MACHINING
INDUSTRY: SURVEY
& FOCUS GROUPS

Prepared for:
TechSolve

Prepared by:
Merissa C. Piazza
Molly Schnoke
Edward (Ned) Hill, Ph.D.

September 2014

2121 Euclid Avenue Cleveland, Ohio 44115
http://urban.csuohio.edu
# TABLE OF CONTENTS

Executive Summary ................................................................................................................................. i

Chapter I: Survey of Machining Businesses ....................................................................................... i

Chapter II: Machining Business Focus Groups .................................................................................. iv

Chapter I: Survey of Machining Businesses ....................................................................................... 1

  Introduction ........................................................................................................................................ 1
  Methodology ....................................................................................................................................... 1
  Survey Analysis ............................................................................................................................... 2

Chapter II: Machining Focus Groups ................................................................................................ 22

  Introduction ........................................................................................................................................ 22
  Methodology ....................................................................................................................................... 22
  Focus Group Results ........................................................................................................................ 23

  *Training and Upgrading Skills* ........................................................................................................ 30

Appendix A ............................................................................................................................................ 32

  A.1. Machine Tool Survey Questionnaire ......................................................................................... 32
  A.2. Occupations Machine Tool Companies Have looked to Fill in the Last Three Years by Length of time to Fill Vacancy ................................................................................................................. 41
  A.3. Workforce Development Resource by Usage and Usefulness .................................................. 41
  A.4. Greatest Challenges for Machining Business Units .................................................................. 42
  A.5. Greatest Challenges for the Machining Industry ....................................................................... 43
  A.6. Greatest Opportunities for Machining Business Units ............................................................... 44

Appendix B ............................................................................................................................................ 46

  B.1. Focus Group Protocol .................................................................................................................. 46
TABLE OF TABLES

Table 1. Products Machining Business Unit Manufactures as a Percentage of Sales ................................. 6
Table 2. Respondents' Top 3 Innovation Challenges .................................................................................. 8
Table 3. Change in Customer Expectation and Profit Margin Alteration .................................................. 12
Table 4. Length of Time to Fill Vacancies by Occupation ....................................................................... 16
Table 5. Workforce Development Resource by Usage and Usefulness ................................................... 17
Table 6. Top Machining Businesses Obtain Information on Innovation ................................................. 20

TABLE OF FIGURES

Figure 1. Respondents by Geographic Location ....................................................................................... 2
Figure 2. Respondent Count by Job Title ................................................................................................. 3
Figure 3. Respondent Counts by Employment (Full-Time Equivalent) and Sales ..................................... 4
Figure 4. Respondent Counts by Business Unit Function ...................................................................... 4
Figure 5. Industries Served by Respondents .......................................................................................... 5
Figure 6. Respondents Engaged in Various Types of Machining ............................................................. 6
Figure 7. Innovation Resources Utilized by Respondents .................................................................... 8
Figure 8. Innovation Investment(s) by Respondents in the Next Three Years ...................................... 9
Figure 9. Challenges in Respondents' Business Due to New Materials .................................................. 10
Figure 10. Workforce Issues: Challenges in Hiring Employees ............................................................... 14
Figure 11. Total Length of Time to Fill Vacancies by All Occupations ................................................... 15
Figure 12. External Training Providers Used by Respondents to Upgrade Employee Skills .................. 17
Figure 13. Greatest Challenges in the Machining Industry over the Next Three Years for the Business Unit and Industry ........................................................................................................ 18
Figure 14. Greatest Opportunities in the Machining Industry over the Next Three Years for the Business Unit and Industry ........................................................................................................... 19
Figure 15. Respondents Method of Receiving Information on Machining ............................................. 21
EXECUTIVE SUMMARY

The Center for Economic Development (the Center) at the Maxine Goodman Levin College of Urban Affairs at Cleveland State University was retained by TechSolve to produce an online survey and conduct focus groups of Ohio businesses in the machining industry. The survey and focus groups are part of a broader effort managed by TechSolve for the Ohio Manufacturing Institute to develop a roadmap for the machining industry in Ohio.

This executive summary covers the two main chapters of this report: the Survey of Machining Businesses and Machining Business Focus Groups. The survey examines the responses to the Survey of Machining Businesses and their perceptions regarding the current and future challenges of the industry. The focus group protocol delved deeper into questions unresolved by the survey and extended to descriptions of challenges in developing the workforce for this industry.

CHAPTER I: SURVEY OF MACHINING BUSINESSES

Respondent Demographics

The Survey of Machining Businesses was targeted towards owners or managers who operate machining businesses. Overall, there were 34 respondents that completed the survey. The largest grouping of respondents (39%) reported occupations in upper management (i.e. President, CEO, President & CEO, and CFO). Plant managers and general managers were the second largest occupation (18%). Based upon these outcomes, the survey achieved the targeted demographic of surveying owners or employees who operate machining business.

Respondents were from 18 different counties throughout the state of Ohio. The largest number of respondents was situated in Hamilton County (where the city of Cincinnati is located). In addition, a majority of respondents were from small businesses (less than 50 employees).

The top three industries that machining businesses serve are Automotive (21%), Aerospace (15%), and Energy (14%). These industries traditionally require specific parts and assemblies to be manufactured by machining businesses. It then follows that the most appropriate terms to describe their function was Manufacture Discrete Parts (25 respondents), followed by Manufacture Assemblies (21 respondents). To understand the structure of the machine tool industry, it is important not only to comprehend which industries are supplied, but also how these products are diversified in the machining business units’ product portfolio. A majority of respondents diversify their machining products so that their specific products are not more than 50% of their overall sales. By diversifying their products, owners and operators can maintain flexibility in a market dominated by fluctuating metal prices and increasing customer demands.

As suppliers, the machining industry must be nimble enough to receive orders and fill them within a timely manner to meet customers’ demands. In order to operate in this way, machining businesses can be engaged in a variety of types of machining. In general, almost one third of respondents reported that they engage in machining, no matter the type (3-, 4- or 5-axis). The remainder of responses was fairly equally split amongst lathes (16%), milling machines (15%), turning centers (13%), and grinding machines (13%).
Innovation

Although discovery can be haphazard, innovation can be managed in the same way as other operational functions. It is important to understand how machine tool firms acquire resources that result in innovation, whether internally or externally. Almost all of the respondent feedback indicated that innovation resources utilized by machining businesses (85%) are those external to the firm (External non-profit manufacturing or technology centers/organizations; Federal agencies and/or labs; Hired consultants; Professional societies/associations; Trade organizations; Universities and community colleges; Vendors and suppliers). Only 20 responses employed internal work-groups for innovation.

