: (Please check ALL that apply): Greater Oklahoma City, Greater Tulsa, and Outside greater Oklahoma City and greater Tulsa. This question identifies the location/s of the small manufacturers' operations. A portion of Oklahoma's small manufacturers have multiple locations within the state and in some instances outside the state. Also, this question identifies the locality of the small manufacturers in terms of rural or metropolitan.*

*Section 1.0, Q8 - My company has been in business for approximately how long: 0-5 years, 6-10 years, 11-15 years, 16-20 years, or over 20 years. This question identifies the age of the small manufacturer and gives an indication of the small manufacturer's manufacturing experience and technology familiarity and skill.*

The majority of the survey used an ordinal attitude-assessment-type Likert scale to gauge the behavior of small manufacturers and their associated technology transfer

decisions. This type of self-report measure was based on a seven-point summated rating scale: not important (1), moderately not important (2), slightly not important (3), important (4), slightly more important (5), moderately more important (6), and very important (7) (Bordens & Abbott, 2002). However, for Question 2 of Section 2.0 of the survey, respondents can also circle N for neutral or not used as a rating in that question instead of using the Likert rating scale. Finally, several of the survey questions use a nominal scale, which is the lowest level of scale measurement. Some examples of nominal questions in the survey were related to job function, business location, business size, business age, and financial support.

### **3.5 Implementation of the Survey**

The survey questionnaire was mailed out on September 29, 2004 to the small manufacturers on the list obtained from The Alliance. Two days prior to the mail-out, a short reminder note was emailed to the extension agents of The Alliance to announce the survey and its purpose to the manufacturers that they represented. Also, the researcher attended several manufacturing council meetings throughout Oklahoma to announce the upcoming survey and its purpose. The survey package included a survey printed on light blue paper, a cover letter supporting the survey from the President of The Alliance also printed on light blue paper, and a pre-paid and pre-labeled return envelope.

In total, 493 surveys were mailed. The US Post Office returned 13 survey packages as undeliverable. Of the remaining packages, 100 surveys were returned satisfactorily, which resulted in a 20.3 percent response rate for the first mailing (100 out of 493). The collection time for this first mailing was set at six weeks, with the first completed survey returned on October 7, 2004 and the last one returned on November 17, 2004. Despite the six-week time frame for receiving responses, 82 surveys were returned for a 16.6 percent response rate by the third week, which was an excellent response rate compared to similar studies by Collins (1998) and by Hoff (1997).

### **3.6 Summary**

This chapter discussed the research methodologies involved in administering a mail-out survey questionnaire. The developed survey was pretested using a group of small manufacturers. As a result of the pre-test sessions, modifications and corrections were incorporated to improve the survey's overall clarity and outreach. Only one mail-out was conducted and 100 small manufacturers responded out of 493 in this first mail-out, and only 13 survey packages were returned as undeliverable. The response rate for this research study was 20.3 percent, which is an excellent response rate compared to similar studies in the past conducted by Collins (1998) and by Hoff (1997).

## Chapter 4. Data Analysis

This chapter discusses the analysis procedures and results conducted on the data collected from the survey of Oklahoma small manufacturing companies. The primary focus of this data collection and analysis was to answer the six research questions (RQ) stated in Chapter 3. These questions are:

**RQ 1.** What were the critical dimensions of a technology transfer system in a competitive environment?

**RQ 2.** What technology transfer attributes do Oklahoma small manufacturers identify as important to their company in a competitive environment?

**RQ 3.** What would be the organizational structure of a technology transfer program that would best satisfy the needs of the small manufacturer in a competitive environment - i.e., university-based comprehensive (holistic), locally-based network, or uni-dimensional?

**RQ 4.** What should be the underlying emphases of a state technology transfer program to meet future manufacturing industry requirements?

**RQ 5.** What is the small manufacturer's preferred technology transfer deployment process with respect to a technology or innovation to accept,



adopt, and/or transfer it – i.e., a technology adoption process or a technology adaptation process?

**RQ 6.** What are the demographics of small manufacturers in the state, and how do these demographics, combined with the attitudes and preferences of small manufacturers, affect technology transfer needs under competitive pressures?

Since Research Question 6 addresses the demographic data, it will be analyzed first. Therefore, the analysis of the research questions has been presented in the following order: RQ 6, RQ 1 and RQ 2, RQ 3, RQ 4, and RQ 5.

The data analysis for this study has two phases. The first phase discusses the collection, coding, tabulating, and the SPSS<sup>11</sup> / Excel programming required to generate descriptive statistics for the frequency data analysis. As part of this phase, the completed survey questionnaires were interpreted and adjusted for missing values. The second phase describes the inferential analysis on the research data using the SPSS / Excel filtering procedure. Using preselected sequenced parameters, the researcher examines the effect of certain survey responses - (such as preferred technology transfer approach, preferred technology transfer program, preferred technology transfer attitude and policy, and manufacturing technical complexity) on the entire response population. As part of this phase, a manufacturer can be potentially classified into one of 36 distinct technology transfer groups (or combinations) based on the preselected sequenced parameters per

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<sup>11</sup> SPSS is an abbreviation for the Statistical Package for the Social Sciences software by SPSS Inc.

competitive pressure. This resulted in identifying characteristics for each group (or combination) for the analyzed data set.

#### **4.1 Data Interpretation and Missing Values**

Many of the survey questionnaires that were returned had at least one question that the respondents did not answer or had at least one question that the respondents answered several choices when the instructions specifically stated to select only one choice. In both instances, the questions were evaluated as unanswered and treated as missing values. Therefore, when coding the data set into a SPSS / Excel data file, 99 was used to reflect a missing value. However, Question 2 in Section 2.0 of the survey was not treated as a missing value if the respondent gave a neutral or not used (N) response to the question. In this instance, a zero (0) was used to reflect their choice and for frequency analysis purposes. Also, regarding the Likert-type ordinal questions used for several technology transfer matters, a response of (1) represented a small manufacturer's strong disinterest while a response of (7) represented a small manufacturer's high level of interest.

Overall, the survey was well received by Oklahoma small manufacturers as indicated by the response rate. Competitive pressures are adversely affecting small manufacturers and technology transfer assistance is sought to alleviate the pressures. Another indication of this observation is reflected in the responses to Questions 6 and 7

in Section 9.0 of the survey. Thirty Oklahoma small manufacturers (or 30 percent of the respondents) selected multiple items for Question 6 when they were specifically asked to check only one item. And 18 percent of the respondents did the same for Question 7. Both situations were treated as a missing value. Question 6 asked a small manufacturer to indicate their primary source of training / transfer assistance with past technologies, while question 7 asked about their primary source of training / transfer assistance for future new technologies. Both situations indicate that Oklahoma small manufacturers are seeking multiple ways to receive assistance with technologies, old and new, and subsequently alleviate their pressing competitive pressures.

## **4.2 Frequency Data Analysis and Descriptive Statistics**

### **4.2.1 Frequency Data on RQ 6**

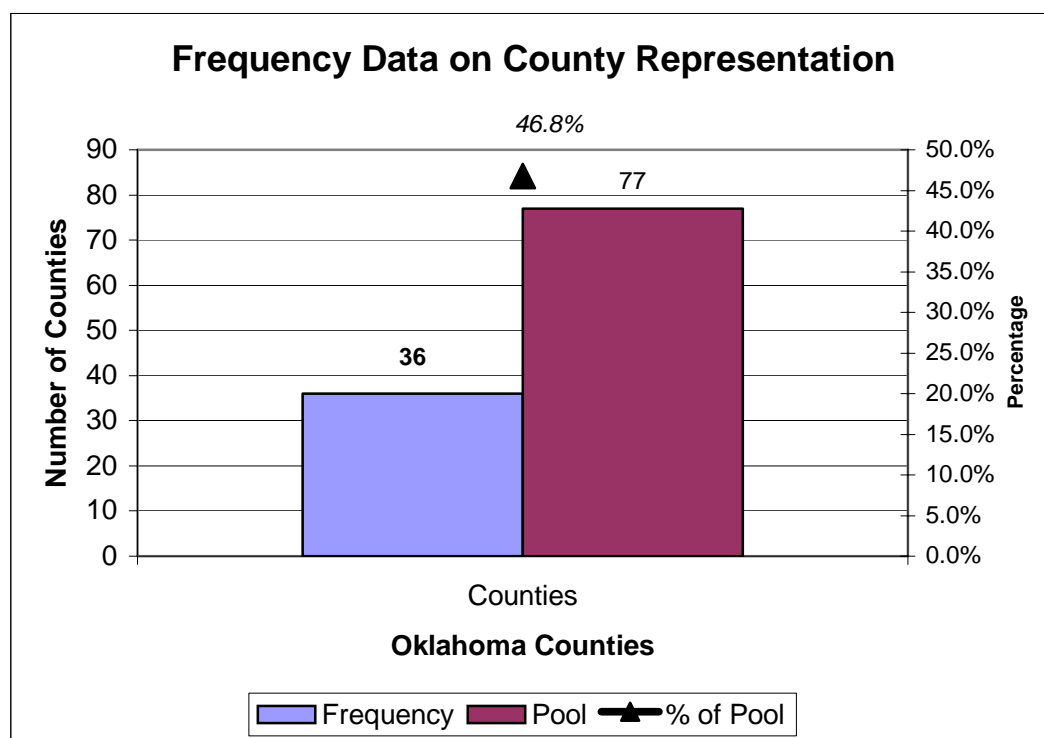
Demographic data was obtained via two sources. The first source was the original three data scrolls<sup>12</sup> obtained from The Alliance. The first scroll was the original data sorted by company name. However, this scroll was kept confidential and the researcher did not have access to it during the analysis phase of this study since it contained identifying remarks about the small manufacturers. Conversely, the second and third scrolls were sorted by company location and company size. Thus, the first demographic frequency analysis presented was conducted on these scrolls and compared to the data obtained from the survey questionnaires, which is the second source of demographic data.

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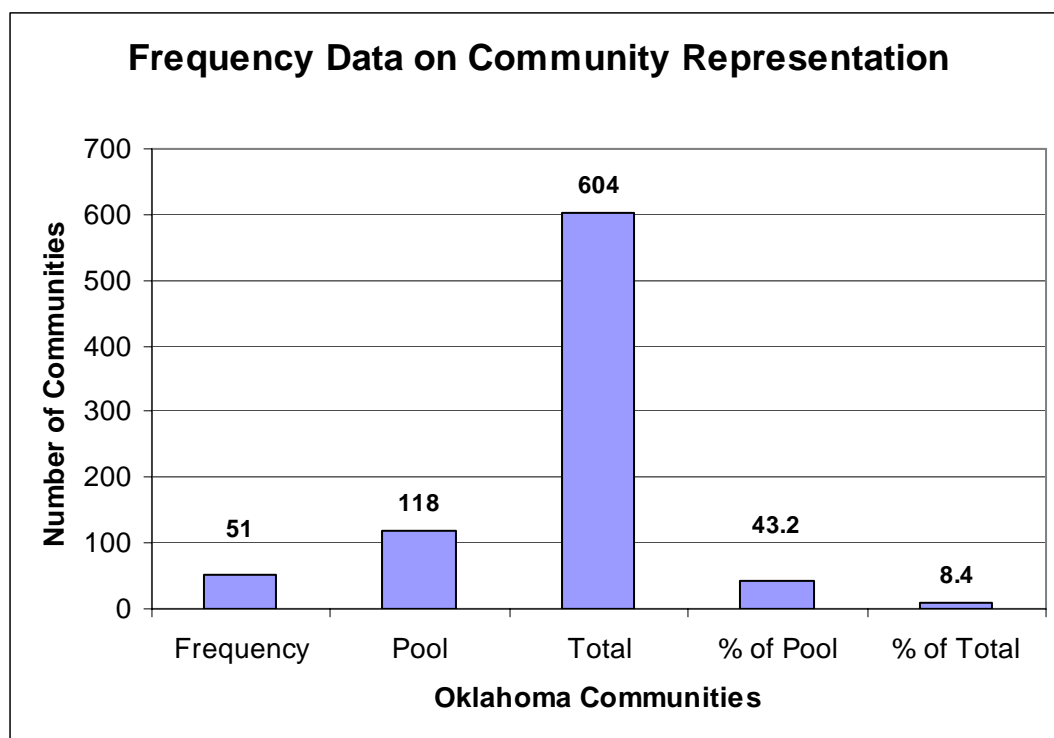
<sup>12</sup> The three data scrolls are the rolled printouts of the three Excel data files obtained from The Alliance.

Overall, both sources of demographic data provided a significant level of detail regarding the respondents and their experiences, attitudes, and preferences towards technology transfer.

The state of Oklahoma is divided into 77 counties. The 100 respondents represented 36 counties (or 46.8 percent). The original survey pool of 493 small manufacturers represented 118 communities of the 604 in Oklahoma. The respondents represented 51 Oklahoma communities (or 43.2 percent of the survey pool or 8.4 percent of the overall total). Figures 10 and 11 summarize these results.



**Figure 10. Frequency Data on County Representation**



**Figure 11. Frequency Data on Community Representation**

The Oklahoma Department of Commerce and Tourism divides the state into five regional areas: Northwest (NW), Northeast (NE), Southwest (SW), Central (C), and Southeast (SE). The survey pool represented all five regional areas; however, no responses were received from the Northwest area. The Northeast area had the most number of small manufacturers included in the survey (239), but the Central area had the highest response rate (21.3).

In terms of community representation by region, the Northeast area had the most number of communities represented with 23. In terms of county representation by region, the Northeast area again had the most counties represented with 15. Figure 12

provides a comparison summary of the regional data. Furthermore, Figure 13, which is a graphical map of the state of Oklahoma provided by [www.nationalatlas.gov](http://www.nationalatlas.gov), is also a comparison summary of the regional data. However, this representation reaffirms the importance of Oklahoma's Interstate Highway 44 (I-44) as Oklahoma's technology corridor. This representation also depicts the spread of small manufacturers' influence and contribution to the state's growth and development and to their surrounding communities. Overall, it can be hypothesized that this map is a vital snap shot of the current conditions and circumstances in the state with respect to economic development and technology transfer participation.

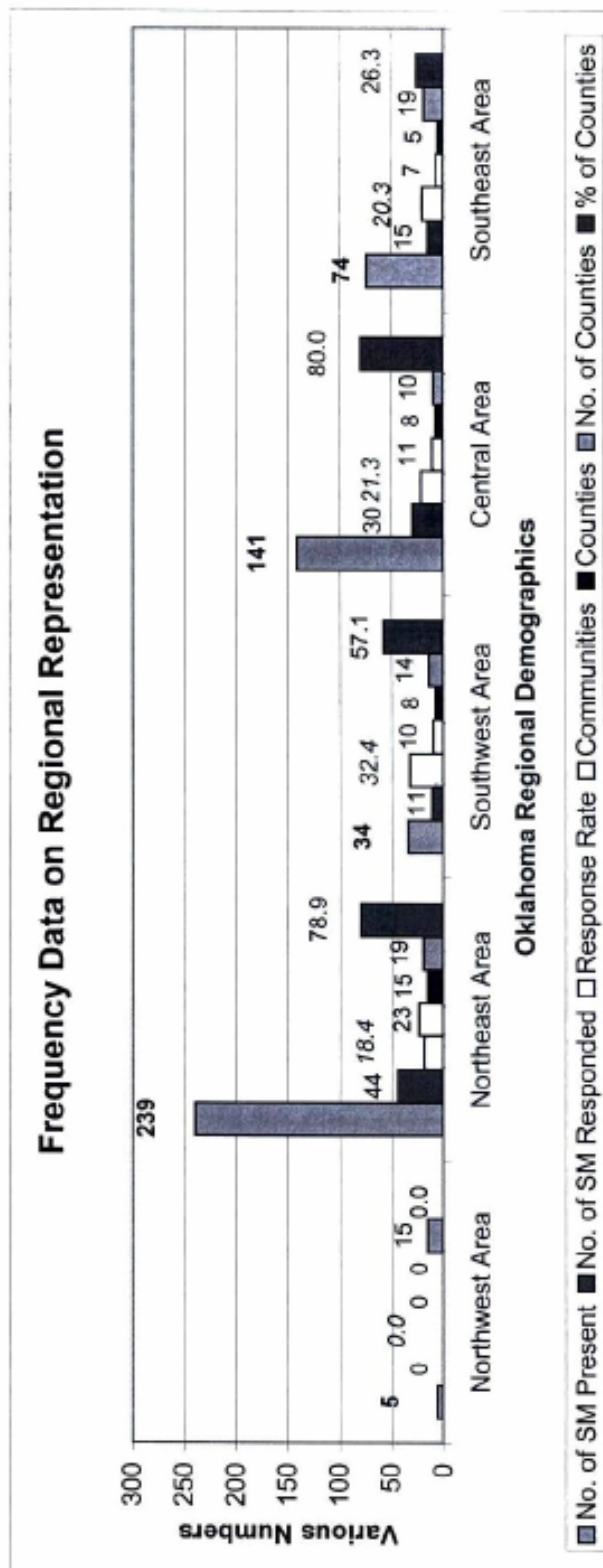
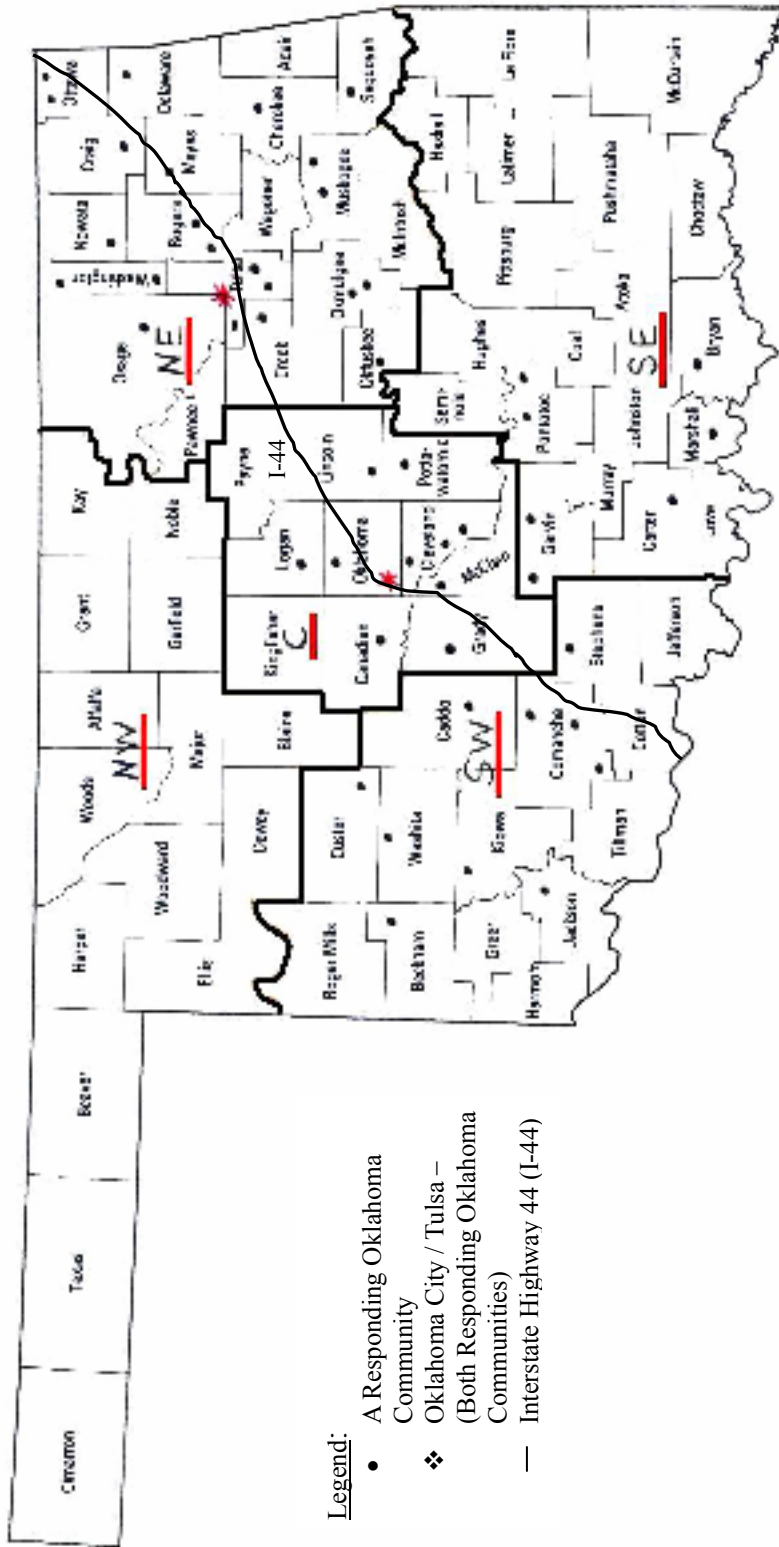


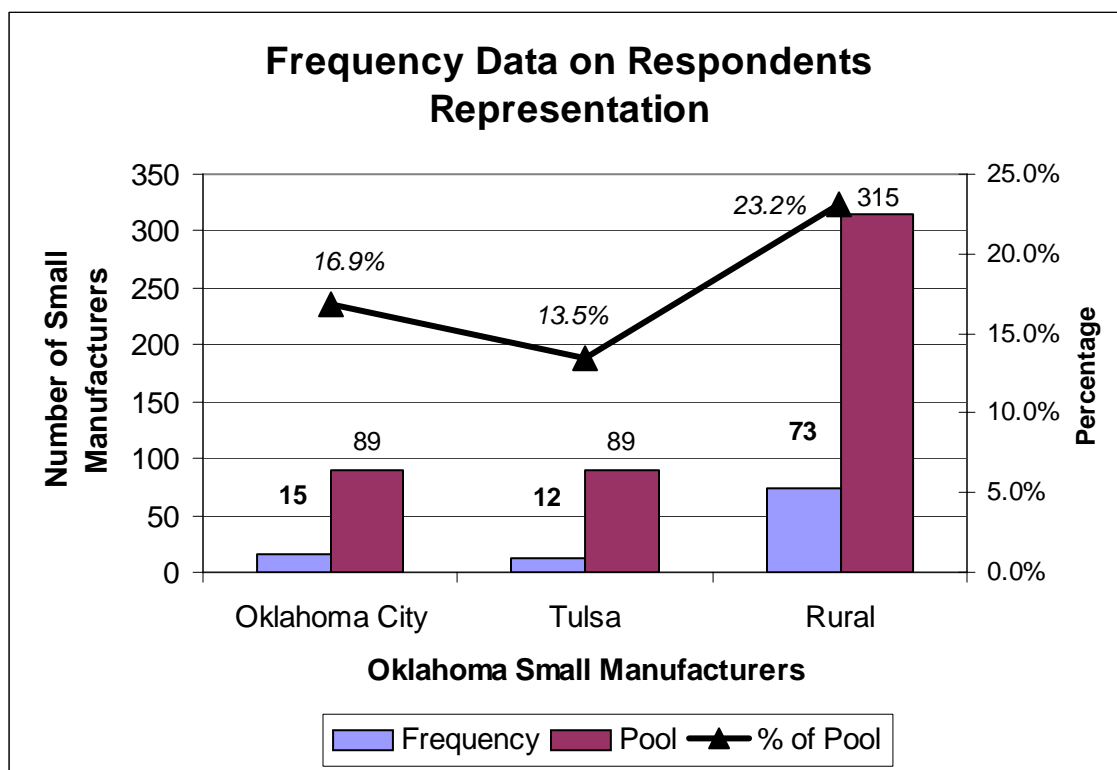
Figure 12. Frequency Data on Regional Representation



**Figure 13.** Map of the State of Oklahoma

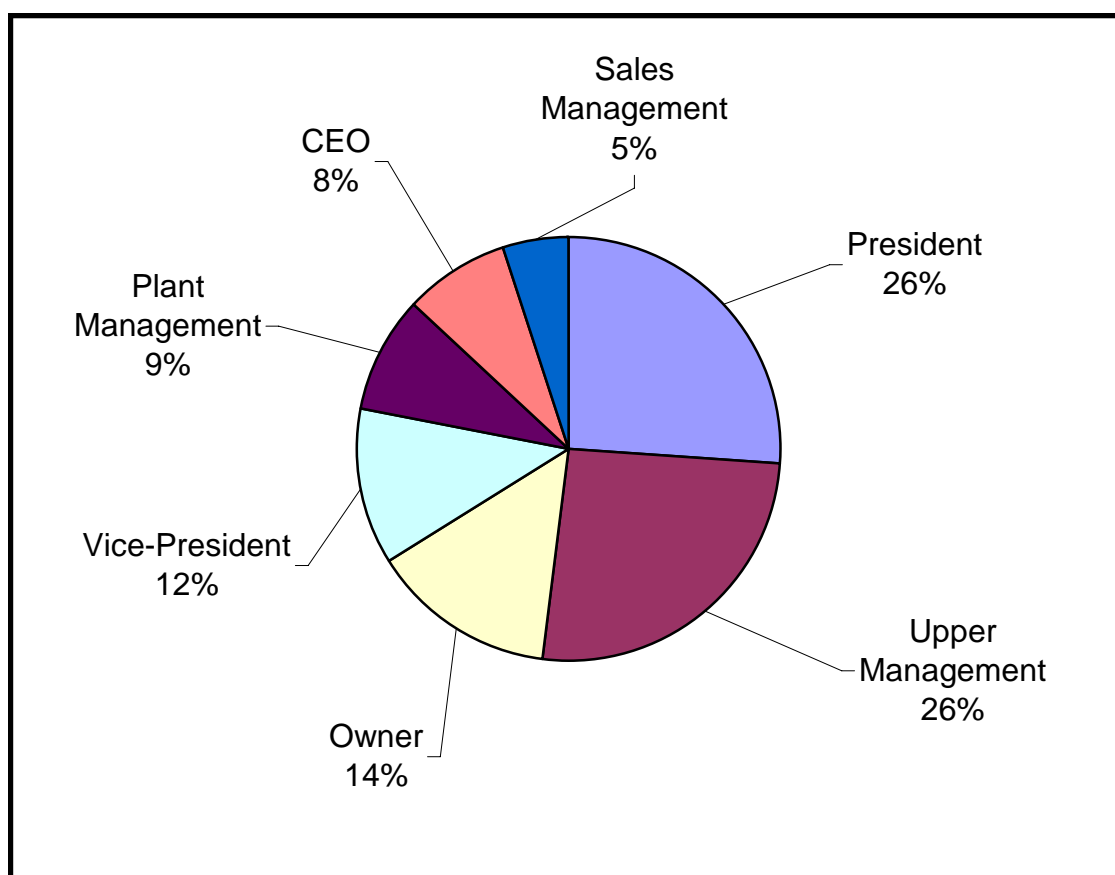


Finally, the company location scroll revealed the following observation. In the survey pool, there were an equal number of small manufacturers represented from Oklahoma's only two metropolitan cities – Oklahoma City and Tulsa (89). However, Oklahoma City had a higher response rate (16.9 percent versus 13.5 percent). The response rate from small manufacturers in rural Oklahoma was 23.2 percent. Figure 14 summarizes these results.



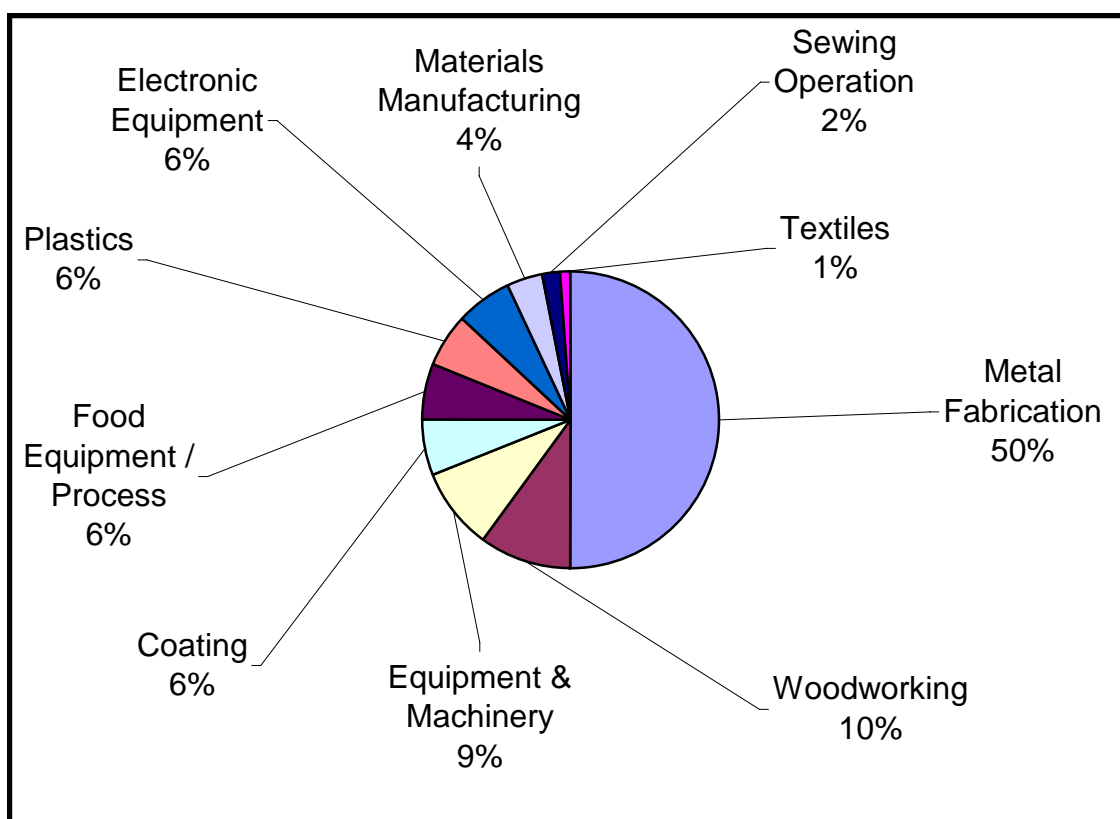
**Figure 14. Frequency Data on Respondents Representation**

The following demographic observations are from the second source of data - the survey questionnaires. Respondents to Question 1 in Section 1.0 held various positions. President and Upper Management accounted for 52 percent of the respondents. Another 14 percent indicated ownership. Also, this question identified who completed the survey. Figure 15 presents a summary of the various job titles.



**Figure 15. Frequency Data on Title of Respondent**

Question 2 of Section 1.0 identified the technology being used in the respondents' manufacturing environment. This gave an indication of the products being developed or produced at the facility. Half of the respondents stated metal fabrication as their primary technology. Figure 16 shows the primary technology used by the respondents. There were 12 missing data points for this frequency data set.



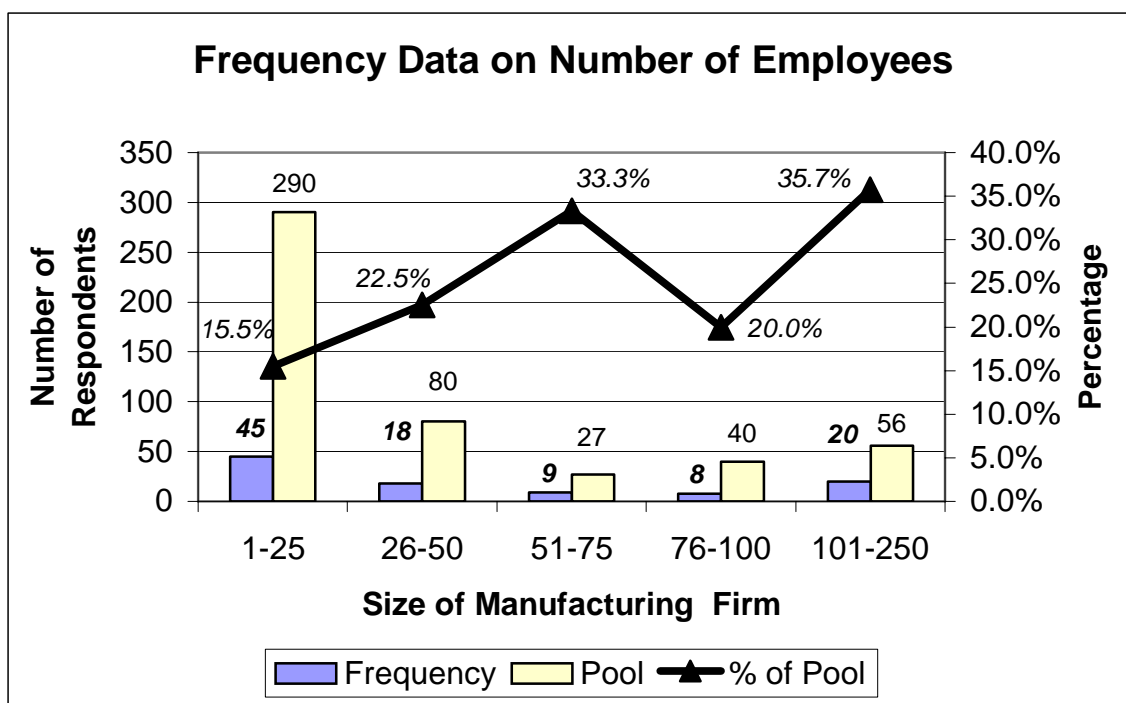
**Figure 16. Frequency Data on Primary Technology of Respondent**

The survey pool included a diverse number of manufacturing industries. The small manufacturers provided a wide spectrum of services for Oklahoma's communities. Question 3 of Section 1.0 identified SIC Codes of respondents. The majority of the respondents stated Fabricated Metal Products (SIC Code 34) and Electrical and Electronic Machinery, Equipment, and Supplies (SIC Code 36). Further, this diversity of manufacturing operations and manufactured products is an indication of the respondents' contributions to the economic and societal well-being of the state of Oklahoma and its communities. Table 3 summarizes the SIC Code data.

