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# New Materials/New Skills for the Trades



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**TABLE OF CONTENTS**

**Acknowledgements**..... iv

**Executive Summary**..... v

**Introduction** ..... 1

**Section I: Lightweight Technology Trends** ..... 3

    New Materials..... 3

    New Forming Technologies..... 4

    New Joining Technologies..... 6

**Section II: Skill Requirements for Tool, Die & Mold Makers** .....6

    What Do Tool, Die & Mold Makers Do?..... 7

    Tool and Die Employment, Demographics, Demand, and Wages ..... 7

    Challenge 1: New Materials and New Processes ..... 13

    Challenge 2: An Aging Workforce ..... 15

    Challenge 3: Trade Impacts and Purchasing ..... 17

**Section III: Recommendations** ..... 18

    Address Training and Apprenticeships as a Common Good..... 18

    Build Stronger Industry Partnerships with Community and Technical Colleges..... 18

    Change Industry Practices..... 19

**Conclusion** ..... 20

**Works Cited** ..... 21

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*CAR's mission is to conduct independent research and analysis to educate, inform and advise stakeholders, policy makers, and the general public on critical issues facing the automotive industry, and the industry's impact on the U.S. economy and society.*

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## **EXECUTIVE SUMMARY**

To comply with stricter fuel economy and emissions regulations, the automotive industry has focused research and development efforts on reducing vehicle mass—also known as lightweighting.

Lightweighting means that automakers are increasingly relying on novel materials and a greater mix of materials in each vehicle. Designing, analyzing, and building automotive tools, dies, molds, jigs, and fixtures to form the wide array of new and advanced materials that are being deployed in current and future vehicles will drive skills changes for both incumbent workers and future apprentices.

First, automotive tool and die producers are grappling with the introduction of new materials and new processes, and the implications of these changes on training the future tool and die workforce. Second, automakers, suppliers, and small tool, die, mold, jig, and fixture shops are also facing increased retirement attrition, and firms struggle to hire and train new apprentices to backfill these departures. Finally, business practices—such as sourcing tool and die build offshore for lower prices—mean that there is less work done in the United States that can be used as a basis to train new apprentices.

Since it can take as long as a decade to train a journeyman tool and die maker, these human capital investments needed to take place in 2007-2009 to support the increased cadence of new and refreshed product launches currently planned. An apprenticeship includes a formal education component—typically done in conjunction with a community or technical college—as well as years of on-the-job training. Ten years ago, the automotive industry was in a downturn, and companies were cutting payrolls—not adding apprentices and training budgets. This has led those companies that are desperate for talent to hire experienced tool and die (and other tradespersons) away from their suppliers and competitors. The companies that these workers leave tend to be smaller firms that do not pay as well or offer as many employment benefits. Large firms may be able to lure sufficient skilled trades talent to backfill immediate needs, but smaller firms have no choice but to keep training new employees.

Based on interviews with the 16 companies, organizations, and institutions that took part in this research, CAR's recommendations include:

- The auto industry must work together to sustain training and apprenticeship programs through the next cyclical downturn in the industry.
- The entire automotive industry reaps the benefits of small firms' support for and involvement in apprenticeship programs—and there needs to be a more viable model of paying for these critical investments rather than relying on smaller firms to continue underwriting the cost.
- Community and technical colleges play a key role in apprenticeship programs, but these institutions struggle to discern the industry's technological direction, to attract students, hire and retain instructors, and invest in modern equipment. It is critical to build and strengthen existing industry-college partnerships to address these needs.
- Tool and die operations need to improve productivity through standardizing intra- and inter-company work and processes, realizing greater process control at materials manufacturers to reduce batch and producer variability, and implementing more scientific problem solving approaches that prioritize critical adjustments to more quickly achieve dimensional tolerance of the part or assembly.

## **INTRODUCTION**

Over the past decade, governments in North and South America, Europe, and Asia have enacted stricter fuel economy and emissions requirements.<sup>1</sup> Reasons for these policies range from curtailing local pollution, promoting energy conservation and independence, and mitigating the impacts of global climate change. To comply with these regulations, the automotive industry has focused research and development efforts in four main areas: improving the efficiency of the internal combustion engine, implementing new powertrain technologies, bringing down the costs of vehicle electrification, and reducing vehicle mass—also known as lightweighting.

In the United States, Federal agencies are in the midst of the Mid-Term Evaluation (MTE) to review light vehicle fuel economy and greenhouse gas emissions regulations. Through the MTE, the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) are reviewing the standards that were set in 2012 for Model Years 2022-2025. The review involves technical assessments of technology readiness, costs, and penetration rates, consumer acceptance, fuel price forecasts, and other factors. Even if this process were to result in changes to the Federal regulations—including a longer time horizon, additional compliance credits, or some other relaxation of standards, the move to improve vehicle efficiency and lower emissions will continue around the globe. The global nature of the automotive industry (and the EPA waiver for California plus the 13 states and the District of

Columbia that allow California to set its own emissions standards) means that no matter what happens through the MTE, the pressure to improve fuel efficiency and reduce emissions will continue throughout the industry. Policy changes in one market (or section of the market) are unlikely to alter products in any meaningful way for those vehicles that automakers produce and sell for global markets.

Mass reduction is complimentary to all other efficiency efforts. Simply stated, lower weight requires less energy to move. Estimates of the efficiency gains from mass reduction vary, but frequently state that a 10 percent reduction in vehicle mass, when coupled with powertrain downsizing, improves the fuel economy of a gasoline vehicle by 6 to 7 percent (Ricardo-AEA, 2015). There are three methods for removing weight from vehicles: downsizing, removing content, and switching to lighter materials. Downsizing and removing content both threaten vehicle performance, and with footprint-based or similar fuel economy standards, downsizing does not aid in regulatory compliance. This leaves the only viable path to reducing vehicle mass as the cost-effective implementation of lightweight materials throughout the vehicle.

Overall, the average weight of a new light vehicle sold in the United States rose steadily from model year 1982 through 2011.<sup>2</sup> From 2011 through 2016, the average weight fell a total of 3.4 percent. Absolute vehicle weight as well as the market composition are factors in

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<sup>1</sup> Brazil, Canada, China, European Union, India, Japan, Mexico, South Korea, and the United States have all established or proposed fuel economy and/or greenhouse gas emissions standards. These nations comprise over 75 percent of the global light vehicle market.