Regarding innovation investment over the next three years, the largest grouping of responses indicated that innovation investments would take place as capital investment (facility improvements, equipment financing, and IT infrastructure); this grouping accounted for over half of the responses (57%). Other innovation financing that machining business were likely to undertake was that of business expansion, either through business acquisition (19%) or working capital for business expansion (14%).

New Materials

New materials consist of a variety of mediums such as ceramics, alloys (high-temperature, nickel-based, iron and cobalt-based) and stainless steels. Many of these materials are difficult to machine. Through innovation in the automotive and aerospace industries the demand for machining of these materials has increased, while the turnaround time and cost margins have decreased.

When asked, “How has the use of new materials (i.e. composites, new alloys, etc.) in your industry caused challenges for your business unit?” Responses were equally dispersed amongst the seven answer categories (challenge in acquiring new materials; current machine tools are not compatible with new materials; business unit does not know methods, processes, or how to machine new materials; workforce is not knowledgeable on how to machine new materials; variation in the quality or specifications of materials; price volatility of new materials causes challenges). This provides an indication that there is no one issue in regards to new materials; rather a host of problems for businesses to contend with and address.

Customer Expectations

Known as a suppliers to many of the large industries in Ohio (automotive, aerospace, etc.), the machining industry faces the pressures of supplying within strict margins and just-in-time delivery schedules. With ever-increasing customer expectations to machine better and faster, we asked respondents in what areas they experienced a change in customer expectation. In addition, we asked how these changing expectations changed industry profit margins (for better or worse).

Overall, the most selected response to how customer expectations have changed their business unit’s profit margin was in regards to delivery time. Although customers expect faster delivery times, two respondents indicated that this can create a profit bonus because machine shops can charge extra for shorter delivery times. However, when customers expect a shorter turnaround, machine shops have to monitor carefully their inventory in order to make sure they have enough stock on hand for other

---


orders. The second-most selected response was prices; respondents indicate that customers’ demand a lower price can narrow their profit margin. Quality and design were third and fourth choices by respondents. Respondents indicated that customers’ expectation of quality is extremely high, but one respondent indicated that customers are moving towards less expensive, lower quality products. Respondents indicated that customer expectation in regards to design changed their business profit margin, especially when customers added complexity and customization to their orders.

Workforce
In the last ten years, there has been a growing demand for workers with skills that are critical to advanced manufacturing and machining industries. Despite growing demand, it has been difficult to attract talented employees with advanced degrees in the science and mathematics areas to fill management and engineering positions in advanced manufacturing. This workforce environment creates a very difficult setting for employers who are looking to hire and expand their businesses. Almost one third of survey respondents stated that one of their challenges is that individuals do not have the appropriate skills for the designated job (32%). The second-most selected categories were finding employees with enough experience for the job (19%), along with finding workers with the appropriate soft skills (i.e. communication, enthusiasm, etc.) for the workplace (19%). These results are further evidence that the supply of people with “middle-skills”

Respondents were asked, “In the last 3 years, has your business unit looked to fill any new position?” If they selected yes, which 97% did, then they were prompted to answer another question. “What occupations have you looked to fill in the last 3 years? Have you had issues finding qualified applicants?” There were eight job categories in which 50% or more respondents agreed that there was a qualified pool of applicants:

• Engineers, 71%
• Office Management, 92%
• Plant Management, 57%
• IT Specialist, 78%
• Machine Operators, 50%
• Model Makers, 50%
• QA/CMM Technicians, 50%
• Other, 71%

There were five job categories in which less than 50% of the respondents found the applicant pool to be qualified. Examining the grouping of jobs in which machine tool respondents indicated that there was not a qualified pool of candidates reveals all occupations in middle-skill job categories.

• Electro mechanical Maintenance Technicians, 33%
• CNC Programmers, 20%
• Tool Makers, 39%
• Machinists, 25%
• Welders, 27%
Respondents actively recruit potential employees using a variety of resources. Overall, 90% of respondents have used web postings and have found this resource useful. Two-thirds of respondents indicated that they use headhunters or recruiters and find this resource very useful. A large grouping of respondents indicated that they have used community college or university/college placement centers in the past and also have found these resources useful.

Fifty-eight percent (58% or 19 respondents) of respondents stated that they used external training providers to upgrade current employees’ skills. The most common training provider used was external non-profit manufacturing or technology centers/organizations and community colleges.

**Overall Challenges & Opportunities**

When asked to identify business unit and industry challenges for the next three years, respondents overwhelmingly replied skilled labor, healthcare costs, and talent retention. However, when asked to name opportunities for the next three years, the respondents’ answers were more varied ranging from reshoring to improved technology.

**Machining Communication**

Gathering information about innovation is essential for machining businesses. Overall, the most popular way that machining businesses obtain information about innovation is through trade publications (28%), followed by conferences and events (24%), and trade shows (21%). A number of respondents’ revealed that they attend the International Manufacturing Technology Show (IMTs) and FABTECH. Another way of learning about innovation is from trade associations. Most respondents belong to the American Society of Mechanical Engineers (SME) and the Society of Manufacturing Engineers (SME). Trade publications provide a third way of learning and the most selected sources were Modern Machine Shop (21 respondents) and Production Machining (14 respondents).

**CHAPTER II: MACHINING BUSINESS FOCUS GROUPS**

**Demographics**

The purpose of the machining focus groups was to provide depth and clarity to unanswered questions of the Survey of Machining Businesses. Focus groups were conducted in three cities in Ohio and were sponsored by each region’s Manufacturing Extension Partnership affiliate—Cleveland (MAGNET), Columbus (PolymerOhio), and Cincinnati (TechSolve)—in July 2014. Machining businesses owners or managers participated. There were a total of 18 participants in the three focus groups, representing 17 different machining firms. The responses from these three focus were very consistent.

**Changing Customer Expectations**

Focus group participants were united in their opinion that the expectations of customers have altered dramatically. Three main points about customer expectations emerged from both the focus groups and the survey. Demand for 100%-on-time delivery, demand for low-cost products, and the ability to do all of this with the highest product quality. In other words, the responses from focus group participants reinforced the findings in the Survey of Machining Businesses.