SIC Code	Title	Frequency
13	Oil Field	1
17	Special Trade Contractors	1
20	Food and Kindred Products	16
23	Apparel and Textile Products made from Fabrics	4
24	Wood Pallet Manufacture	2
25	Furniture and Home Cabinetry	2
26	Paper and Allied Products	7
27	Commercial Printing, Lithographic	1
28	Chemicals and Chemical Preparations	3
30	Fabricated Rubber Products	1
32	Nonmetallic Mineral Products	3
33	Primary Metal Products	1
34	Fabricated Metal Products	49
35	Machinery, except Electrical	13
36	Electrical & Electronic Machinery, Equipment, & Supplies	24
37	Transportation Equipment	16
38	Instruments for Measuring & Testing of Electricity & Electrical Signals	1
39	Clothing Fire Fighting Industry	1
49	Portable Water	1
50	Hospital and Medical Products	2
55	Recreational Vehicles	1
70	Recreational	1
72	Safety and Fitness Products	1

**Table 3. Frequency Data on SIC Code of Respondent**

Question 4 of Section 1.0 revealed that 45% of the respondents fell into the range of 1 to 25 employees. The 101 to 250 range was the next highest percentage with 20% and the 26 to 50 range was a close third with 18%. Using the third data scroll, which was sorted by company size, the 101 to 250 range had the highest response rate for the survey pool (35.7%). The next two highest response rates respectively were 33.3% by the 51 to 75 range and 22.5% by the 26 to 50 range. Figure 17 summarizes company size data.

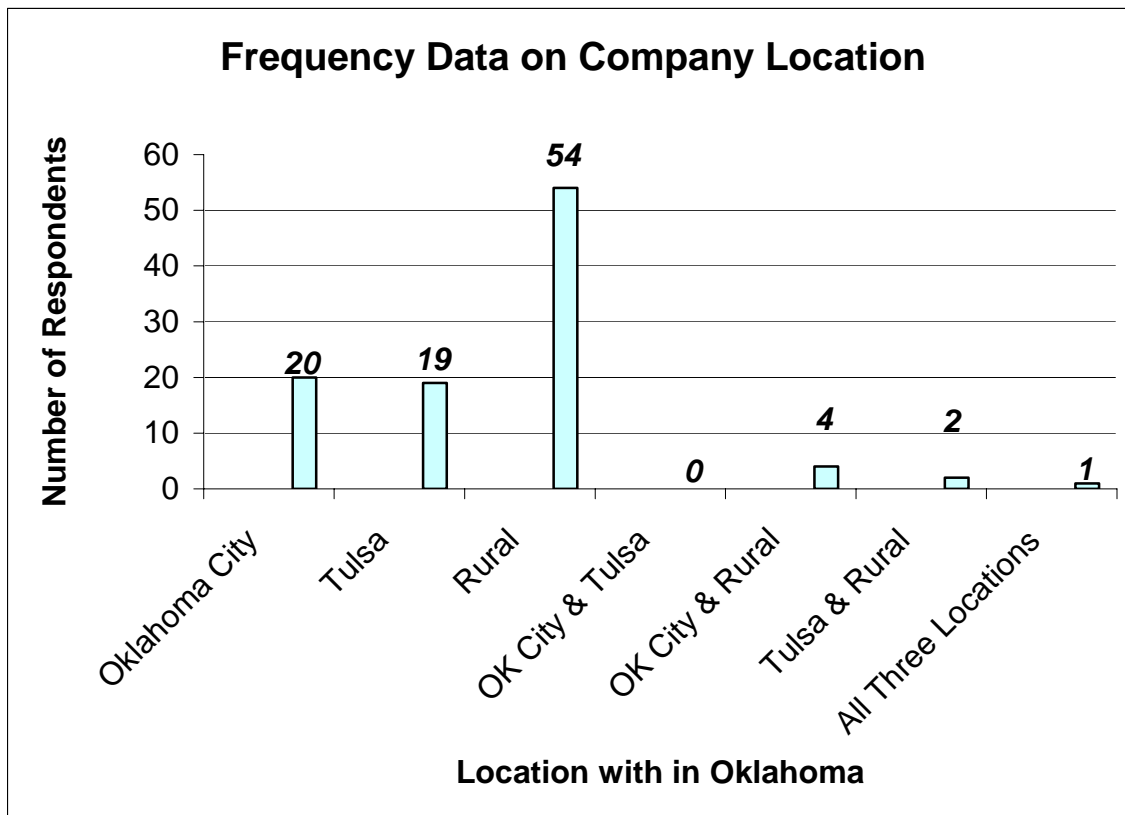


**Figure 17. Frequency Data on Number of Employees**

The size-range frequencies of manufacturing firms in Oklahoma in 1998 were as follows: 1-25 (59), 26-50 (14), 51-75 (8), 76-100 (4), and 101-250 (15) (Collins, 1998). The size-range frequency differences comparing the two studies are as follows: 1-25 (-14), 26-50 (+4), 51-75 (+1), 76-100 (+4), and 101-250 (+5). These differences indicate

a growth trend in the small manufacturer base in Oklahoma during the past seven years. Overall, this shift is a positive one in the sense that Oklahoma's small manufacturers are adding jobs to Oklahoma's labor market, which also supports the fact that small manufacturers in Oklahoma are seeking qualified employees to sustain their growth and remain competitive. However, this shift could also indicate that a percentage of small manufacturers in the 1-25 size range are closing their operations or moving out of state. Either way, the state technology transfer program ought not to let this trend continue unchecked. Frequent technology transfer needs assessments and studies should be planned and carried out to ensure proper awareness and documentation of the actual reasons or circumstances behind this shift. Otherwise, the state program risks losing a vital source of new revenues and job creation for the state of Oklahoma - (i.e., start-ups and new businesses).

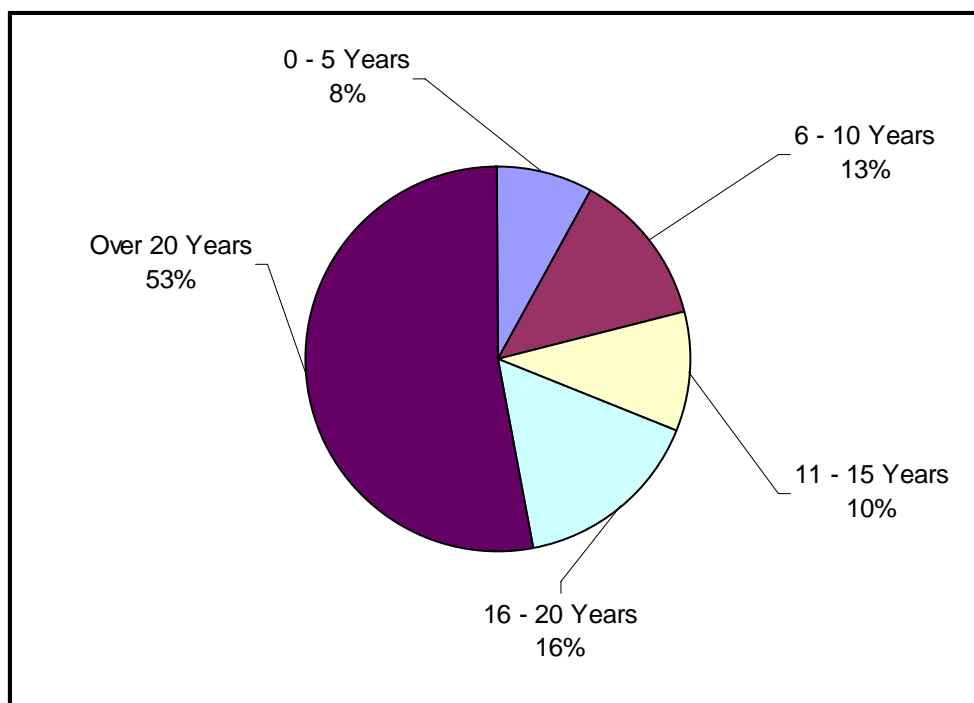
With respect to where the small manufacturers are located, answers to Question 6 of Section 1.0 revealed that 54% are located in rural areas while 39% are located in metropolitan areas. Furthermore, the remaining 7% of the respondents are located in multiple locations, both rural and metropolitan. Their breakdown is as follows: 4% in Oklahoma City and Rural, 2% in Tulsa and Rural, and 1% in Oklahoma City, Tulsa, and Rural. These results indicate that Oklahoma small manufacturers (both rural and metropolitan) had an equally vested interest in the deployment of technology transfer in today's highly competitive environment (54% versus 46%). Figure 18 summarizes company location data.



**Figure 18. Frequency Data on Company Location**

The last demographic frequency analysis for Research Question 6 (RQ 6) addresses responses to Question 8 of Section 1.0, which focuses on the age of the manufacturing firm. The analysis revealed that over 53% of the respondents are in the over 20 years range. This is encouraging for small manufacturers in today's highly competitive environment. This group's manufacturing experience and technology familiarity and skill is a definite advantage. On the other hand, start-ups and new businesses (0-5 years) represented 8% of the small manufacturers surveyed. A summary of the age data is presented in Figure 19.

With respect to the age of the manufacturing base in Oklahoma, in 1998 46% of the small manufacturers were under 16 years and 54% were over 16 years (Collins, 1998). Today, 31% of the manufacturing base is under 16 years and 69% is over 16 years. These numbers represent a 15% shift in the age of small manufacturers in Oklahoma in the past seven years. Overall, this shift is a positive one in the sense that Oklahoma has gained (and/or retained) more experienced small manufacturers. However, this shift also shows an increasing trend in the age of the small manufacturers in Oklahoma (i.e., a negative shift). If this trend continues unchecked, the state technology transfer program risks losing a vital segment of Oklahoma's industrial base and Oklahoma's economic well-being, reflected mostly in the communities that depend on their small manufacturers.



**Figure 19. Frequency Data on Age of the Manufacturing Firm**

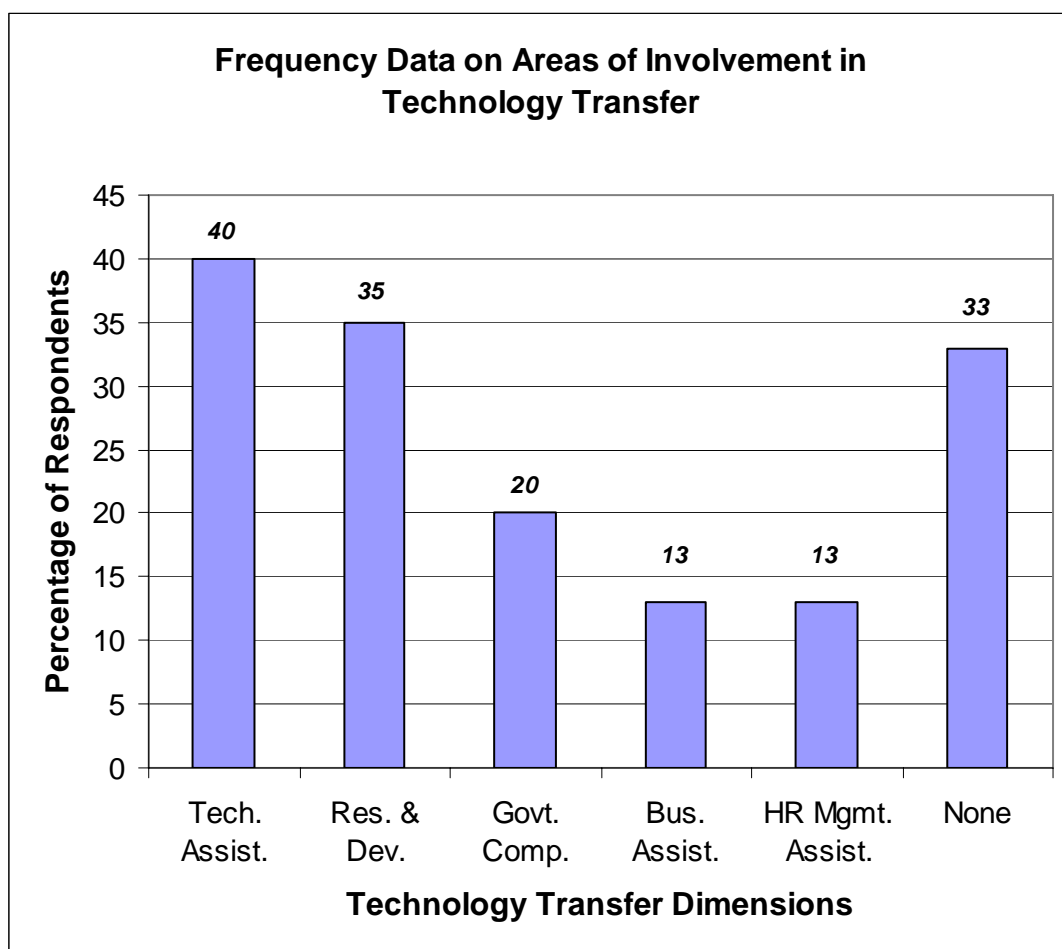


#### 4.2.2 Frequency Data on RQ 1 and RQ 2

Research Question 1 determines the requisite parts of a flexible and robust technology transfer program, which is an important first step for today's competitive environment. Survey Question 7 of Section 1.0 establishes a common starting point to develop such a program. The question reveals present technology transfer activities of small manufacturers. Currently, 40% and 35% of the respondents are actively involved in the Technical Assistance and Research and Development dimensions of technology transfer respectively. Noticeably, 33% are not involved at all with any technology transfer dimensions. In other words, these three percentages - (40%, 35%, and 33%) are indicating that Oklahoma small manufacturers are either very interested in technology transfer or do not have any interest/time for technology transfer, to deal with their competitive pressures. Figure 20 summarizes frequency data on areas of involvement in technology transfer.

For an in-depth look, Question 1 of Section 2.0 asked small manufacturers to rate each dimension using a 7-point Likert-scale. Descriptive statistics revealed the following. First, with respect to technical assistance, the overall mean was 4.84, which would be just below the Likert-scale "slightly more important" ranking. The standard deviation between responses for this dimension was 1.954 and the median was 5.00. This result affirms the respondents' commitment to the technical assistance dimension as evidenced in Figure 20.

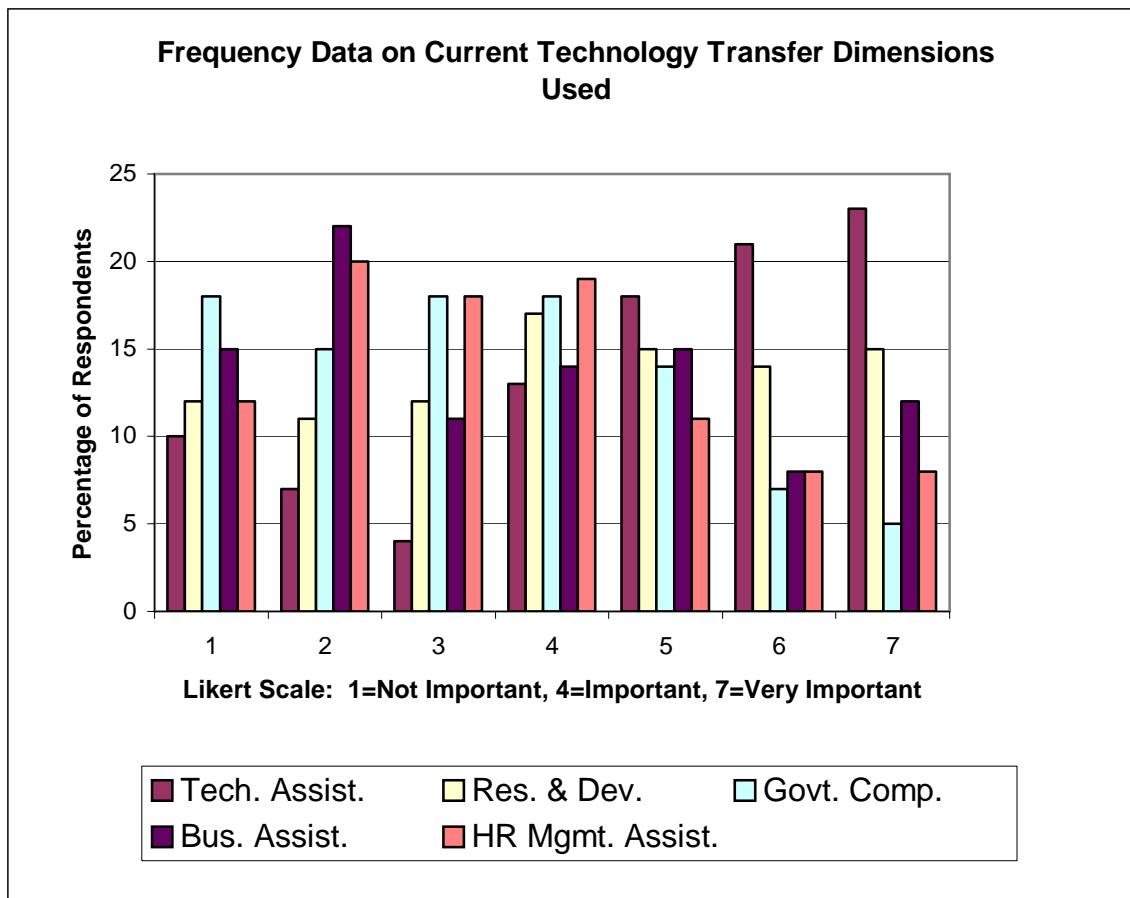
Second, for the research and development dimension, the mean was slightly lower (4.19). The standard deviation was 1.964 and the median was 4.00. Again, these results indicate that research and development is an important activity for Oklahoma small manufacturers to remain competitive.



**Figure 20. Frequency Data on Areas of Involvement in Technology Transfer**

The results for the remaining three technology transfer dimensions were: governmental compliance ( $\mu = 3.38$ ,  $\sigma = 1.758$ , median = 3.00), business assistance ( $\mu = 3.66$ ,  $\sigma = 1.984$ , median = 4.00), and human resource management assistance ( $\mu = 3.55$ ,  $\sigma = 1.782$ , median = 3.00). These three dimensions ranked between “slightly not important” and “important.” A ratings summary by the manufacturers of the technology transfer dimensions is provided in Figure 21.

To remain competitive, small manufacturers are not actively participating in governmental compliance, business assistance, or human resource management assistance, when compared to the technical assistance and research and development technology transfer dimensions. The demographic analysis results revealed that 63% of the manufacturers had 50 or fewer employees and 20% of the manufacturers had 101 to 250 employees, and 16% had been in business for 16 to 20 years and 53% had been in business over 20 years. These types of small manufacturers are very interested in sustaining and developing further their core technological competencies in this increasingly competitive environment. As a result, these manufacturers are more inclined to concentrate more on technical assistance and research and development to maintain their core technological competencies and remain competitive. The relationship of firm age and the position of the core technologies on the Technology S-curve could represent the technology transfer dimensions that the “small” manufacturer needs in order to remain competitive (Burgelman, Christensen, & Wheelwright, 2004; and Collins, 1998).



**Figure 21. Frequency Data on Current Technology Transfer Dimensions Used**

Question 2 of Section 2.0 provided insights on the type of technology transfer delivery system used by Oklahoma small manufacturers over the past seven years. The small manufacturers were asked to rate the ten predominant technology transfer agencies currently available in Oklahoma. Further, a neutral or not used (N) response option was included in this question to reflect the possibility that a small manufacturer had not used or did not know of a delivery system. The performance of these delivery systems was not being evaluated. These ten technology transfer agencies were simply being benchmarked to discover patterns of use. Also, this study, combined with a previous study by Collins

(1998), provides collectively an insightful 12-year benchmark period on technology transfer delivery system utilization in Oklahoma, dating back to 1993.

Table 4 provides descriptive statistics excluding neutral responses for Question 2, Section 2.0 of the survey. According to these results, the OSU Engineering Extension program and the Vo-Tech system received a high level of interest during the past seven years. Both had a mean higher than 4.00, which corresponds to an “important” to “slightly more important” rating on the Likert scale. However, a 2.089 standard deviation for the OSU Engineering Extension Program indicates a mixed response. The small manufacturers utilized this program occasionally to remain competitive during the past seven years. The least utilized program was the Oklahoma Center for Integrated Design and Manufacturing (OCIDM), which had a mean just below “moderately not important” ( $\mu = 1.93$ ).

The Alliance was the most utilized and recognized technology transfer delivery system in the past seven years. The Alliance, which is a broker/agents type of delivery system, received the following:  $\mu = 5.04$  = “slightly more important,”  $\sigma = 1.689$ , median = 5.00, and mode = 7.00. Oklahoma small manufacturers relied heavily on The Alliance to retain their competitive advantages. It can be hypothesized that the technology pull model of The Alliance seems to work best with Oklahoma small manufacturers to resolve their competitive pressures.

<b>Frequency Data on Delivery Systems Used</b>				
<b><i>Descriptive Statistics Excluding Neutral Responses</i></b>				
<b>[ Question 2, Section 2.0 - Current Study (Najd, 2005) ]</b>				
<b>Delivery Systems</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Median</b>	<b>Mode</b>
OCIDM	1.93	1.385	1.00	1.00
SBDC	2.33	1.328	2.00	2.00
REI	2.81	1.861	2.00	1.00 & 2.00
DEQ	3.05	1.696	3.00	2.00
ODOL	3.12	1.778	3.00	1.00
Cooperative Extension	3.20	1.824	3.50	1.00
University System	3.27	2.011	2.50	2.00
OSU Engineering Extension	4.23	2.089	4.00	2.00
Vo-Techs	4.52	1.827	5.00	6.00
The Alliance	5.04	1.689	5.00	7.00

**Table 4. Frequency Data on Delivery Systems Used**

According to Table 5, which provides descriptive statistics on just the neutral responses for Question 2, Section 2.0 of the survey, Oklahoma small manufacturers are more aware of Oklahoma's technology transfer delivery systems. Since need is the ultimate motivation for change, the competitive environment of the past seven years has raised the awareness of technology transfer delivery systems in Oklahoma. The relatively high percent change statistic exhibited in the past seven years indicate that small manufacturers in Oklahoma are seeking technology transfer assistance to resolve their competitive pressures, more so than in the previous five years as documented by Collins (1998). A very high percentage of respondents in 1998 were not familiar with, or had not used many of the delivery systems.

<b>Comparison Chart on Delivery Systems Not Used</b>				
<i>Neutral Responses to Question 2, Section 2.0 ( in Percent )</i>				
<b>Delivery Systems</b>	<b>Past Study (Collins, 1998)</b>	<b>Current Study (Najd, 2005)</b>	<b>Difference b/w Studies</b>	<b>Percent Change</b>
University System	65	64	1	1.5
SBDC	77	72	5	6.5
OCIDM	86	78	8	9.3
Cooperative Extension	82	72	10	12.2
REI	83	72	11	13.3
ODOL	67	52	15	22.4
DEQ	73	52	21	28.8
OSU Engineering Extension	75	51	24	32.0
Vo-Techs	52	23	29	55.8
The Alliance	73	15	58	79.5

**Table 5. Comparison Chart on Delivery Systems Not Used**

The Vo-Tech system had a 56% percent change, which is a noteworthy improvement. Also, responses to Questions 6 and 7, Section 9.0 of the survey further support this turn-around. With respect to past technologies, the Vo-Tech system was the third preferred source of training / transfer assistance. However, for future new technologies, the Vo-Tech system is the second preferred source of training / transfer assistance. For additional in-depth discussion on this important aspect, please refer to Section 4.2.4 of this study.

The most notable outcome during the past seven years is how well The Alliance has been perceived and utilized by Oklahoma small manufacturers to resolve their competitive pressures. The Alliance had the highest percent change of all the ten

technology transfer delivery systems in Oklahoma (80%). The Alliance model seems to be a good fit for the state of Oklahoma and seems to be an excellent source of help for small manufacturer to remain competitive. Furthermore, the noteworthy percent change figures for the top five delivery systems reconfirm overall the work by Masten, Hartmann, and Safari (1995), where exposure, affiliation, and comprehensiveness (Collins, 1998; and Osborne, 1989) of the technology transfer delivery system were deemed important aspects in the deployment of technology transfer. Notwithstanding, this turn-around in the neutral responses in just seven years is a tremendous advantage for Oklahoma small manufacturers in today's competitive environment.

On the other hand, Table 5 indicates only a 1.5% percent change for the University System. It can be hypothesized that Oklahoma small manufacturers were not as likely to approach the University System as compared with the other delivery systems for technology transfer assistance in a competitive environment. This conclusion provides a new perspective to a prior finding in Collins (1998). In the 1998 study, Collins concluded that Oklahoma small manufacturers were interested in a "holistic" university-based comprehensive structure for a state technology transfer program, where small manufacturers can receive "comprehensive" solutions to their technology transfer problems. However, with only a 1.5% percent change in the past seven years, small manufacturers are indicating that under competitive pressures, they are not likely to utilize such a "holistic" university-based program. The reasons cited for this decision are their limited time and resources. Interestingly enough, the "holistic" university-based program is still the predominant approach currently preferred by small manufacturers in



Oklahoma as indicated by subsequent results provided in Section 4.2.3 of this study. Thus, it can be hypothesized that Oklahoma small manufacturers will look for and count on the “holistic” university-based program to provide long-term solutions to their current top ten competitive pressures. In the meantime, they prefer the broker/agents type of technology transfer delivery system, such as The Alliance, to quickly and effectively navigate through and manage their competitive pressures, particularly for the short term. For additional in-depth reflection on these new important perspectives, please refer to Section 4.2.3 of this study for discussion on organizational structure preferences and Section 4.2.4 of this study for discussion on timeliness and financial concerns.

Sections 3.0 to 7.0 of the survey addressed Research Question 2, which focused on the attributes of the five technology transfer dimensions discussed previously for Research Question 1. This crucial next step develops interlocking mechanisms for a flexible and robust technology transfer program. Further, these attributes determined the overall significance of the dimensions. This is vital in a competitive environment, and the main concern of Research Question 2. Overall, these four sections in the survey further reveal present technology transfer activities of small manufacturers in Oklahoma.

Survey Questions 1 and 2 in Section 3.0 provide additional insight into the technical assistance dimension. Currently, small manufacturers are engaged in all five technical support techniques expressed in Question 1 - In-Person Direct Assistance, Communication Access, Technology News Releases, Literature Review, and Agent as a Liaison. Their mean was at least 4.00 or higher, which equates to an “important” rating

on the Likert scale. However, the Communication Access attribute received a mean of 5.13, which equates to “slightly more important.”

For the types of technical assistance addressed in the second question in Section 3.0, only Productivity Improvement and Ergonomics and Safety scored an “important” rating (4.00). This further suggests the two key areas to be addressed for small manufacturers are the New Product Development and Worker’s Compensation competitive pressures. Also, several small manufacturers suggested four additional areas not mentioned in the question that are of interest currently: Lean Technology, Lean Manufacturing, Past Pricing History, and Marketing and Advertising. These four areas reflect well on the top ten competitive pressures list. Table 6 provides a statistical summary of the technical assistance attributes.

Survey Questions 1 to 4 in Section 4.0 addressed the attributes of the research and development dimension. Overall, the respondents considered research and development an important part of their company’s strategy ( $\mu = 4.68$ ,  $\sigma = 1.874$ , median = 5.00, and mode = 6.00 and 7.00). New product development, existing product enhancement, applications research and development (commercialization of a product), and confidentiality were all also considered to be essential elements of a technology transfer program supporting small manufacturers - (mean equal or greater than 4.00). CRADA’s and basic research scored just below “important.” These results further emphasize and detail the importance of the New Product Development competitive pressure. Table 7 summarizes the research and development attribute frequency data for reference.

<b>Frequency Data on Technical Assistance Attributes</b>				
<i>Descriptive Statistics</i>				
<b>Questions 1 and 2, Section 3.0</b>				
<b>Attribute</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Median</b>	<b>Mode</b>
In-Person Direct Assistance	4.95	1.795	5.00	6.00
Communication Access	5.13	1.574	5.00	6.00 & 7.00
Tech. News Releases	4.15	1.879	4.00	4.00
Literature Review	4.29	1.657	5.00	5.00
Agent as a Liaison	4.02	2.026	4.00	5.00
Plant Design/Layout	3.90	2.219	4.00	1.00
Quality Control	3.95	2.282	4.00	1.00
Process Technologies	3.82	2.026	4.00	1.00
Engineering Design	3.36	2.058	3.00	1.00
Operations Research	2.73	1.629	3.00	1.00
Energy Management	2.51	1.524	2.00	1.00
Manufacturing Technologies	3.77	1.978	4.00	1.00
Workplace Design	3.49	2.051	4.00	1.00
Productivity Improvement	4.36	2.273	5.00	6.00 & 7.00
Ergonomics and Safety	4.11	2.075	5.00	6.00
Lean Technology	7.00	n/a	n/a	n/a
Lean Manufacturing	6.00	n/a	n/a	n/a
Past Pricing History	7.00	n/a	n/a	n/a
Marketing and Advertising	5.00	n/a	n/a	n/a

**Table 6. Frequency Data on Technical Assistance Attributes**

For the governmental compliance attributes addressed by Survey Questions 1 and 2 in Section 5.0, the respondents considered only OSHA safety and loss control and non-threatening assistance as “important.” These results further emphasize and detail the importance of the Worker’s Compensation competitive pressure currently faced by Oklahoma small manufacturers. Table 8 presents the governmental compliance attribute frequency data for reference.

<b>Frequency Data on Research and Development Attributes</b>				
<i>Descriptive Statistics</i>				
<b>Questions 1, 2, 3, and 4, Section 4.0</b>				
<b>Attribute</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Median</b>	<b>Mode</b>
R & D Strategy	4.68	1.874	5.00	6.00 & 7.00
New Product Development	5.23	1.959	6.00	7.00
Existing Product Enhancement	5.00	1.772	6.00	6.00
Basic Res. - New Technology	3.83	1.976	4.00	4.00
Applications R & D	4.05	2.002	4.00	6.00
CRADA's	3.97	2.049	4.00	4.00
In-House Res. - Confidentiality	4.77	1.928	5.00	7.00

**Table 7. Frequency Data on Research and Development Attributes**

<b>Frequency Data on Governmental Compliance Attributes</b>				
<i>Descriptive Statistics</i>				
<b>Questions 1 and 2, Section 5.0</b>				
<b>Attribute</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Median</b>	<b>Mode</b>
OSHA Safety & Loss Control	4.14	2.035	4.00	6.00 & 7.00
Hazardous Chemical Ass.	3.32	2.017	3.00	1.00
Governmental Compliance Ass.	3.52	1.966	3.00	1.00
Equal Employ. Opportunity Ass.	3.10	1.861	3.00	1.00
Trade Mark / Patent Ass.	3.46	2.206	3.00	1.00
Non-Threatening Assistance	4.96	1.947	6.00	7.00

**Table 8. Frequency Data on Governmental Compliance Attributes**

Survey Questions 1 and 2 in Section 6.0 addressed the attributes of the business assistance dimension. The respondents considered only marketing study assistance and support as “important” - ( $\mu = 4.15$ ,  $\sigma = 2.022$ , median = 4.00, and mode = 1.00 and 5.00). This result further emphasizes and details the importance of the Marketing competitive

pressure currently faced by Oklahoma small manufacturers. Table 9 illustrates the business assistance attribute frequency data for reference.

<b>Frequency Data on Business Assistance Attributes</b>				
<i>Descriptive Statistics</i>				
<b>Questions 1 and 2, Section 6.0</b>				
<b>Attribute</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Median</b>	<b>Mode</b>
Financial Consulting	3.36	1.935	3.00	1.00
Loan Processing Assistance	3.01	1.858	3.00	1.00
Marketing Study Ass. & Support	4.15	2.022	4.00	1.00 & 5.00
Patenting Process Assistance	3.23	2.112	3.00	1.00
Venture Capital Assistance	2.85	2.036	2.00	1.00
Temp. Low Cost Facilities	3.45	2.309	3.00	1.00

**Table 9. Frequency Data on Business Assistance Attributes**

Survey Question 1 in Section 7.0 addressed the attributes of the fifth and last technology transfer dimension - human resource management assistance. For this dimension, the respondents considered employee benefits, insurance, and worker's compensation training as "important" - ( $\mu = 4.31$ ,  $\sigma = 1.790$ , median = 4.00, and mode = 4.00). The employee selection assistance attribute was slightly below "important" - ( $\mu = 3.96$ ,  $\sigma = 1.713$ , median = 4.00, and mode = 4.00). These two results further emphasize and detail the importance of three of the top ten competitive pressures currently faced by Oklahoma small manufacturers - Qualified Employees (1<sup>st</sup>), Worker's Compensation (2<sup>nd</sup>), and Human Resources (8<sup>th</sup>).

To remain competitive, small manufacturers in Oklahoma are not actively participating in human resource management assistance as a dimension (or field of interest) - ( $\mu = 3.55$ ,  $\sigma = 1.782$ , median = 3.00, and mode = 2.00). However, the attributes of this technology transfer dimension are of interest to sustain their competitive advantage. Therefore, there are growth potential and work opportunities in this dimension for future human resource management specialists. In the meantime, due to limited resources and a highly competitive environment, small manufacturers in Oklahoma will continue their involvement in the attributes, especially worker's compensation, instead of the dimension as a whole, for the near future. Table 10 summarizes the various human resource management assistance attributes.

<b>Frequency Data on Human Resource Management Assistance Attributes</b>				
<i>Descriptive Statistics</i>				
Question 1, Section 7.0				
<b>Attribute</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Median</b>	<b>Mode</b>
Employee Selection Assistance	3.96	1.713	4.00	4.00
Employee B., Ins., & W. Comp.	4.31	1.790	4.00	4.00
Labor/Mgmt Relations Assistance	3.35	1.700	3.00	4.00

**Table 10. Frequency Data on Human Resource Management Assistance Attributes**

Overall, small manufacturers in Oklahoma value their time and resources. Responses to questions for Research Questions 1 and 2 emphasize the importance of competitive pressures and their effect on decision-making in a small manufacturing

environment. The respondents indicated a need for a robust and flexible technology transfer program that complements their activities, and in some cases supplements their activities, to retain their competitive advantages. Particularly, respondents are actively engaged in technical assistance and research and development activities, while only partially participating in human resource management assistance activities. Furthermore, the respondents' decisions with respect to technology transfer delivery systems indicate a strong desire to balance their short-term objectives with their long-term goals to sustain and potentially increase their competitive advantages, within their limited resources.