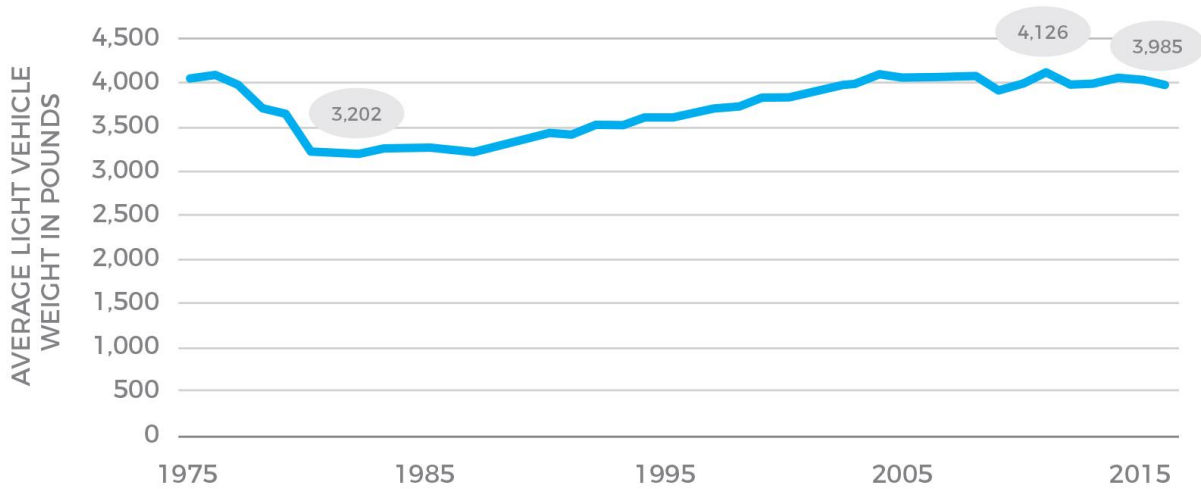
<sup>2</sup> Since this is a production-weighted average, the increase in average vehicle weight reflects not just the weight of individual vehicle models, but also the shift from small- and mid-size cars to CUVs, SUVs, and trucks.

determining the overall average weight of the U.S. fleet. Consumer and regulatory demands also impact the overall average light vehicle weight—with comfort and convenience features comprising a larger and larger share of total vehicle weight over time (Zoepf, 2010).

The trend toward greater use of lightweight materials means that automakers are increasingly relying on advanced materials and a greater mix of materials in each vehicle, and these material changes have the potential to impact the work being done by skilled trades workers and technicians who are employed by firms in the automotive tool, die & mold industries.

Designing, analyzing, and building automotive tools, dies, molds, jigs, and fixtures to form the wide array of new and advanced materials being deployed in current and future vehicles may change skill needs not only for incumbent workers, but also for the future workforce. Much of incumbent worker training on forming new materials and using new processes is being conducted by automakers, suppliers, and equipment vendors, and may not be making its way into the curricula for new skilled trades apprentices.

Figure 1: U.S. Average Light Vehicle Weight in Pounds, Model Years 1975-2016 (preliminary)



Source: (U.S. Environmental Protection Agency, 2016)

### **SECTION I: LIGHTWEIGHT TECHNOLOGY TRENDS**

Moving toward lighter weight vehicles has been a constant goal in the automotive industry. Lighter vehicles can achieve increased performance and use propulsion technologies more efficiently. Henry Ford himself once said that, “Strength is never just weight—either in men or things. Whenever anyone suggests to me that I might increase weight or add a part, I look into decreasing weight and eliminating a part!” (Ford, 1923)

#### ***New Materials***

New materials with better performance characteristics are introduced into light vehicle production for various reasons, but primarily for increasing crashworthiness, minimizing noise and vibration, lowering overall cost, and improving fuel economy and greenhouse gas emissions performance. Between 2010 and 2040, CAR projects the automotive industry will increase use of:

- Advanced High Strength Steels (AHSS)—both dual phase and complex phase
- Ultra High Strength Steels (UHSS)—Boron/Martensite
- Aluminum—5000/6000 series
- Magnesium
- Carbon Fiber Reinforced Plastics (CFRP) and Composites

(Center for Automotive Research, 2017 (Forthcoming))

While use of many materials will expand, the automotive industry will simultaneously reduce dependence on mild steels (from 55 percent of vehicle composition to about 5 percent) and High Strength Low Alloy Steel (HSLAS) from (25 percent to 2 percent). It should be noted that the increased use of high strength steels is expected to peak at around 15 percent of total vehicle weight composition in 2020, and then fall to

roughly 5 percent usage by 2040 as other lightweight materials gain share.

In terms of lighter-weight materials, UHSS steel and aluminum use will grow steadily, especially in safety-cage parts and components (e.g. frames and rails). The use of third generation steels with better formability properties will grow rapidly. Magnesium use will grow, particularly in applications such as instrument panel crossbeams. To achieve large net weight reductions (around 10 percent) will require some use of CFRP—with most applications in reinforcements rather than panels. Higher strength aluminum usage is expected to increase further along the development horizon—between 2025 and 2030—with 96 percent of vehicle programs considering aluminum for body-in-white applications in 2030 and beyond.

Aluminum is experiencing rapid growth in closure panel applications (i.e. doors, hoods, deck lids, fenders, and lift gates), and 90 percent of vehicle programs will consider the use of aluminum before 2020. After 2020, magnesium and advanced steels and composite use for closures is expected to increase dramatically, with magnesium use concentrated in lift gates. Magnesium applications are limited due to extreme corrosion issues with the material; magnesium must be isolated from other metals through coatings or adhesive bonding as well as from the elements.



Materials suppliers are generally more optimistic about the future applications for their advanced material products than are automakers.

Automakers tend to follow a path of incremental material technology improvements to mitigate risks, such as:

- Part failure and vehicle recall;
- Field service and repairability;
- Adequate part supply at competitive prices;
- End-of-life recycling and public health issues;
- Cost barriers;<sup>3</sup>
- Customer acceptance.

### ***New Forming Technologies***

Most manufacturing technologies for forming and joining metals are mature, which means the technology has been in wide usage (for mass production) for many years. Some technologies are developing; these may be currently utilized in low-volume production currently, particularly for premium products. Economies of scale and improvements in design and efficiency have the potential to bring the cost of these not-yet-mature technologies to a level where mass-production applications will be possible in the not-too-distant future (5-10 years). Finally, there are a few automotive forming and joining technologies that are on a longer-term development path, and are currently only in use in very low volume applications (up to 5,000 units annually). These technologies are generally quite costly, and are used only in concept vehicles or very high-end luxury vehicles such as supercars. With additional research and development, these technologies may mature over the long-term (10 or more years).

- **Steel Forming:** Mature technologies for forming steel include: stamping (regular, laser-welded blanks, tailor rolled blanks, hot direct/in-direct), roll forming, hydroforming, forging, casting, and sintering. Hot forming is a near-term developing technology that is expected to be mature by 2020, and 3D printing is expected to remain on a long-term development pathway through 2020.
- **Aluminum Forming:** Mature technologies for forming aluminum include: stamping (regular, laser-welded blanks), roll forming, hydroforming, forging, extrusion, and high pressure die-casting. Super forming and warm forming aluminum are two processes that could move from long-term development to short-term development horizon by 2020. Like steel, 3D printing aluminum is expected to remain on a long-term development pathway through 2020.
- **Magnesium Forming:** Many manufacturing processes for forming magnesium are currently in the short-term development window, including: high pressure die-casting and forging for closures and powertrain components. By 2020, high pressure die-casting for closures is expected to be a mature technology, but the remaining short-term processes will likely not be mature by that point. Processes that are in longer-term development for magnesium and expected to remain so include stamping and warm forming closures, powertrain, and body structures and 3D printing of magnesium. High pressure die-casting for body structures could move from a long-term development process to short-term by 2020.