---

3 Reshoring is the return of jobs to the United States after they had been previously offshored.
100% On-Time Delivery

Customers demand that machining companies have near-perfect on-time delivery. The firms that can meet his standard can differentiate themselves from their competitors. The ability of businesses to achieve on-time delivery depends on a number of factors including raw material delivery (the availability and wait time from suppliers), subcontractors, fluctuation in order volume and changes, and insufficient workforce capacity.

Though focus group participants identified shorter and near-perfect delivery times as a significant challenge to their business, meeting this expectation is complicated by the inability of customers to forecast their future orders. According to focus group participants, this lack of forecasting is not a new problem for the industry. On-time delivery today, however, requires improving the capability of machining customers to predict accurately their needs and enhancing communication with machining businesses.

The demand for on-time delivery has an additional impact on inventory management and the cash-carrying costs of machining businesses. Customer expectations for on-time delivery can become burdensome to the machining company because companies have to carry more raw materials and more finished goods on hand, both of which create inventory costs. Driving up inventories has forced some businesses to develop new ways to hold and maintain their inventory. One participant indicated that they have developed a consignment arrangement with one of their suppliers where stock is kept on the shelves at the plant and the firm does not pay for the product until it is used.

Comments from focus group participants about on-time delivery:

- Forecasting [from customers] has never been very good – they are never sure [what they will need]
- They [the customer] want the flexibility to say I want this [product], then a few days later change and say, no I want this.
- What the customer wants changes every week. It is a constant challenge.
- Their forecasts are inaccurate – they have an inability to forecast for change, but they want a very narrow promised delivery time.

Customer Cost Constraints

Another challenge to machining businesses is customer demands for cost reductions. Though focus group members spent a considerable amount of time explaining challenges related to shorter delivery times and less time discussing cost, participants stated that there is a constant push to lower cost.

Quality Demands

The ability to produce a high quality product is not a new requirement of the machining industry. However, the degree to which customers will accept errors or mistakes has narrowed, further squeezing the profit margin of firms. Focus group participants, in all cities, agreed that customer expectations related to product quality are very exact – “The quality bar is very high.”

Challenges across on-time-delivery, quality, and price

Focus group participants cited lack of communication with customers as an increasing challenge. Machining businesses feel that they have the know-how and ability to make the products customers want. At times, this requires the ability to communicate with customers and the engineers who design the products to work out design errors. A number of participants state that many customers had
become so bureaucratic that they lost the ability that they once had to talk to the customer about essential information about their orders. This included instances where the machining operation had identified design errors in the drawings the customer had sent over, yet there was nobody on the customer’s side to talk about the problem. Historically, this was not the case and participants felt it was a relatively new experience.

Addressing Industry Challenges

Having to increase quality, decrease cost, and speed-up delivery time are significant pressures in the machining industry, and each machining business is taking steps to address them. To meet competitive requirements and reduce costs, many machining businesses are turning to lean manufacturing techniques to drastically cut cycle time and increase their competitive edge. Focus group participants identified a number of proactive changes they are making, such as equipment monitoring and preventative maintenance.

Machine Monitoring & Preventative Maintenance

Measuring machine and workforce performance is becoming increasingly important as a way to decrease downtime and increase efficiency. Focus groups participants in all three cities stated that economic forces have forced them to look at aspects of their operations not previously examined and look for process innovation and improvements. Focus group participants also specified a number of operations and maintenance considerations they are making in order to make their operations more efficient. These include conducting quick-change repairs instead of total machine disassembly and deploying redundant equipment to reduce downtime so that while one machine is being worked on, another is operating.

Machining firms understand that actions need to be taken and technologies employed to identify operational efficiency gaps and weaknesses. Most know that they need to leverage key data metrics including overall equipment effectiveness (OEE) and total effective equipment performance (TEEP). In addition, many are aware of, and interested in, machine monitoring technologies, such as MTConnect. However, it is interesting to note, only one participant is actively utilizing monitoring equipment in their operation. This company was able to monitor each shift and machine to know which machines had low production. It was up to management operation to determine if this was related to low worker productivity or poor machine functionality. Either way, this particular machining business was able to address productivity issues in a timely manner. With increased interest in machine monitoring technologies, a number of participants across the three focus groups stressed that this is not an effort to reduce the number of employees, but to get them involved in the overall management of the business and invested in their work. Companies want their staff to understand what is current in their industry. In addition, it is the hope that employees will become invested in the business and feel a personal connection to its future.

---

5 MTConnect is royalty free standard protocol suitable for use with any type or manufacturing device. It can be used on the shop floor for production dashboard or monitoring, equipment effectiveness, production reporting and tracking, energy conservation, and quality control.
Innovation Investments

Focus group participants were asked about the types of innovation initiatives and investments they might make over the next three years. Some firms do not have concrete plans for capital investments stating we “Don’t have plans, but aspirations.” All respondents indicated that they regularly make capital investments and will continue to do so in the future. Others indicated that they need to replace equipment whose life cycle is coming to an end or is already obsolete. On a positive note, some participants indicated they are looking for new or additional space since they expect to expand their business operations. Overall, many firms indicated that automation was a top investment priority.

New Materials

Machining processes that produce parts for the latest designs need to be able to work with advanced materials. Advanced materials for this industry are defined as ceramics, hard-to-machine metals such as hardened-steel and alloys, as well as composites and polymers. There are added production challenges that come with these new materials. The new materials can be difficult to machine, but they can create highly intricate parts which are good for the customer. To address this, focus group participants said they are relying on their network of tool suppliers to find new tools that can work these new materials. Some say that the onus is on the machining firms to learn how to work with them, with one participant mentioning that they worked with their raw material supplier before ordering to meet the parts specifications. By shifting the new material specification onto the raw material supplier, the machining company shifted the quality burden to the supplier and away from themselves.

Workforce Development

Workforce questions were asked in the Survey of Machining Businesses because our previous research suggested that workforce issues were an impediment to business function and innovation in Ohio. This was validated in the survey. To delineate further issues of workforce from the survey, the focus group protocol included a section on workforce. The focus group facilitators prepared a variety of questions regarding workforce challenges for machining businesses as prompts. Nonetheless, the participants naturally discussed workforce issues as a business impediment without prompting by the focus group facilitators. This occurred in all three cities. In many instances, workforce issues were discussed within the first fifteen minutes of the focus group starting.