#### **4.2.3 Frequency Data on RQ 3**

Research Question 3 determined the desired organizational structure of a technology transfer program that would best satisfy the needs of Oklahoma small manufacturers in a competitive environment. According to the results for Survey Question 1 in Section 8.0, respondents want a single-source, statewide technology transfer program that provides all the required technology transfer assistance within one unit ( $\mu = 4.45 =$  "important,"  $\sigma = 1.777$ , median = 5.00, and mode = 5.00 and 6.00). Furthermore, such a program must provide assistance in a non-threatening way as previously mentioned.

In Question 2 of Section 8.0, respondents were asked to rate three organizational structures for technology transfer delivery systems: University-Based Comprehensive

“Holistic” Structure (Approach 1 or A1), Uni-Dimensional Structure (Approach 2 or A2), and Locally-Based Network Structure (Approach 3 or A3). Oklahoma small manufacturers preferred Approach 1 and Approach 3. Both approaches received an “important” rating on the Likert scale. Approach 1’s “holistic” comprehensive nature and Approach 3’s “broker-agent” style were a better fit than Approach 2’s “fragmented” method for delivering technology transfer assistance to Oklahoma small manufacturers in a competitive environment. A statistical summary for Questions 1 and 2 in Section 8.0 is provided in Table 11.

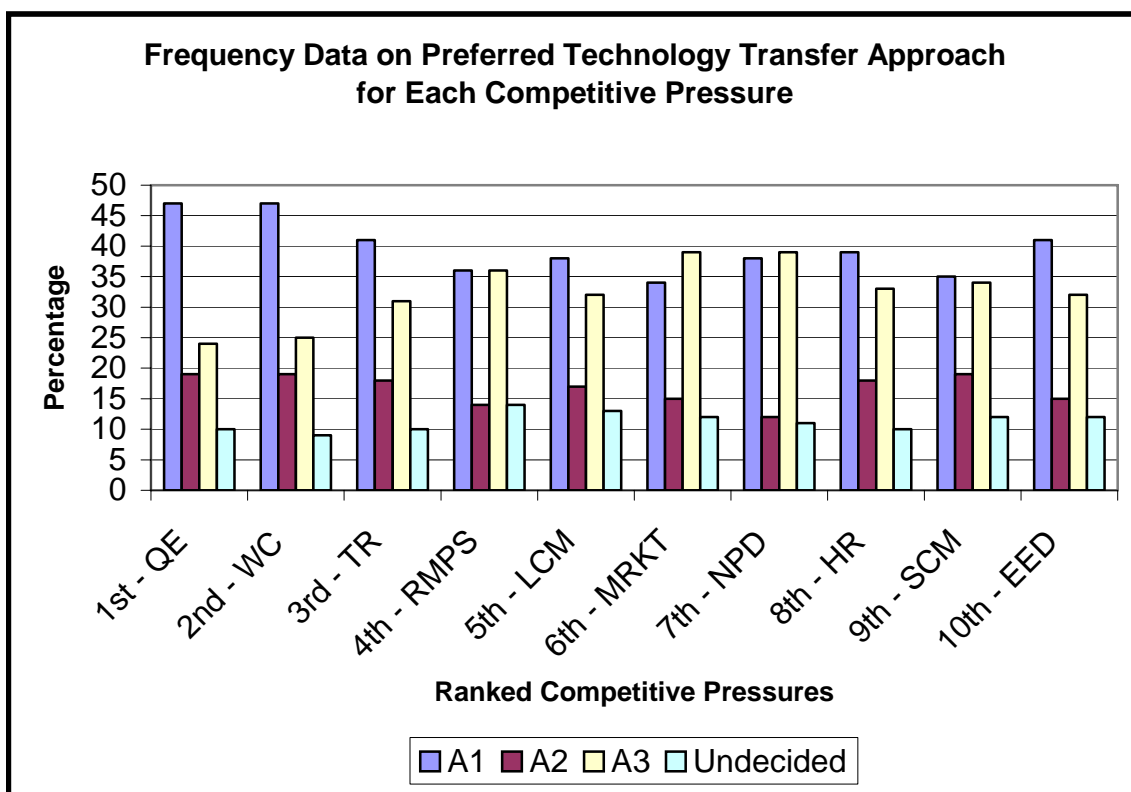
<b>Frequency Data on Organizational Structure</b>				
<i>Descriptive Statistics</i>				
<b>Questions 1 and 2, Section 8.0</b>				
<b>Item</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Median</b>	<b>Mode</b>
Single Source, Statewide Program	4.45	1.777	5.00	5.00 & 6.00
University-Based Structure ( A1 )	4.73	1.750	5.00	6.00
Uni-Dimensional Structure ( A2 )	3.22	1.504	3.00	4.00
Locally-Based Network Structure ( A3 )	4.52	2.031	5.00	6.00

**Table 11. Frequency Data on Organizational Structure**

The third and last question in Section 8.0 of the survey asked Oklahoma small manufacturers to indicate which approach from the three approaches mentioned previously would be most beneficial to resolve each of the top ten ranked important competitive pressures listed earlier in the study. Predominately, Approach 1 and Approach 3 were selected for all ten competitive pressures. This result is consistent with



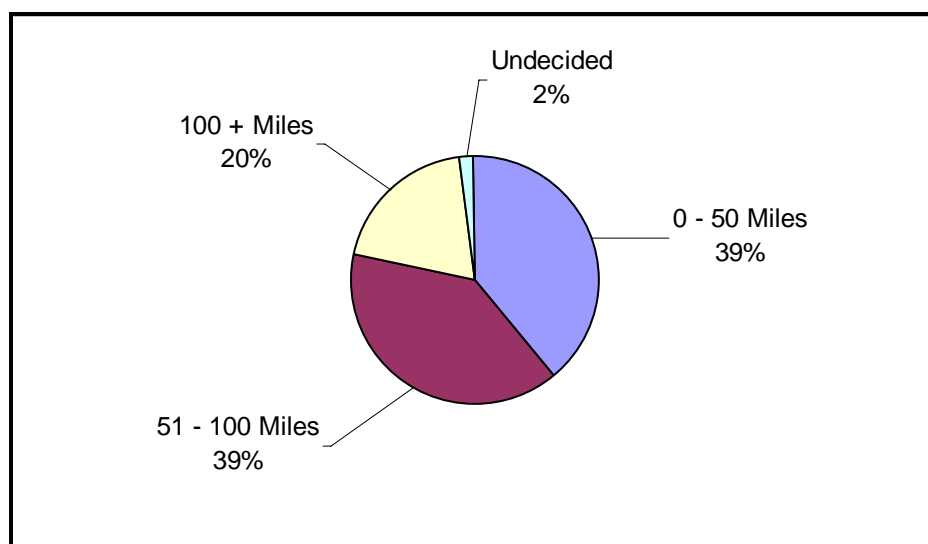
the “important” rating achieved for Approaches 1 and 3 in the previous question. Thus, it can be hypothesized that Oklahoma small manufacturers prefer the streamlined-solution capability offered by Approaches 1 and 3 to retain their competitive advantages. Figure 22 provides a preference summary for all top ten ranked competitive pressures.



**Figure 22. Frequency Data on Preferred Technology Transfer Approach for Each Competitive Pressure**

Regional boundaries for Oklahoma’s state-wide technology transfer program were established by the results from Question 1 of Section 9.0. The frequency data analysis showed the following: 39% of the respondents preferred to travel a distance of 0-50

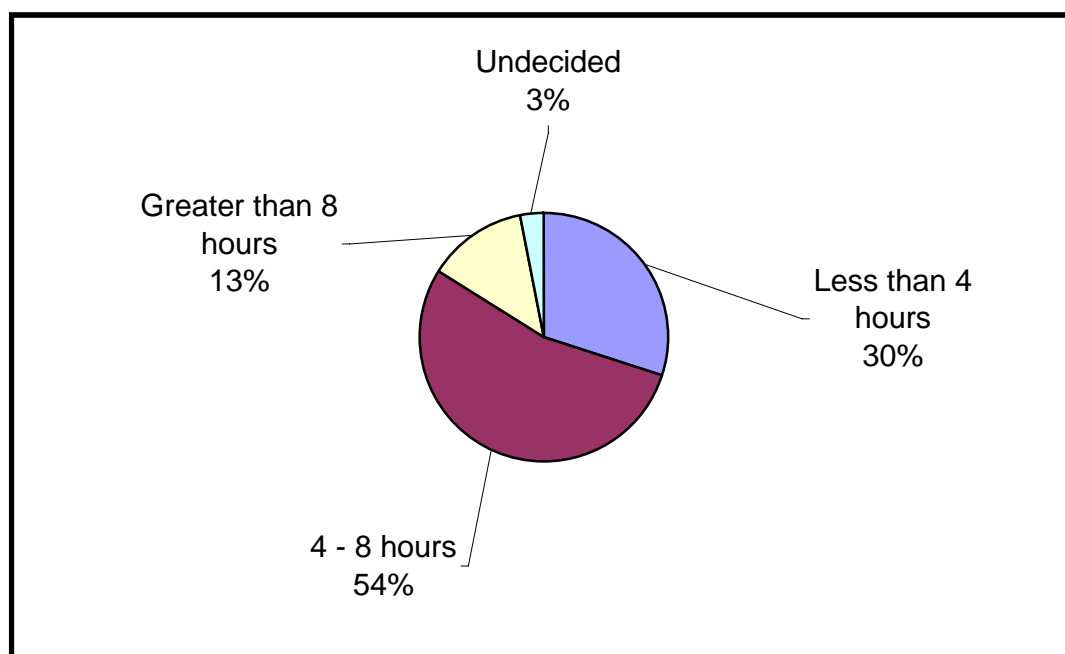
miles; 39% of the respondents preferred to travel a distance of 51-100 miles; and 20% preferred to travel a distance of over 100 miles. Therefore, regional offices or off-site locations for meetings with Oklahoma small manufacturers for technology transfer assistance should be within a 100-mile radius. Figure 23 shows travel preferences of Oklahoma's small manufacturers.



**Figure 23. Frequency Data on Traveling Distance**

Question 2 of Section 9.0 establishes duration time for technology transfer meetings. Predominately, 54% of the respondents favor 4 to 8-hour meetings - (1 Day), while 30% of the respondents favor meeting for less than 4 hours - (1/2 Day). Only 13% of the respondents favor meetings that last more than 8 hours (or more than one day). These results compliment the traveling distance preferences discussed earlier and

reemphasize the need for regional offices or off-locations to accommodate small manufacturers. Albeit, their competitive pressures limit their ability to allocate resources for technology transfer meetings that are longer than one day and/or are located farther than 100 miles. Figure 24 shows technology transfer meeting duration frequency results.



**Figure 24. Frequency Data on Technology Transfer Meeting Duration**

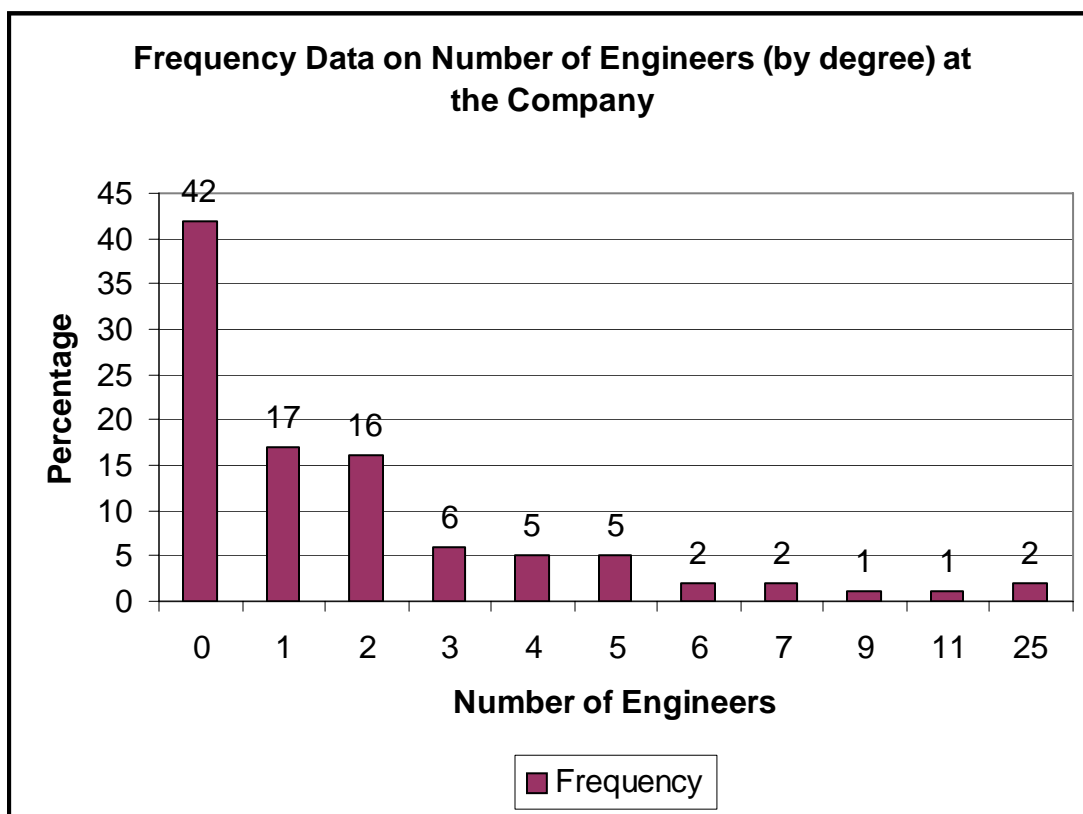
Overall, responses to questions for Research Question 3 emphasized how small manufacturers in Oklahoma prefer to handle their competitive pressures. Figure 22 on page 194 summarizes the approach preferences with respect to their competitive pressures. In addition, technology transfer assistance needs to come from a single-source statewide program without the threat of citations. Competitive advantages for the long-

term need to be developed in university-based comprehensive settings (Approach 1). Likewise, small manufacturers will seek short-term solutions to their competitive pressures via the locally-based network arm (Approach 3) of the state-wide program. In both instances, delivery of technology to small manufacturers needs to occur via regional or off-location meetings within 100 miles and last no more than one day. These two scenarios indicate that the state-wide technology transfer program should be robust and flexible to maximize the efforts of small manufacturers in this highly competitive environment.

#### **4.2.4 Frequency Data on RQ 4**

Research Question 4 addressed the underlying emphases of a state technology transfer program that would meet future manufacturing industry requirements in a competitive environment. The first step in this process is to determine the technical ability of small manufacturers in Oklahoma and their potential to deploy technology with more success, especially in a competitive environment. Survey Question 5 in Section 1.0 dealt with this issue by determining the number of engineers (by degree) employed by the small manufacturers. By employing engineers, the small manufacturers can streamline their interactions with the state technology transfer program. The frequency analysis determined that technical expertise is low among the respondents. Over 42% of the respondents do not employ any engineers. This result slows down the technology deployment process within a major segment of the small manufacturers in Oklahoma.

There was one company that did not respond to this question. Figure 25 summarizes the frequency data on the number of engineers (by degree) at the companies.



**Figure 25. Frequency Data on Number of Engineers (by degree) at the Company**

Survey Question 9 in Section 1.0 addressed technical complexity of small manufacturers in Oklahoma. This question clarifies the technology needs of small manufacturers according to their technical complexity in their manufacturing operations. Eighty percent of the respondents have small-batch and unit production facilities. Another 14% of the respondents have large-batch and mass production facilities. Only

5% operate continuous process production operations. Since 80% have customized work and rely heavily on the human operator, this further emphasizes the importance of the technical assistance and human resource management assistance dimensions of technology transfer in the state program. Moreover, this result further emphasizes the importance of the top two competitive pressures currently faced by small manufacturers - Qualified Employees and Worker's Compensation. Figure 26 presents the technical complexities of the respondents.

Question 3 of Section 9.0 determines the activity patterns of the respondents. Attending trade shows and conventions improves the competitive advantages of small manufacturers by being introduced to current or new technologies. According to the results, the state program's mission ought to reflect a "demand-pull" situation. Oklahoma small manufacturers are actively attending trade shows and conventions, especially in the past three years, looking for solutions to their problems (or competitive pressures). In addition, this result suggests integrating the "demand-pull" mission into any of the three approaches to technology transfer immediately to streamline the technology deployment process of the state technology transfer program. There was one respondent that attended 715 trade shows in the past three years. Figures 27 and 28 present the frequency data on the number of trade shows and the number of conventions respectively (excluding the 715).

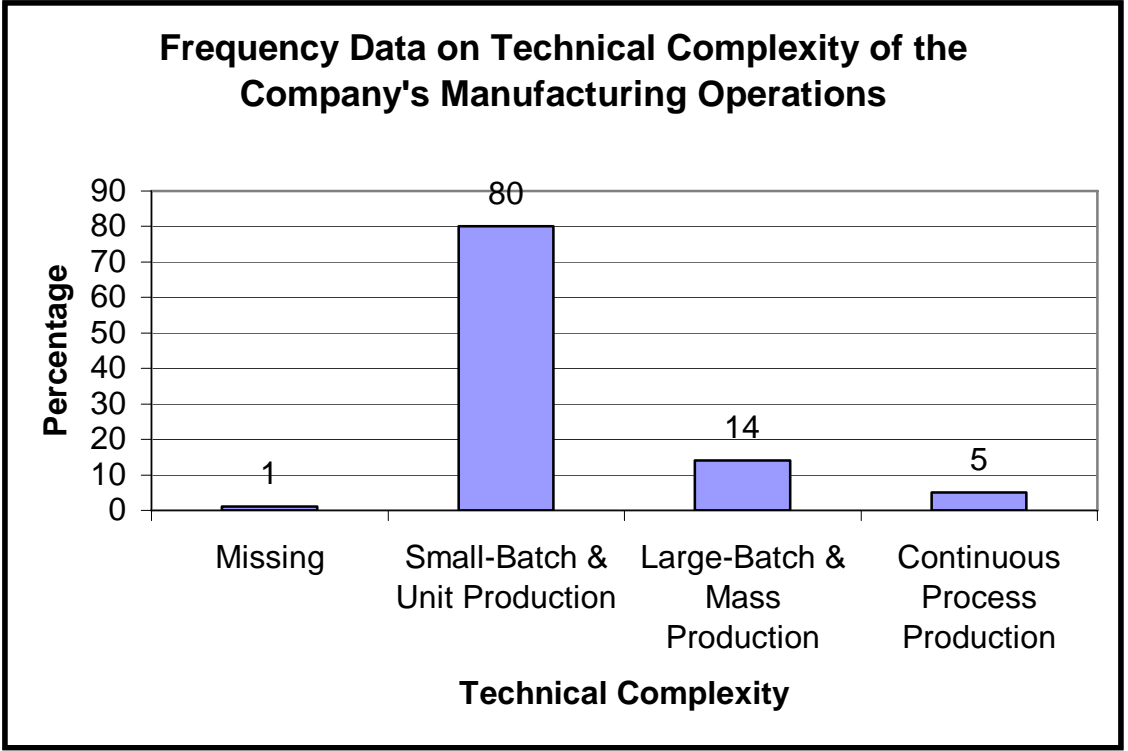


Figure 26. Frequency Data on Technical Complexity of the Company's Manufacturing Operations

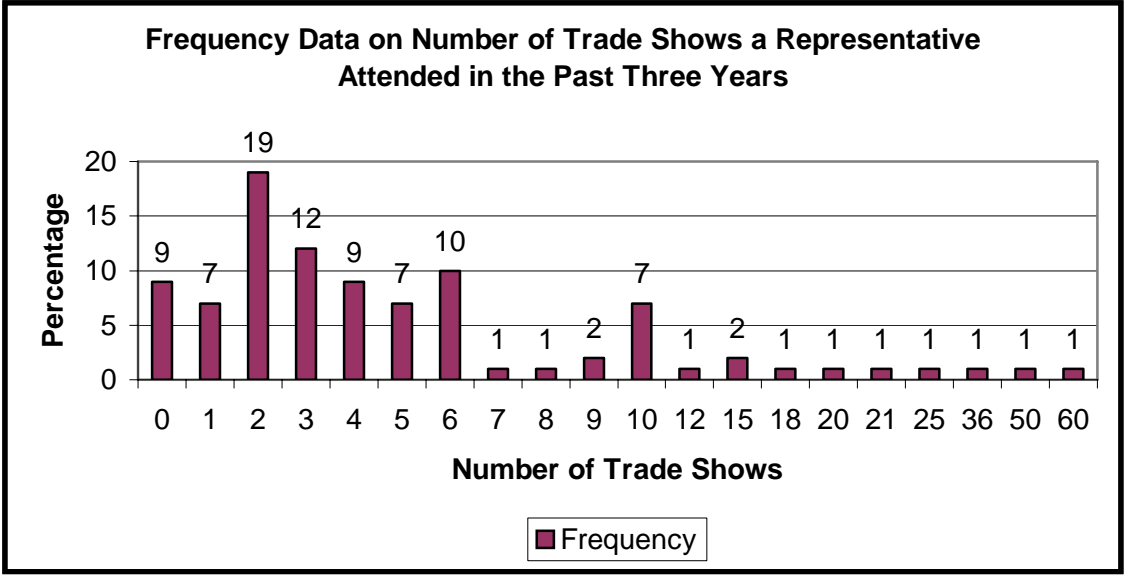
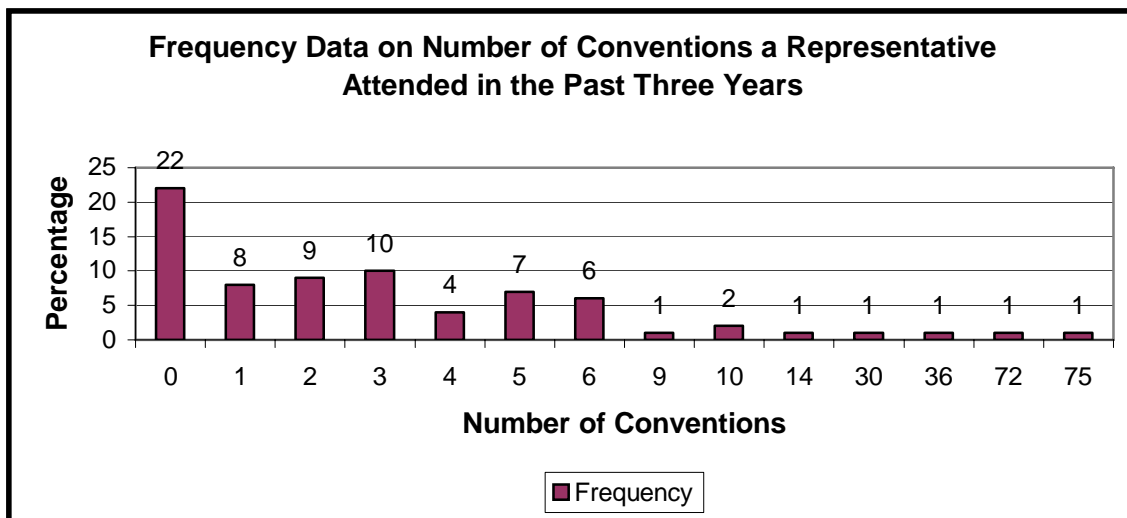


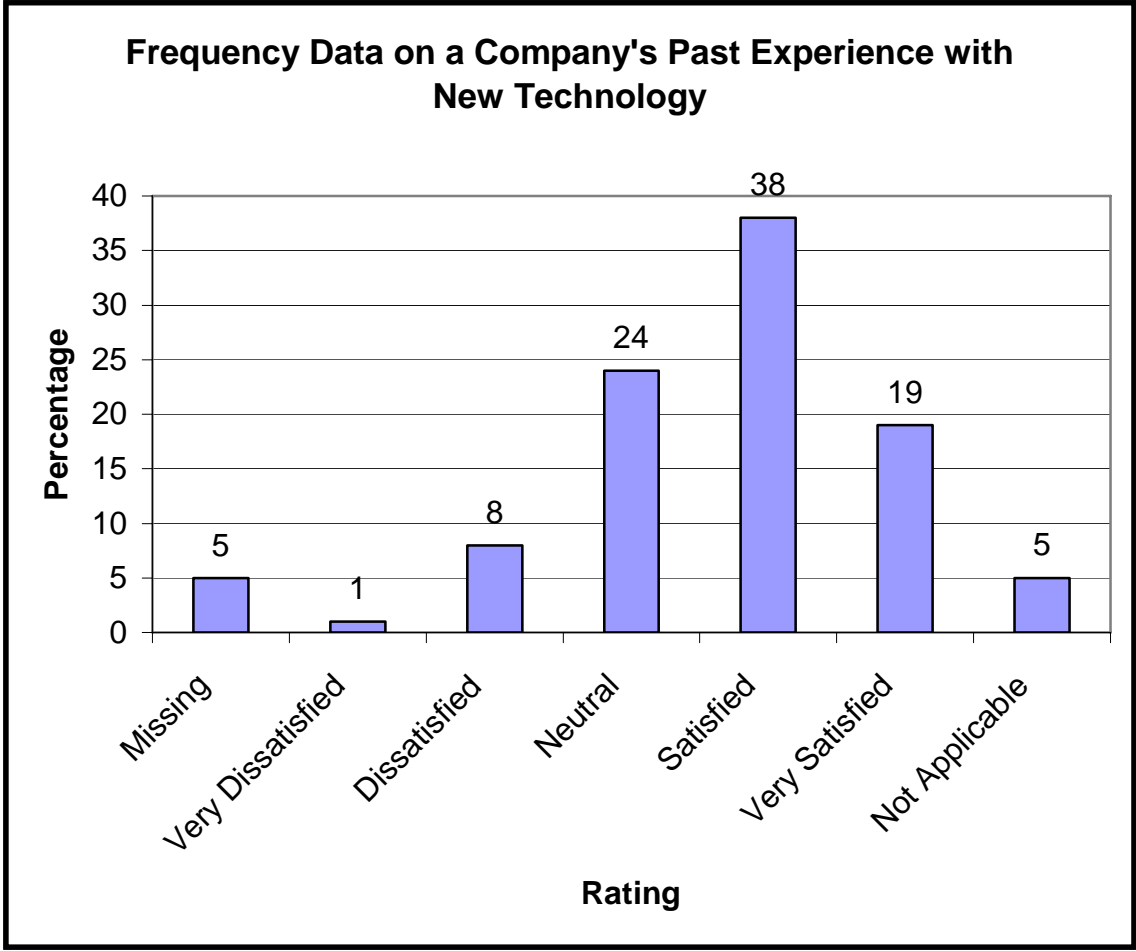
Figure 27. Frequency Data on Number of Trade Shows a Representative Attended in the Past Three Years



**Figure 28. Frequency Data on Number of Conventions a Representative Attended in the Past Three Years**

Question 4 of Section 9.0 determined a manufacturer's past technology transfer experience with new technology. Thirty eight percent of the respondents were satisfied and 19% were very satisfied. These are encouraging results compared with only 8% as dissatisfied and 1% as very dissatisfied. Overall, these results reflect well on the small manufacturers' experiences with new technology in the near past; however, this is not a guaranteed outcome when operating under an increasingly competitive environment in the future. Figure 29 recaps the past experiences.





**Figure 29. Frequency Data on a Company's Past Experience with New Technology**

Question 5 of Section 9.0 addressed barriers to new technology. Determining a preliminary list of potential barriers to technology deployment establishes the foundational pillars of a flexible and robust state technology transfer program relative to the technology adoption continuum presented by Hoff (1997). The analysis results recognized potential technology adoption/rejection decision outcomes of small manufacturers operating under competitive pressures.

The number one barrier to new technology is work force skills (54%), which is consistent with the currently number one competitive pressure - Qualified Employees. The next four barriers are: financing (44%), lack of understanding and training with the technologies (37%), transfer and implementation difficulties (33%), and technology appropriateness (32%). The remainder of the barrier list is presented in Figure 30. Collectively, the list is a broad reflection on the technology transfer decisions of small manufacturers in Oklahoma. This list is not an exhaustive list; however, it is an excellent starting point from which to begin a dialog with small manufacturers addressing their technology transfer needs to resolve their competitive pressures.

In Question 6 of Section 9.0, respondents identified their primary source of training / transfer assistance with past technologies and identified their primary source of training / transfer assistance for future new technologies in Question 7 of Section 9.0. Several respondents, as previously mentioned, selected multiple sources for Question 6 and Question 7 - (30 percent and 18 percent respectively). For the remainder of the respondents with respect to past technologies, the top four responses were in-house expertise (25%), vendors (20%), Vo-Tech (10%), and industry associations (6%). With respect to future new technologies, the top four responses were: vendors (24%), Vo-Tech (19%), in-house (17%), and industry associations (12%). Figures 31 and 32 present the frequency data for Questions 6 and 7 of Section 9.0.

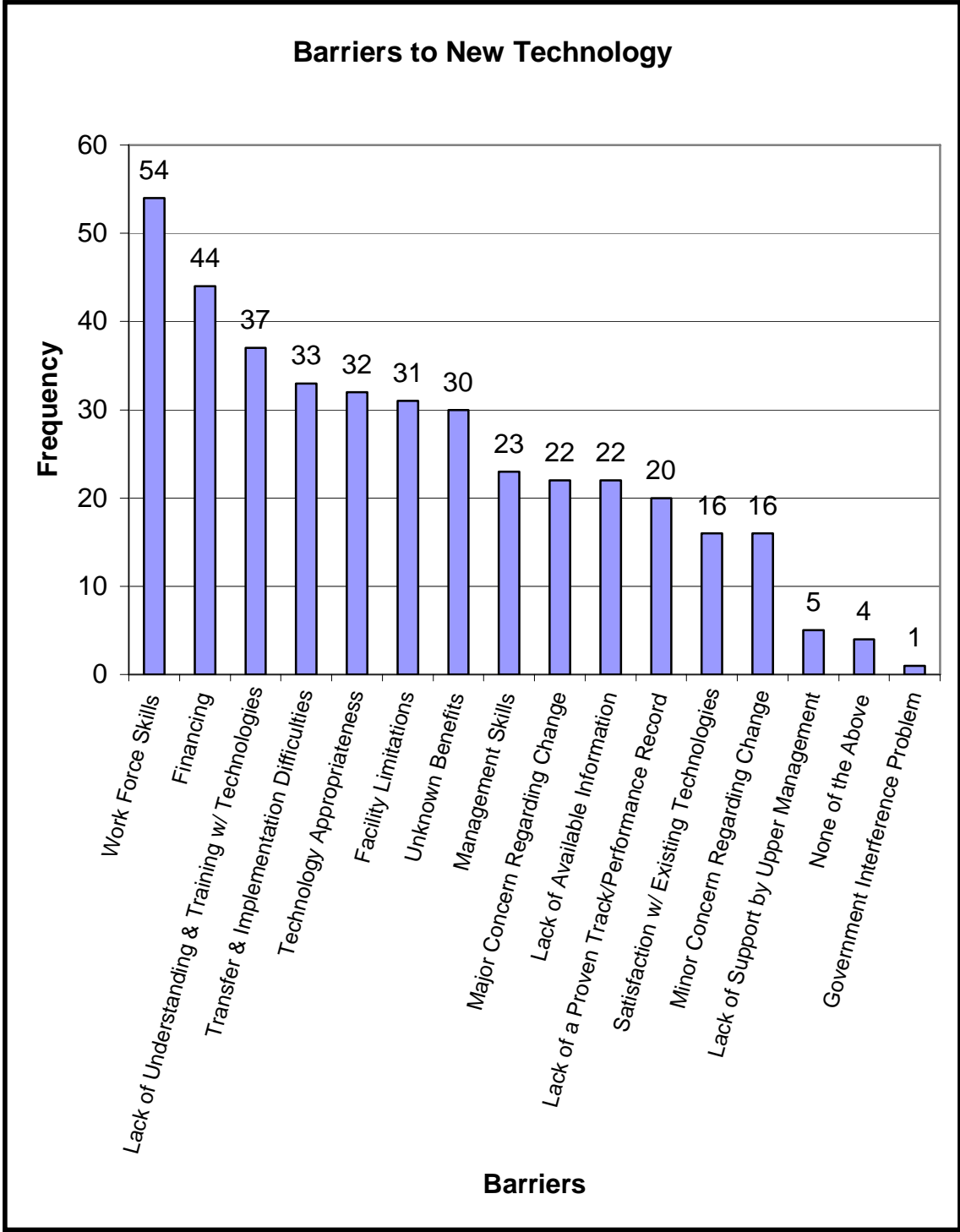
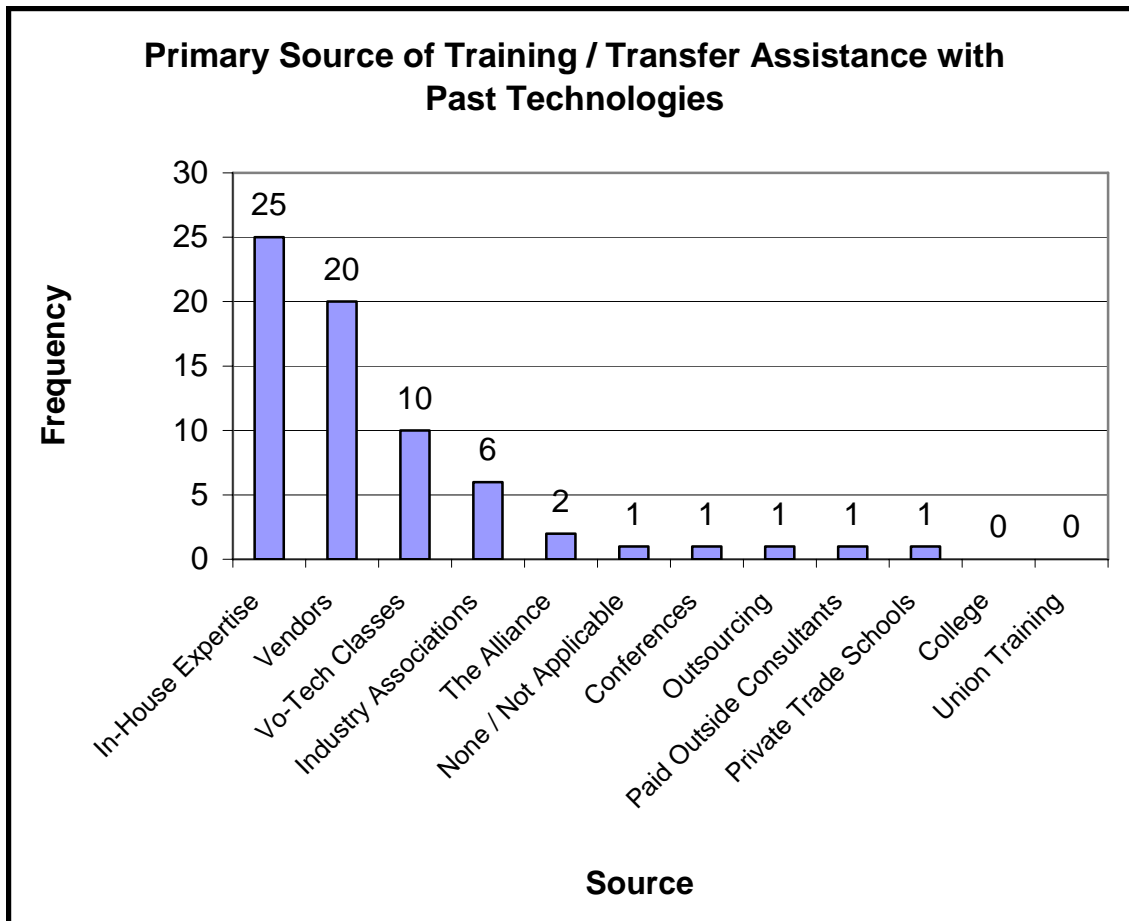
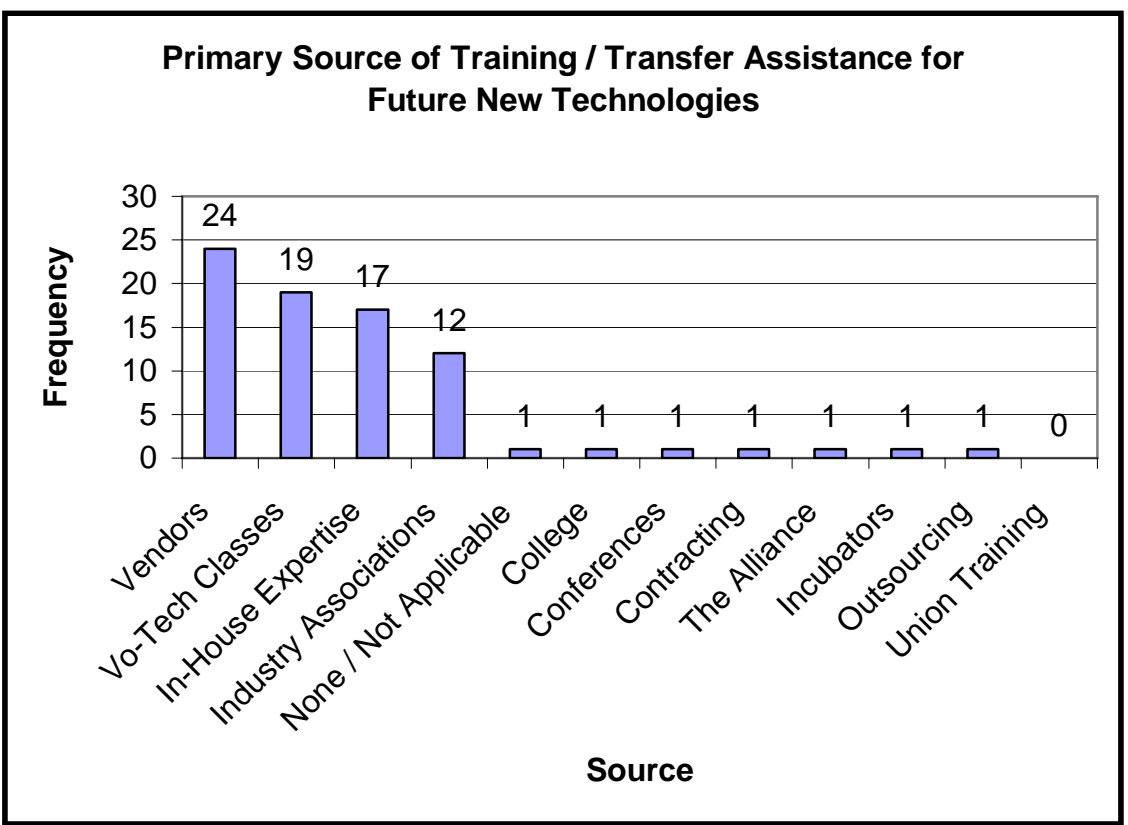