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<sup>3</sup> For a more detailed discussion of cost and barriers to achieving mass reduction, see (Baron, Identifying Real World Barriers to Implementing Lightweighting Technologies and Challenges in Estimating the

Increase in Costs , 2016) and (Baron & Modi, Assessing the Fleet-wide Material Technology and Costs to Lightweight Vehicles, 2016)

- **Plastics Forming:** Injection molding is the mature manufacturing process for plastics forming in the automotive industry. Over molding with inserts is on a short-term development pathway, but is expected to be a mature technology by 2020. As with 3D printing of other materials, 3D printed plastics remain on a longer-term development horizon.
- **Composites Forming:** Manufacturing processes for forming composites are unlikely to see significant advancements in the short term. Resin transfer molding is used in mid-volume production, and breakthroughs would be required to move this technology to mass-production capability. As with the other materials that can be 3D printed, additive manufacturing forming is unlikely to move from very low-volume applications before 2020.

### *The Prospects for 3D Printing*

For most production parts and component applications, 3D printing is on a long-term technology development pathway. However, that does not mean the automotive industry is not invested in 3D printing nor that it will eventually change the way parts, components, and vehicles are manufactured. There are many current applications for 3D printed parts and components in the automotive industry—including prototype and test parts, 3D visualization and modeling, as well as for tooling, gages, jigs, and fixtures. 3D printing is also being used to create tooling. (Bubna & Humbert, 2016) To achieve wider use in original equipment automotive and parts manufacturing, 3D printing cycle times will have to improve significantly. However, when 3D printing technology becomes more cost-effective and suitable first for aftermarket or service parts before use in mass production, it will radically change the work of skilled trades workers and technicians who are employed by firms in the automotive tool, die & mold industries. Eventually, for the most complex parts, 3D printing could render dies and molds obsolete.

## *New Joining Technologies*

In terms of joining technologies, use of resistance spot welding is projected to decline, as automakers and suppliers rely more heavily on adhesives and mechanical fasteners to join advanced materials. Joining mixed materials in vehicle and parts assembly will require greater use of adhesives, as well as coatings to prevent corrosion (such as galvanic corrosion that occurs when steel and aluminum are joined directly). Mechanical fasteners, which have been utilized since the automotive industry first began, will remain in production, though traditional screws, bolts, and rivets are being replaced by newer forms—e.g. flow screws and self-piercing rivets. Eventually, use of adhesives may overtake mechanical fasteners, as automakers and suppliers determine if “adhesives only” processes are successful and sufficiently durable. Another area that fits in the category of joining technologies is the use of tailor-welded/tailor-rolled/laser-welded blanks. This technology eliminates the need for additional parts or brackets by combining materials with different properties in one metal blank. The use of these specialized blanks is expected to increase through 2030, and then fall off as composites joined by adhesives take the place of mechanical joins and tailored metal blanks.

### **SECTION II: SKILL REQUIREMENTS FOR TOOL, DIE & MOLD MAKERS**

Skilled trades workers in the automotive industry build and maintain the machinery and equipment necessary to manufacture automotive parts and components, assemblies, and vehicles.

Automotive skilled trades occupations include electricians, welders, millwrights, pipefitters, machine repair, computer numerical control (CNC) machinists, mold makers, and tool and die workers. These occupations require an apprenticeship—which entails classroom and on-

the-job training of at least two years. This report focuses on the category of workers who design, analyze, and build automotive tools, dies, molds, jigs, and fixtures—a category commonly referred to as “tool and die workers.”

The original premise of this research was that the introduction of new materials and new processes described in Section I would change the skills and knowledge base for skilled trades workers—especially tool, die, mold, jig, and fixture makers and die designers. Interviews with key industry stakeholders revealed that materials and process changes are, in fact, driving training needs for incumbent skilled trades workers, and some of these new skill areas are even being addressed in apprenticeship training. However, automakers, suppliers, and key stakeholders expressed several concerns beyond the changing skill needs. In context, the skills changes driven by new materials and processes are important, but not the only factors that loom large in preparing the automotive skilled trades workforce of the future. In nearly every interview conducted in the course of this research, automaker and supplier executives raised two main concerns:

- 1) The aging skilled trades workforce and the difficulty many employers face in recruiting, training, and retaining younger workers to backfill skilled trades positions, and
- 2) Dramatic changes in the automotive industry’s tool, die, and mold purchasing patterns over the past decade that have altered the allocation of tool, die, and mold building activity that is done domestically.

This report addresses both the original intent of the research (skills changes driven by new

materials and new processes), as well the two additional topic areas that arose in discussions with industry stakeholders.

### ***What Do Tool, Die & Mold Makers Do?***

The job of tool, die, and mold making involves translating blueprints and computer models into a plan to build tools, dies, molds, jigs, fixtures, and assemblies. These workers use mechanically and computer controlled machining equipment, lathes, grinders, laser and water cutting machines, electrical discharge machines (EDM), as well as a variety of hand and power tools to shape material (generally metal) and assemble holding, cutting, punching, and measuring components. To do this, tool and die workers must:

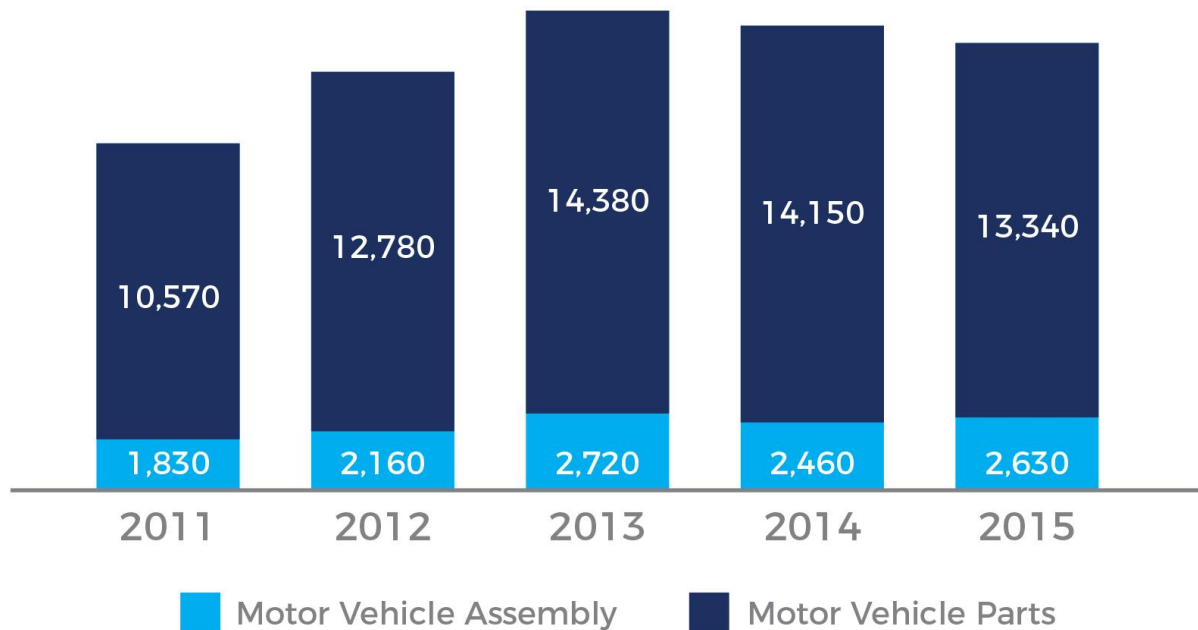
- **Pay close attention** to measurement, and utilize advanced measurement tools;
- **Lay out** metal stock according to the print/model, and machine surface to the required contours;
- **Set up** and operate a variety of conventional and computer numerically controlled machine tools;
- **Conduct tool** tryout to make sure the parts produced meet the specifications required, and if not, modify and adjust the tool or die until it does produce in-spec parts or assemblies; and
- **Inspect and test the tools, dies, and molds** for any defects and repair them.