Overall, focus group participants were primarily concerned about the availability of skilled labor. These worries also extended into the future. Moreover, participants were not only anxious about the current and future skilled labor markets for their industry but for the entire manufacturing sector. When asked about traditional “white-collar” jobs such as management, engineering, and information technology, participants did not have the same concerns as they had for skilled labor or “blue-collar” jobs. It is interesting to note that the topic of conversation in relation to workforce was exactly the same as discussed by the focus groups that the Center facilitated in in 2009 to identify high demand occupations in the manufacturing sector for the Ohio Skills Bank.7

Talent Recruitment

Focus group participants described talent recruitment as a pivotal crisis for manufacturing today, and called for a change in how people envision the manufacturing workplace environment. Participants unanimously agreed that the heart of the recruitment problem is how manufacturing is perceived in this

country and in the state of Ohio. Three targets were identified by focus group participants to improve the supply of potential workers for manufacturing companies: (1) the general public, (2) the education system, and (3) parents, specifically mothers.

First, focus group participants maintained that the general public today does not understand what manufacturing does. In order to counter this, the public must understand that today’s manufacturing can be a rewarding career for young people. Second, participants believe that the current education system focuses too much on the notion that the only option post-graduation is to go to a 4-year university. Educators and guidance counselors need to acknowledge that not every child is “college material” and be ready to advise students about different types of educational and career options. Third, participants indicated that the most important hurdle to attracting the future workforce is parental bias. There is opportunity for advancement in a manufacturing career. Moreover, focus group participants noted that if a younger person enters a manufacturing career they can work and attend college at night, which is most likely going to be paid for by the company.

Some of the comments and suggestions offered by participants:
- We need to convince mothers it is a good career for their children. We’ll pay for training, college, etc. This is good business. We wonder if young individuals realize the potential for earning in this trade.
- We need to talk to the parents, not the kids.
- Nobody wants to have their kids do this job.

**Training and Upgrading Skills**

The lack of basic skills is limiting the pool of candidates for jobs in machining businesses. When asked what their biggest challenge in hiring new employees was, they indicated that getting employees to show up on time and pass a drug test posed significant barriers. One participant noted that, “At the entry-level it is attendance, ability to function within the culture and being dependable.”

Since skilled trade employees are difficult to find, many companies need to grow their own workforce by starting a new employee at an entry-level or lower-skilled position, such as in the utility department. They then have the ability to test and observe individuals with the goal of eventually moving them to the plant floor. This tactic was discussed by participant’s at all three focus groups. One participant said that in his estimation, only 1 out of 15 who start out will become a skilled machinist. Furthermore, focus group participants indicated that it takes a very long time and a significant investment to move someone from an entry-level position to a skilled job in the company, citing that it takes anywhere from 5 to 10 years to move through this process. Never the less, the need to ‘up-skill’ workers is essential.

Several focus group participants indicated that their businesses had internal training programs or strategies to address the skills gaps in their current workforce. Fifty-eight percent (58%) of survey respondents indicated that they use external training providers to upgrade the skills of their employees. Many of the focus group participants from mid-sized and smaller companies indicated that they used external training programs and providers, while the larger companies generally had internal training in place.
Addressing the Workforce Challenge Regionally

Participants from the three cities all acknowledged they had workforce issues, but how they went about addressing them differed by city. The Cleveland focus group displayed a greater degree of collaboration and cooperation in addressing the workforce issues than did the other cities. Participants said they felt a commitment to the manufacturing industry to find solutions. These solutions would ultimately benefit each of them. On the other hand, the Cincinnati focus group participants demonstrated a greater degree of competitiveness and heightened concerns about the poaching of employees by other companies, resulting in a reluctance to make significant investments in training. In Columbus, the environment was described as somewhat fragmented, although it seemed to meet the needs of employers.

These responses surprised focus group facilitators, especially since the Cincinnati workforce system has worked to integrate itself into a regional entity to alleviate the skills gap: Partners for a Competitive Workforce (PCW). When asked about the workforce development system, respondent did not know of any effort to reduce the skills gap aside from their individual efforts working with community colleges or vocational technical trainers. However, the responses from all of the groups indicate knowledge of particular efforts within the system. It could be the case that individuals in the Cleveland focus group were more involved in workforce development than those in Cincinnati or Columbus.

---

CHAPTER I: SURVEY OF MACHINING BUSINESSES

INTRODUCTION
The Center for Economic Development (the Center) at the Maxine Goodman Levin College of Urban Affairs at Cleveland State University deployed an online survey of Ohio businesses in the machining industry. Chapter I examines the responses to the Survey of Machining Businesses and their perceptions regarding the current and future challenges of the industry. The machining industry is large, both domestically and worldwide. Dollar-volume production of machine tools worldwide in 2012 was $93.2 billion with U.S. consumption at $8.7 billion. Gaining insight into the challenges of these innovative suppliers to Ohio’s manufacturing industries can shed light on how public policy can be shaped to assist and grow this industry.

METHODOLOGY
The Survey of Machine Tool Businesses’ questionnaire was designed by the Center to identify current and future challenges of the machining industry. Questions regarding macro-economic trends, changes in end-user requirements, changes in technology, changes in production process, and changes in customers’ expectations were incorporated to delineate the challenges of the industry. The Survey of Machining Businesses questionnaire was created and developed by the Center with advisement from Dr. Edward (Ned) Hill, Dean of the Maxine Goodman Levin College of Urban Affairs at Cleveland State University and subject matter expert in advanced manufacturing. For a copy of the questionnaire, see Appendix A. 1.

The survey was an Internet-based survey, deployed through the survey software Qualtrics. The survey was tested with 25 machine tool companies on May 20, 2014. After the testing phase, the full survey was conducted over a four-week period starting May 27, 2014 using a list of contacts and email addresses from TechSolve. Contacts were emailed on consecutive Tuesdays. In order to facilitate greater response rates, the Center contacted potential respondents via phone to encourage participation. Moreover, the research team contacted regional and statewide manufacturing associations to encourage their members to participate. In addition, an incentive of entry into a drawing to win one of two $25 gift cards was offered to respondents.