Figure 30. Barriers to New Technology



**Figure 31. Frequency Data on Primary Source of Training / Transfer Assistance with Past Technologies**

The results to these two questions do indicate a change of preference among small manufacturers in Oklahoma. To remain competitive, respondents would rather consult with vendors regarding future new technologies and reduce their over-head costs and payroll expenses. Furthermore, by considering vendors over in-house expertise, respondents are indicating how they want to overcome their number one barrier to new technology - (work force skills). In other words, vendors will train and assist with future new technologies and thus increase and improve the knowledge base of employees. For the state-wide technology transfer program, these results indicate the preferred meeting



**Figure 32. Frequency Data on Primary Source of Training / Transfer Assistance for Future New Technologies**

locations for training and / or transfer assistance with future new technologies and highlight which technology transfer delivery systems in Oklahoma small manufacturers will contact in the future. If a technology transfer delivery system is capable of conducting outreach training or transfer activities in this highly competitive environment, then its chances of success increases, and as a result, it is recognized more by the small manufacturers.

Monetary and financial impacts of technology transfer projects were addressed in Question 8 of Section 9.0. In a competitive environment, small manufacturers are hesitant to pay for technology transfer services. Past research indicates a reluctance to use technology transfer programs that charged fees for services (Clarke and Dobson, 1991). However, a recent study by Collins (1998), coupled with this study, shows an increasing trend in the number of small manufacturers willing to subsidize technology transfer assistance. Table 12 and Figure 33 provide a comparison view of the financial conditions of today's small manufacturers in Oklahoma over the past seven years.

<b>Frequency Data Comparison Chart on Pay for Services</b>				
<i>Responses to Question 8, Section 9.0</i>				
<b>Percent Pay Range</b>	<b>Past Study <i>Collins, 1998</i></b>	<b>Current Study <i>Najd, 2005</i></b>	<b>Difference b/w Studies</b>	<b>Percent Change</b>
Missing	0	4	4	n/a
Cannot Pay	53	33	-20	-37.7
Can Pay	47	63	16	34.0
0 - 5 %	5	9	4	80.0
6 - 10 %	6	10	4	66.7
11 - 15 %	2	3	1	50.0
16 - 20 %	6	4	-2	-33.3
21 - 25 %	7	7	0	0.0
26 - 50 %	13	13	0	0.0
51 - 75 %	1	6	5	500.0
76 - 100 %	7	18	11	157.1

**Table 12. Frequency Data Comparison Chart on Pay for Services**

Currently, 63 of the manufacturers indicated they would pay for services, while 33 said they would not pay. There were 4 missing data points for this question. Overall,

there was a clear separation between the respondents. A major portion of the manufacturers is willing to pay for 90-100 percent of the costs (18), while 19 respondents are willing to pay for less than 10% of the costs. Also, 6 respondents are willing to pay for 51-75 percent of the costs. The 76-89 percent pay range was not selected, and thus it was joined with the 90-100 percent pay range. This formed a new percent pay range - (76-100 percent) and allowed for a similar comparison with a prior study.

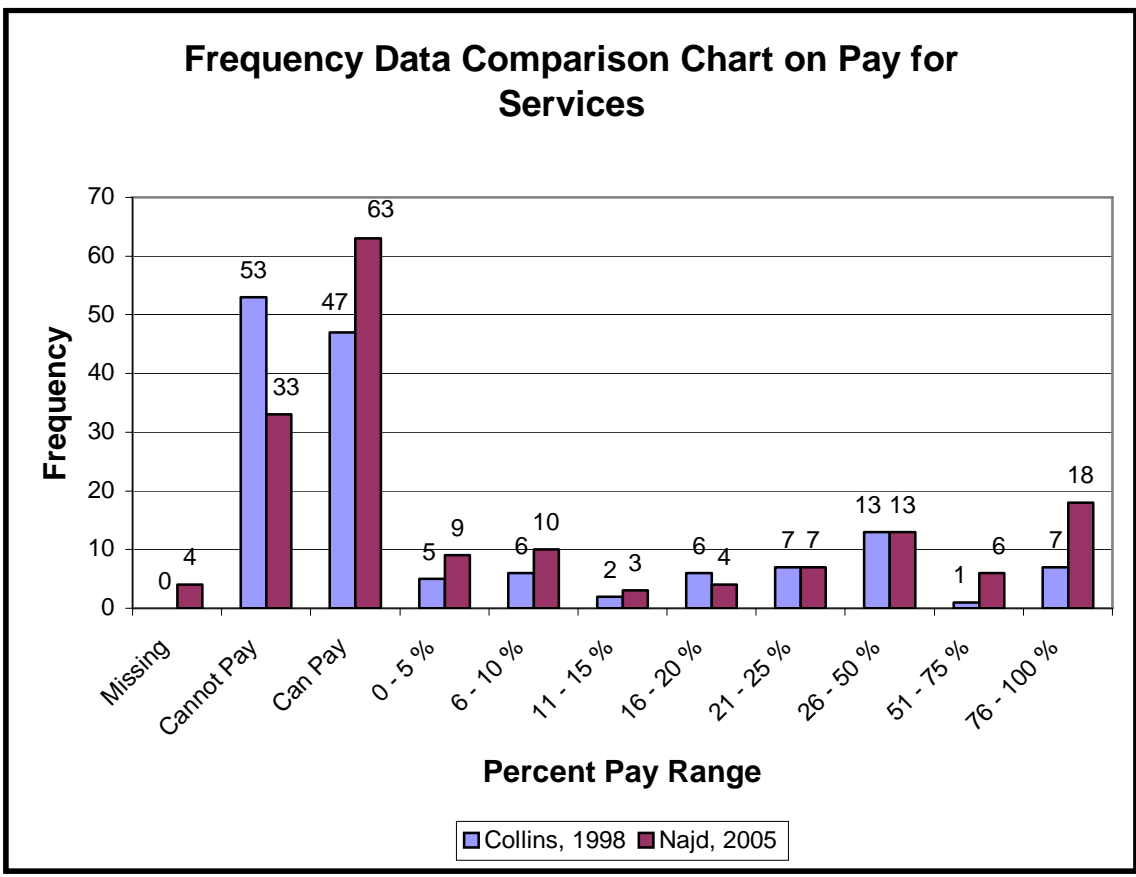


Figure 33. Frequency Data Comparison Chart on Pay for Services

Data collected seven years ago by Collins (1998) indicated that only 47 respondents were willing to pay for services, with only 7 respondents willing to pay for 76-100 percent of the costs. Eleven respondents were willing to pay for less than 10% of the costs. Also, 1 respondent was willing to pay for 51-75 percent of the costs. The differences and percent change between the two studies are summarized in Table 12.

The 1998 data suggests that economic justification played an important role in funding technology transfer projects. The 2005 data further suggests that the justification factor is heightened further when confronted by the severity of today's competitive pressures. It can be hypothesized that the financial decisions of small manufacturers in Oklahoma have shifted from being risk averse to being risk oriented. More manufacturers are willing to pay for the entire costs of technology transfer projects to remain competitive. Furthermore, more manufacturers are willing to initiate technology transfer projects by partially subsidizing the costs, up to at least 10%. It can be further hypothesized that subsidizing technology transfer projects by small manufacturers in Oklahoma will occur more frequently in this competitive environment. Oversight or administrative entities, such as a technology transfer delivery system and/or a state-wide program, can influence this trend. And in certain situations and with certain competitive pressures, these entities can even reverse this trend.

For the time being, this increasing trend, coupled with the fact that financing was the second most important barrier to transferring new technology, indicates that small manufacturers will risk and spend their hard earned dollars to retain their competitive



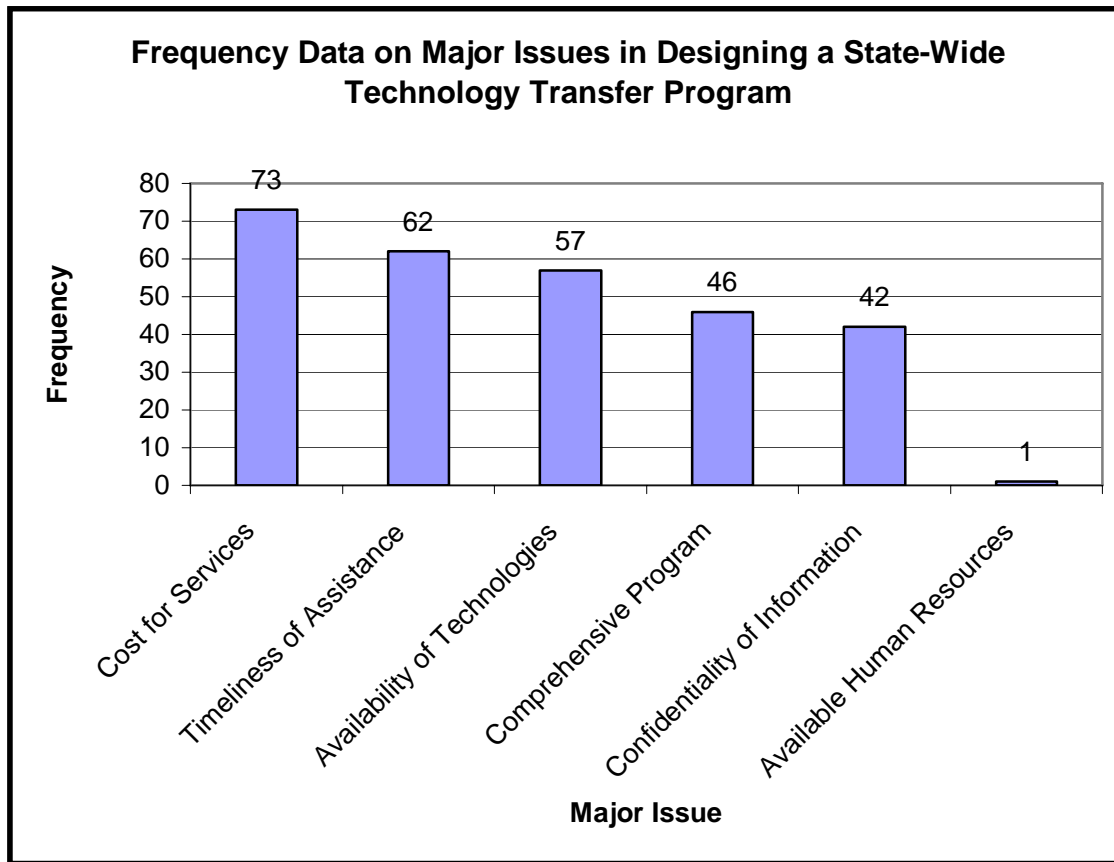
advantages. Operating under increasingly competitive pressures involves making risky decisions, especially financial decisions. If there are no other choices or options for the small manufacturers in Oklahoma to deal with this competitive reality, then spending on a new “costly” technology and/or relying on expensive vendor or Vo-Tech classes is a decision easily reached, which has the potential for agreeable outcomes. This state of affairs assumes an efficient and/or effective transfer process.

Oklahoma small manufacturers are currently an active group as depicted by their numerous trade show/convention attendances in the past three years. As a result, small manufacturers are looking for opportunities to retain and even increase their competitive advantages, and they are willing to pay for these new technologies (or risky opportunities), again if and only if there are no other options since financing is an important barrier. The implication for the state-wide technology transfer program would then be how to maximize the return on the “critical” technology transfer investments of the small manufacturers. For additional in-depth discussion on this implication, please refer to Section 4.3 of this study.

Survey Question 9 of Section 9.0 identified possible departments or concentration areas within the state technology transfer program crucial for successful technology deployment in a competitive environment. Seventy three small manufacturers in Oklahoma selected “cost for services” as the major issue when designing a state program. The remainder of the list is as follows: timeliness of assistance (62), availability of technologies (57), comprehensive program (46), confidentiality of information (42), and

available human resources (1). These results further emphasize the importance of financing and economic decision making, the turnaround time in coordinating with manufacturers, the research and development efforts of technology transfer specialists, the importance of multiple solution path integration, the selectivity of information sharing, and the availability of reliable and knowledgeable work force pool. In other words, a state program's infrastructure and associated delivery systems, agencies, and technology transfer approaches ought to evenly and continuously emphasize the five technology transfer dimensions previously discussed, especially in competitive environments. It can be even hypothesized that the state program ought to be autonomous and financially independent, to accomplish its mission/s and objective/s. Figure 34 presents the frequency data on the major issues in designing a state-wide technology transfer program.

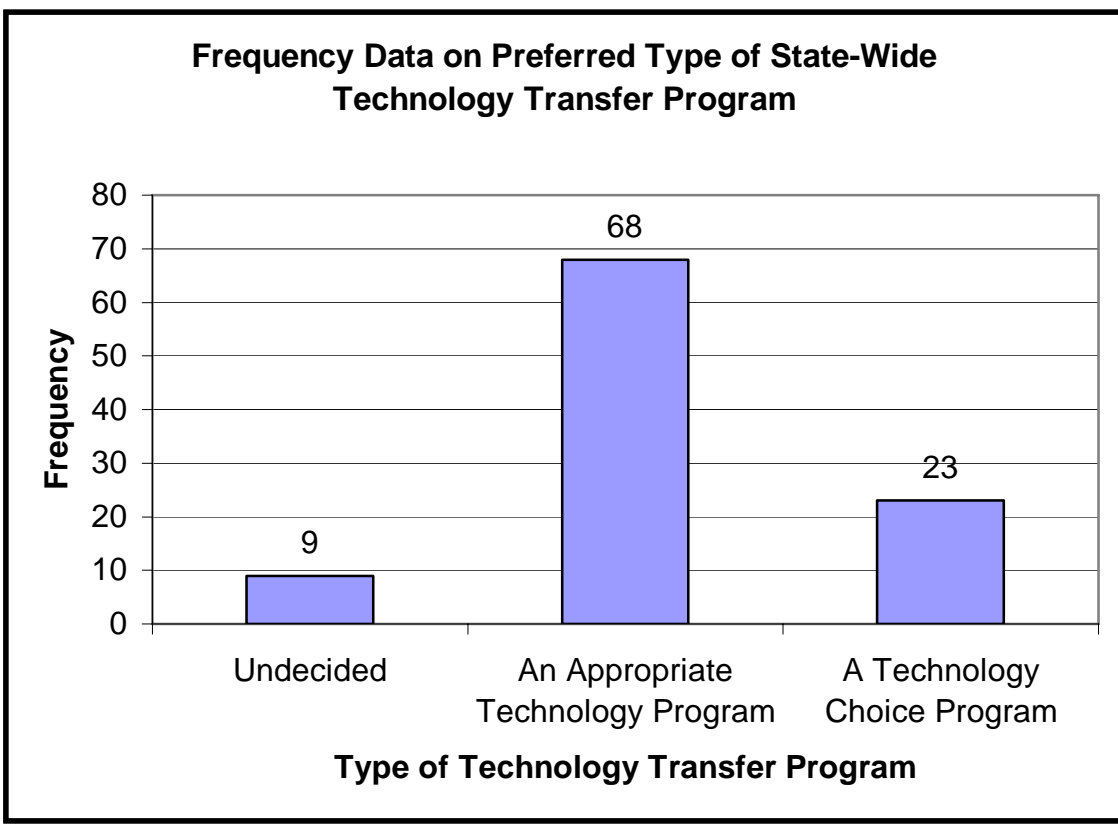
Survey Question 10 of Section 9.0 identified the preferred type of state-wide technology transfer program. Predominately, the respondents prefer an Appropriate Technology program (68%) to meet their future technology requirements. This type of program approach provides a preferred long-term technology transfer solution but may not generate the quickest short-term results for small manufacturers. Only 23% of the respondents selected the Technology Choice program, which provides a quick "technology transfer" fix that may not be the cheapest or generate the best long-term results.



**Figure 34. Frequency Data on Major Issues in Designing a State-Wide Technology Transfer Program**

These results support the desire of a majority of small manufacturers to find optimal long-lasting technology solutions to their competitive pressures. At the same time, these results indicate that a small percentage (23%) of small manufacturers cannot delay resolving their pressing competitive pressures. Furthermore, the state program would benefit greatly from considering the top five barriers to new technology and from the major issues outlined in the previous question as it balances the needs of both distinctive technology transfer groups - the Appropriate Technology group and the Technology Choice group. Each group has unique ways and viewpoints in deploying

technology solutions as outlined in Chapter 2 of this study. Figure 35 presents the frequency data on the preferred type of state-wide technology transfer program.



**Figure 35. Frequency Data on Preferred Type of State-Wide Technology Transfer Program**

Survey Question 11 of Section 9.0 determined the level of commitment of small manufacturers to successfully deploy technologies to alleviate their competitive pressures. A majority of the respondents believe it is “very important” to develop expertise on existing and subsequent manufacturing or production technologies (30).

Another 26 respondents believe it is “moderately more important.” The statistical results were:  $\mu = 5.38$ ,  $\sigma = 1.604$ , median = 6.00, and mode = 7.00. These results signify that small manufacturers in Oklahoma are committed to remain competitive and to retain and/or increase their competitive advantages. Table 13 presents the statistical results on developing expertise on technologies.

<b>Frequency Data on General Questions</b>				
<b><i>Descriptive Statistics</i></b>				
<b>Questions 11 and 12, Section 9.0</b>				
<b>Item</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Median</b>	<b>Mode</b>
Developing Expertise on Technologies	5.38	1.604	6.00	7.00
Making Plant/Office Space Available	4.06	1.881	4.00	4.00

**Table 13. Frequency Data on General Questions 11 and 12 of Section 9.0**

Survey Question 12 of Section 9.0 also determined the level of commitment of small manufacturers to successfully deploy technologies to alleviate their competitive pressures. The analysis results for this question were not as imperatively clear as compared with the previous question on developing expertise. For this question, which asked about making plant/office space available for experimentation with new technology to resolve competitive pressures, the majority of the respondents were in the “important” range (20). The next two highest groups were in the “slightly more important” and “moderately not important” ranges, both of which had 16. The statistical results were:  $\mu = 4.06$ ,  $\sigma = 1.881$ , median = 4.00, and mode = 4.00.

These results indicate that small manufacturers in Oklahoma are willing to experiment with new technologies. According to the results on barriers to new technology, two-thirds of the manufacturers have adequate facilities for experimentation. Furthermore, according to the statistical results in Table 9 (page 190), small manufacturers do not consider providing low cost facilities important. Therefore, it can be again hypothesized that small manufacturers in Oklahoma are fiscally focused. However, they are willing to make room within their facilities for experimentation with new technologies, which is potentially expensive, but on the other hand, they save by not relocating to off-site facilities for experimentation. Table 13 presents the statistical results on making plant/office space available.

Overall, the results of the previous two questions revealed a strong commitment to technology transfer by Oklahoma's small manufacturers. Their active research and development activities seeking technology solutions demonstrate deep resolve to remain involved and viable in today's highly competitive environment. Therefore, involving Oklahoma's small manufacturers in the development of the program is the most important first step for the state-wide technology transfer program. Complementing and supplementing their dynamic atmosphere is then the most important second step. Together, these two initial steps facilitate the success and growth of the program, especially in resolving competitive pressures.

Survey Question 13 of Section 9.0 assessed current technology transfer needs of small manufacturers in Oklahoma. This compiled list, which is summarized in Table 14,

establishes a starting point for the state technology transfer program. Providing prompt feedback and transfer assistance is critical in this competitive environment. Additionally, the diversity of responses emphasizes the important role of the state technology transfer program. Also, this diverse list underscores the need for a state-wide program in the state to sustain and strengthen the manufacturing base of Oklahoma and the vitality of Oklahoma's communities. Acting in any other way risks losing businesses to other states.

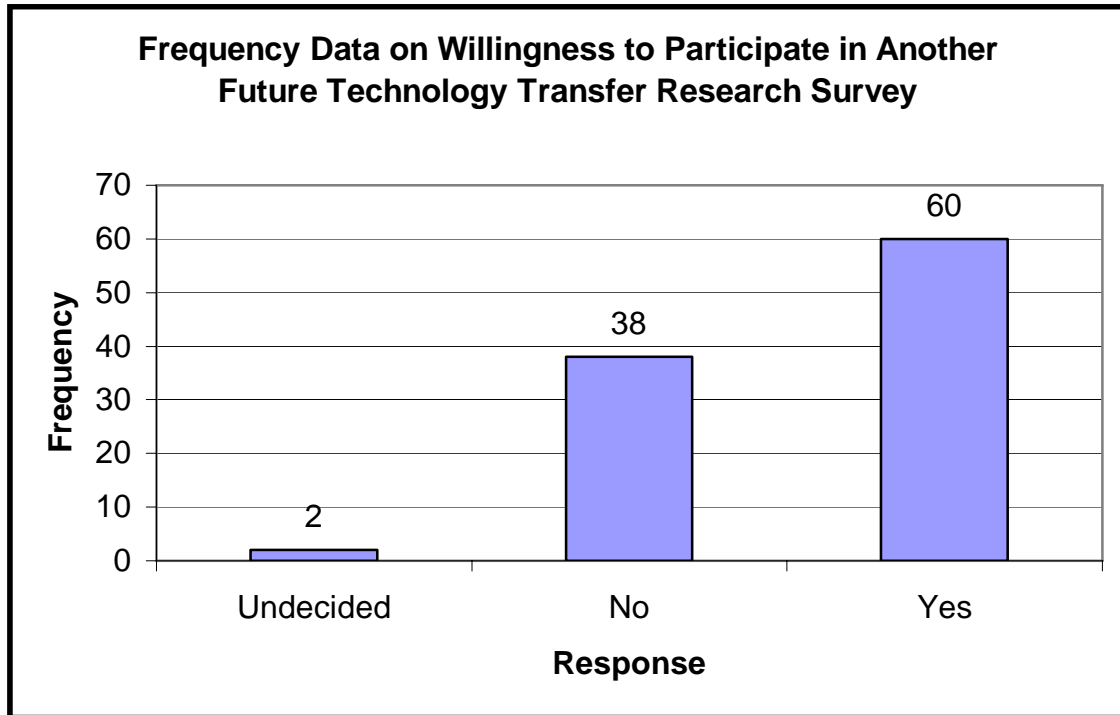
Survey Question 14 of Section 9.0 is the final question addressing Research Question 4. The question's objective was to determine the level of commitment and interest of small manufacturers to continue developing their state technology transfer program. Sixty respondents said yes to participating in a future study focusing on technology transfer programs and their related cost drivers and risk factors. Fifty cost drivers and risk factors were identified, but not included in this study, as pertinent to successful technology transfer. Again, if a state technology transfer program emphasizes and encourages tracking and accounting of these fifty drivers and factors as it interacts with manufacturers, then the probability of developing a sustainable, robust, and flexible state technology transfer program is increased even further, especially in a highly competitive environment. Figure 36 summarizes the responses for a future survey study.

In summary, the analysis results for Research Question 4 provided the following underlying emphases of a state technology transfer program, which meets future manufacturing industry requirements of small manufacturers in Oklahoma operating in a competitive environment:

<b>Current Technology Transfer Needs</b> ( <i>Question 13, Section 9.0</i> )
Adequate Technology Research and Development
Adult and Change Orientation Education
Computer Programming and Training
Confidentiality of Trade Research
Cost Engineering
Electrical and Electronics Engineering
Energy Assessment and Building Maintenance
Engineering Economics and Financial Planning
FDA Compliance Assistance
Government Contracting
Industrial Machining
Industrial Processing
Management and Employee Training
Managing a R&D Department
Manufacturing Technology Research and Development
Marketing
Material Design, Handling, and Automation
Minority / Women Owned Small Businesses
New Process Technology
New Product Development
New Product Engineering and Design
Operation and Location Analysis
Plant Design and Construction Planning
Production Space Design and Management
Quality Control and Environmental Testing
Sound Room Design
Time Studies and Facility Layout
Trade and Manufacturing Barriers and Tariffs
Trade Mark Assistance
Understanding Manufacturing Costing
US Manufacturing Governance Policy
Web-Based Marketing and Sales

**Table 14. Current Technology Transfer Needs**





**Figure 36. Frequency Data on Willingness to Participate in Another Future Technology Transfer Research Survey**

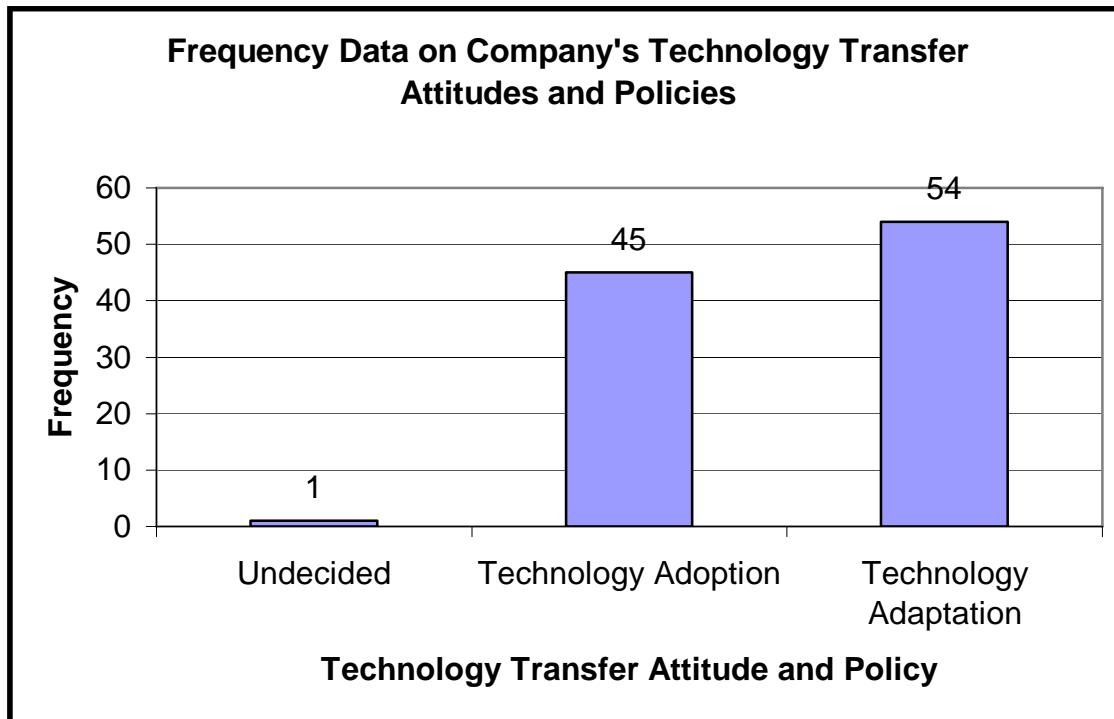
- Communication, integration, and coordination in technology transfer decision-making by all parties involved;
- Education and training with present and future technologies;
- Incorporating technical complexities of manufacturing and production operations in technology deployment;
- Specialization in all five dimensions of technology transfer and their attributes;
- Quickness and thoroughness of technology transfer solutions to competitive pressures relative to a technology adoption continuum built

around the constructs of small manufacturing enterprises;

- Inclusion of demand-side, supply-side, and infrastructure technology policy elements;
- Providing technology transfer services at reasonable costs;
- Emphasizing “demand-pull” technology transfer actions and activities;
- Providing focused Appropriate and Choice technology transfer delivery programs.

#### **4.2.5 Frequency Data on RQ 5**

The objective of Research Question 5 was to determine a small manufacturer’s preferred deployment process with respect to a technology or innovation to accept, adopt, and/or transfer it. Responses to Survey Question 10 of Section 1.0 revealed a relatively even split between the two opposing philosophies to technology deployment. Fifty four respondents preferred a technology adaptation deployment process, compared with 45 respondents preferring a technology adoption deployment process. There was one undecided respondent in the data set. Figure 37 summarizes the frequency data on the two deployment processes.



**Figure 37. Frequency Data on Company's Technology Transfer Attitudes and Policies**

The chosen process can influence greatly a company's attitudes and policies when considering a technology or innovation. Furthermore, each process influences greatly the overall technology experiences of small manufacturers, as they deal with external and/or internal competitive pressures. Each process is unique and is also influenced greatly by the various "unique" competitive pressures. Therefore, small manufacturers benefit greatly by recognizing their preferred deployment process and its implications prior to making technology transfer decisions. Since adoption measures involve radical quick technology investment and transfer decisions, there is no turning back; however, adaptation measures allow for adjustments since they involve slow gradual technology investment and transfer choices.

Overall, the implications of both deployment processes upon the barriers to new technologies discussed earlier will be unique to each process, including the barrier itself. As a result, the financial and economic impacts of each deployment process are numerous and far reaching for small manufacturers, given their limited resources. Since the data suggest that small manufacturers in Oklahoma are willing to take risks in the face of pressing competitive pressures, technology transfer decisions, especially decisions involving technology adoption or technology adaptation, will weigh more heavily on their bottom line.

On the other hand, by recognizing the technology transfer attitudes and policies of the small manufacturers, the state-wide technology transfer program can reduce the financial burdens and economic impacts of technology transfer decisions. Identifying (or knowing) the preferred deployment process of small manufacturers can also streamline the technology transfer assistance and activities of the state program, as it joins the small manufacturers in resolving the competitive pressures.

Finally, by integrating the survey's data, especially demographic and technology transfer preferences data (such as the five dimensions of technology transfer and their attributes and the age of the company) of small manufacturers in Oklahoma with their technical complexity of manufacturing operations (i.e., small batch, large batch, or continuous process), their preferred technology transfer programs (i.e., appropriate or choice), their preferred deployment processes (i.e., adoption or adaptation), and their preferred technology transfer approaches (i.e., A1, A2, or A3) can lead to an informative

and valuable system dynamics perspective of their overall technology transfer experiences, as they resolve their competitive pressures. The state technology transfer program can benefit greatly from this systems view as it establishes the technology transfer policies of the state with respect to small manufacturing enterprises. This system dynamics perspective is established and discussed in more detail in the next section of the study.