Tool and die makers possess a broad array of mechanical, mathematical, analytical, and engineering knowledge. They must have an understanding of the production process, and be adept at using computers and electronic tools. Tool, die, and mold makers must utilize well-developed problem-solving skills, good judgement in decision-making, and work well within a team manufacturing environment.

### ***Tool and Die Employment, Demographics, Demand, and Wages***

In 2015, the automotive and parts industries employed nearly 16,000 tool and die workers (U.S. Department of Labor, Bureau of Labor Statistics, 2017). Tool and die workers who do not work directly for automotive firms would add another 16,000 workers—however, the workers in this category do not exclusively produce output that is used by the automotive industry, so it is not valid to add the two employment totals together (U.S. Department of Labor, Bureau of Labor Statistics, 2017). Figure 2 shows total tool and die employment just for the motor vehicles and parts manufacturing industries.

Figure 2: Tool and Die Employment in Motor Vehicle & Parts Manufacturing, 2011-2015



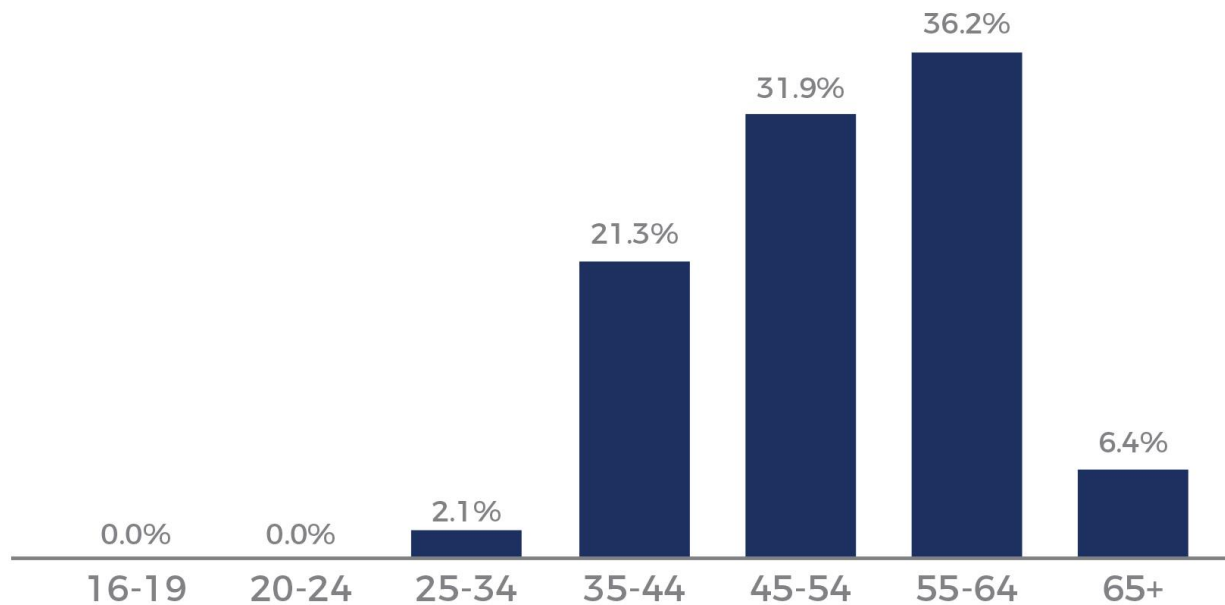
Source: (U.S. Department of Labor, Bureau of Labor Statistics, 2017)

The total number of tool and die workers in U.S. motor vehicle and parts industries has fallen since 2013—including a nearly 4 percent drop between 2014 and 2015. The future projections are for tool and die employment levels across all industries to contract by over 10 percent between 2014 and 2024.

However, the top line erosion in employment levels obscures what is going on under the

surface of the labor market. A vast majority—nearly three out of every four tool and die makers—are over the age of 45. The share of tool and die workers under the age of 35 across all industries is just over 2 percent, and roughly 2 in 5 current tool and die workers are either currently eligible to retire—or will be eligible in the next 5-7 years. Retirement attrition creates a need to hire thousands of new tool and die workers to backfill these positions.

Figure 3: Tool and Die Workers—Age Distribution for All Industries, 2015



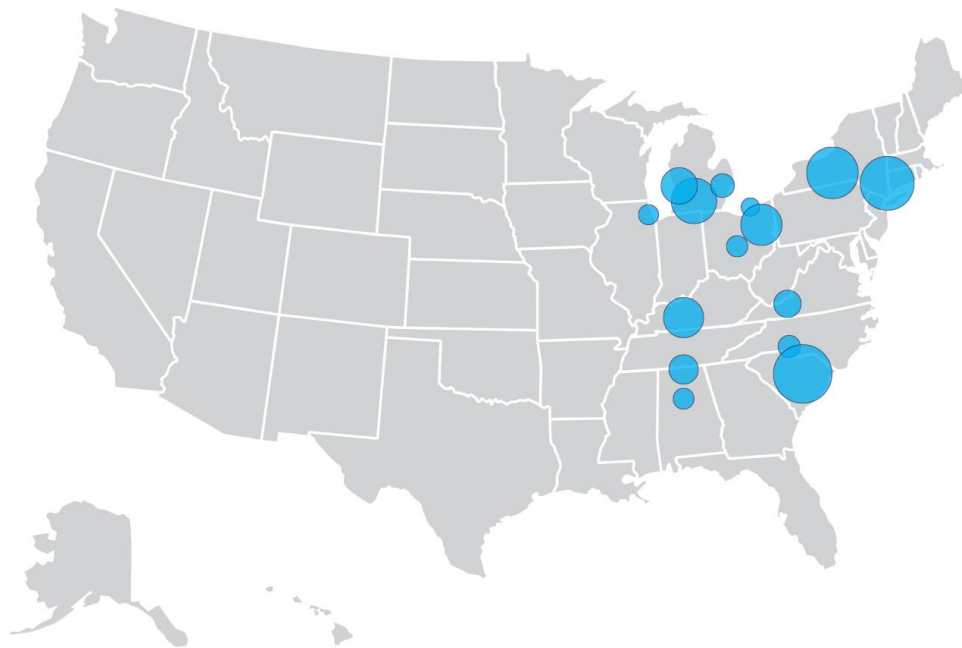
Source: (U.S. Department of Labor, Bureau of Labor Statistics, 2017)