This survey did not use any sampling method to select participants and did not have a survey frame to estimate a population. Since this survey was not meant to be statistically significant, the Center is not able to quantify traditional statistical survey statistics (response estimation, over- or under-representation, non-response estimation, etc.). It is important to acknowledge that there may be bias in responses to the survey. Survey participant selection bias may have occurred due to the fact that individuals and businesses solicited by the Center to participate in the survey were selected from a pool of contacts collected by TechSolve; this selection was not random. Moreover, the authors acknowledge the selection bias of using an Internet-based collection mechanism. If a potential respondent did not have an email address or a computer, they were not able to participate in the survey and were therefore not represented in the sample of respondents; this is reflected in non-response bias.

10 We would like to thank TechSolve, MAGNET, PolymerOhio, The Precision Machine Products Association (PMPA), and Ohio Manufacturers’ Association (OMA) for distributing the survey to appropriate contacts.
SURVEY ANALYSIS

Respondent Demographics

Overall, there were 34 respondents that completed the survey. These respondents were from a variety of locations throughout the state of Ohio. Figure 1 is a thematic map of the state of Ohio displaying respondent count shaded by county. The largest number of respondents originated in Hamilton County (where the city of Cincinnati is located).

Figure 1. Respondents by Geographic Location

The Survey of Machining Businesses was targeted towards owners or managers who operate machining businesses. Figure 2 illustrates the respondent count by job title. The largest grouping of respondents (39%) reported occupations in upper management (i.e. President, CEO, President & CEO, and CFO). Plant managers and general managers were the second-largest occupation (18%) that responded to the survey. Based upon the outcomes in Figure 2, the survey achieved the targeted demographic of surveying owners or employees who manage machining business.

11 Respondent count shading was used in order to ensure the confidentiality of respondents
Respondents were asked in one question, “Approximately, how many full-time employees does your company employ?” and, in a subsequent question, were asked to indicate approximate company sales. Figure 3 displays the number of respondents to these two questions. The results show that a majority of respondents from small businesses (less than 50 employees). Most respondents had less than 50 employees (4 respondents had 1 to 25 employees; 13 respondents had 26 to 50 employees), and a vast majority of respondents had sales of less than $50 million a year.
There are a wide variety of business functions within the machining industry. Figure 4 displays respondent counts of business unit functions. The most often selected category was *Manufacture Discrete Parts* (25 respondents), followed by *Manufacture Assemblies* (21 respondents). Respondents engaged in a variety of business functions within the machining industry, many selecting more than one function.
Figure 5 illustrates the industries served by respondents, which are sectors that traditionally require specific parts and assemblies to be manufactured by machining businesses (Figure 4). The top industries selected by respondents were Automotive (21%), Aerospace (15%), Energy (14%), and Consumer Products (14%).

**Figure 5. Industries Served by Respondents**

In understanding the structure of the machine tool industry, it is important not only to comprehend which industries are supplied (Figure 5), but how these products are diversified in machining business units’ product portfolios. Table 1 shows the product types that are produced by machining businesses divided into two groups according to whether these products’ sales account for more than 50% of sales, or less than 50%. It should be noted, Table 1 represents a portion of the respondent categories, since many of the machining products indicated by respondents could not be aggregated and displayed in order to maintain respondent confidentiality. A majority of respondents diversify their machining products so that their products are not more than 50% of their overall sales. By diversifying their products, owners and operators can maintain agility in a market dominated by fluctuating metal pricing and increasing customer demands.
Table 1. Products Machining Business Unit Manufactures as a Percentage of Sales

<table>
<thead>
<tr>
<th>Number of Products</th>
<th>Greater than 50% of Sales</th>
<th>Less than 50% of Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Aerospace/Aircraft</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Automation Systems</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Consumer Products</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Construction Products</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Electrical Products</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Parts &amp; Components</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>11</td>
<td>37</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
<td><strong>56</strong></td>
</tr>
</tbody>
</table>

As suppliers, the machining industry must be nimble in order to receive orders and fill them on time to meet customers’ demand and satisfaction. In order to operate in this way, machining businesses can be engaged in a variety of types of machining. Figure 6 demonstrates the variation of responses pertaining to the different categories in which machining respondents engage. In general, almost one third of respondents reported that they engage in machining, no matter the type (3-, 4- or 5-axis). The remainder of responses was fairly equally split amongst lathes (16%), milling machines (15%), turning centers (13%), and grinding machines (13%).

Figure 6. Respondents Engaged in Various Types of Machining

Note: EDM= Electrical Discharge Machining
CNC= Computer Numerical Control
Respondents Could Select More than One Response; N=168
Innovation

As the world pulled itself out of the worst recession seen in eighty years, manufacturing leaders understood that the playing field had, once again, changed. The U.S. regained its footing in understanding what its manufacturing assets were and how to leverage them to remain competitive with the rest of the world. Moreover, businesses began to resharer\textsuperscript{12} products and reinvested their operations. Manufacturers that survived the Great Recession also had to reestablish production processes to get a better handle on product quality and supply chain oversight.

In the post-Great Recession period there has been considerable discussion centering on innovation. Conversations of how manufacturing can innovate and facilitates can retain their competitive advantage has penetrated manufacturing research. This discourse traditionally held in boardrooms has spread to Main Street. In 2014, The Brooking’s Institution released a report on “The Rise of Innovation Districts” and how the mix of entrepreneurs, start-ups, educational institutions, commercial development, medical campuses, and increased connectivity through urban transit and transport is revolutionizing the urban environment and economic development.\textsuperscript{13}

In the state of Ohio, innovation and new technology can be found throughout the economy and the machining industry. With new technology that taps underground shale for natural gas, the Utica and Marcellus shale deposits have brought new growth to sectors of the machining industry. A few survey respondents indicated that they have purchased or are looking to purchase capital equipment powered by natural gas. Other companies have found that since they became suppliers to the energy industry the cost structure of the industry is lower, so they can now increase investment.