### **4.3 Filtering Analysis**

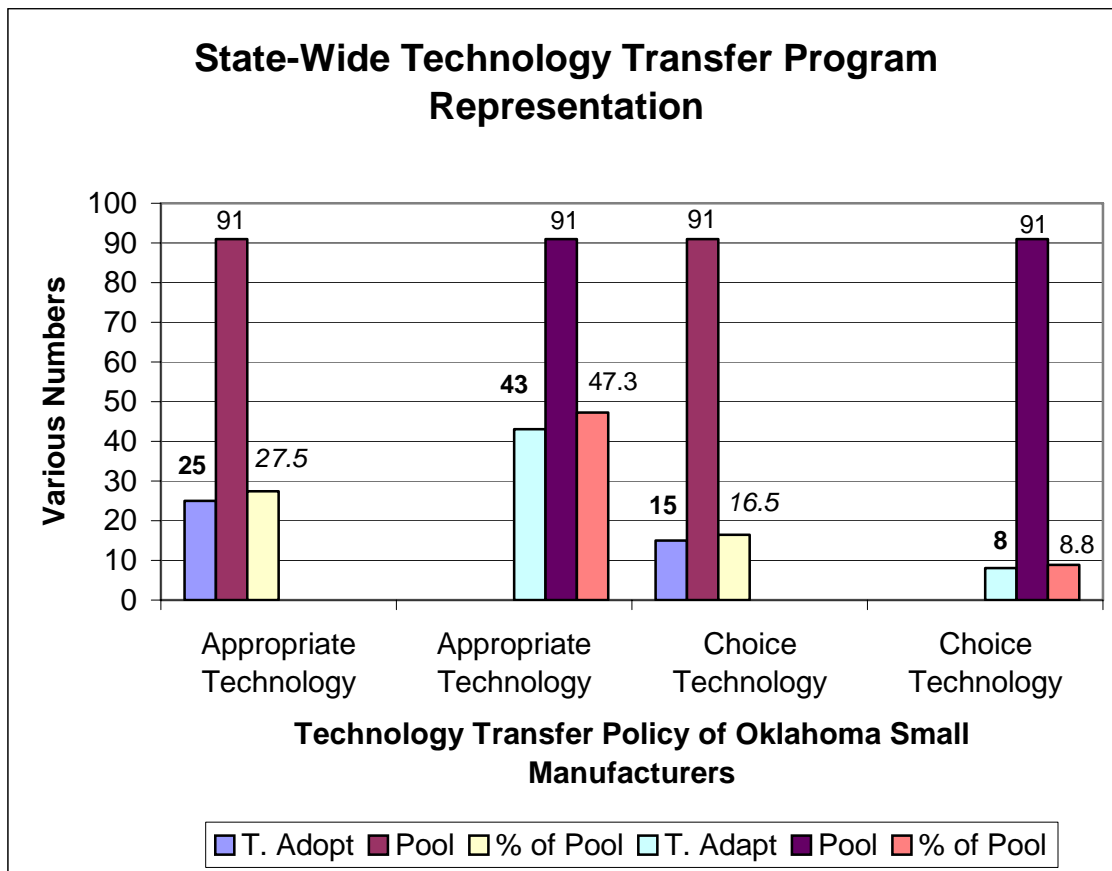
The second phase of the analysis for this study was to run a filtering (cluster) analysis on the entire data set from the survey questionnaire. The goal of this analysis is to divide the respondents into distinct groups for easier technology transfer policy and assistance decisions by the state program technology transfer agents/specialists. The filtering analysis was divided into two parts. The first part dealt with the implications presented by the respondents' choices to questions dealing with preferred technology transfer program and preferred technology transfer attitude and policy. Figure 9 and Table 2 in Section 2.8 (page 130) of this study summarized the four possible combinations and their consequences. The second part of the filtering analysis used the results of the first part and further filtered the data according to survey responses to two other important survey questions - (preferred technology transfer approach and manufacturing technical complexity). Again, there was the potential for a respondent to be classified into one of 36 distinct technology transfer groups per identified top-ten

competitive pressure. Overall, the filtering analysis phase was an inferential analysis procedure, which permitted the identification of characteristics for each group (or combination) within the survey pool. The SPSS / Excel filtering functions were used for this phase.

Figure 38 presents the results for the first phase of the filtering analysis, which were based on the responses to two survey questions - [preferred technology transfer programs - (i.e., appropriate technology-AT or technology choice-TC) and preferred deployment processes - (i.e., technology adoption-TO or technology adaptation-TA)]. Forty three respondents chose the most optimal path<sup>13</sup> for technology transfer. This group will likely not face cost or time overruns. This group preferred appropriate technologies and preferred to adapt them. The next two groups chose less optimal paths to successful technology transfer. Both of the two groups will likely not face cost overruns; however, they will likely face time overruns but for different reasons. A group of 25 respondents chose appropriate technologies and preferred to adopt the technologies, while a group of 8 respondents preferred adaptation processes and chose technology choice as their preferred method of screening and selecting technologies. Finally, a group of 15 respondents will likely face both cost and time overruns in their technology transfer experiences - (i.e., the least optimal path to successful technology transfer). This group preferred technology choice programs and preferred adoption processes for technology deployment.

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<sup>13</sup> For a small manufacturer to be on the most optimal path for technology transfer, he/she prefers Appropriate Technology (AT) programs and uses Technology Adaptation (TA) deployment processes.



**Figure 38. Filtering Analysis Results for the State-Wide Technology Transfer Program Representation**

The results summarized in Figure 38 present three implications for the state-wide technology transfer program. First, since approximately half of the respondents are on an optimal path to successful technology transfer, the state program should advise them to stay on this path and further increase their competitive advantages. However, for the remaining three groups identified in Figure 38, the state program needs to look at additional in-depth adjustments and solution recommendations, especially for the small manufacturers preferring technology choice programs and technology adoption processes - (i.e., the least optimal path to successful technology transfer). This second implication

(or policy initiative) could face structural and organizational resistance from the small manufacturers, especially if they have been in business for a long time and they are set in their technology transfer patterns. To maximize these three groups' technology transfer investments, the state program could first try to identify ways to shift the small manufacturers to another technology transfer path. Initial attempts might include identifying their work force skills, recognizing their technology appropriateness limitations, identifying their financial constraints, and ascertaining their technology transfer planning horizon, all within their individual "competitive pressures" arena. Moreover, since Oklahoma small manufacturers are currently an active group looking for opportunities and willing to pay for those opportunities, it can be hypothesized that they are ready to accept change and move to other technology transfer paths to retain and even increase their competitive advantages.

Finally, a third implication for the state program is to implement policies that shift the burden of change and risk exposure across the entire small manufacturing industry, so that no one small manufacturer in Oklahoma is overly exposed. The state program can accomplish this by investing money and resources, especially facility and personnel resources, in technology research and development and transfer research and development. These activities can culminate in the establishment of a technology transfer database accessible to both the state program and to the small manufacturers in Oklahoma. Furthermore, this expert-system "warehouse" database can provide information regarding appropriate technology and technology choice programs and their associated technologies. Also, this database can include information regarding the



“competitive pressure” experiences of small manufacturers (i.e., their technology transfer comments under competitive circumstances), which is valuable given Oklahoma’s “experienced and aging” small-manufacturer base. This database can include information regarding the advantages and disadvantages of adopting or adapting the selected “solution” technologies. Such initiatives from the state program also decrease the burden of paying for technology transfer projects and assistance, which Oklahoma small manufacturers are willing to do. Also, such initiatives can sustain, grow, strengthen, and revitalize the small manufacturing base of Oklahoma, which is a growing and aging population, and increase the vitality of Oklahoma’s communities at the same time.

For the second part of the filtering analysis, the results from the first part, which were based on two questions, were further filtered using survey responses to another two important survey questions - [preferred technology transfer approach - (i.e., A1, A2, or A3) and manufacturing technical complexity - (i.e., small batch - SB, large batch - LB, or continuous process - CP)]. Also, responses concerning areas of involvement in technology transfer-AITT, age of the small manufacturers-ASM, and barriers to technology transfer-BTT were also collated with the second part of the filtering analysis to infer specific perspectives about the respondents. The overall filtering sequence was arranged per competitive pressure. The following presents the filtering sequence:

- Level 1. Competitive Pressures - e.g., QE, WC, or NPD
- Level 2. Technology Transfer Approaches - e.g., A1, A2, or A3
- Level 3. Technical Complexities - e.g., SB, LB, or CP

- Level 4. Technology Transfer Programs - e.g., AT or TC
- Level 5. Technology Transfer Attitudes and Policies - e.g., TO or TA
- Level 6. Small Manufacturers Characteristics - e.g., AITT, ASM, or BTT

Levels 2 to 5 provide 36 technology transfer classification possibilities per identified top-ten competitive pressure in Level 1. Some of the combinations using Levels 1 to 5 have no matches - (i.e., they have no survey respondents). Also, some of the respondents could not be classified because of missing values for any of the questions in Levels 1 to 5 in their survey. After the respondents were grouped into identifiable clusters, the filtered data in Level 6 was analyzed further to infer additional identifiable characteristics for the cluster in question, to better understand (and if possible) resolve the competitive pressures under consideration. Overall, this analysis procedure proved to be an important differentiation process to divide the survey pool into manageable technology transfer policy clusters for the state technology transfer program, to resolve competitive pressures.

Since there are three approaches to technology transfer (Level 2) per competitive pressure (Level 1), the filtered results are best represented by a three-sided pyramid structure. Each side of the pyramid represents the filtered results associated with each approach. Basically, each top ten competitive pressure would then be represented by a separate pyramid, which summarizes the technology transfer preferences and activities of the small manufacturers for the competitive pressure in question. Figure 39 shows this pyramid representation as viewed from the top of the pyramid and Figure 40 shows this

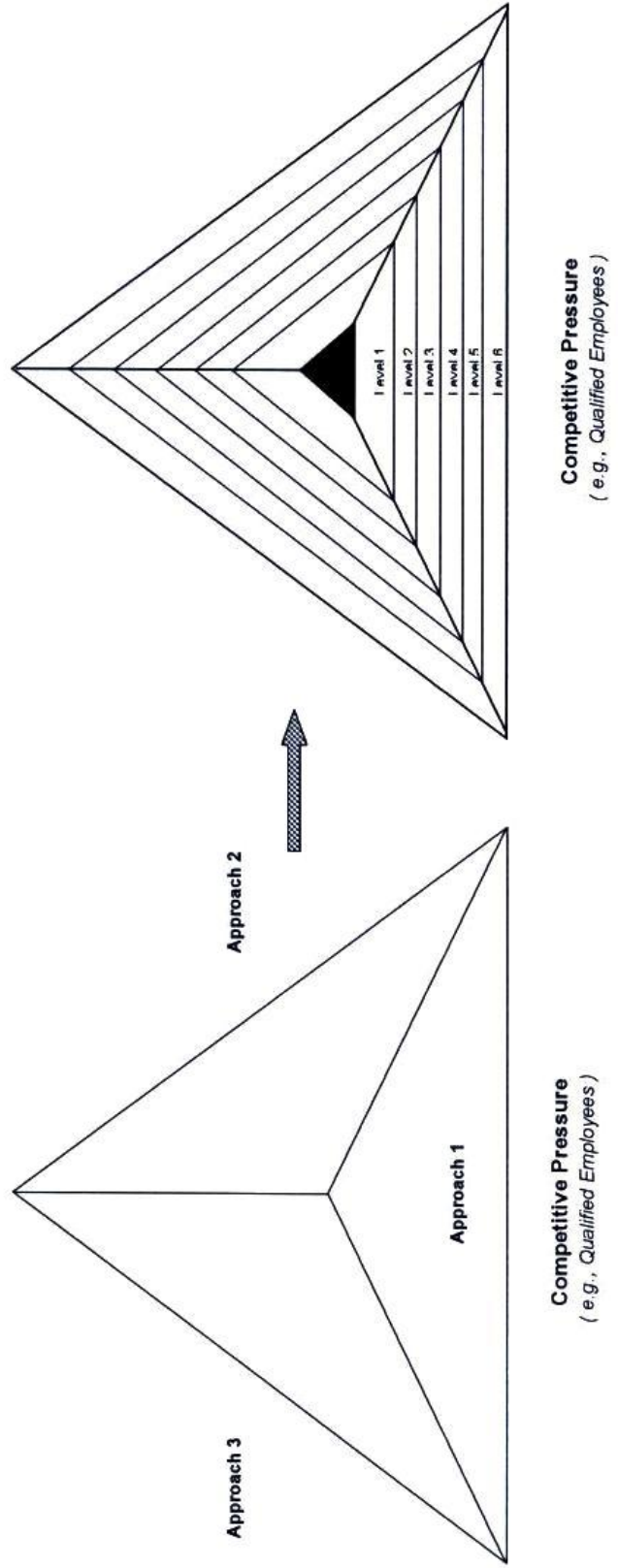
pyramid representation as viewed from a typical side of the pyramid. Also, Figures 41 and 42 are photographs of pyramid models built to physically and visually present the “metamodeling” approach outlined and discussed in this study.

For this second part of the filtering analysis, three competitive pressures out of the 10 were selected for further investigation. Qualified Employees - (QE) and Worker’s Compensation - (WC) were selected because they were the first and second most important competitive pressure currently faced by small manufacturers in Oklahoma. The third choice was New Product Development - (NPD), which is ranked seventh on the top ten list. The researcher selected the seventh competitive pressure because it can serve as a job creation indicator. The development of new products usually requires infrastructure investments and commercialization studies, all of which are new job growth and revenue opportunities. Also, sensing how small manufacturers in Oklahoma are handling the New Product Development competitive pressure can serve as an indicator for new technology and technology transfer “emerging” markets, which again offers job creation chances. The remaining seven competitive pressures can be analyzed in a future study.

As stated earlier, responses concerning areas of involvement in technology transfer-AITT, age of the small manufacturers-ASM, and barriers to technology transfer-BTT were also collated with the second part of the filtering analysis. These three variables establish initial observations regarding the competitive vulnerabilities of small manufacturers in Oklahoma. Also, these three variables combined with the information

obtained from Level 1 to Level 5 in the Nizam Pyramid establish immediately an introductory technology transfer assistance framework for the state program. With this framework, the state program can eliminate technology and transfer vulnerabilities and can enhance and/or increase the competitive advantages of small manufacturers. These observations (or inferences) include both general and specific accounts regarding the competitive status of Oklahoma's small manufacturers. The remaining variables can be included and analyzed in a future study.

The results of the second part of the filtering analysis are summarized by the following three figures. Figure 43 presents the Nizam Pyramid for the Qualified Employees (QE) competitive pressure. Figure 44 presents the Nizam Pyramid for the Worker's Compensation (WC) competitive pressure. And Figure 45 presents the Nizam Pyramid for the New Product Development (NPD) competitive pressure. Also, Table 15 presents a frequency results summary chart for the three Nizam Pyramids.



**Figure 39. A 3-Dimensional View of the Nizam Pyramid for the Development of a Technology Transfer Program in a Competitive Environment**

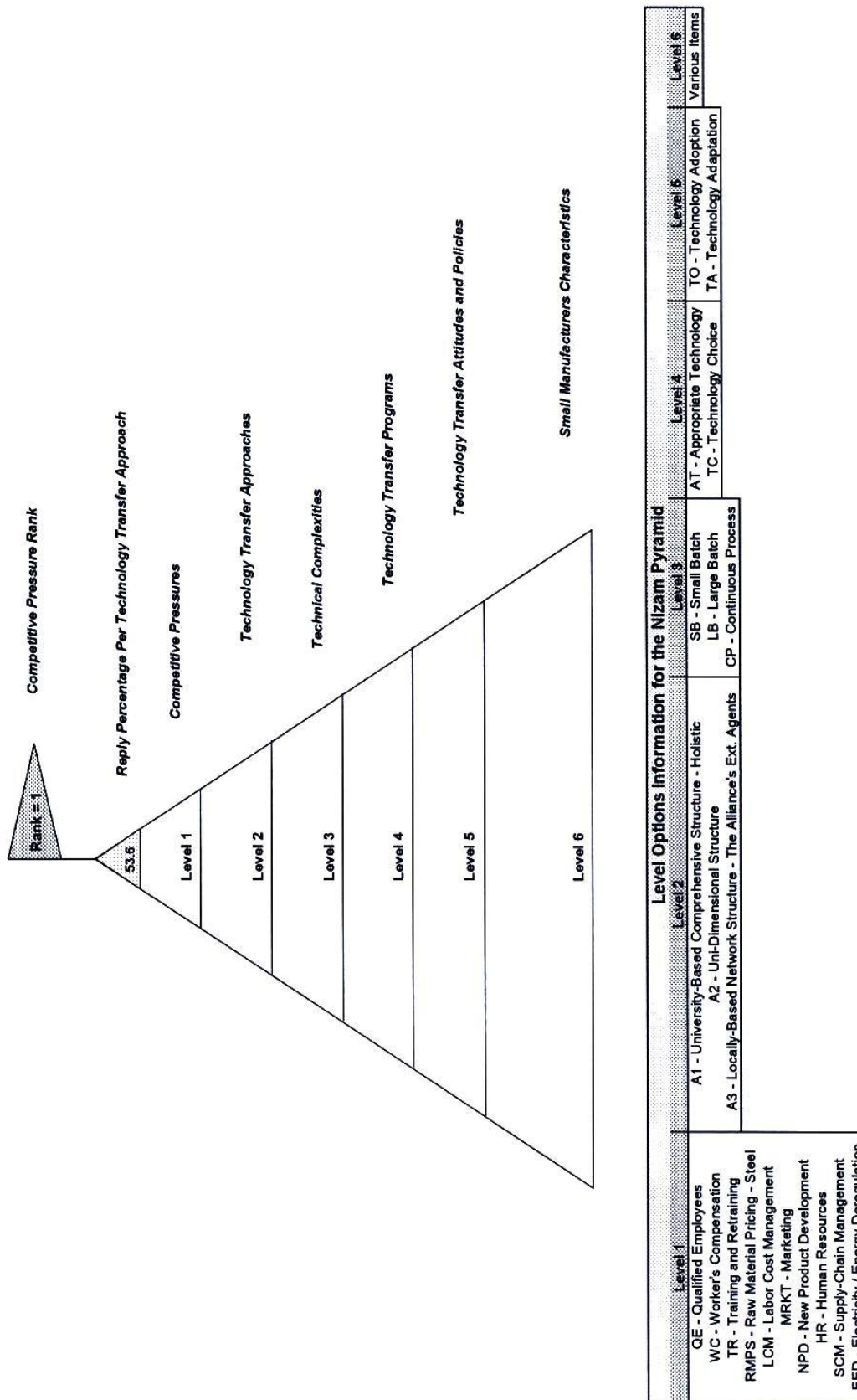


Figure 40. A Typical Side View of the Nizam Pyramid for the Development of a Technology Transfer Program in a Competitive Environment

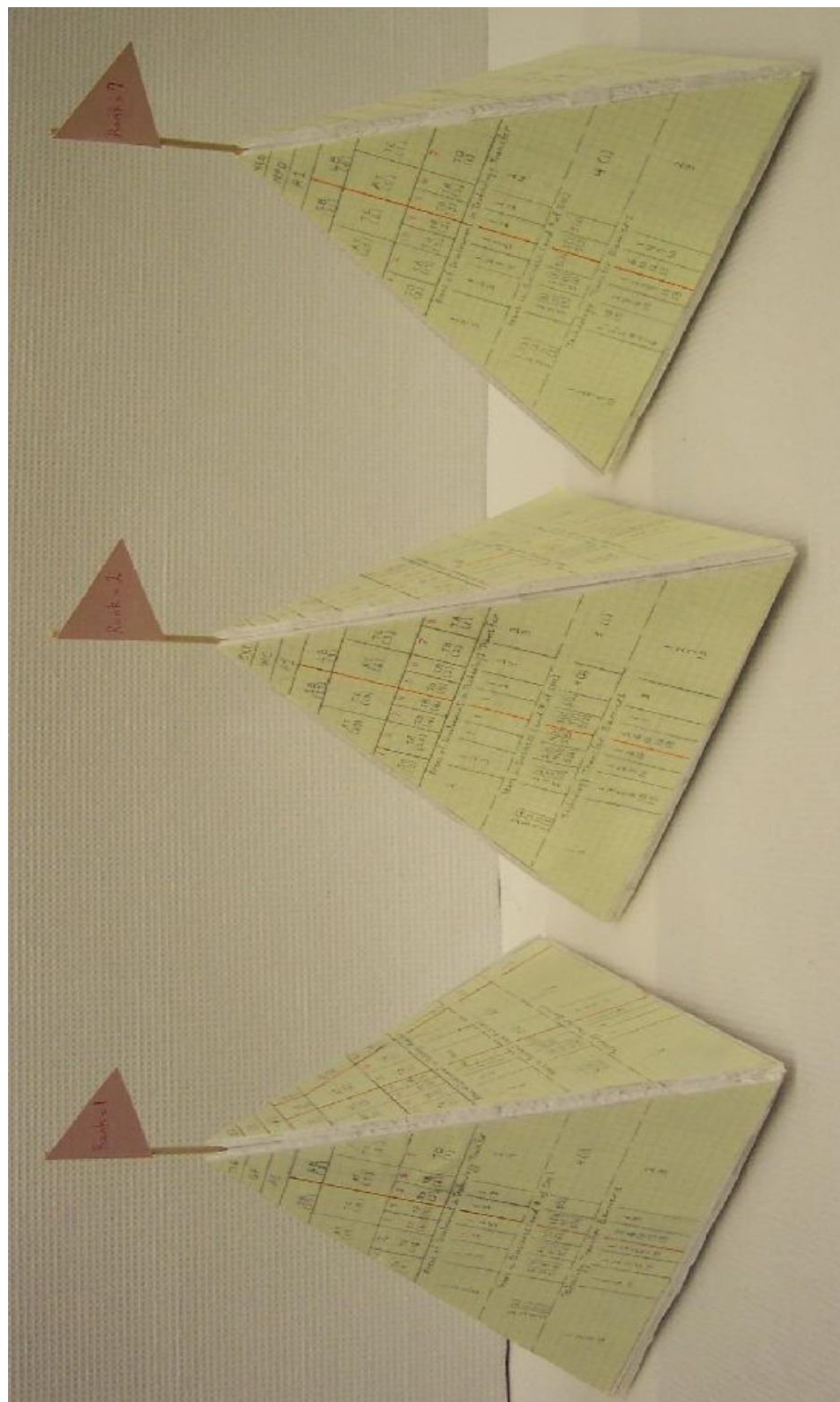
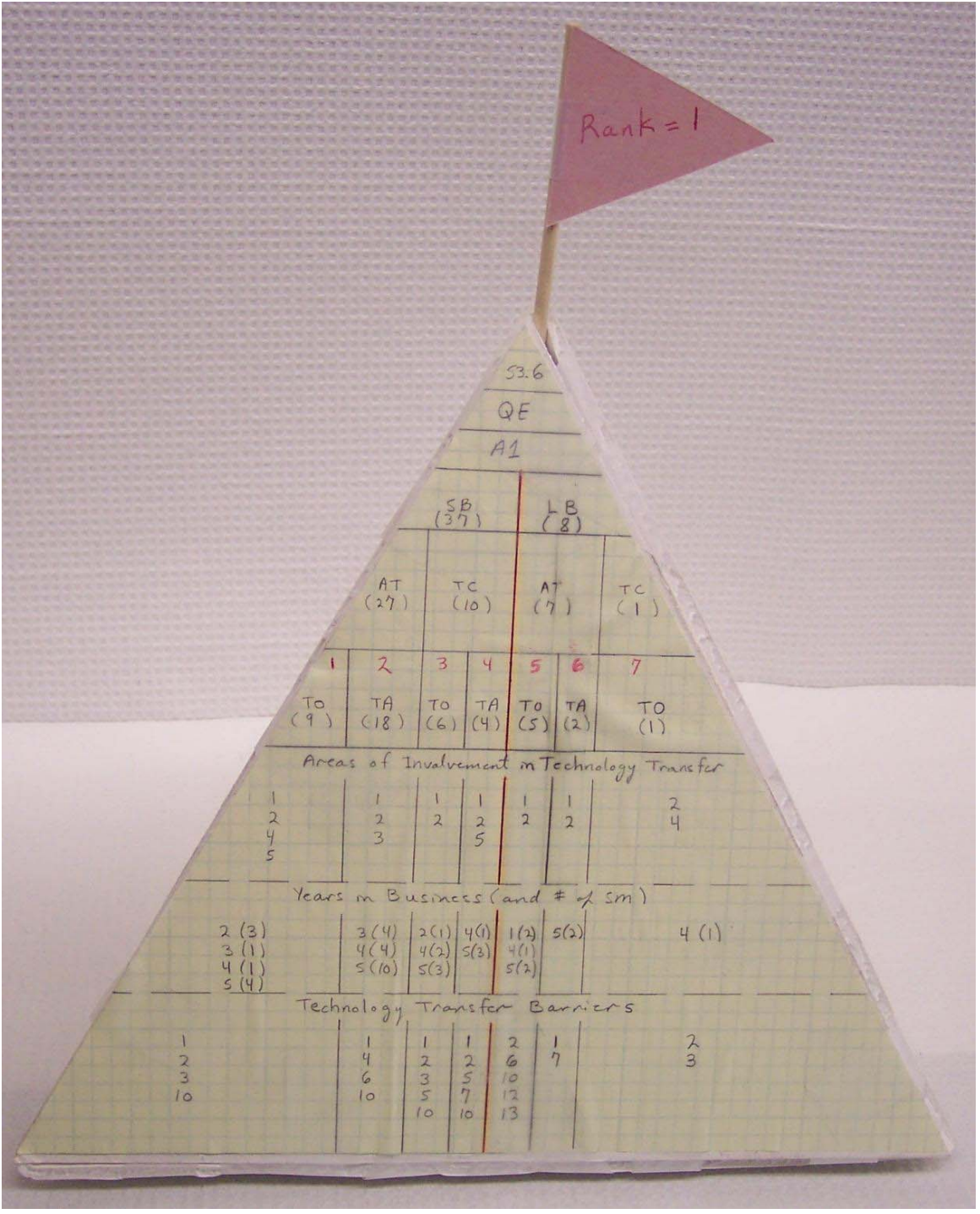


Figure 41. The Nizam Pyramid Models for Three of the “Top Ten” Competitive Pressures



**Figure 42. The Nizam Pyramid Model for the Qualified Employees Competitive Pressure**



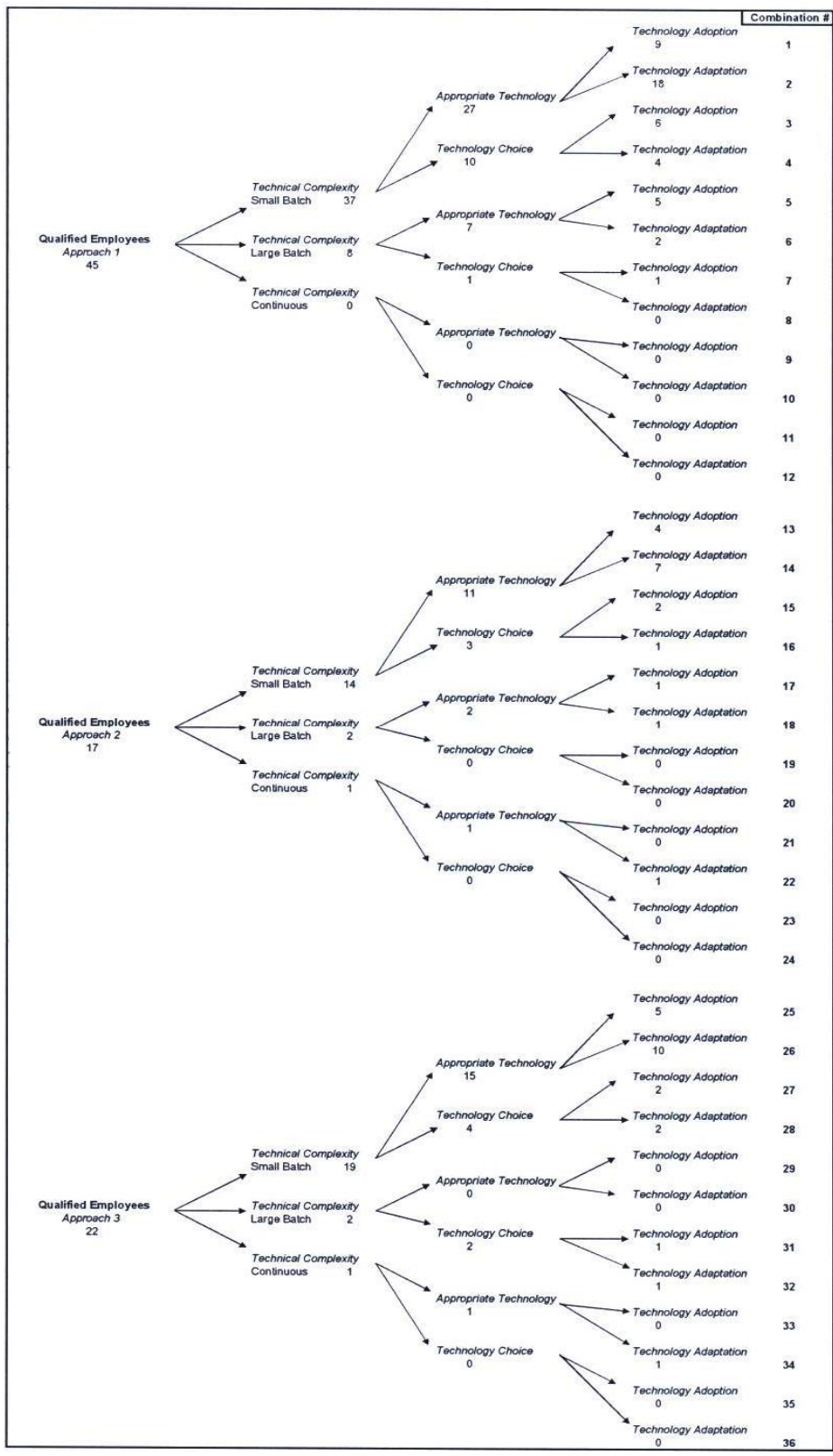


Figure 43. The Nizam Pyramid for the Qualified Employees Competitive Pressure

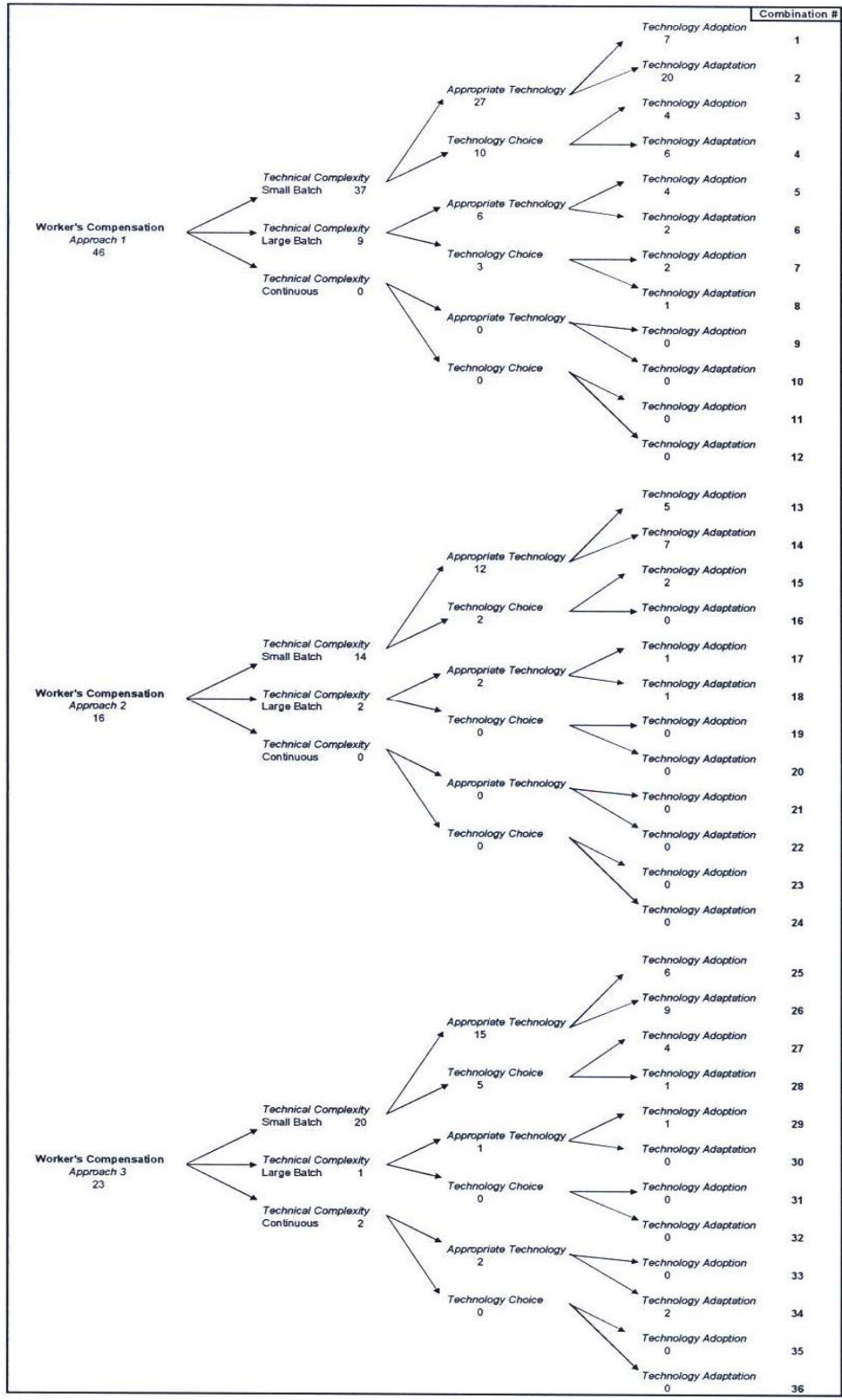


Figure 44. The Nizam Pyramid for the Worker's Compensation Competitive Pressure

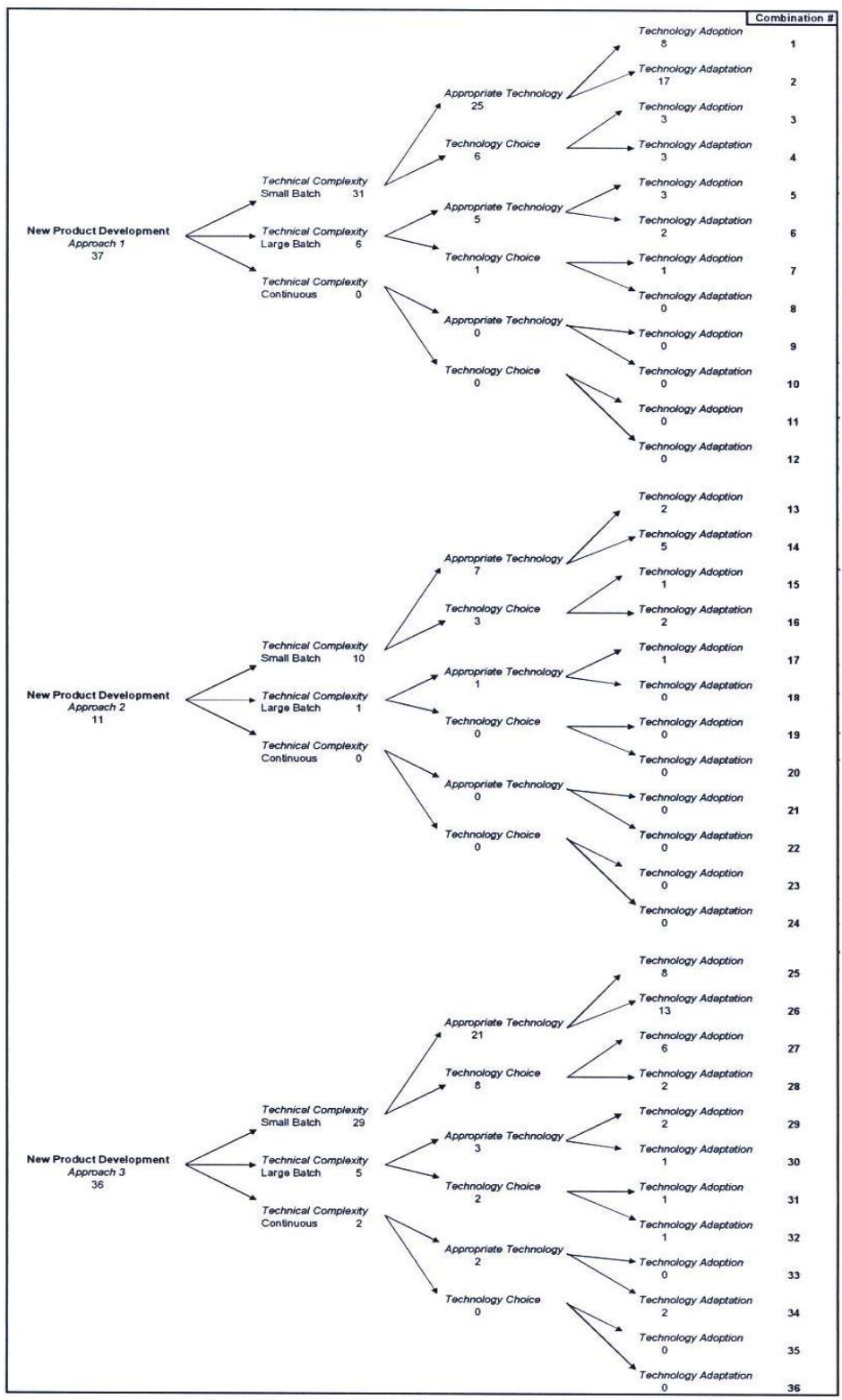


Figure 45. The Nizam Pyramid for the New Product Development Competitive Pressure