One company executive who was interviewed for this research noted that nearly 80 percent of his company’s current tool and die workforce could retire today. Without sufficient lead time, the only replacements for retiring tool and die makers to work the incumbent workers more hours or to hire experienced tool and die makers away from suppliers and competitors. Over time, the practice of hiring from suppliers and customers should drive up average wages in this occupation if labor supply remains relatively constant. One respondent characterized it this way, “we’re in a crisis, and people don’t realize it yet.”

Indeed, hiring demand for tool and die workers in the motor vehicle and parts industries has been strong—especially given the overall decline in employment and the outlook for the total number of tool and die workers employed in the industry. The top three regions for tool and die absolute demand in the motor vehicle and parts industry in 2016 were:

1. Grand Rapids-Wyoming, Michigan (MSA)
2. Detroit-Warren-Dearborn, Michigan (MSA)
3. Charlotte-Concord-Gastonia, North Carolina-South Carolina (MSA)

Figure 4: Automotive Tool and Die Labor Demand in 2016



Source: (Burning Glass, 2017)

In terms of relative labor demand (job postings per 10,000 people employed) in the occupation and sector, the top three regions for motor vehicle and parts tool and die workers in 2016 were:

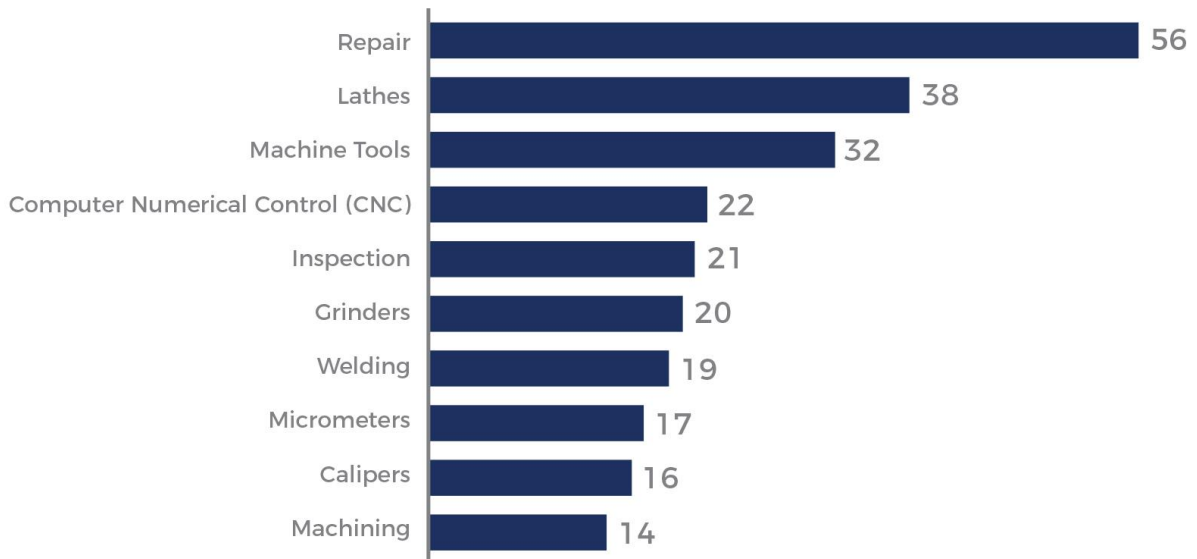
1. Sumter, South Carolina (MSA)
2. Danbury, Connecticut (MNECTA)
3. Ithaca, New York (MSA)

Skilled trades jobs—and tool and die work in particular—can be an attractive employment option for technically inclined young workers. In 2016, the average annual wage for a tool and die worker in motor vehicle manufacturing was nearly \$66,000—with a 10<sup>th</sup>-to-90<sup>th</sup> wage percentile range of \$52,970 to \$78,160. Annual wages in the motor vehicle parts sector are slightly lower: the average annual wage is \$55,000—with a 10<sup>th</sup>-to-90<sup>th</sup> wage percentile range of \$35,860 to \$75,200 (U.S. Department of

Labor, Bureau of Labor Statistics, 2017). Overtime is a common occurrence in skilled trades occupations, and annual wages can grow even higher during periods of peak launch activity. In a recent review of future vehicle launches, CAR determined that the total demand for tool and die hours could rise by more than 80 percent between calendar year 2017 and 2019. This high demand spike will drive annual tool and die worker earnings even higher as there are not sufficient new workers entering the workforce in the next two years. This means much of the work will be done using overtime hours of the current workforce.

Tool and die repair, and use of lathes, machine tools, and CNC machines top the list of specialized skills in greatest demand for tool and die workers in the motor vehicle and parts industries.

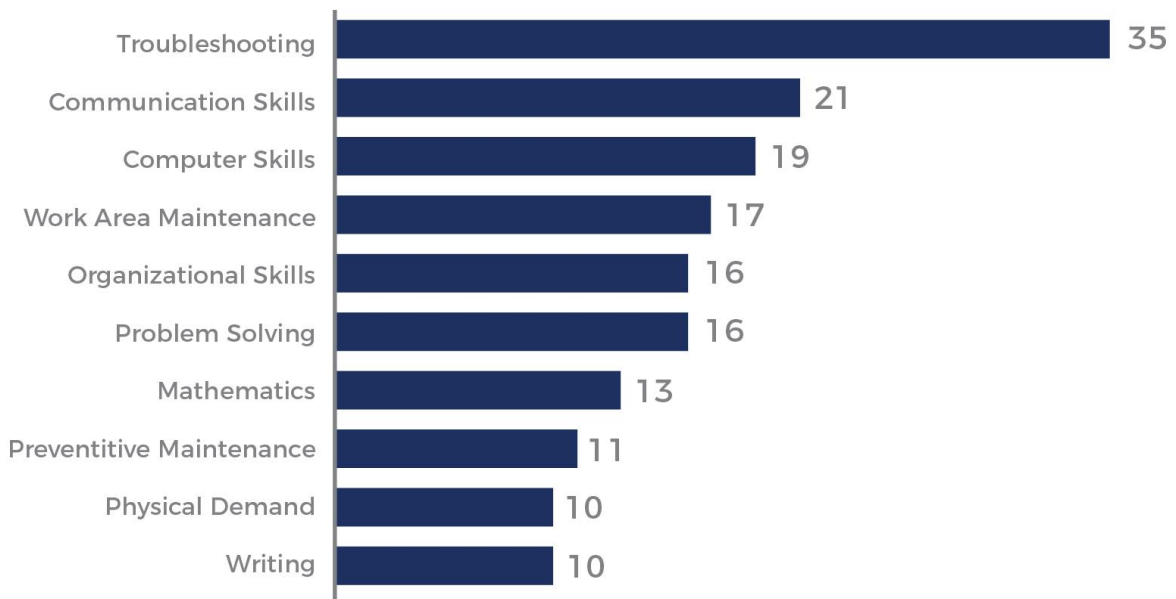
Figure 5: Top 10 Specialized Skills in Demand for Motor Vehicle and Parts Industry Tool and Die Workers, 2016 (number of job postings that list the skill)