Although discovery can be haphazard, innovation can be managed in a similar way as other operational functions. It is important to understand how machine tool firms are acquiring innovation resources, whether internally or externally. Figure 7 exhibits respondent counts by innovation resources that machining firms use. Almost all of the respondents (85\%) indicated that the innovation resources they utilize are external to the firm (\textit{External non-profit manufacturing or technology centers/organizations; Federal agencies and/or labs; Hired consultants; Professional societies/associations; Trade organizations; Universities and community colleges; Vendors and suppliers}). Only 20 responses employed \textit{internal work-groups} to innovate. This firm is dominated by small and medium sized manufactures and their reliance on external sources of innovation may well differ from larger firms.

\begin{footnotesize}
\textsuperscript{12} Reshoring is the return of jobs to the United States after they had been previously offshored.
\end{footnotesize}
There are many factors that prevent businesses from innovating. Table 2 shows the responses for the question, “Please order your top 3 innovation challenges that your businesses unit struggles with.” Overall, the most selected challenge was upgrading skills of workforce (31%), closely followed by changes in customer expectations (30%).

**Table 2. Respondents' Top 3 Innovation Challenges**

<table>
<thead>
<tr>
<th>Machining Innovation Challenges</th>
<th>Ranked #1</th>
<th>Ranked #2</th>
<th>Ranked #3</th>
<th>Frequency of Top 3 Ranking</th>
<th>Percent of Respondents who Ranked Challenge in Top 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upgrading skills of workforce</td>
<td>12</td>
<td>9</td>
<td>6</td>
<td>27</td>
<td>31%</td>
</tr>
<tr>
<td>Changes in customer expectations (delivery time, quality, and/or prices)</td>
<td>14</td>
<td>9</td>
<td>3</td>
<td>26</td>
<td>30%</td>
</tr>
<tr>
<td>Regulatory environment (environmental, import/export compliance)</td>
<td>3</td>
<td>4</td>
<td>8</td>
<td>15</td>
<td>17%</td>
</tr>
<tr>
<td>Integrated computer manufacturing: design, model, simulation and production</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>8%</td>
</tr>
<tr>
<td>Working with new materials (composites and hard to machine materials)</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>6%</td>
</tr>
<tr>
<td>Information networking, monitoring, and connecting machine tools and other manufacturing assets</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>5%</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30</strong></td>
<td><strong>29</strong></td>
<td><strong>27</strong></td>
<td><strong>86</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
Financing innovation investment, especially over the last few years due to the recession, has been challenging. However, most respondents (74%) indicated that financing issues over the last three years were not applicable to them. We can only speculate why financing was not a barrier to these firms; either they did not have trouble obtaining financing or they had not looked to make innovation investments at that time due to business conditions.

We asked a forward looking question, “What type(s) of innovation investment(s) are you looking to make in the next three years?” (Figure 8). The largest grouping of responses indicated that innovation investments would take place in capital investment (*facility improvements, equipment financing, and IT infrastructure*); this grouping accounted for a little over half of the responses (57%). Other innovation investment that machining business were looking to undertake was that of business expansion, either through *business acquisition* (15 responses) or *working capital for business expansion* (11 responses).

**Figure 8. Innovation Investment(s) by Respondents in the Next Three Years**

![Pie chart showing innovation investment distribution. Facility Improvements: 18, Equipment Financing: 17, Acquiring New Businesses: 15, IT Infrastructure: 11, Working Capital for Business Expansion: 11, Work-in-process Inventory: 11, Other: 3, N/A: 5, N=81.](image)
New Materials

New materials in machining have been identified as those that are required to operate at high temperature or have high strength that is combined with lightweight or relatively low cost composites.\(^{14}\) New materials consist of ceramics,\(^{15}\) alloys (high-temperature, nickel based, iron and cobalt based) and stainless steels.\(^{16}\) Through innovation in the automotive and aerospace industries the demand for machining of these materials has increased, while the turnaround time and cost margins have decreased.

In order to understand the state of machining in Ohio today, it is essential to know how machining businesses are responding to the demand for new materials. Figure 9 presents the responses to the question: “How has the use of new materials (i.e. composites, new alloys, etc.) in your industry caused challenges for your business unit?” Overall, responses were equally dispersed across the seven answers. This indicates that manufacturers need to address a host of problems.

**Figure 9. Challenges in Respondents’ Business Due to New Materials**

---


Customer Expectations

The machining industry suppliers many of the large industries in Ohio (automotive, aerospace, etc.) and faces the pressures of supplying products within strict profit margins and just-in-time delivery schedules. Ever-increasing customer expectations to machine better, faster and cheaper caused us to question respondents where they have experienced a change in customer expectations. In addition, we asked how these changing expectations affected their profit margin (for better or worse).

Table 3 displays the tabulation from the first question, as well as a summary of how customer expectations altered their profit margins of the machine tool companies and companies that use machine tools. Overall, the most selected response was a change in customer expectation in regards to delivery time. Customers expect faster delivery times, which can create increased profit for machine shops. However, when customers expect a shorter turnaround, machine shops have to monitor carefully their inventory in order to make sure they have enough stock on hand for other orders. The second most selected response was prices; respondents indicate that customers demand lower prices that will narrow their profit margin unless they increase units of production. Quality and design were third and fourth choices by respondents. Respondents indicated that customers’ expectation of quality is extremely high, but customers are also using cheaper materials. Changes in customers’ expectation in design, on the other hand, results when customers add complexity to the part and customized standard products or ask for unique products.
<table>
<thead>
<tr>
<th>Respondent Count</th>
<th>Profit Margin Alteration</th>
</tr>
</thead>
</table>
| **Delivery Time** | • Inventory Planning: have to do a better job and improved margins; have larger inventories due to just-in-time delivery; need to hold more stock to cover unknown demands  
• Late charges if not on time  
• Working more overtime to meet customer demand  
• Customers have an expectation of faster delivery time  
• Based upon shorter delivery times, can create an inventory control problem of having enough stock  
• Profit margin increased, customers are willing to pay for shorter delivery times |
| 23               |                                                                                         |
| **Prices**       | • Prices are much lower  
• Narrow profit margin                                                                 |
| 21               |                                                                                         |
| **Quality**      | • Customer's expectation of quality is extremely high  
• Customers are trending toward cheaper, lower quality products  
• Customers have eliminated their own quality control departments forcing machining companies to do inspections  
• Closer tolerances increase cost  
• Customer's expectation is high for quality, but allowing for IESS downtime; this equates to a necessary increase productivity and efficiency for the shop. |
| 18               |                                                                                         |
| **Design**       | • Customers require more engineering and design help since they have cut back on internal engineering functions  
• Increased due to added complexity (i.e. design, engineering)  
• Growth due to increase in customization  
• Require more design validation                                                                 |
| 17               |                                                                                         |
| **Products**     | • New opportunities with new products  
• Decreased profit margin due to wide range of products  
• As technology increases so does the complexity of the product, which both helped and hindered profit margin |
| 8                |                                                                                         |
| **Traceability** | • Longer machine qualifications                                                          |
| 7                |                                                                                         |
| **Process**      | • Profits increased due to greater complexity  
• Profits slightly decreased due to more stringent acceptance criteria  
• Expectations are on less human intervention on process and higher automation content |
| 6                |                                                                                         |
Workforce