Frequency Results for the Three Nizam Pyramids Summary Chart ( QE, WC, and NPD Competitive Pressures )							
Level 2	Level 3	Level 4	Level 5	C #	Level 1 - # of Respondents		
					QE	WC	NPD
A1	SB	AT	TO	1	9	7	8
			TA	2	18	20	17
		TC	TO	3	6	4	3
			TA	4	4	6	3
	LB	AT	TO	5	5	4	3
			TA	6	2	2	2
		TC	TO	7	1	2	1
			TA	8	0	1	0
	CP	AT	TO	9	0	0	0
			TA	10	0	0	0
		TC	TO	11	0	0	0
			TA	12	0	0	0
A2	SB	AT	TO	13	4	5	2
			TA	14	7	7	5
		TC	TO	15	2	2	1
			TA	16	1	0	2
	LB	AT	TO	17	1	1	1
			TA	18	1	1	0
		TC	TO	19	0	0	0
			TA	20	0	0	0
	CP	AT	TO	21	0	0	0
			TA	22	1	0	0
		TC	TO	23	0	0	0
			TA	24	0	0	0
A3	SB	AT	TO	25	5	6	8
			TA	26	10	9	13
		TC	TO	27	2	4	6
			TA	28	2	1	2
	LB	AT	TO	29	0	1	2
			TA	30	0	0	1
		TC	TO	31	1	0	1
			TA	32	1	0	1
	CP	AT	TO	33	0	0	0
			TA	34	1	2	2
		TC	TO	35	0	0	0
			TA	36	0	0	0
<b>Total # of Respondents per Pressure</b>					<b>84</b>	<b>85</b>	<b>84</b>

Table 15. Frequency Results for the Three Nizam Pyramids Summary Chart

The results summarized in Table 15 provide a unique look at the survey data. Specifically, the 5-level filtering sequence separated the survey data into distinct combinations (or clusters), which provide definitive snapshots of the technology transfer experiences of small manufacturers in Oklahoma under competitive pressure. Table 16 presents a review of 17 combinations of interest for each of the three competitive pressures. Overall, these 17 combinations of interest represent 77% of the survey pool for Qualified Employees, 81% for Worker's Compensation, and 76% for New Product Development.

<b>Frequency Results for Combinations of Interest</b> <i>( QE, WC, and NPD Competitive Pressures )</i>							
					<b>Level 1 - # of Respondents</b>		
<b>Level 2</b>	<b>Level 3</b>	<b>Level 4</b>	<b>Level 5</b>	<b>C #</b>	<b>QE</b>	<b>WC</b>	<b>NPD</b>
A1	SB	AT	TO	1	9	7	8
			TA	2	18	20	17
		TC	TO	3	6	4	3
			TA	4	4	6	3
	LB	AT	TO	5	5	4	3
			TA	6	2	2	2
		TC	TO	7	1	2	1
A2	SB	AT	TO	13	4	5	2
			TA	14	7	7	5
	LB	AT	TO	17	1	1	1
			TA	18	1	1	N/A
	CP	AT	TA	22	1	N/A	N/A
A3	SB	AT	TO	25	5	6	8
			TA	26	10	9	13
		TC	TO	27	2	4	6
	LB	AT	TO	29	N/A	1	2
	CP	AT	TA	34	1	2	2
<b>Total # of Respondents per Pressure</b>					<b>77</b>	<b>81</b>	<b>76</b>

**Table 16. Frequency Results for Combinations of Interest**

Tables 17 and 18 present total frequencies sorted by technology transfer approach and by technical complexity respectively for the 17 combinations of interest - (i.e., sorted using Level 2 and Level 3 variables respectively of the Nizam Pyramid). According to Table 17, a university-based comprehensive delivery approach (A1) was the most preferred across all three competitive pressures. Likewise, according to Table 18, the majority of the respondents in the 17 combinations had a small batch manufacturing operation (SB) for all three competitive pressures. Table 18 shows that the technical complexity factor is not applicable for a number of combinations and competitive pressures. Again, the technical complexity factor is a manufacturing structural fact of the survey respondents.

<b>Level 2 Frequency Results for Combinations of Interest</b> <i>( Including Combination and Competitive Pressure Information )</i>				
<b>Level 2</b>	<b>C #'s</b>	<b>QE</b>	<b>WC</b>	<b>NPD</b>
A1	1 - 7	45	45	37
A2	13, 14, 17, 18, 22	14	14	8
A3	25, 26, 27, 29, 34	18	22	31

**Table 17. Level 2 Frequency Results for Combinations of Interest**

<b>Level 3 Frequency Results for Combinations of Interest</b> <i>( Including Level 2, Combination, and Competitive Pressure Information )</i>					
<b>Level 2</b>	<b>Level 3</b>	<b>C #'s</b>	<b>QE</b>	<b>WC</b>	<b>NPD</b>
A1	SB	<b>1 - 4</b>	37	37	31
	LB	<b>5 - 7</b>	8	8	6
	CP	<b>N/A</b>	N/A	N/A	N/A
A2	SB	<b>13 - 14</b>	11	12	7
	LB	<b>17 - 18</b>	2	2	1
	CP	<b>22</b>	1	N/A	N/A
A3	SB	<b>25 - 27</b>	17	19	27
	LB	<b>29</b>	N/A	1	2
	CP	<b>34</b>	1	2	2

**Table 18. Level 3 Frequency Results for Combinations of Interest**

For the small manufacturers characteristics in Level 6 of the Nizam Pyramid associated with the Level 1-5 filtering analysis procedures, a numbering key code was devised to collate and summarize the Level 6 results for the 17 combinations of interest. The three small manufacturer characteristics (or variables) used for this level of differentiation are as follows: areas of involvement in technology transfer-AITT, age of the small manufacturers-ASM, and barriers to technology transfer-BTT. The goal of this step was to establish initial observations regarding the competitive vulnerabilities of small manufacturers in Oklahoma. Table 19 presents the Nizam Pyramid key code for Level 6 analysis and results.

<b>The Nizam Pyramid Key Code for Level 6</b>	
<i>( Selected Survey Questions for Level 6 Filtering Analysis Identification )</i>	
Number	Description
<b>Question 7, Section 1.0 - Areas of Involvement in Technology Transfer?</b>	
1	Technical Assistance
2	Research and Development
3	Governmental Compliance
4	Business Assistance
5	Human Resource Management Assistance
<b>Question 8, Section 1.0 - Age of the Small Manufacturer (and # of SM's)?</b>	
1	0 - 5 years ( # )
2	6 - 10 years ( # )
3	11 - 15 years ( # )
4	16 - 20 years ( # )
5	Over 20 years ( # )
<b>Question 5, Section 9.0 - Barriers to Technology Transfer?</b>	
1	Work force skills
2	Financing
3	Facility limitations
4	Management skills
5	Unknown benefits
6	Technology appropriateness
7	Major concern regarding change
8	None of the above
9	Lack of readily available information on the technology
10	Lack of understanding and training with the technologies
11	Lack of support by upper management
12	Lack of a proven track / performance record with the technology
13	Transfer and Implementation difficulties
14	Satisfaction with existing technologies
15	Minor concern regarding change
16	Other: Please specify

**Table 19. The Nizam Pyramid Key Code for Level 6**



The first step to assess the competitive vulnerabilities is to determine the outcome of their technology transfer decision paths discussed earlier in the study and again summarized by Table 2 in Chapter 2. For the selected 17 combinations, respondents in combinations numbered 2, 6, 14, 18, 22, 26, and 34 are on an optimal path to successful technology transfer. These respondents will have minimal cost and time overruns when deploying a technology. Respondents in combinations numbered 1, 4, 5, 13, 17, 25, and 29 are on a less optimal path to successful technology transfer. Cost or time overruns will be an issue when deploying a technology. Finally, combinations numbered 3, 7, and 27 represent the least optimal path to successful technology transfer. Respondents in these combinations will likely face both cost and time overruns through out their technology transfer experience. Table 20 summarizes the affect of technology transfer program and technology transfer attitude and policy choices - (i.e., Levels 4 and 5 of the Nizam Pyramid) on the respondents' technology transfer experiences, along with the technical complexity and technology transfer approach preferences of the respondents - (i.e., Levels 2 and 3 of the Nizam Pyramid).

Table 20 also presents the number of respondents for each of the three competitive pressures according to the decision path outcomes and their corresponding combination numbers. For example, combination #2, which is an optimal decision path, had the highest number of respondents for approach 1 and for the three competitive pressures. Likewise, combinations #14 and #26, which are also optimal decision paths, had the highest number of respondents for approach 2 and 3 respectively, across all three competitive pressures. Further, the respondents in all three combinations (2, 14, and 26) were all small batch and unit production manufacturing operations.

Levels 4 and 5 Decision Path Outcomes for Combinations of Interest ( Including Levels 1, 2, and 3 Information )						
Level 2	Level 3	C #	Level 4 and 5	Level 1		
			Technology Transfer Decision Path Outcome?	# of Respondents		
				QE	WC	NPD
A1	SB	1	Less Optimal	9	7	8
		2	Most Optimal	18	20	17
		3	Least Optimal	6	4	3
		4	Less Optimal	4	6	3
	LB	5	Less Optimal	5	4	3
		6	Most Optimal	2	2	2
		7	Least Optimal	1	2	1
A2	SB	13	Less Optimal	4	5	2
		14	Most Optimal	7	7	5
	LB	17	Less Optimal	1	1	1
		18	Most Optimal	1	1	N/A
	CP	22	Most Optimal	1	N/A	N/A
A3	SB	25	Less Optimal	5	6	8
		26	Most Optimal	10	9	13
		27	Least Optimal	2	4	6
	LB	29	Less Optimal	N/A	1	2
	CP	34	Most Optimal	1	2	2
<b>Total # of Respondents per Pressure</b>				<b>77</b>	<b>81</b>	<b>76</b>

**Table 20. Levels 4 and 5 Decision Path Outcomes for Combinations of Interest**

The first task for the state-wide technology transfer program using the information outlined in the previous example is to identify the respondents that switched between technology transfer approaches when considering the three competitive pressures. The next task is to determine the specific reasons why the respondents switched between the approaches. The respondents in this scenario are already on the most optimum path to successful technology transfer. However, determining the

respondents' perceived advantages (or disadvantages) to using the different approaches (A1, A2, or A3) for technology transfer assistance with the different competitive pressures highlights the strengths (or weaknesses) of the approaches to resolve their pressures and establishes a check list and a framework to resolve the pressures, considering their "small batch" technical complexity.

Performing a similar assessment on all paths (or 36 combinations) across all top ten competitive pressures is of paramount importance for the state program. Another overall implication for the program is using this assessment and enhancing the technology transfer delivery systems already in Oklahoma to better match each delivery system with each competitive pressure and combination to efficiently and effectively resolve the competitive pressures. This assessment process boosts the technology transfer experiences of Oklahoma's small manufacturers and reduces their competitive vulnerabilities.

The previous scenario addressed the potential situations for respondents on optimal technology transfer decision paths and the implications of their approach choices on the three competitive pressures. Nevertheless, changing to a different path is another option available to small manufacturers, which can assist their technology transfer approach preferences. However, this option addresses mainly the respondents on less optimal or least optimal paths to successful technology transfer. For the smaller number of small manufacturers on the less than optimal paths, the state program must also recognize potential cost and/or time overruns in their assistance activities, unless the

small manufacturers switch to the most optimal path. In either case, coordinating the assistance between all concerned parties, especially between the small manufacturer and the delivery system for the competitive pressure in question, minimizes or eliminates potential overruns. This coordinator role again will retain and/or increase the competitive advantages of Oklahoma's small manufacturers.

Information provided in Level 6 can further clarify the reasons why the respondents, for a particular competitive pressure, preferred a particular approach, switched between the approaches, preferred a particular technology transfer path, or preferred to switch to another more optimal technology transfer path. The following three tables present the Level 6 analysis results for the combinations of interest, to further explain the technology transfer experiences of Oklahoma small manufacturers. These results are presented using the key code outlined earlier in Table 19 (page 241). Table 21 presents the results regarding the areas of involvement in technology transfer. Table 22 presents the results regarding the age of the small manufacturers (and the number of small manufacturers). And Table 23 presents the results regarding the barriers to technology transfer. Next is an examination of the Level 6 analysis results for combinations 2, 14, and 26. These three combinations had the highest number of respondents in this study for the three competitive pressures under consideration.

Level 6 Analysis Results per Combination and Competitive Pressure						
( Question 7, Section1.0 - Areas of Involvement in Technology Transfer? )						
Level 2	Level 3	C #	TT Decision Path Outcome?	QE Q # 7, S 1.0	WC Q # 7, S 1.0	NPD Q # 7, S 1.0
A1	SB	1	Less Optimal	1, 2, 4, 5	2	1, 4, 5
		2	Most Optimal	1, 2, 3	1, 2, 3	1, 2, 3
		3	Least Optimal	1, 2	1	1, 2, 3, 4
		4	Less Optimal	1, 2, 5	1	1, 3, 5
	LB	5	Less Optimal	1, 2	1	1, 2
		6	Most Optimal	1, 2	1, 2	1, 2
		7	Least Optimal	2, 4	2, 4	2, 4
A2	SB	13	Less Optimal	1, 2, 4	1, 4	2
		14	Most Optimal	1, 2	2, 3	1
	LB	17	Less Optimal	None	None	1, 2
		18	Most Optimal	1, 2, 3, 4, 5	1, 2, 3, 4, 5	N/A
	CP	22	Most Optimal	1, 2, 3, 4, 5	N/A	N/A
A3	SB	25	Less Optimal	1, 2	1, 2	1, 2
		26	Most Optimal	1, 2	1, 2, 5	1, 2
		27	Least Optimal	None	1, 5	1, 2, 5
	LB	29	Less Optimal	N/A	1, 2	1, 5
	CP	34	Most Optimal	1, 2, 3, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5

**Table 21. Level 6 Analysis Results per Combination and Competitive Pressure for Survey Question 7 of Section 1.0**

<b>Level 6 Analysis Results per Combination and Competitive Pressure</b>						
<i>( Question 8, Section 1.0 - Age of the Small Manufacturer (and # of SM's)? )</i>						
Level 2	Level 3	C #	TT Decision	QE	WC	NPD
			Path Outcome?	Q # 8, S 1.0	Q # 8, S 1.0	Q # 8, S 1.0
A1	SB	1	Less Optimal	2 (3), 3 (1), 4 (1), 5 (4)	2 (2), 3 (1), 4 (1), 5 (3)	1 (2), 2 (3), 3 (1), 5 (2)
		2	Most Optimal	3 (4), 4 (4), 5 (10)	3 (2), 4 (5), 5 (13)	3 (3), 4 (5), 5 (9)
		3	Least Optimal	2 (1), 4 (2), 5 (3)	2 (1), 4 (1), 5 (2)	2 (1), 4 (1), 5 (1)
		4	Less Optimal	4 (1), 5 (3)	4 (1), 5 (5)	5 (3)
	LB	5	Less Optimal	1 (2), 4 (1), 5 (2)	1 (1), 4 (1), 5 (2)	1 (1), 5 (2)
		6	Most Optimal	5 (2)	5 (2)	5 (2)
		7	Least Optimal	4 (1)	4 (2)	4 (1)
A2	SB	13	Less Optimal	1 (1), 2 (2), 5 (1)	1 (1), 2 (2), 5 (2)	4 (1), 5 (1)
		14	Most Optimal	1 (1), 3 (1), 4 (1), 5 (4)	1 (1), 3 (1), 4 (1), 5 (4)	3 (1), 4 (1), 5 (3)
	LB	17	Less Optimal	5 (1)	5 (1)	1 (1)
		18	Most Optimal	5 (1)	5 (1)	N/A
	CP	22	Most Optimal	4 (1)	N/A	N/A
A3	SB	25	Less Optimal	1 (2), 2 (2), 3 (1)	1 (2), 2 (3), 3 (1)	1 (1), 2 (4), 3 (1), 5 (2)
		26	Most Optimal	2 (3), 4 (1), 5 (6)	2 (3), 3 (2), 5 (4)	1 (1), 2 (3), 3 (1), 5 (8)
		27	Least Optimal	5 (2)	4 (1), 5 (3)	2 (1), 4 (1), 5 (4)
	LB	29	Less Optimal	N/A	1 (1)	4 (1), 5 (1)
	CP	34	Most Optimal	2 (1)	2 (1), 4 (1)	2 (1), 4 (1)

**Table 22. Level 6 Analysis Results per Combination and Competitive Pressure for Survey Question 8 of Section 1.0**

Level 6 Analysis Results per Combination and Competitive Pressure						
( Question 5, Section 9.0 - Barriers to Technology Transfer? )						
Level 2	Level 3	C #	TT Decision	QE	WC	NPD
			Path Outcome?	Q # 5, S 9.0	Q # 5, S 9.0	Q # 5, S 9.0
A1	SB	1	Less Optimal	1, 2, 3, 10	1, 2	1, 2, 7, 9, 10
		2	Most Optimal	1, 4, 6, 10	1, 3, 5, 6, 10, 15	1, 2, 3, 4, 5, 6, 10, 15
		3	Least Optimal	1, 2, 3, 5, 10	1, 2, 3, 10	2, 3, 6, 10
		4	Less Optimal	1, 2, 5, 7, 10	1, 2, 10	1, 2, 3, 7, 10, 13
	LB	5	Less Optimal	2, 6, 10, 12, 13	2, 6, 10, 12, 13	6, 10, 12, 13
		6	Most Optimal	1, 7	1, 7	1, 4, 7, 10
		7	Least Optimal	2, 3	3	2, 3
A2	SB	13	Less Optimal	1, 2	1, 2, 3, 9, 10	1, 2, 5, 12
		14	Most Optimal	1	1, 2, 9, 10, 13	3, 6, 9, 12, 13, 14, 15
	LB	17	Less Optimal	1, 4, 9, 10	1, 4, 9, 10	1, 2, 5, 6, 7, 10, 12, 13
		18	Most Optimal	1, 5	1, 5, 13	N/A
	CP	22	Most Optimal	6, 14	N/A	N/A
A3	SB	25	Less Optimal	1, 2, 3, 9	1, 2, 3, 9, 10	1, 2, 3, 9, 10, 13
		26	Most Optimal	1, 3, 13	1, 4, 5, 6, 7, 13, 14	1, 4, 5, 6, 7, 10, 13
		27	Least Optimal	14	1, 4, 10, 14	1, 2, 4, 5, 10, 12, 14
	LB	29	Less Optimal	N/A	1, 2, 5, 6, 7, 10, 12, 13	1, 2, 4, 5, 9, 10
	CP	34	Most Optimal	6, 12, 13	6, 12, 13, 14	6, 12, 13, 14

**Table 23. Level 6 Analysis Results per Combination and Competitive Pressure for Survey Question 5 of Section 9.0**

For combination #2, the Level 6 analysis results indicate that the respondents in this cluster are all predominately active in three technology transfer dimensions across all three competitive pressures - technical assistance, research and development, and governmental compliance. Also, the respondents in this combination have at least 11 years of manufacturing experience, with at least nine having 20 or more years of experience. In terms of technology transfer barriers for this combination, management skills were a barrier when confronting the qualified employees and new product development competitive pressures. For worker's compensation and new product development pressures, facility limitations, unknown benefits, and minor concern regarding change were the leading barriers. Financing was only an issue for this combination with respect to the new product development competitive pressure. Finally, all respondents on this most optimal technology transfer path faced the same set of barriers with all three competitive pressures - work force skills, technology appropriateness, and lack of understanding and training with the technologies.

The respondents on this path prefer a university-based comprehensive solution (Approach 1) for technology transfer and have a small batch manufacturing operation. The implication for the state program is to first facilitate and coordinate between the small manufacturers and a university research institution, like Oklahoma State University or The University of Oklahoma, and relay a detailed report summarizing the technology transfer experiences of this combination for the three competitive pressures. The next step for the state program is finding additional avenues and resources to support and complement both parties. For example, work force skills was the main barrier for a



majority of the survey respondents. Therefore, the state program can initiate a new labor-training policy or reemphasize a current labor program to increase the skills of Oklahoma's work force. This measure can remedy the work force skills barrier and can reduce the impact of Oklahoma's number one competitive pressure - qualified employees. Most importantly, this measure addresses the competitive vulnerabilities on a state-wide level.

Furthermore, this group faces retraining issues given their age breakdown, their technology appropriateness questions, and their lack of understanding and training with current technology solutions. Convincing this group to take nighttime Vo-Tech classes to become acquainted and skilled with today's technologies will not be as difficult when compared to a group on a less than optimal path to successful technology transfer. The state program might even offer reduced fees for the classes, especially since small manufacturers preferred Vo-Tech classes as their second primary source of training or transfer assistance with future new technologies to resolve their competitive pressures.

Regarding the competitive status of small manufacturers in combination #14, the Level 6 analysis results indicate a mixed combination of technology transfer activities to remain competitive. Respondents are predominately active in technical assistance and research and development activities to hold back qualified employees competitive pressures. To decrease worker's compensation pressures, small manufacturers are active in research and development and governmental compliance technology transfer activities. For the new product development competitive pressure, respondents are predominately active in the technical assistance dimension of technology transfer.

This combination had the same number of respondents (7) for two competitive pressures - (QE and WC). However, the make up of the combination is different. There are only 3 respondents common to both competitive pressures, which means each competitive pressure (QE or WC) included four different respondents. In terms of the manufacturing experience of this combination, the respondents also had the same age distribution for the qualified employees and worker's compensation competitive pressures, but again the make up was different for each pressure. For the new product development competitive pressure, the age distribution was similar to the other two pressures; however, this pressure had one less respondent in the over 20 years range and one less respondent in the 0 to 5 years range. Overall, this combination had a good amount of manufacturing experience given that at least 4 respondents across the three competitive pressures had 16 years or more.

In terms of barriers to technology transfer for combination #14, work force skills was a concern when dealing with only the qualified employees and worker's compensation competitive pressures. Likewise, lack of readily available information on the technology and transfer and implementation difficulties were only a concern with the worker's compensation and new product development competitive pressures. Further, for the worker's compensation competitive pressure, financing and lack of understanding and training with the technologies were also a concern for the small manufacturers. Finally, there were also five additional barriers to technology transfer related only with the new product development competitive pressure. They were: facility limitations, technology appropriateness, lack of a proven track / performance record with the technology, satisfaction with existing technologies, and minor concern regarding change.

Respondents in combination #14, just like in combination #2, are on the most optimal path to successful technology transfer. Furthermore, they have a small batch and unit production manufacturing operation also like the respondents in #2. However, respondents in combination #14 prefer the uni-dimensional approach to technology transfer. The main characteristic of this approach option is providing only one type of technology transfer assistance, such as business assistance, technical assistance, research and development, governmental compliance, etc. The one advantage of this approach is the high level of technical support available to small manufacturers to solve problems using its highly specialized technical staff. However, given the various technology transfer activities and barriers in this combination relative to just three competitive pressures (QE, WC, and NPD), the small manufacturers would need to contact several entities to receive all their required assistance to remain competitive. This arrangement lacks efficiency in communication, coordination, and technology transfer assistance.

To overcome this “fragmented” method for delivering technology transfer assistance to Oklahoma small manufacturers, especially in a competitive environment, the state technology transfer program can intervene on behalf of the small manufacturers and coordinate their activities with the different uni-dimensional entities. The goal would be to minimize the number of unnecessary interactions between a small manufacturer and a uni-dimensional entity. Further, this arrangement is executed well when the respondents are on the most optimal path to successful technology transfer, which is the case in this scenario (Combination #14). However, this will not be the case for the other 9 possible combinations associated with approach 2 that are not the most optimal

technology transfer paths. Therefore, respondents on these other paths run the risk of incurring additional unnecessary cost and/or time overruns each time they contact a different uni-dimensional entity for technology transfer assistance. At this point, the remaining option for the state program is to find a way to work and coordinate with the small manufacturer, if so desired, to switch to another technology transfer approach (A1 or A3), or to switch to a more optimal path within approach 2, or to switch to a more optimal path in approach 1 or 3, or to switch to the most optimal path in approach 1 or 3. Albeit, these four options require that the state program be flexible and robust when dealing with the small manufacturers, to again minimize and/or eliminate their competitive vulnerabilities.

Finally, combination # 26 was the last combination analyzed using the Level 6 characteristics. Just like the previous two combinations (#2 and #14), combination #26 was also a small batch and unit production manufacturing cluster and on a most optimal path to successful technology transfer. The respondents in this manufacturing cluster were all active in technical assistance and research and development activities across all three competitive pressures. However, respondents in this combination were also critically involved in human resource management assistance activities, in an attempt to resolve their specific worker's compensation competitive pressures, which was the second most important competitive pressure for Oklahoma's small manufacturers.

In terms of the manufacturing experience of this combination, the respondents had a minimum of 6 years for the qualified employees and worker's compensation

competitive pressures. For the new product development competitive pressure, the respondents also had a minimum of 6 years of manufacturing experience; however, one respondent was in the 0 to 5 years age range. Overall, this combination, like the previous two, also had an excellent amount of manufacturing experience. At least 4 respondents in this combination had 20 years or more of manufacturing experience across the three competitive pressures.

For this combination, the common barriers across all three competitive pressures were work force skills and transfer and implementation difficulties. Facility limitations were only a concern for the qualified employees competitive pressure. Satisfaction with existing technologies was only a concern for respondents grappling with worker's compensation pressures. And lack of understanding and training with the technologies was only a concern for the new product development competitive pressure. Finally, there were four technology transfer barriers in common for the worker's compensation and new product development competitive pressures. The four barriers were: management skills, unknown benefits, technology appropriateness, and major concern regarding change.

Respondents in combination #26, unlike in combinations #2 and #14, preferred the third possible technology transfer approach - (A Locally-Based Network - A3). Respondents preferring this approach rely extensively on the broker agents located strategically across the state to maximize their experiences with technology transfer. As an added competitive advantage to the respondents in this combination, these agents are

part of a larger brokering network, with each broker serving a particular region or territory in the state. This arrangement allows for direct contact with the respondents and allows for collaboration among the broker agents to promptly minimize and/or eliminate the respondents' technology transfer barriers. However, the quickness of this solution arrangement is tempered by the fact that the solution is a temporary one - (i.e., for the short-term). Even though the respondents on this path will not face cost and time overruns, the repeated contact efforts with the broker agents to find a solution eventually becomes a burden on this type of technology transfer approach (A3). This is especially the case when the small manufacturing industry is facing difficult industry-wide competitive pressures and when the small manufacturers are all confronting similar technology transfer barriers, such as work force skills, transfer and implementation difficulties, lack of understanding and training with the technologies, technology appropriateness, and major concern regarding change, all which are also some of the main barriers for this combination and for the industry as whole.

The state program can enact several technology transfer policies to alleviate the shortcomings of this approach, especially in this highly competitive environment. First, the program can increase the number of broker agents in the network to expand the network's outreach in current and new areas in the state. This will ensure that adequate information and prompt feedback are exchanged between the locally-based offices (old and new ones) and the small manufacturers and are circulated throughout the network (or state). Furthermore, this policy measure will be helpful and informative for the small manufacturers in the northwest region of Oklahoma, since there were no respondents from that area included in this study.

Sponsoring, coordinating, or conducting statewide conventions, conferences, seminars, training programs, Vo-Tech classes, and college/university level courses is another policy initiative that the state program can initiate, support, and/or fund. Since the resources of small manufacturers and the resources of the locally-based network approach itself are limited and valuable, such a policy will preserve those resources for individualized one-on-one technology transfer assistance. As a result, the state program's efforts, both monetary and human resources, can be used to resolve common industry-wide competitive pressures and barriers, which can overwhelm the network approach. This relationship (or arrangement) can also serve to satisfy the desire of small manufacturers in Oklahoma for a single-source, state-wide technology transfer program that provides all the required technology transfer assistance within one unit in a non-threatening way, as indicated earlier by the analysis results for Research Questions 2 and 3. If the state program starts and continuously advocates this type of relationship (or arrangement) between all concerned parties, then the state ensures a positive continuous technology transfer experience for its manufacturing base and especially for its small manufacturers as they try to resolve their competitive pressures. Finally, this type of relationship (or arrangement) can directly increase small manufacturer participation rates in future technology transfer decision-making processes and studies to resolve all top-ten competitive pressures currently faced by small manufacturers in Oklahoma.

#### 4.4 Summary

This chapter analyzed data collected from the survey questionnaire and collected from two survey respondent information scrolls. The survey questions and the information scrolls were coded and analyzed using frequency data analysis methods. This procedure produced important identifiable manufacturing industry characteristics regarding the experiences of small manufacturers in Oklahoma with technology transfer. Also, a 6-Level filtering (clustering) technique was used to determine noteworthy differences between the respondents and between the competitive pressures. This filtering technique was developed using five of the 40 survey questions in a predetermined order to further divide the data set into identifiable and manageable technology transfer policy groups (or combinations). Overall, this filtering technique provided a pyramid-like decision structure with 36 different policy group paths for each of the manufacturing industry-wide top-ten competitive pressures.

The first noteworthy outcome from using this filtering technique was that small manufacturers considered all three technology transfer approaches to be important when resolving the three considered competitive pressures - (QE, WC, and NPD). Prior research indicated that only Approach 1 was important. The second noteworthy outcome was that the majority of the respondents, which also have small batch manufacturing operations, preferred the most optimal path to successful technology transfer in all three technology transfer approach options for the three considered competitive pressures - (i.e., combinations #2, #14, and #26). The small manufacturers on these three paths in



the Nizam Pyramid will likely not face cost or time overruns when deploying a technology. As a result, the state-wide technology transfer program can more efficiently and effectively minimize and/or eliminate the technology and transfer vulnerabilities of these three small manufacturing groups, and thus easily enhancing and/or increasing their competitive advantages, across all three considered competitive pressures.

The third noteworthy outcome was that 15% to 16% of the respondents in all three technical complexity category options - (SB, LB, and CP) across the three competitive pressures could not be classified into one of the 36 policy combinations available on the Nizam Pyramid. This is a noteworthy percentage of the survey pool, which the filtering technique could not assist. As a result, the state program should be mindful of this group's technology transfer wishes when establishing technology deployment policies. Moreover, assessing and accommodating the competitive status of this "unclassified" group is an additional noteworthy step towards ensuring a robust and flexible state program that minimizes and/or eliminates the competitive vulnerabilities of all small manufacturers in Oklahoma.