Source: (Burning Glass, 2017)

In terms of more general or “baseline” skill demand for motor vehicle and parts tool and die workers, troubleshooting, communication, and computer skills top the list of high demand skills.

Figure 6: Top 10 Baseline Skills in Demand for Motor Vehicle and Parts Industry Tool and Die Workers, 2016 (number of job postings that list the skill)



Source: (Burning Glass, 2017)

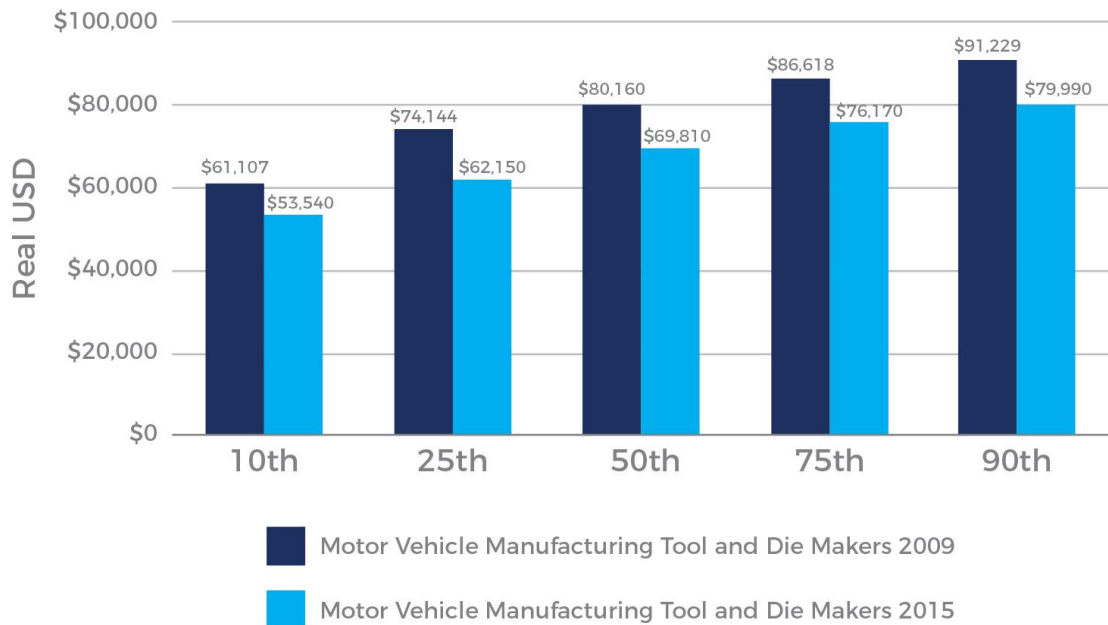


For all the apparent demand for tool and die workers, it is curious that inflation-adjusted annual wages in the occupation have not grown during the automotive recovery. One might expect average wages to be lowered by the changing mix of workers—with younger new hires earning lower annual pay. That is, indeed what seems to be happening: average annual wages for tool and die workers in both nominal and real (inflation-adjusted) terms fell between 2009 and 2015. In motor vehicle manufacturing, real annual wages of tool and die workers fell by 13 percent between 2009 and 2015, while

inflation-adjusted average annual wages for tool and die workers in motor vehicle parts manufacturing fell 11 percent.

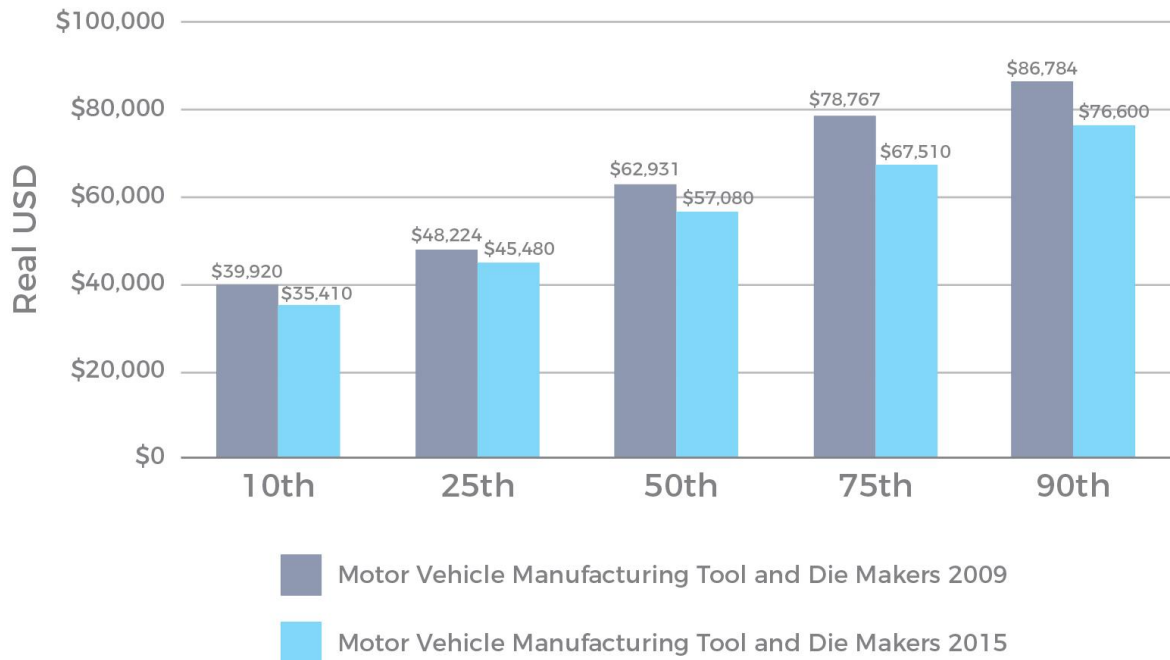
However, examining pay by percentiles shows that average annual wages have not even kept pace with inflation for even the tool and die workers on the top end of the scale. As is shown in Figure 7 and Figure 8, at each percentile cut, the tool and die worker earns lower real annual wages in 2015 than he or she did in 2009—at the start of the automotive recovery.