In the last ten years, there has been a significant workforce demand for those occupations that supply the advanced manufacturing and machining industries. Overall, there has been a hollowing out within middle-skilled jobs — whereby individuals stay in lower skilled manual jobs or pursue non-technical careers, which require post-secondary education. This is compounded with the fact that it has been difficult to attract talented employees with advanced degrees in the science and mathematics areas to fill management and engineering positions in advanced manufacturing industries. This workforce environment creates a very difficult setting for employers who are looking to hire and expand their businesses.

Middle-skilled jobs are defined traditionally as jobs that require less than a bachelor’s degree but more than a high school diploma. These jobs are the backbone of the machining industry – machinists, lathe workers, and technicians. First in the Midwest has been crying out for years that they cannot find qualified workers to fill vacancies, because of both a decline in the supply of new entrants and the exit of incumbent workers due to retirement. An audit by the Government Accountability Office of a representative sample of 200 Workforce Investment Boards (WIBs) found that WIBs had a hard time filling middle-skill occupations, which they also identified as high-growth occupations, because individuals lack skills to participate in re-training.\(^\text{17}\)

Figure 10 presents the challenges in workforce reported by machining businesses in our survey cohort. Almost one third stated that individuals do not have the appropriate skills for the designated job (32%). Tied for second place that employers have a difficult time finding employees with enough experience for the job (19%) and finding employees with the appropriate soft skills (i.e. communication, enthusiasm, etc.) for the workplace (19%).

It is not easy for employers to find individuals for science, technology, engineering, and mathematic (STEM) occupations. According to a Brookings report, the median duration of a STEM vacancy is more than twice that of a non-STEM vacancy.\textsuperscript{18} We wanted to verify this finding within the machining industry. Respondents were asked, “In the last 3 years, has your business unit looked to fill any new positions?” If respondents selected yes, which 97% did, they were prompted with another question. “What occupations have you looked to fill in the last 3 years? Have you had issues finding qualified applicants?” Figure 11 displays the total length of time to fill vacancies by all occupations from respondents. The most commonly selected answers were \textit{less than 3 months} and \textit{3 to 6 months}.

Table 4, breaks out responses to the follow-up question by occupation. Table 4 contains information on the most frequent response of the number of months it took to fill the vacancy, a Sparkline (mini bar graph) of the length of time to fill the vacancy, and the percentage of respondents that indicated that there was a qualified pool of applicants for the occupation. On the whole, the most common response for the length of vacancy by occupation was 3 to 6 months. Eight occupational categories with 50% or more respondents agreed that there was a qualified pool of applicants (Engineers, 71%; Office Management, 92%; Plant Management, 57%; IT Specialist, 78%; Machine Operators, 50%; Model Makers, 50%; QA/CMM Technicians, 50%; and Other, 71%). There were five occupational categories where less than 50% of the respondents found the pool to be qualified (Electro mechanical Maintenance Technicians, 33%; CNC Programmers, 20%; Tool Makers, 39%; Machinists, 25%; and Welders, 27%). Examining the groups of occupations in which machine tool respondents indicated there was not a qualified pool of candidates reveals that all occupations were in middle-skill job categories.

---

19 Each Sparkline in Table 4 is a replication of Figure 11 but by each occupation.
Table 4. Length of Time to Fill Vacancies by Occupation

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Number of Months to Fill Vacancy by Most Frequent Response (% of Total Occupation)</th>
<th>Length of time to fill position</th>
<th>There was a qualified pool of applicants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineers</td>
<td>3 to 6 months (48%)</td>
<td>71%</td>
<td></td>
</tr>
<tr>
<td>Office Management</td>
<td>Less than 3 months (50%)</td>
<td>92%</td>
<td></td>
</tr>
<tr>
<td>Plant Management</td>
<td>3 to 6 months (43%)</td>
<td>57%</td>
<td></td>
</tr>
<tr>
<td>IT Specialists</td>
<td>Less than 3 months (36%)</td>
<td>78%</td>
<td></td>
</tr>
<tr>
<td>Electro mechanical Maintenance Technicians</td>
<td>N/A (31%)</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>CNC Programmers</td>
<td>6 to 9 months (29%)</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Machine Operators</td>
<td>Less than 3 months (67%)</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Model Makers</td>
<td>N/A (60%)</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Tool Makers</td>
<td>Less than 3 months &amp; 6 to 9 months (24%)</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>QA/CMM Technicians</td>
<td>3 to 6 months (40%)</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Machinists</td>
<td>3 to 6 months (41%)</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Welders</td>
<td>3 to 6 months (38%)</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td>Other (sum)</td>
<td>Less than 3 months (43%)</td>
<td>71%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3 to 6 months (29%)</td>
<td>49%</td>
<td></td>
</tr>
</tbody>
</table>

Note: The bar graph displays each column in order of length of time. The first column indicates “N/A”, the second column indicates “Less than 3 months”, third “3 to 6 months”, fourth “6 to 9 months”, fifth “9 to 12 months”, and the last column indicates “Greater than 12 months”.