The fourth and final noteworthy outcome from using this filtering technique was that it established a system dynamics perspective on the technology transfer experiences of small manufacturers in Oklahoma. The characteristics of these small manufacturers were not analyzed and presented individually but rather collectively to form a broad interrelated model (or framework) of their technology transfer preferences and decisions and how these preferences and decisions relatively and comparatively effect their

competitive positioning in today's highly competitive manufacturing environment. In other words, this filtering technique allowed the researcher to elevate the importance of identifying and knowing the characteristics of Oklahoma's small manufacturers, in order for the state technology transfer program to initiate and implement sound deployment policies and delivery systems and to monitor, adjust, revise, or change such policies and delivery systems.

## **Chapter 5. Summary, Conclusions, and Future Research**

This chapter summarizes the research outcomes of this study. It contains a discussion based on the data supplied by 100 respondents in the state of Oklahoma. While the data is from only a sample of the small manufacturing base in the state, the researcher believes the results can be generalized to the entire Oklahoma small manufacturing industry.

In order to make relevant longitudinal conclusions, it was necessary to relate a number of the findings of this study to past research. Conclusions in general were presented based on the results of the frequency data analysis and the filtering (cluster) analysis. These conclusions were compared to the work of Weijo, Willoughby, Collins, Hoff, and others. Finally, a list of future research topics has been presented to generate additional research studies in the field of technology transfer.

### **5.1 Research Contributions**

This research study provided 12 research contributions to the body of knowledge concerning technology transfer. First, it has presented an approach for developing a

state-wide technology transfer program for small manufacturers operating under competitive pressures. This approach seeks to improve the transfer of technology via a path of least resistance. Furthermore, the technical complexity of the small manufacturer's operations was included in the approach. Depending on the choices made by the small manufacturer, the approach offered four technology transfer decision paths with varying degrees of risk and varying optimal conditions/outcomes. The characteristics of the small manufacturers were then incorporated into the decision paths and analyzed to further develop specific technology transfer policies applicable to the various small manufacturing groups (or combinations) resulting from the filtering analysis approach. This decision path matrix and this approach overall are new contributions to the body of knowledge.

The structural foundation and framework of the approach was developed based on a "needs assessment" survey questionnaire, which was administered to small manufacturers in Oklahoma. The survey questionnaire, which was the second research contribution, consisted of 40 questions and had a 20.3 percent response rate - (100 out of 493 small manufacturers). This was an exceptional response rate compared to similar studies by Collins (1998) and by Hoff (1997). The collection time for the survey was set at six weeks. However, by the third week, 82 surveys were returned for a 16.6 percent response rate in that time frame. Lastly, the 100 responses along with two data scrolls generated over 14,000 data points. This considerable amount of data greatly enriched the process of developing the approach.

The third research contribution of this study related to the decision-making processes of small manufacturers. Today, technology transfer interventions are a crucial element of business survival in a highly competitive manufacturing environment. This is especially the case for small manufacturers. Their limited resources and capabilities are stretched to the limit trying to resolve their competitive pressures and at the same time still compete successfully. As a result, the main issues that arise for the small manufacturers in this environment concern the technology transfer approaches, the technology transfer programs, and the technology transfer attitudes and policies that they must consider and embrace in order to benefit from emerging technologies and remain competitive. The approach developed in this study helps to resolve these issues by integrating, streamlining, and benchmarking their preferred technology transfer interventions (or decisions) and communicating them in a systems dynamic perspective. This will prove to be invaluable to the small manufacturers when faced with survival implications in their decision-making processes.

In 1997, Hoff developed a technology adoption continuum incorporating risk factors. The goal of the continuum was to determine a means for measuring the correctness of a technology transfer decision relative to deploying the right technologies. This achievement allowed analyses to be conducted determining if there are certain factors that are associated with making the right decision regarding the adoption or rejection of a technology. The fourth contribution of this study was adding to her work a technology transfer decision matrix within which this correctness issue is further demarcated and applied under appropriate technology or technology choice paradigms

and under technology adoption or technology adaptation principles. In other words, the approach developed in this study could serve as the backdrop for implementing Hoff's adoption continuum.

Further defining the role of decision factors (or technology transfer demand factors), such as the dimensions, attributes, approaches, and programs preferred by small manufacturers in Oklahoma, was the fifth research contribution of this study. Collins (1998) established a technology transfer baseline for the state of Oklahoma and its small manufacturing industry. The dimension and attribute preferences and the status of technology transfer within the state were included in this baseline. This study contributed to his efforts by infusing a longitudinal perspective (i.e., seven years) on the status of small manufacturers within the state and on their technology transfers decisions incorporating the effects of competitive pressures. Jointly, these two studies confirmed a previous proposition by Amendola and Gaffard in 1988 that an economy, especially a competitive manufacturing economy, no longer adjusts passively to a technology (appropriate or choice) through the diffusion (or transfer) processes. In fact, it is the technology and transfer choices of today's small manufacturers together with the manufacturing economy that are actively shaping not just the manufacturing operations but are also shaping a state's technology delivery systems, technology base, and overall economy.

Three important observations provided by this study, as well as Collins', supported this proposition (and phenomenon). The first observation was the percent

increases in the usage of certain technology transfer delivery systems in Oklahoma. This observation indicated developmental, usage, and growth patterns of the delivery systems in the state. For instance, over the past seven years, small manufacturers utilized the broker/agent model, such as The Alliance (i.e., Approach 3), extensively for technology transfer assistance to resolve their competitive pressures. As a result, the state, with feedback from the small manufacturers, invested more into this delivery system to ensure a broader coverage area, which at the same time helped the state's local economies.

The second observation was the high number of trade shows and conventions attended by Oklahoma's small manufacturers in the past three years. This observation was a clear indicator of the small manufacturers' willingness and desire to travel and seek out "solution" technologies. This new active role of small manufacturers to join technology researchers and developers is a clear attempt to change and improve their technology base. This new base could significantly and positively influence manufacturing productivity and profit margins.

The third observation supporting this new active joint role was the increase in the number of small manufacturers in Oklahoma that are willing to pay for 76% to 100% of the costs of a technology transfer project. This willingness observation is important because it is a direct link to the financial condition of the small manufacturers in today's economy. Also, this shift or trend could serve as a relevant and timely feedback mechanism into the state's economy and research and development activities, which can then serve as feedback mechanisms to continue supporting the technology transfer

activities of the small manufacturers and to continue resolving their competitive pressures. These feedbacks increase the economic returns and technology investment returns of all participating parties.

The sixth research contribution of this study was the ability of the philosophy and methodology framed within the Nizam Pyramid to market technology transfer tools to small manufacturers. Weijo (1987) advocated a marketing strategy to promote government/private sector transfer of technology. Specifically, this strategy should emulate the technology transfer approach being used by private sector organizations, such as small manufacturer, to identify and develop new product ideas and to increase the competitive position of these organizations. The Nizam Pyramid could serve in that capacity as a marketing tool to promote technology transfer and/or to begin the technology transfer process.

The seventh research contribution was providing a definitive tangible way to convey a technology to a small manufacturer. The Nizam Pyramid allowed a small manufacturer or state agency to collectively sense the status and potential outcome of a technology. This contribution when combined with the continuum developed by Hoff (1997) further extends and clarifies the range of adoption and nonadoption technology transfer decisions by small manufacturers. The potential decisions of small manufacturers when considering a particular technology (i.e., adoption, leaning towards adoption, neutrality, leaning towards rejection, and rejection) are greatly enhanced and improved by considering both the pyramid and the continuum simultaneously.



Testing the standardization aspect of a technology when considered for transfer was the eighth research contribution of this study. Hoff (1997) suggested that there is a need for technology developers to provide technologies, which are more easily modified to fit into different manufacturing systems. Since the Nizam Pyramid includes a manufacturer's technical complexity of manufacturing operations along with their technology transfer approach, program, and attitude and policy preferences, the technology developers will have an easier time designing for different manufacturing systems. The Nizam Pyramid facilitates the standardization of a technology, especially since the more standardized the technology, the more rapid the adoption and diffusion of that technology would be in a competitive environment (Hoff, 1997).

The ninth research contribution of this study was providing a path to visually inspect and monitor Hoff's adoption continuum incorporating risk factors at work. Hoff (1997) suggested that marketing, commercialization, and technology transfer efforts should address the risk factors on the adoption continuum as a whole, especially incompatibility and difficulty of modification. She further suggested that a state technology transfer program's infrastructure should emphasize these efforts for successful deployment, especially at small manufacturers, and that the director of such a program should seek to transfer technologies inclusive of the adoption continuum. The Nizam Pyramid could serve in this capacity and allow for the visualization of Hoff's technology transfer continuum as the development of a robust and flexible state technology transfer program is in progress.

The tenth research contribution of this study was providing an additional lens through which all parties - (i.e., the small manufacturers and the delivery systems) engaged in technology transfer activities and/or implementing technology transfer contracts can view how close each of the parties is to successfully deploying a technology or not, and what the state program needs to do to support their efforts. The systems dynamic view provided by the Nizam Pyramid provided this lens with several other interchangeable parts, mainly the presence of these activities and contracts under ranked competitive pressures.

The eleventh research contribution of this study extended the work of previous technology adoption research by differentiating between technology adoption and technology adaptation technology transfer processes. Prior to this study, there was no clear indication and application of these two different technology transfer processes. Past research referred to the literal connotation of technology adoption – (i.e., technology transfer and technology adoption were synonymous within the context of technology diffusion). However, this study referred to the actual translatable meaning and encompassed all the theoretical nuances and actual procedures and their associated implications with adopting a technology rather than adapting a technology, and vice-versa. This study has clearly established that adaptation processes have vastly different implications than adoption processes for technology transfer programs (i.e., appropriate technology and technology choice transfer programs), for small manufacturers, and for the state technology transfer program in general.

The twelfth and final research contribution of this study related to the work by Willoughby (1990). His research focused on the three mutually interdependent dimensions of technology management - (organizational, cultural, and technical) and their relationship to planning, designing, and implementing an appropriate technology transfer program or a technology choice transfer program. The approach presented in this study could be used to harmoniously integrate the three technology management dimensions and to simultaneously resolve the competitive pressures of small manufacturers. By recognizing the financial and human resource limitations and the technology transfer barriers of the small manufacturers, the integration process is simplified. This recognition phase has an even greater impact if and when all the characteristics of the small manufacturers are collectively screened and considered, which the Nizam Pyramid philosophy and methodology could provide.

## **5.2 Results and Conclusions**

The 100 survey responses provided a rich detailed history of the technology transfer experiences of small manufacturers in Oklahoma over the past seven years. The frequency analysis results and the filtering (cluster) analysis results combined to give a broad snap shot of those experiences. In general, according to the results, Oklahoma's small manufacturers realize and recognize their technology transfer needs in today's competitive manufacturing environment. Any future state-wide technology transfer program, as well as the state of Oklahoma itself, could benefit greatly and broadly by

utilizing these results to meet and complement current and future technology transfer needs and decisions of small manufacturers, its primary constituency.

Based on the results in Chapter 4, the following could be concluded:

1. The “Alliance” model established and promoted by OCAST since 1991 could benefit greatly from the approach depicted in the Nizam Pyramid. The pyramid’s complementary nature could highlight further the advantages of the “Alliance” model;
2. The majority of the small manufacturers will not consider and attend a technology transfer meeting that lasts longer than 8 hours (or more than one day). This is a noteworthy shift from seven years ago, when there was no clear indication or preference. Today’s competitive environment is limiting a small manufacturer’s ability to allocate additional resources for attending technology transfer meetings. The approach presented in this study will optimize a small manufacturer’s resources;
3. The approach presented in this study could simplify and streamline the technology transfer decisions of the small manufacturers and the policy initiatives of the state program. This ability will allow the small manufacturer and/or the state in general to leverage additional resources (human and monetary) from federal agencies and the federal budget. For each additional and new dollar the state government invests in its small business development programs, such as STTR and SBIR, because of and

directly related to applying the approach highlighted in this study, the federal government will match - (i.e., match dollar for dollar);

4. The approach presented in this study could help evaluate and assess the advantages and disadvantages of the three technology transfer approaches (A1, A2, and A3) as related to the 10 technology transfer delivery systems available in Oklahoma within the context of Oklahoma's "top ten" competitive pressures. This will allow the state program to better market the three approaches to the small manufacturers as they are attempting to eliminate their competitive vulnerabilities;
5. Using the approach in this study could lead to a well-organized and planned state technology transfer program. Eventually, this program could then lead to a burst of new innovations and technology transfer tasks, functions, and perspectives that could keep US manufacturers, particularly Oklahoma manufacturers, at the forefront of today's competitive global economy. Moreover, such a program could make that outcome and transition possible in a more efficient and effective way (or path);
6. A higher response rate from the 26-50 employee size range to the 51-75 employee size range and from the 76-100 employee size range to the 101-250 employee size range could indicate that middle to large sized small manufacturing firms are at a cross-road with their business operations as related to how technology transfer could assist them to sustain or grow their operations under competitive pressures. Conversely, small manufacturers in the 1-25 employee size range had the lowest response

rate. This could indicate a lack of interest in technology transfer and its contribution to their manufacturing operations. If the competitive environment is difficult for the firms in this range, then these firms are more likely to relocate or cease operations much easier than larger firms. The impact(s) of such decisions are not as critical on the firm and on its surrounding community, and the decisions themselves are not as difficult to make;

7. Over the past seven years, there was substantial improvement in the recognition rates for the state's delivery systems. This could be an indication that Oklahoma has done a better job of advertising and marketing its delivery systems. On the other hand, these improvements in that time span could also indicate a stronger desire by the small manufacturers to seek out the delivery systems in order to remain competitive. Either way, this is a positive trend and an encouraging outcome for the state's economy. Moreover, further applying the approach presented in this study could increase these improvements in the recognition rates even more. Eventually, this could lead to minimal or insignificant neutral response rates for the state's delivery systems;
8. The approach presented in this study helped evaluate barriers to technology transfer together with other characteristics of small manufacturers. This advantage enables the state program to collectively view the status of small manufacturers. Furthermore, this collective view appropriately and adequately supports the technology transfer activities of

small manufacturers in a “comprehensive competitive pressure” continuum similar to Hoff’s adoption continuum;

9. The state program’s coordination role between the three technology transfer approaches could be very important to achieve the technology transfer goals of small manufacturers. For instance, while the OSU delivery system, which is an example of Approach 1, is conducting research to identify and resolve state-wide long-term issues of the worker’s compensation competitive pressure, such as workplace redesign research, The Alliance, which is an example of Approach 3, could be directing and managing individualized efforts to resolve specific small manufacturer short term issues. This could include small manufacturers with small batch, large batch, or continuous process manufacturing operations. At the same time, the developer of the technology in question would be working directly with the small manufacturers to redesign the technology, which is an example of Approach 2. Once all of these three activities are in place, the state program would then ensure that the work effort is not duplicated and ensure the necessary resources are available to complement and support this work effort state-wide;
10. Another aspect to the state program’s coordinator/supportive role is achieving the best with the given circumstances. The resources of small manufacturers are limited. Therefore, if a small manufacturer is not on the most optimal decision path to successful technology transfer, then the state program could try to ensure the next best optimal path/s. Only a few of

the small manufacturers, especially small manufacturers in the 101-250 employee size range, could afford considering both technology transfer programs (appropriate or choice) and/or both technology transfer attitudes and policies (adoption or adaptation). One feasible solution for this scenario could be for the state program to intervene and ensure that one of the three technology transfer approaches can compensate for any shortcomings due to the inability to switch programs and/or attitudes and policies. This intervention solution or fall back position would also need to include considerations for all three types of technical complexities - (SB, LB, or CP);

11. All three technology transfer approaches - (A1, A2, and A3) are important and are being used by the small manufacturers in Oklahoma for the three considered competitive pressures;
12. The majority of the small manufacturers in Oklahoma are already on the most optimal decision path to successful technology transfer - (i.e., combinations #2, #14, and #26). This is also the case regardless of the chosen technology transfer approach and for the three considered competitive pressures;
13. Technical assistance and research and development were the two predominant areas of involvement in technology transfer by Oklahoma's small manufacturers in the applicable combinations found in the Nizam Pyramid for the three considered competitive pressures;



14. Work force skills and financing were the predominant technology transfer barriers faced by Oklahoma's small manufacturers in the applicable combinations found in the Nizam Pyramid for the three considered competitive pressures;
15. Oklahoma's small manufacturing industry is an active and experienced but aging base;
16. A higher percentage of the small manufacturers in Oklahoma are willing to pay for more of the costs of technology transfer projects than seven years ago;
17. Oklahoma's small manufacturers still considered all five technology transfer dimensions and their attributes to be important. They still desire technology transfer assistance within a multitude of combinations involving the dimensions and their attributes during the past seven years;
18. The majority of Oklahoma's small manufacturers have small-batch and unit production manufacturing operations and are under constant competitive pressure, just like the large-batch and continuous process small manufacturers;
19. The top five technology transfer barriers currently faced by Oklahoma's small manufacturers are:
  - a) Work Force Skills
  - b) Financing
  - c) Lack of Understanding and Training with the Technologies

- d) Transfer and Implementation Difficulties
  - e) Technology Appropriateness
20. The top five major issues to designing a state-wide technology transfer program tailored to the small manufacturers in Oklahoma are:
- a) Cost to the Small Manufacturer for Services
  - b) Timeliness of Assistance
  - c) Availability of Technologies
  - d) Comprehensive Technology Transfer Program
  - e) Confidentiality of Information
21. Oklahoma's small manufacturers preferred an appropriate technology transfer program. The number of respondents who indicated such a preference was almost three times as many as the respondents who preferred a technology choice transfer program;
22. The majority of Oklahoma's small manufacturers preferred technology adaptation processes. This indicates that small manufacturers want to proceed with technology transfer in a slow calculated pace. However, it should be noted that 45% of the respondents indicated a preference to technology adoption processes;
23. The majority of Oklahoma's small manufacturers are willing to participate in another more in-depth survey in the near future that focuses on technology transfer programs and their related cost drivers and risk factors.

### **5.3 Research Implications for the Small Manufacturing Industry**

As a result of this research, the author believes that there are several implications for small manufacturers that consider technology transfer an integral part of their competitive strategies. Currently a majority of the small manufacturers considers appropriate technologies for technology transfer. Also, they consider adaptation processes for putting technology transfer into practice. As noted earlier, the outcome of such a combination of decisions prepare a small manufacturer to be on the most optimal decision path to successful technology transfer. However, there is a significant difference between indicating this outcome preference and actually realizing it and benefiting from it under competitive pressures. Furthermore, the most optimal path at times can be a lengthy journey, filled with setbacks and failures. But there will be substantial rewards along the way. Also, the overall outcome could be influenced by the preparedness status of the small manufacturer to start this path. The first item representing this status could be checking to see if there is a “qualified” engineer working at the manufacturing company. Past research studies by Hoff (1997) and West (1990) indicated that having an engineer positively influenced the technology transfer experiences of manufacturing companies. However, it should be noted that the majority of Oklahoma’s small manufacturers currently do not employ engineers, which is already a critical setback despite being on the most optimal decision path. Therefore, Oklahoma’s small manufacturers need to consider hiring additional engineers.

Hiring additional engineers could be difficult since there is already a shortage of qualified employees, which is the number one competitive pressure currently faced by Oklahoma's small manufacturers. Furthermore, work force skills was the predominant technology transfer barrier commonly faced by Oklahoma's small manufacturers in the applicable combinations found in the Nizam Pyramid for the three considered competitive pressures - (i.e., QE, WC, and NPD). As a result, providing reeducation opportunities, creating an eligible qualified pool of engineers, and/or maintaining a database of prospective engineers could collectively be the number one priority for the state technology transfer program to support the technology transfer activities of small manufacturers. In fact, the state program and a small manufacturer could jointly subsidize the salary and/or benefits of a prospective engineer in the beginning, especially for the first year or two years of employment. This reduces the financial burden on the small manufacturer and allows the technology transfer journey to start on a positive note. Overall, this policy initiative could be the start of a state-wide technology transfer co-op program. Such an initiative could also serve to mitigate hiring difficulties - (i.e., on a full-time basis) due to company structural and/or organizational configurations and company size constraints and/or limitations, especially for the small manufacturers in the 1-25 employee size range, which is the predominant employee size range in Oklahoma.

Many technology transfer barriers do not have monotonic effects on transfer resistance throughout the "most optimal" journey; yet they differentiate among the various transfer resistance levels (or adoption decisions) on Hoff's adoption continuum. This is especially the case for certain barriers that have systemic effects on the journey.

Furthermore, whether or not certain barriers increase or decrease a company's transfer resistance during the journey is dependent upon that company's other characteristics and its position on the adoption continuum. Therefore, a technology transfer agent of the state program, along with a representative from the small manufacturer, should jointly assess the small manufacturer's current position along the technology adoption continuum to sustain and maintain the "most optimal" journey and achieve its intended goals. Also by applying the results of this research, this joint effort is greatly enhanced. The 6-Level filtering procedure could prepare the agent and the representative to have a successful technology transfer journey all-around - (i.e., prior to the journey, during the journey, and after the journey). As a result, this complete effort before, during, and after the journey could very well establish the necessary feedback mechanisms and control loops to counter the systemic effects of certain barriers to ensure the success of the current journey and to ensure subsequent journeys are just as successful, if not more successful.

#### **5.4 Future Research**

This research study provided several intriguing outlooks for small manufacturers in Oklahoma. The past seven years has not dramatically changed their technology transfer needs. However, their needs now must be provided within the context of a highly competitive manufacturing environment. This environment has slowly gained momentum during the past seven years. Moreover, this momentum shift has forced

manufacturers to consider newer, more competitive technologies as their core technological competencies change in a sincere attempt to remain competitive in this environment. Therefore the research results and the technology transfer concepts provided in this study only begin to turn the tide back in favor of the small manufacturer, especially in Oklahoma. There are many opportunities for further research in this area to ensure that an enduring and flexible foothold is established, which can assist to resolve current and future competitive pressures.

The following are suggestions for future technology transfer research studies. It should be noted that several of the suggestions are a continuation of this research study.

1. Determination of why there were still many neutral responses to Survey Question 2 in Section 2.0. There were noteworthy improvements with several of the technology transfer delivery systems in Oklahoma during the past seven years, such as The Alliance and the Vo-Techs delivery systems. However, for the remainder of the delivery systems, additional research is necessary.
2. Identification of critical cost drivers and risk factors of technology transfer programs. Again, it should be noted that fifty cost drivers and risk factors were identified, but not included in this study, as pertinent to successful technology transfer. Already, a majority of Oklahoma's small manufacturers in this study were willing to participate in another more in-depth survey in the near future to accomplish this task.

3. Application of additional identifying levels into the Nizam Pyramid filtering approach. The effects of organizational change, organizational culture, organizational management, organizational (company) structure, and corporate structure can further identify the technology transfer policy requirements of the 36 combinations established by the pyramid approach and more importantly, can further distinguish between the 36 combinations.
4. Development of an expert system (ES) model, a systems dynamic (SD) model, and/or an analytical hierarchy process (AHP) model based on the research results of this study. The steps in the Nizam Pyramid filtering approach could be programmed. This programmed process can then provide sequenced, conditioned, and individualized technology transfer services to small manufacturers in a logical progression. Furthermore, the research results could also help the state technology transfer program develop specific conditional models and requisite policies based on the unique simulation capabilities of the three different modeling programs. Overall, this effort could provide a databank of measurements related to the correctness of a technology transfer decision and its correlated technology transfer decision paths, particularly paths with least optimal to most optimal circumstances and consequences.
5. Determination of why several small manufacturers switched (or did not switch) technology transfer approaches for the three considered competitive pressures. Recognizing and tracking the reasons for switching

(or for not switching) between approaches could identify additional advantages and/or vulnerabilities of the approaches (and in essence of the technology transfer delivery systems in the state) as seen from the small manufacturer's point of view. Also, since respondents in this study preferred different approaches for the competitive pressures, this could lead to a better understanding of the competitive pressures and the reasons why they caused the small manufacturer to switch (or not to switch). Essentially, this could also lead to a better understanding of the dynamic relationship between competitive pressures and applicable technology transfer approaches and delivery systems in the state. This can result in developing important feedback mechanisms and control loops that capture small manufacturer and system insights to improve current technology transfer delivery systems in Oklahoma and to create new ones in the future if needed.

6. Performing a more in depth comparative study involving the research results of this study with the study by Collins (1998). The state of Oklahoma could benefit greatly from investigating the technology transfer trends of its small manufacturing base operating in today's competitive environment with the competitive environment of seven years ago. Essentially, recognizing any shifts in the preferred set of technology transfer dimensions and attributes in the past seven years could further ensure Oklahoma's technology transfer program remains dynamic, holistic, robust, flexible, and resilient. Furthermore, both studies present



an excellent opportunity for data mining research studies. The combination of the 7,000 data points from Collins' effort and the over 14,000 data points from this study produces a rich data set of over 21,000 data points, all of which is related to the technology transfer experiences of small manufacturers in Oklahoma, dating back to 1993. This future effort could be a truly insightful 12-year benchmark period highlighting the technology transfer delivery system utilization patterns for the state of Oklahoma. In addition, this future effort could culminate in a technology transfer benchmarking study for the state of Oklahoma reflecting on this 12-year period.

7. Application of the Nizam Pyramid filtering approach to the remaining seven competitive pressures not considered in the analysis phase of this research study - (i.e., TR, RMPS, LCM, MRKT, HR, SCM, and EED). The remaining small manufacturers characteristics (or variables) not considered in the analysis phase of this study can also be included and analyzed to further understand the three considered competitive pressures and to further evaluate the remaining seven competitive pressures. This "comprehensive" analysis procedure of the competitive pressures (including all the associated characteristics or variables) will further enrich the state program's knowledge and understanding of the dynamic relationship between the top ten competitive pressures and the applicable technology transfer approaches and delivery systems in the state. In fact, future research attempts can include other competitive pressures not

included in the survey questionnaire and thus not considered in this study, such as the second set of top ten (unranked) competitive pressures - (#11 to #20). They were:

- a) Tort Reform
  - b) Tax Reform
  - c) Globalization
  - d) Budgeting
  - e) Trade Treaties
  - f) Education
  - g) Enhanced Manufacturing Process
  - h) Overcapacity
  - i) Environmental Regulation Compliance Cost
  - j) Salesmen / Sales Channels
8. Repeating the research methodologies presented in this study in other states. Applying the concepts outlined in this study on a national scale will further strengthen US manufacturing industries and the many communities dependent upon them. In fact, the results of such a national study could likely support the establishment of a national office of technology transfer - i.e., US Department of Technology Transfer.

## 5.5 Significance

This research study was very helpful in determining the technology transfer needs of small manufacturers in Oklahoma. The survey results provided evidence that small manufacturers need: multiple technology transfer dimensions and attributes, multiple technology transfer programs, and multiple technology transfer processes. The delivery of this complex assortment of technology transfer assistance was requested in the form of multiple technology transfer approaches dependent upon the competitive pressure/s under consideration.

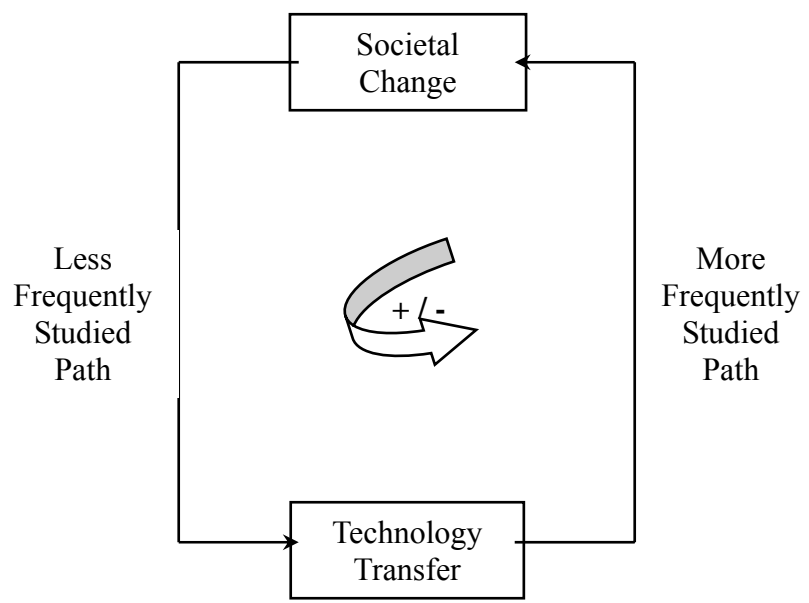
Furthermore, the results of this research expanded knowledge in several areas of Industrial Engineering. Specifically, this research study impacts the areas of technology transfer, technology forecasting, technology integration, technology and operations management, technology organization, strategic management, total quality, and technology policy. Technology transfer models could be improved by recognizing and addressing adoption and adaptation factors as well as appropriate and choice factors that impact technology transfer decisions under various competitive pressures. Also, these models will benefit from recognizing and addressing technology transfer approach and technical complexity factors that impact technology transfer decisions under various competitive pressures. Overall, significance of certain factors could then lead to changes in the way in which technologies are developed and transferred (e.g., developers, with input from technology transfer agents, might consider easier means of modifying their products so that they can be implemented in several different manufacturing operations

that also have different technical complexities to resolve different applicable competitive pressures).

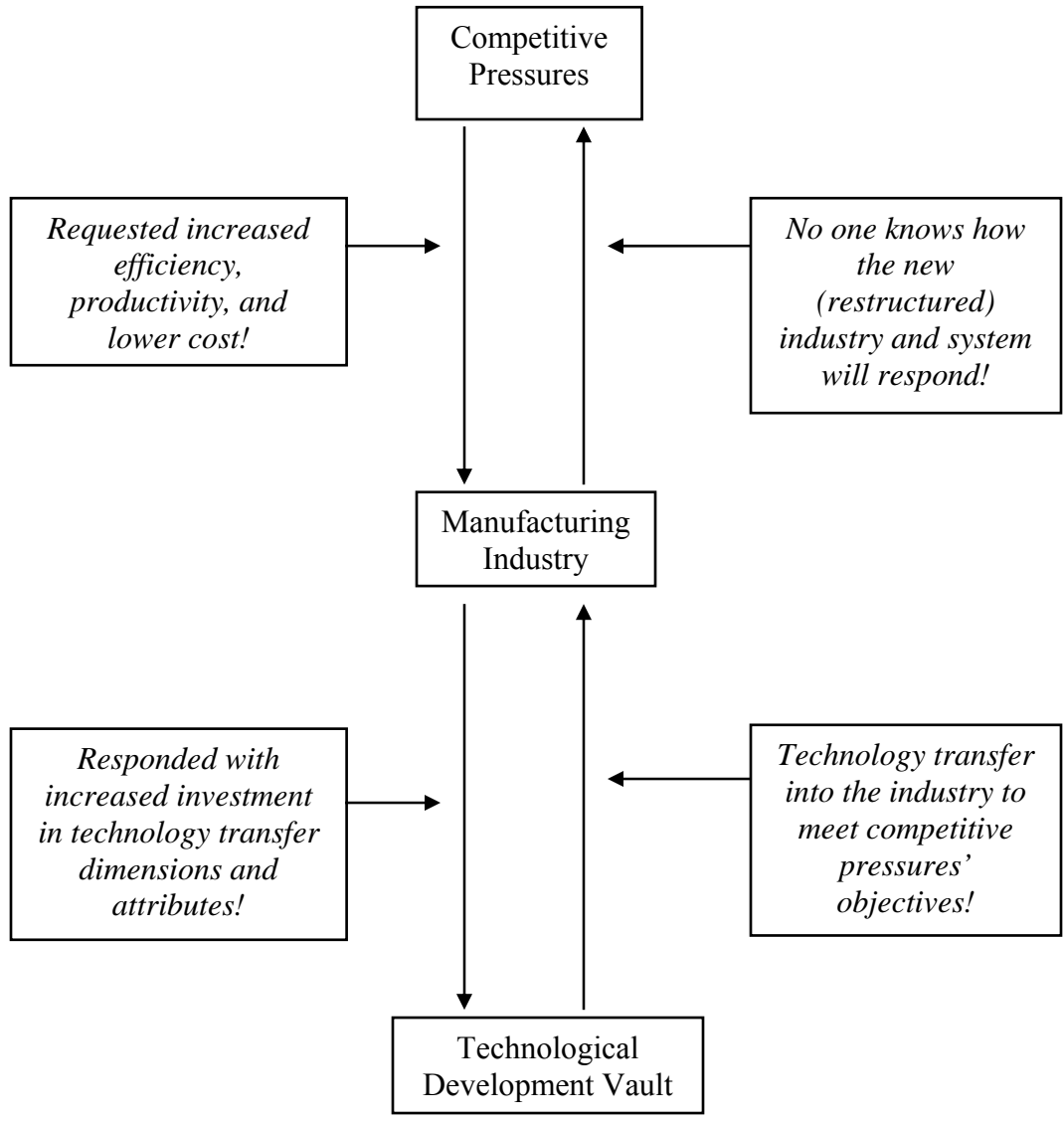
Identification of certain significant factors also contributes to the areas of multi-criteria decision making and multi-attribute evaluation of industrial projects. The approach and factors presented in this study are not mentioned collectively in the application of multi-criteria decision making tools and multi-attribute evaluation tools. Moreover, integrating the approach and factors presented in this study with more traditional economic evaluations of technology transfer costs should result in a more complete systems and critical-mass viewpoints of the issues that should be considered in any technology acquisition model.

This research study was also very helpful in exploring the impact of societal changes, such as competitive pressures, as it pertained to technology transfer to small manufacturers in Oklahoma. The implementation and acceptance of new advanced technologies initiate new “restructuring competitive pressure” cycles, which can potentially reshape almost every aspect of how day-to-day operations in the manufacturing industry are performed. And so it is reasonable to conclude that technology transfer initiated a change in the manufacturing industry, and now this change has a life of its own. What is generally known now and continually studied is how technology transfer effects society, but what is less studied is the effect of major societal changes, such as competitive pressures, will have on the way technology transfer is conducted, especially in a competitive environment. Figures 46 and 47 depict and clarify this situation further.