*Figure 7: Inflation-adjusted Average Annual Wages for Tool and Die Workers in Motor Vehicle Manufacturing, 2009 & 2015*



Source: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment Statistics, May 2008 and May 2016.

Figure 8: Inflation-adjusted Average Annual Wages for Tool and Die Workers in Motor Vehicle Parts Manufacturing, 2009 & 2015



Source: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment Statistics, May 2008 and May 2016.

### Challenge 1: New Materials and New Processes

Key industry stakeholders and lightweighting subject matter experts CAR interviewed broadly supported this project’s original hypothesis that new materials and processes are driving skills changes for tool and die and other skill trades workers. Most employers interviewed for this research are addressing skill increments associated with introduction of new materials and processes through on-the-job training. One employer characterized the new materials and process training as, “Only the last 20% of skilled trades training is in current new technologies, and those are changing all the time.”

While there is tremendous change in the training for tool and die design and build, there are many constants; these include that the industry still requires skilled trades workers who have a lifelong learning commitment, machining

knowledge, ability to read engineering drawings, and problem solving abilities, some of the changes identified include:

- A better understanding of metallurgy and the chemical properties of the materials their tools will form;
- Knowledge of how physics (holding and clamping), different processing (heating and quenching), and various types of joints affect the formed part; and
- Improving productivity by prioritizing critical adjustments to achieve dimensional tolerance of the overall part or assembly.

Several respondents discussed how the same grade of metal or other new material may vary widely from batch to batch or from supplier to supplier, and these batch and supplier variations need to be taken into account when designing and building an automotive metal forming tool.

This process can be problematic when the tryout material could vary in important ways from the production material. The production material may be supplied from a different mill, or even from a different supplier based on corporate purchasing department decisions.

How the tool, die, or mold is designed and built depends on the temper and specific characteristics of the material, and even materials for the tools themselves are changing. For tool designers, this means improvement in use of simulation tools to plan for material variation and minimize the adjustments needed once the tool is in production. When designing for high-strength low-alloy steels, springback is a big problem, and the designer has to factor in overbending to compensate for the more aggressive springback characteristics. Some manufacturers are pushing more of the burden for tryout into the simulation phase to minimize physical tryout time; this requires better data and an even more sophisticated use of simulation prior to building the tool (Kubin, 2016). On the build side, tool and die workers need to understand that these issues occur, and know how to spot an issue and how to problem solve systematically to adjust for these variances. Tool and die makers need to understand new materials the tools will form, as well as new materials utilized in construction of the tool, dies, molds, jigs and fixtures.

The use of higher-strength metals can sometimes mean that tools are not as robust as they once were, and the tools require more maintenance and repair. Some surface treatments and other post-processing actions can improve die life, however, tools that wear out quicker and require more maintenance means that the tradesperson may spend more time problem solving and fixing tools. The build and repair skill sets are very

closely linked; it is difficult—and some told us “near impossible”—to train workers to maintain and support a tool in production if that worker has never built a tool before. Here, again, purchasing plays a role. Offshoring tool builds can mean there are fewer domestically-sourced tools on which to train new skilled maintenance and tradespersons in how to maintain and repair the tools once they are in production.

New materials are often introduced in conjunction with new or substantially updated equipment and processing. One respondent expressed a concern that companies may purchase new equipment, but not fully realize the capabilities of the machines. Vendor training—often bundled with the equipment purchase—may not be long or in-depth enough to help tradespersons fully realize the capabilities of the machinery and process. The learning curve to get the most out of new equipment investments can be very long without the guidance of experienced training providers. Several of the automakers reported that they work very closely with their equipment vendors to refine and focus the training sessions on just those parts of the overall course that are important to their company’s business. This can mean trimming broad overviews so that the training time can be spent drilling down in certain areas, or customizing the new equipment training to include automaker-specific training needs (such as a particular type of robot or self-fastening join technology).

Often, materials suppliers themselves are involved in performing characterization, validation, and training development with the introduction of new materials or processes. Some “new” materials in the auto industry are not all that new; automotive is just now moving into materials that have been used in the aerospace

industry for years. However, there is little opportunity for auto to learn best practices or to rely on simulation data created in aerospace. Aerospace has not only lower volumes than auto, but also more stringent material qualification process for aircraft. Processes developed and used in aerospace may not be robust when scaled to meet the required production demands in the automotive industry. In addition, the aerospace industry does not confront the same range of complex shapes, short cycle times, the amount of batch variation, or the number of sourcing changes that occur regularly in the higher production volumes that are more common in the automotive industry.

Many of the study respondents addressed the issue of the urgent need to have new skills imparted to the incumbent workers and apprentices quickly. One company leader said, “We can’t wait on the government or state (to ramp up training), we have to do it ourselves.” This do-it-yourself approach can lead to training that veers far afield from original standards over time, or that does not impart a portable credential to the workforce; structured apprenticeship training programs are needed, and that structure has historically been provided by governments or labor unions. There are other organizations and trade groups that work to fill this role, such as the Lightweight Innovations for Tomorrow center, Tooling U-SME, Edison Welding Institute, National Tooling and Machining Association, Precision Metalforming Association, the SAE International, and some local area manufacturers’ associations are all involved in developing training and standards for the tooling and machining industries.

Training budgets were often among the first cuts that were made as the industry headed into the 2009 downturn. Some automakers and suppliers

interviewed reported that—even eight years later—they are still struggling to get basic training and apprenticeship programs reestablished. “Training is the first thing we cut in the downturn. We’re trying to change that for the next downturn,” said one supplier leader. Given the lead-time can be as long as 10 years to fully train a master tradesperson, it is imperative that industry remain committed to training and apprenticeships through the next market contraction in this highly cyclical industry to support critical skilled trades development.