Table 5 illustrates data collected on respondents’ usage of workforce development resources, and how they rate their usefulness. Overall, 90% of respondents have used web postings and have found this resource useful. Two-thirds of respondents indicated that they use headhunters/recruiters and find this resource very useful. A large grouping of respondents indicated that they have used community college or university/college placement centers in the past and have found this resource useful. It is interesting to note that respondents have not used many of the workforce development resources from the state of Ohio (Ohio Means Jobs Website, Ohio Means Jobs Service Centers, or Ohio Means Jobs Internship Website). For detailed responses, see Appendix A.2.
Table 5. Workforce Development Resource by Usage and Usefulness

<table>
<thead>
<tr>
<th>Resources</th>
<th>Used Resource</th>
<th>Highest response count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohio Means Jobs Website</td>
<td>30%</td>
<td>N/A (31%)</td>
</tr>
<tr>
<td>Ohio Means Jobs Service Centers</td>
<td>21%</td>
<td>N/A (45%)</td>
</tr>
<tr>
<td>Ohio Means Internships Website</td>
<td>4%</td>
<td>N/A (86%)</td>
</tr>
<tr>
<td>Community College Placement Centers</td>
<td>73%</td>
<td>Useful (54%)</td>
</tr>
<tr>
<td>University/College Placement Centers</td>
<td>52%</td>
<td>Useful (60%)</td>
</tr>
<tr>
<td>Job Fairs</td>
<td>65%</td>
<td>Useful (33%)</td>
</tr>
<tr>
<td>Website Postings</td>
<td>90%</td>
<td>Useful (50%)</td>
</tr>
<tr>
<td>Headhunters/Recruiters</td>
<td>66%</td>
<td>Very Useful (39%)</td>
</tr>
<tr>
<td>Other</td>
<td>80%</td>
<td>Very Useful (83%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>51%</strong></td>
<td><strong>Useful (38%)</strong></td>
</tr>
</tbody>
</table>

Fifty eight percent (58% or 19 respondents) of respondents stated that they used external training providers to upgrade current employees’ skills. Figure 12 displays the type of providers used by these 19 respondents. The most common training provider used was External non-profit manufacturing or technology centers/organizations and Community colleges. For detailed responses, see Appendix A.3.

Figure 12. External Training Providers Used by Respondents to Upgrade Employee Skills
Overall Challenges & Opportunities

Literature provides evidence of the overall benefit of a skilled workforce for the economy. It is the return to employees’ skills that is an important attribute to education and further training, and will only become more intense as the world continues to compete on a global scale. Economists have shown that regional skill-level inequality can explain one third of income inequality, with the skill inequality reflecting historical schooling patterns and immigration. At the regional level, these studies have linked work skills to either wages or income.

Figure 13 displays a wordle\(^{22}\) of the most common phrases used by our survey respondents to describe the challenges in the machining industry over the next three years. For business unit and industry, *skilled labor, healthcare costs, and talent retention* were some of the greatest challenges that respondents indicated. For detailed responses, see Appendix A.4. and A.5.

**Figure 13. Greatest Challenges in the Machining Industry over the Next Three Years for the Business Unit and Industry**

<table>
<thead>
<tr>
<th>Business Unit Challenges</th>
<th>Industry Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>qualified labor</td>
<td>skilled labor</td>
</tr>
<tr>
<td>healthcare costs</td>
<td>government regulation</td>
</tr>
<tr>
<td>talent retention</td>
<td>hiring</td>
</tr>
<tr>
<td>government regulation</td>
<td>growth</td>
</tr>
<tr>
<td>skilled labor</td>
<td>international competition</td>
</tr>
<tr>
<td>healthcare costs</td>
<td>government regulation</td>
</tr>
<tr>
<td>skilled labor</td>
<td>healthcare costs</td>
</tr>
<tr>
<td>government regulation</td>
<td>international competition</td>
</tr>
<tr>
<td>qualified labor</td>
<td>healthcare costs</td>
</tr>
<tr>
<td>healthcare costs</td>
<td>government regulation</td>
</tr>
<tr>
<td>skilled labor</td>
<td>international competition</td>
</tr>
</tbody>
</table>

N=64  
N=88  
Source: www.wordle.net

---


\(^{22}\) A wordle is an info graphic that displays the most common words in larger font.
Figure 14 presents a wordle of the greatest opportunities to the machining industry over the next three years. Unlike respondents’ responses to the challenges to the business unit and industry which rallied around a few responses, the responses for the greatest opportunities for the business unit and industry were more varied. For detailed responses, see Appendix A.6. and A.7.

**Figure 14. Greatest Opportunities in the Machining Industry over the Next Three Years for the Business Unit and Industry**

<table>
<thead>
<tr>
<th>Business Unit Opportunities</th>
<th>Industry Opportunities</th>
</tr>
</thead>
</table>

Source: www.wordle.net
Machining Communication

Gathering information about innovation from industry experts is an important consideration for machining businesses. As mentioned earlier, most of the resources that machine tool businesses use to gain information about innovation are external to the firm (Figure 7). Table 6 presents the responses to the question: “Please rank the top 3 ways you rely on the most for receiving information on machining innovation.” The most popular way to obtain information about machining was that of trade publications (28%), followed by conferences and events (24%), and trade shows (21%).

Table 6. Top Machining Businesses Obtain Information on Innovation

<table>
<thead>
<tr>
<th>Information Source</th>
<th>Ranked #1</th>
<th>Ranked #2</th>
<th>Ranked #3</th>
<th>Frequency of Top 3 Ranking</th>
<th>Percent of Respondents who Ranked Source in Top 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade Publications</td>
<td>12</td>
<td>6</td>
<td>5</td>
<td>23</td>
<td>28%</td>
</tr>
<tr>
<td>Conferences/Events</td>
<td>8</td>
<td>3</td>
<td>9</td>
<td>20</td>
<td>24%</td>
</tr>
<tr>
<td>Trade Shows</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>17</td>
<td>21%</td>
</tr>
<tr>
<td>Internet Searches</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>16</td>
<td>20%</td>
</tr>
<tr>
<td>Trade E-Newsletter</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>6%</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>LinkedIn/Facebook</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td>27</td>
<td>26</td>
<td>82</td>
<td>100%</td>
</tr>
</tbody>
</table>

The infographic of Figure 15 displays three methods surveyed for information on machining: Trade Shows Attended, Societies/Associations, and Periodicals and Newspapers. A number of respondents answered that they attend the International Manufacturing Technology Show (IMTs) and FABTECH. Overall, most respondents belong to the American Society of Mechanical Engineers (SME) and the Society of Manufacturing Engineers (SME), but after these two groups, belonging to societies was widely dispersed among a variety of groups.

As indicated earlier in Table 6, the majority of respondents gain information on innovation from trade publications. Based upon the responses in Figure 15, one can see that the machining industry consumes a significant amount of information through periodicals and newspapers. The most frequently selected responses in this category were Modern Machine Shop (21 respondents) and Production Machining (14 respondents).