For the state technology transfer program, there are three significant policy initiatives that it should promote and lobby for immediately. The first initiative is to ask the Oklahoma state legislature to increase the funding and support for research parks, with an emphasis on technology research and development and transfer research and development. The results in this study indicated a need to focus on both the technology and transfer aspects of technology transfer, separately but concurrently, mindfully, and conjunctly.



**Figure 46. A Positive or Negative Feedback Loop**



**Figure 47. The Technology Transfer Cycle for the Manufacturing Industry Under Competitive Pressures**

This two-pronged approach allows for the development of technologies that resolve competitive pressures and at the same time allows for the development of transfer mechanisms that reach as many small manufacturers as possible, who urgently need these technologies to compete successfully. Coincidentally, this initiative creates new product development opportunities and new job opportunities and increases the tax base, which is a winning combination for the small manufacturers as well as for the state. As a result, this initiative directly confronts the seventh-ranked competitive pressure (New Product Development) and directly opens new avenues to seek out and hire qualified employees, which is the number one ranked competitive pressure. This initiative also implies that the funding of higher education is a priority and is intrinsically tied to the success of the research parks, since the state will inevitably need a skilled work force for the research parks, which also happens to be the number one barrier to technology transfer.

The second initiative is to better advertise and broadly market the existence of Oklahoma's technology transfer delivery systems. This study focused on the 10 most recognized delivery systems in the state. These 10 systems are capable in meeting the technology transfer requirements of the state's small manufacturers. However, there is a need to better showcase how each delivery system can uniquely assist with each different competitive pressure that small manufacturers in Oklahoma are currently facing or will face in the near future. Furthermore, the state program should develop checklists, feedback mechanisms, and control loops to better prepare for future new competitive pressures. These activities in fact are more likely to determine the outcome of the feedback loop represented in Figure 46 - (i.e., a positive or a negative recurring outcome)

than any new more advanced technology intervention/s, any new technology transfer intervention/s, or any new technology transfer delivery system/s in general can or will determine.

Several of the delivery systems in Oklahoma are already well established and have a good rapport with the small manufacturers. The state program should not overlook this, but rather build on it to effectively eliminate any issues or concerns, especially cultural barriers (Collins, 1998). Utilizing these relationships fully can be a considerable advantage for the state program and can be an immeasurable asset for the state in general. But, the door should be kept open for the possibility of creating new delivery systems if the competitive conditions warrant such a decision and the current delivery systems cannot deal with (or refuse to deal with) the situation. This is an unlikely event, however, the future is unpredictable and needs change.

The third policy initiative for the state technology transfer program to undertake is to plan and organize a retreat involving representatives from the 10 delivery systems mentioned in this study and from other delivery systems and involving a representative sample of small manufacturers from all five regional areas of the state. The main purpose for this retreat is two-fold. First, the retreat allows the state technology transfer program to coordinate between the delivery systems with input from the small manufacturers, to reassess the technology transfer capabilities of each system with feedback from the small manufacturers, and to redraw state technology transfer boundaries with input from the small manufacturers. This last activity ensures that technology transfer assistance is accessible to every small manufacturer in all 77 Oklahoma counties.



The second purpose for the retreat is to draft, and eventually publish, a mission statement and a working white paper for the state's new technology transfer program. These two documents will layout the future technology transfer goals, objectives, and plans for the state. The new Oklahoma Department of Technology Transfer will be in charge of administering and overseeing the program. This bold step is a clear and strong signal to all manufacturers, especially small manufacturers, that the state is serious about resolving current and future competitive pressures. Furthermore, the researcher believes this step will focus and concentrate the state's efforts and the technology transfer delivery systems' efforts in resolving competitive pressures. Also, the researcher believes this step will give a sense of direction (and a map for the future) for all parties engaged in technology transfer and affected by today's competitive environment, as well as by tomorrow's competitive environment. Lastly, the researcher believes this step will provide the widest possible technology transfer assistance-coverage network for the state's small manufacturers in an effective and efficient manner.

Based on the empirical data gathered from the survey questionnaire, the organizational structure of the proposed state technology transfer program in Oklahoma should be a multi-faceted program and should be flexible enough to meet the technology transfer needs of all 36 combinations discussed earlier. In fact, it could be hypothesized that the program's branches would be much like the levels in the Nizam Pyramid. A Secretary of Technology Transfer will be the main person in charge of administering the program. Also, this person will serve as the state's technology transfer adviser to the Governor of the State of Oklahoma and will serve as the state's chief technology officer

(CTO). The budget for this new department could be allocated from Oklahoma's share of several federal bills, which were mentioned earlier in the study. Also, the State of Oklahoma could create additional new funding streams to complement and supplement the federal funds.

Figure 48 provides a graphical representation of the state program's organizational structure. There are similarities between the various branches in the program with the filtering analysis levels presented earlier in Chapter 4. The secretary of the program directs technology transfer policy for the state and reports to the governor's office. Furthermore, this person will promote and campaign for technology transfer legislation and budgeting referendums at the state and national levels.

The two under-secretaries for the program would each be in charge of the two main types of technology transfer programs - Appropriate Technology and Technology Choice. Their main objective is to develop appropriate and choice programs within the framework and outcomes presented by the Nizam Pyramid approach. Their activities would then be used to further develop a comprehensive adoption/rejection technology transfer continuum for the state under competitive pressures. Hoff's continuum would serve as the standard model from which to start this process.

The three assistant under-secretaries are the next level in the model for the state program. Each of the three assistant under-secretaries would be responsible for a technology transfer approach - (i.e., A1, A2, or A3). Their overall task is to develop the

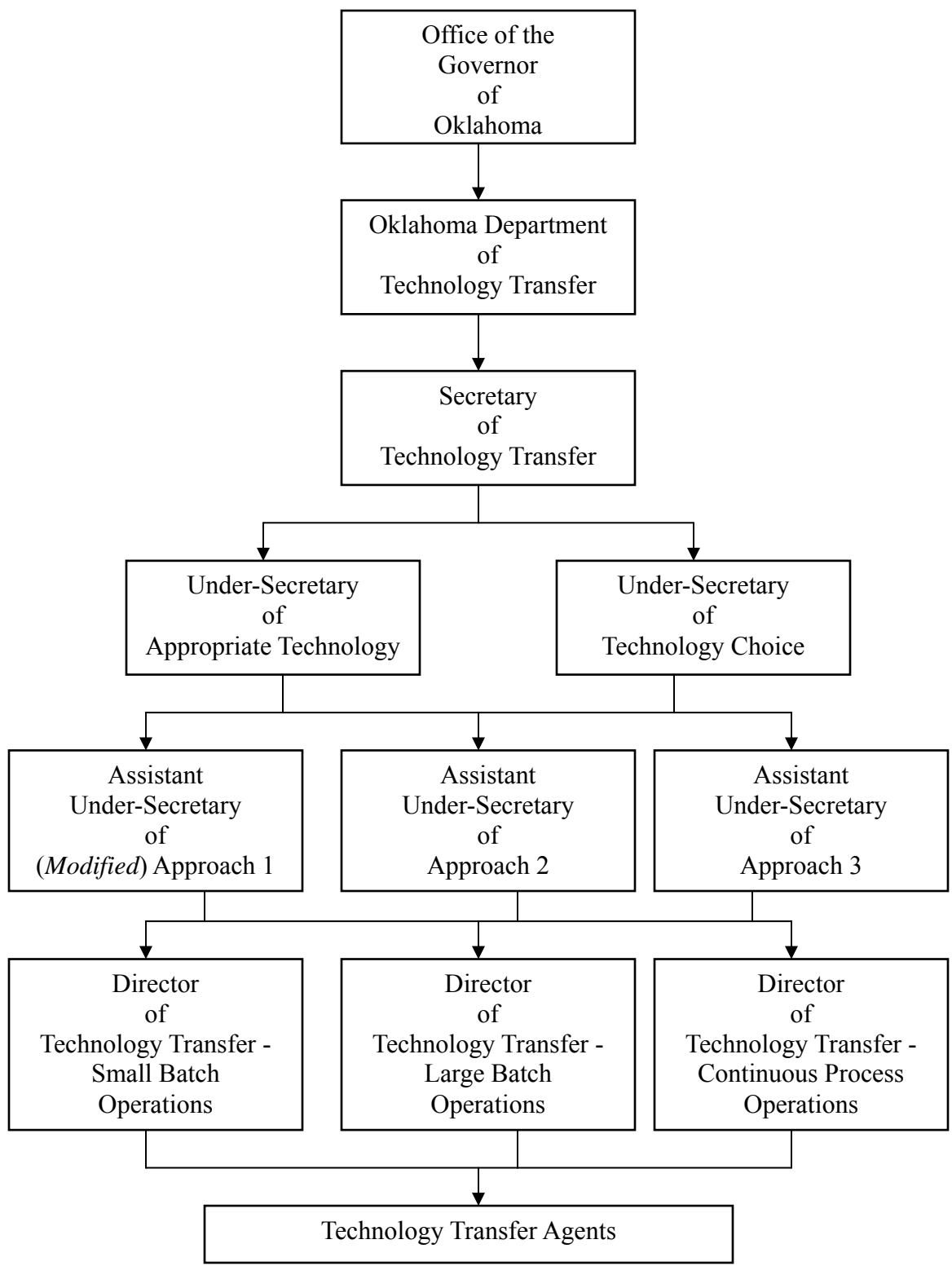
state's infrastructure and technology transfer delivery systems throughout the state. Along the way, the three assistant under-secretaries would accommodate and incorporate appropriate or choice technology principles to handle all types of competitive pressures. Overall, the three assistant under-secretary branches together with the two under-secretary branches would serve as the research and development support group. Their combined activities would represent the control loops for the state program.

It should be noted that the assistant under-secretary of Approach 1 would be working with and using an already modified infrastructure for Approach 1 for the state of Oklahoma. Collins recommended several modifications and variations based on his research results in 1998. Section 2.4.4 of this study reviews and summarizes his work. As a result, this assistant under-secretary would be responsible for further developing and implementing the modified model for Approach 1.

The three technology transfer director positions are the next level in the model for the state program. Each of the three directors represents one of the three technical complexity categories addressed and included in this research study - (i.e., SB, LB, or CP). Their overall mission is to develop technology transfer solutions for small manufacturers with various technical complexity setups and operating under various competitive pressures. Their overall objectives are: to minimize down time and costs, to maximize small manufacturers' investment returns on their technology transfer decisions, and to increase small manufacturers' competitive advantages.

The final level in the model for the state program includes the technology transfer agents. The main mission for the agents is to reach out and interact one-on-one with small manufacturers all across the state. Their main objective is to coordinate and implement technology transfer solutions for the various competitive pressures. Furthermore, these technology transfer agents are specialized in the various technology transfer dimensions and attributes and in the two types of technology transfer attitudes and policies (or technology transfer processes) discussed earlier in this study - (i.e., technology adoption and technology adaptation).

Overall, the three director branches together with the technology transfer agents would serve as the frontline support group for the state program. This group would have the most one-on-one (personal) contact with the state's small manufacturers. Since this group is the eyes and ears of the state program, it would be reasonable to conclude that the program's success depends on the energy, excitement, and enthusiasm level of this group, especially when faced with the tasks of tracking, tracing, and resolving difficult and complex competitive pressures. In other words, the frontline support group would serve as the feedback mechanisms to the state program to ensure an effective and efficient technology transfer environment for the small manufacturers as well as for the program and the state.



**Figure 48. Organizational Structure for a State Technology Transfer Program in Oklahoma**

Increasing the prospect of the state of Oklahoma establishing a state-wide technology transfer program that meets the technology transfer needs of small manufacturers as they try to resolve their competitive pressures is probably the single most important significance of this research study. Furthermore, adding this research study to past efforts, mainly Collins (1998) and Hoff (1997), increases greatly the prospect of this event occurring and increases the chances of establishing a technology transfer program that is appropriate, sensible, and judicious for Oklahoma's small manufacturers, who are operating under a variety of exceptionally competitive pressures.

In effect, the prospect of having a state technology transfer program is stimulating for the state's economy, especially for the economies of Oklahoma's numerous communities that depend on the success of their distinct groups of small manufacturers. Accordingly, the approach outlined and presented in this study designs not only technology delivery systems but also designs thriving small manufacturing communities in Oklahoma and of various sizes - (i.e., SB, LB, or CP) within which these systems might be successfully located and successfully deployed in a competitive environment (Bijker & Law, 1992).

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**APPENDICES**

**Appendix A**

Oklahoma State University Institutional Review Board Approval Form

For Research Involving Human Subjects

### Oklahoma State University Institutional Review Board

Date: Tuesday, September 28, 2004

IRB Application No EG053

Proposal Title: The Development of a Technology Transfer Program for Small Manufacturers in a Competitive Environment

Reviewed and  
Processed as: Exempt

Approval Status Recommended by Reviewer(s): **Approved**

Protocol Expires: 9/27/2005

Principal  
Investigator(s):

Nizam Samir Najd  
322 Engineering North  
Stillwater, OK 74078

David B Pratt  
322 Engineering North  
Stillwater, OK 74078

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The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact me in 415 Whitehurst (phone: 405-744-1676, colson@okstate.edu).

Sincerely,



Carol Olson, Chair  
Institutional Review Board

**Appendix B**

Survey Cover Letter



THE ALLIANCE

OKLAHOMA ALLIANCE FOR MANUFACTURING EXCELLENCE, INC.

525 South Main, Suite 210  
Tulsa, Oklahoma 74103-4503  
Telephone (918) 592-0722  
Fax (918) 592-1417

**The Development of a Technology Transfer Program for Small Manufacturers in a Competitive Environment**

September 20, 2004

Dear Oklahoma Manufacturer,

The School of Industrial Engineering & Management at Oklahoma State University-Stillwater in cooperation with the Oklahoma Alliance for Manufacturing Excellence, Inc. is conducting a survey of small manufacturers in Oklahoma with respect to technology transfer. The intent of the survey is to determine what types of technology transfer assistance Oklahoma manufacturers could benefit from in order to respond more effectively and efficiently to the numerous competitive pressures currently faced in their respective lines of work. Your support is needed to complete and return this survey to ensure that your needs are included in the results.

The survey is designed so the respondent will not be asked sensitive questions. It will take about 20 minutes to complete. Furthermore, a third party non-biased person will collect the returned survey questionnaires. As a result, names of the respondents are not known by the researcher, and cannot be used in any phase of the data analysis. This will maintain complete confidentiality of the information provided.

Your responses to these questions are extremely vital to the success and validity of the study and to the State of Oklahoma's overall effort to develop the most appropriate, sensible, and judicious technology transfer programs for small manufacturers.

If you have questions or concerns, please contact Mr. Nizam S. Najd at (405) 332 - 0712 or via email at [nizam.najd@okstate.edu](mailto:nizam.najd@okstate.edu). Again, thank you for your interest and participation with this research project. Your time and energy are appreciated.

Sincerely,

Roy Peters, Ed.D.  
President

Nizam S. Najd  
Researcher



## **Appendix C**

### Survey Instrument

### SURVEY QUESTIONNAIRE

The Oklahoma Alliance for Manufacturing Excellence, Inc. and Oklahoma State University School of Industrial Engineering and Management are conducting a survey of small manufacturers in Oklahoma with respect to technology transfer. Your support is needed to complete and return this survey to ensure that your needs are included in the results. Your response to these questions is extremely vital to the success and validity of the study. Your individual responses to this survey will be confidential. This survey will take 20 minutes to complete.

Technology Transfer, as used in this study, refers to planning, coordinating, and deploying technological innovations as needed to increase competitiveness.

#### Section 1.0 Background Information

Questions 1 and 2 require you to fill in the appropriate answer. Check the most relevant answer(s) for the remaining questions in this section.

1. My job title is: \_\_\_\_\_.
  
2. The primary technology which is used to manufacture the products of your company is? (Example: Woodworking, Metal Fabrication, etc.).
  
3. My company manufactures products in the following industries: (Please check **ALL** that apply)
  - \_\_\_\_\_ Food and Kindred Products (SIC Code 20)
  - \_\_\_\_\_ Fabricated Metal Products (SIC Code 34)
  - \_\_\_\_\_ Machinery, except Electrical (SIC Code 35)
  - \_\_\_\_\_ Electrical and Electronic Machinery, Equipment, & Supplies (SIC Code 36)
  - \_\_\_\_\_ Transportation Equipment (SIC Code 37)
  - \_\_\_\_\_ Other: Please Specify \_\_\_\_\_
  
4. The number of full-time employees in my company are:    \_\_\_ 1-25                   \_\_\_ 26-50                   \_\_\_ 51-75  
                                                                                   \_\_\_ 76-100                   \_\_\_ 101-250
  
5. Approximately how many **engineers** (by degree) does your company employ?  
                                   \_\_\_ Number of engineers employed as of September 1, 2004
  
6. My company is located in: (Please check **ALL** that apply)  
                   \_\_\_ Greater Oklahoma City    \_\_\_ Greater Tulsa    \_\_\_ Outside greater Oklahoma City and greater Tulsa

7. My company is currently involved with technology transfer in one or more of the following areas. (Please check **ALL** that apply)

Technical Assistance  
 Research and Development  
 Governmental Compliance  
 Business Assistance  
 Human Resource Management Assistance  
 None

8. My company has been in business for approximately how long:       0-5 years       6-10 years  
 11-15 years       16-20 years       over 20 years

9. How would you characterize the technical complexity of your manufacturing operations? (Please check the **ONE** that best describes your manufacturing operations)

Customized work and relies heavily on the human operator -- (Small-batch & unit production)  
 Long production runs of standardized parts w/ no customized work -- (Large-batch & mass production)  
 Entire process is mechanized and outcomes are predictable -- (Continuous process production)

10. How would you characterize your company's technology transfer attitudes and policies when considering a new technology or innovation to accept, adopt, and/or transfer it to meet external and/or internal competitive pressures on your company? (Please check the **ONE** that best describes your company's philosophy with respect to technology transfer)

Prefer radical quick processes of transferring or accepting an innovation -- (Technology Adoption)  
 Prefer slow gradual processes of transferring or accepting an innovation -- (Technology Adaptation)

**Section 2.0 Current Technology Transfer Programs Used**  
**Circle the most appropriate answer.**

1. How important have the following areas of technology transfer been to your company as you strive to resolve your competitive pressures? (Please circle the provided scale with 1=not important to 7=very important)

Technical assistance by experts for specific technologies	1	2	3	4	5	6	7
Research & development assistance for new products/processes	1	2	3	4	5	6	7
Governmental compliance assistance specific to your company	1	2	3	4	5	6	7
Business assistance in marketing, financing, and mgmt. support	1	2	3	4	5	6	7
Human resource management for employee selection & training	1	2	3	4	5	6	7

2. Which technology transfer agencies have been of importance in meeting the technology transfer needs for your company as you strive to resolve your competitive pressures? (Please circle the provided scale with N=Neutral/Not Used and 1=not important to 7=very important)

The Alliance for Manufacturing Excellence	N	1	2	3	4	5	6	7
State-wide Technology Centers (Vo-Tech)	N	1	2	3	4	5	6	7
Department of Environmental Quality	N	1	2	3	4	5	6	7
OSU Engineering Extension Program	N	1	2	3	4	5	6	7
Oklahoma Center for Integrated Design & Manufacturing	N	1	2	3	4	5	6	7
Oklahoma Department of Labor	N	1	2	3	4	5	6	7
Rural Enterprises, Incorporated (REI)	N	1	2	3	4	5	6	7
Small Business Development Commission (SBDC)	N	1	2	3	4	5	6	7
State University System (Major State-supported Universities)	N	1	2	3	4	5	6	7
Cooperative Extension Service Technology Transfer Program	N	1	2	3	4	5	6	7

### Section 3.0 Technical Assistance

Circle the most appropriate answer.

1. Rate the following technical support techniques based on your company's current technology transfer needs as you strive to resolve your competitive pressures. (Please circle the provided scale with 1=not important to 7=very important)

In-person direct assistance by a technology transfer professional	1	2	3	4	5	6	7
Have access via telephone, internet, e-mail, or FAX to technology transfer agencies	1	2	3	4	5	6	7
Receive important new release technology transfer information by mail related to your particular industry	1	2	3	4	5	6	7
Literature review of existing/new technologies for a new product/process in your company	1	2	3	4	5	6	7
Have a technology transfer agent act as a liaison between a small manufacturer and a research facility	1	2	3	4	5	6	7

2. Rate the level of importance the following types of assistance have been to your company as you strive to resolve your competitive pressures. (Please circle the provided scale with 1=not important to 7=very important)

Plant/Facility Design and Layout	1	2	3	4	5	6	7
Quality Control (including ISO 9000 Certification)	1	2	3	4	5	6	7
Process Technologies	1	2	3	4	5	6	7
Engineering Design of New Products	1	2	3	4	5	6	7
Operations Research	1	2	3	4	5	6	7
Energy Management	1	2	3	4	5	6	7
Manufacturing Technologies	1	2	3	4	5	6	7
Workplace Design	1	2	3	4	5	6	7
Productivity Improvement	1	2	3	4	5	6	7
Ergonomics and Safety	1	2	3	4	5	6	7
Other: _____	1	2	3	4	5	6	7

The following scale applies to all the questions that follow unless otherwise noted.

1	2	3	4	5	6	7
Not Important			Important			Very Important

#### Section 4.0 Research & Development

Circle the most appropriate answer.

1. How important is research and development as part of your company's strategy as you strive to resolve your competitive pressures?
 

	1	2	3	4	5	6	7
--	---	---	---	---	---	---	---
  
2. In which of the following areas would research and development be most beneficial for your company as you strive to resolve your competitive pressures:
 

	1	2	3	4	5	6	7
New Product Development	1	2	3	4	5	6	7
Existing Product Enhancement	1	2	3	4	5	6	7
Basic Research (new technologies)	1	2	3	4	5	6	7
Applications Research (Commercialization of a product)	1	2	3	4	5	6	7
  
3. Do you believe a cooperative research agreement between your company and a research facility would be beneficial when developing a new product or process as you strive to resolve your competitive pressures?
 

	1	2	3	4	5	6	7
--	---	---	---	---	---	---	---
  
4. How important is in-house research to protect confidentiality for new products as you strive to resolve your competitive pressures?
 

	1	2	3	4	5	6	7
--	---	---	---	---	---	---	---

#### Section 5.0 Governmental Compliance

Circle the most appropriate answer.

1. How important are these types of governmental assistance to your company as you strive to resolve your competitive pressures?
 

	1	2	3	4	5	6	7
OSHA Safety and Loss Control	1	2	3	4	5	6	7
Hazardous Chemical Assistance Program	1	2	3	4	5	6	7
Governmental Compliance Assistance	1	2	3	4	5	6	7
Equal Employment Opportunity Assistance	1	2	3	4	5	6	7
Trade Mark/Patent Application and Registry	1	2	3	4	5	6	7
  
2. How important would governmental assistance be if services were provided without the threat of receiving a citation for out of compliance violations as you strive to resolve your competitive pressures?
 

	1	2	3	4	5	6	7
--	---	---	---	---	---	---	---

**Section 6.0 Business Assistance****Circle the most appropriate answer.**

1. How important are the following areas of business assistance to your company as you strive to resolve your competitive pressures?

Financial Consulting	1	2	3	4	5	6	7
Loan Processing Assistance	1	2	3	4	5	6	7
Marketing Study Assistance and Support	1	2	3	4	5	6	7
Patenting Process Assistance	1	2	3	4	5	6	7
Venture Capital Assistance	1	2	3	4	5	6	7

2. How important would temporary low cost facilities be to the startup of your company or new product as you strive to resolve your competitive pressures?

1	2	3	4	5	6	7
---	---	---	---	---	---	---

**Section 7.0 Human Resource Management Assistance****Circle the most appropriate answer.**

1. How important are the following areas of Human Resource Management assistance to your company as you strive to resolve your competitive pressures?

Employee Selection Assistance	1	2	3	4	5	6	7
Employee Benefits, Insurance, and Worker's Compensation Training	1	2	3	4	5	6	7
Labor/Management Relations Assistance	1	2	3	4	5	6	7

**Section 8.0 Organizational Structure of Technology Transfer****Please provide a response to each of the following questions.**

1. How important would a single source, statewide technology transfer agency be to you as you strive to resolve your competitive pressures? Such an agency would provide technical assistance, research and development, governmental compliance, business assistance, and human resource management assistance within one unit.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

2. How important are the following three approaches of technology transfer to your company as you strive to resolve your competitive pressures?

- Approach 1** - One agency where you can get all of the technology transfer assistance you need.      1      2      3      4      5      6      7
- Approach 2** - Different agencies which provide only one specific type of assistance.      1      2      3      4      5      6      7
- Approach 3** - A system where you contact one person who will arrange meetings with other technology transfer agencies.      1      2      3      4      5      6      7

3. Please indicate which approach from the three approaches outlined in the previous question would be most beneficial to resolve each of the following **top ten ranked** important competitive pressures currently faced by Oklahoma manufacturers - (Please check **ONLY ONE** for each pressure).

<i>Competitive Pressures</i>	<b>Approach 1</b>	<b>Approach 2</b>	<b>Approach 3</b>
1. Qualified Employees			
2. Worker's Compensation			
3. Training & Retraining			
4. Raw Material Pricing - Steel			
5. Labor Cost Management			
6. Marketing			
7. New Product Development			
8. Human Resources			
9. Supply-Chain Management			
10. Electricity/Energy Deregulation			

**Section 9.0 General Questions**

Please provide a response to each of the following questions.

1. How many miles would you be willing to travel to a technology transfer meeting that discusses ways to resolve competitive pressures?

\_\_\_\_ 0 – 50 miles      \_\_\_\_ 51 – 100 miles      \_\_\_\_ Greater than 100 miles

2. How many hours could you be away from work to attend a technology transfer meeting?

\_\_\_\_ Less than 4 hours      \_\_\_\_ 4 – 8 hours      \_\_\_\_ Greater than 8 hours

3. Approximately how many **trade shows or conventions** has a representative from your company attended in the past three years?

\_\_\_\_ Number of trade shows      \_\_\_\_ Number of conventions

4. In general, how would you describe your company's **past experiences** with new technology? (Please check **ONLY** one item)

Very dissatisfied       Dissatisfied       Neutral       Satisfied  
 Very satisfied       Not applicable

5. Please check the items listed below which you consider barriers to new technology at your company as you strive to resolve your competitive pressures - (Please check **ALL** that apply).

<input type="checkbox"/> Work force skills	<input type="checkbox"/> Lack of readily available information on the technology
<input type="checkbox"/> Financing	<input type="checkbox"/> Lack of understanding and training with the technologies
<input type="checkbox"/> Facility limitations	<input type="checkbox"/> Lack of support by upper management
<input type="checkbox"/> Management skills	<input type="checkbox"/> Lack of a proven track/performance record with the technology
<input type="checkbox"/> Unknown benefits	<input type="checkbox"/> Transfer and Implementation difficulties
<input type="checkbox"/> Technology appropriateness	<input type="checkbox"/> Satisfaction with existing technologies
<input type="checkbox"/> Major concern regarding change	<input type="checkbox"/> Minor concern regarding change
<input type="checkbox"/> None of the above	<input type="checkbox"/> Other: Please specify _____

6. What has been your **primary source of training / transfer assistance** with past technologies? (Please check **ONLY** one item)

<input type="checkbox"/> Vendors	<input type="checkbox"/> College
<input type="checkbox"/> Vo-Tech Classes	<input type="checkbox"/> Industry Associations
<input type="checkbox"/> None/Not Applicable	<input type="checkbox"/> Union Training
<input type="checkbox"/> In-House Expertise	<input type="checkbox"/> Other: Please specify _____

7. What do you believe should be your **primary source of training / transfer assistance** for future new technologies? (Please check **ONLY** one item)

<input type="checkbox"/> Vendors	<input type="checkbox"/> College
<input type="checkbox"/> Vo-Tech Classes	<input type="checkbox"/> Industry Associations
<input type="checkbox"/> None/Not Applicable	<input type="checkbox"/> Union Training
<input type="checkbox"/> In-House Expertise	<input type="checkbox"/> Other: Please specify _____

8. Would your company be willing to provide financial support for technology transfer services that would aid you in resolving your competitive pressures?

Yes       No

If yes, what percent of the total cost for technology transfer assistance would you be willing to pay if the average cost of a technology transfer project is \$1,000? (Please check **ONLY** one item)

<input type="checkbox"/> 0-5	<input type="checkbox"/> 6-10	<input type="checkbox"/> 11-15	<input type="checkbox"/> 16-20	<input type="checkbox"/> 21-25
<input type="checkbox"/> 26-50	<input type="checkbox"/> 51-75	<input type="checkbox"/> 76-89	<input type="checkbox"/> 90-100 Percent	



9. What would the major issues be if you were able to design a state-wide technology transfer program tailored to the small manufacturers in Oklahoma as they strive to resolve their competitive pressures? (Please check ALL that apply)

Comprehensive technology transfer program  
 Confidentiality of information  
 Cost to the small manufacturer for services  
 Timeliness of assistance  
 Availability of technologies  
 Others: Please specify \_\_\_\_\_

10. What type of state-wide technology transfer program would best support your company's technology transfer needs?

An Appropriate Technology Program - (provides a preferred long-term solution but may not generate the quickest short-term results)  
 A Technology Choice Program - (provides a quick fix that may not be the cheapest or generate the best long-term results)

**Please use a scale with 1=not important to 7=very important for questions 11 and 12 below.**

11. How important is it to your company to develop expertise on existing and subsequent manufacturing/production technologies to meet company goals, especially the goal to resolve your company's competitive pressures?

1      2      3      4      5      6      7

12. How important is it to your company to make plant/office space available for experimentation with new technology to support company goals, especially the goal to resolve your company's competitive pressures?

1      2      3      4      5      6      7

13. Do you currently have any technology transfer needs that will require assistance? If so, please explain.

14. Would you be willing to participate in another more in-depth survey in the near future that focuses on technology transfer programs and their related cost drivers and risk factors?

Yes       No

**THE OKLAHOMA ALLIANCE FOR MANUFACTURING EXCELLENCE, INC. AND OKLAHOMA STATE UNIVERSITY SCHOOL OF INDUSTRIAL ENGINEERING AND MANAGEMENT EXTEND THEIR SINCERE APPRECIATION AND GRATITUDE FOR TAKING TIME TO PARTICIPATE IN THIS RESEARCH PROJECT. YOUR FEEDBACK WILL PROVIDE VALUABLE INFORMATION ON HOW OKLAHOMA SHOULD PROVIDE TECHNOLOGY TRANSFER SERVICES TO MANUFACTURERS ACROSS THE STATE.**

**THANK YOU!**

## VITA

Nizam Samir Najd

Candidate for the Degree of

Doctor of Philosophy

Dissertation: THE DEVELOPMENT OF A TECHNOLOGY TRANSFER PROGRAM FOR SMALL MANUFACTURERS IN A COMPETITIVE ENVIRONMENT

Major Field: Industrial Engineering and Management

Biographical:

Personal Data: Born in Santa Monica, California, on December 17, 1969, the son of Mr. Samir Abdullah Najd and Mrs. Intisar Azzam Abou-Alhosn.

Education: Graduated from Ramona High School, Ramona, California in June 1988; received Bachelor of Science degree in Civil Engineering from University of California-Irvine, Irvine, California in June 1993; received Master of Science degree in Civil Engineering from Oklahoma State University, Stillwater, Oklahoma in May 1995. Completed the requirements for the Doctor of Philosophy degree with a major in Industrial Engineering and Management at Oklahoma State University in July, 2005.

Experience: Worked for Design System Management as a project planner and coordinator (1993); employed as a part-time lecturer, research associate, and teaching associate for the Civil and Environmental Engineering department and for the Industrial Engineering and Management department, Oklahoma State University, Stillwater, Oklahoma (1994-Present).

Professional Memberships: Tau Beta Pi (national engineering honor society), Chi Epsilon (Civil Engineering honor society), Phi Beta Delta (international scholars honor society), Sigma Xi Scientific Research Society, American Society of Civil Engineers, Institute of Industrial Engineers, Institute for Operations Research and the Management Sciences, International Association for Management of Technology, and World Watch Institute.

Name: Nizam S. Najd

Date of Degree: July, 2005

Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Study: THE DEVELOPMENT OF A TECHNOLOGY TRANSFER  
PROGRAM FOR SMALL MANUFACTURERS IN A COMPETITIVE  
ENVIRONMENT

Pages in Study: 330

Candidate for the Degree of Doctor of Philosophy

Major Field: Industrial Engineering and Management

Scope and Method of Study: The purpose of this study was to determine the desirable technology transfer dimensions, attributes, approaches, programs, and processes and the desirable organizational structure which could be used to develop a state technology transfer program for small manufacturers in a competitive environment. A survey questionnaire was sent to 493 rural and metropolitan manufacturers across the state of Oklahoma in eight different SIC codes. The questionnaire consisted of 40 questions which determined the small manufacturers' attitudes towards technology transfer in a competitive environment. Frequency data analysis was used to gather detailed perspectives on the survey respondents operating under competitive pressures and filtering (cluster) analysis was used to further divide the survey respondents into 36 distinct technology transfer policy groups to infer additional in-depth technology transfer viewpoints regarding these 36 distinct combinations.

Findings and Conclusions: The frequency data analysis identified the top attributes in the five technology transfer dimensions to be: technical assistance - (communication access), research and development - (new product development), governmental compliance - (non-threatening governmental assistance), business assistance - (marketing study assistance and support), and human resource management - (employee benefits, insurance, and worker's compensation training). Three technology transfer approaches were important and were actively used. For three of the "top-ten" competitive pressures, the filtering analysis revealed that the majority of the small manufacturers were already on the most optimal decision path to successful technology transfer - (i.e., they preferred appropriate technology programs and technology adaptation processes). The technical assistance and research and development dimensions and the workforce skills and financing barriers were the predominant technology transfer characteristics faced by Oklahoma's small manufacturers in the applicable combinations found in the Nizam Pyramid. The Nizam Pyramid was a "metamodeling" approach developed to summarize the filtered data and to provide an overall representation of the organizational structure for Oklahoma's state-wide technology transfer program.

ADVISER'S APPROVAL: Dr. David B. Pratt