### ***Challenge 2: An Aging Workforce***

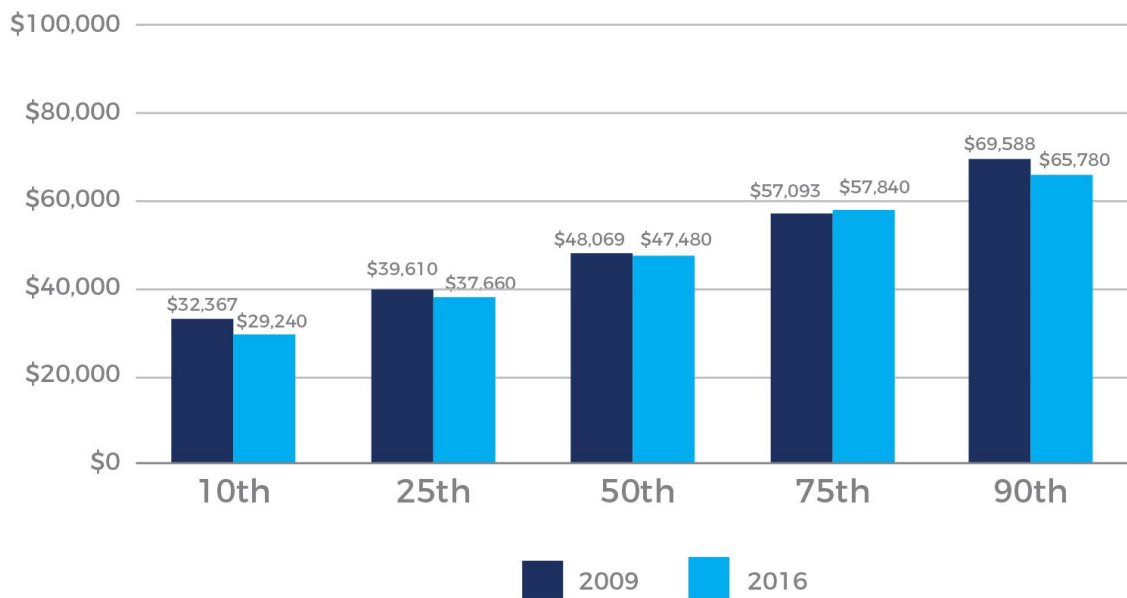
“All the good toolmakers are old,” is a verbatim quote from one of the interview respondents, but the sentiment was common in all of the discussions with industry leaders related to this research. The aging workforce is a challenge that will get worse before it gets better, as over 42 percent of the current workforce is age 55 and above, and will be eligible to retire in the next five to seven years. Workers who were not eligible to retire or take early retirement during the downturn have now accumulated the age and years of service they need to retire. In addition, the industry downturn in 2009 impacted older workers’ retirement funds, and many delayed their retirement as a result. The stronger stock market has put many workers in a position where they are now more comfortable retiring, and firms are anticipating a surge in retirement attrition. Another factor that will drive increased retirement attrition is that employers that have difficulty hiring new workers often meet demand by working additional overtime hours. Long-term sustained overtime may be a positive for worker earnings, but over time, older workers may burn out and make the decision to retire instead.

In many companies, it is already too late to begin hiring to backfill anticipated retirement attrition.

It takes ten or more years of combined apprenticeship training and work experience to become a master tool and die designer or builder. In order to meet the current demand, the automotive industry should have hired new apprentices starting around 2007-2009. Workforce demographics and the retirement bubble threaten to constrain the auto industry's ability to deliver on the planned cadence of new product launches and minor refreshes in the next few years. CAR estimates that the hours of tool and die build required to support launch and product refreshes at just the Detroit Three automakers will increase by 60 percent between 2017 and 2019. Both captive and independent tool shops will struggle to meet the coming demand (Harbour, 2016). As one respondent noted, "there will be a shortage if we wait too long to act."

Smaller tool shops report that they are doing all that they can to get new apprentices and experienced tradespersons, and that there is significant upward pressure on wages. Unlike tool and die wages in motor vehicle assembly and motor vehicle parts manufacturing industries, nominal wages for tool and die workers in the overall tool, die, mold, jig, and fixture manufacturing industry (includes companies that serve auto as well as other industries) have been rising. In fact, nominal wages grew between 2009 and 2016 for every percentile ranking except for the 10<sup>th</sup> percentile; however, in real terms, inflation-adjusted average annual wages in the tool, die, mold, jig, and fixture industry have only grown for tool and die workers at the 75<sup>th</sup> percentile.

*Figure 9: Inflation-adjusted Average Annual Wages for Tool and Die Workers, Tool, Die, Mold, Jig, and fixture Manufacturing, 2009 & 2015*



Source: U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment Statistics, May 2008 and May 2016.

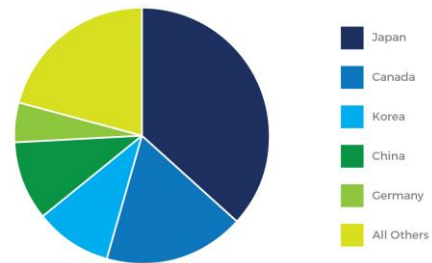
Automakers, parts suppliers, and independent tool and die shops that service the auto industry all report challenges in hiring, and that it is difficult to find qualified and motivated individuals to train. Since demand has grown, so too has the move to hiring experienced tool and die workers from other companies. There are pitfalls to this approach, however. One large supplier executive noted that, “we steal them from other companies—but everyone comes with their own culture and way of doing things.” Even with experienced hires, firms need to train in their own unique processes and procedures. Several smaller tool shop owners reported another pitfall: that they invest in apprenticeship training, only to see the worker move to a larger employer for more pay or better benefits. In speaking about this issue, one tool shop owner lamented, “there’s no loyalty anymore.” The auto industry’s demand for low global tooling prices make it difficult for smaller shops to compete with compensation packages offered by automakers and larger tier 1 suppliers.

**Challenge 3: Trade Impacts and Purchasing**

An unexpected finding in this research was that automakers’ and suppliers’ purchasing decisions are playing a role in eroding skilled trades talent development. Since the early 2000s, there has been consistent pressure for automotive tooling firms to build tools, dies, and molds at “China price.” Few firms could meet these lower prices and continue to produce a large portion of their tooling in the United States, so the tool build phase has been largely offshored to China and other low-cost countries. One respondent mentioned that there are times when a tool built offshore “is cheaper than just buying the components in the United States.” China is the third largest importer of tool and die for metal cutting—with \$53B in imports for consumption in 2016. The dollar value of China’s 2016 tooling

imports was 4.3 times larger than imports from that country in 2009.

*Figure 10: Imports of Metal Cutting Dies, 2016*



Source: (U.S. International Trade Commission, 2017)

A result of offshoring of tool and die build is that the size of the entire U.S. tool and die industry has been nearly cut in half, while automotive tooling capacity in low-cost countries has ramped up. While the “China price” is often cheaper, the product often needs to go through tryout and be modified or repaired before it can go into full-scale production in the United States.

Automotive tooling customers want low prices, but they also want U.S. quality standards and local die maintenance and repair. Several of the tooling suppliers interviewed for this research report that the skillsets in low-cost countries are not as developed as in the United States. This means the offshore-built tool will be shipped back to a U.S. tool shop to fix and support it in production. This business model has been working, but is not sustainable over the longer-term. As one respondent said, “We’re OK now, but won’t be when everyone retires or dies. If the upcoming generation never made a tool, how can they fix it?”

The U.S. tool shops that remain have largely survived because they are pursuing a strategy that takes China into account. There are three basic strategies: (1) design in the United States, build in China, do tryout and launch support in

the United States; (2) a hybrid variant of the first strategy where some tools and dies are built domestically, and some offshore; and (3) do virtually no design and build in the United States, and specialize in tryout and launch support for tools and dies when they come back from China. Both the first and third strategies are valid strategies in the short-term, but long-term—absent sufficient orders for domestic builds (coupled with an aging automotive tool and die workforce)—the industry will soon run out of people who know what needs to be done to make these tools work in tryout and production.

This is not a simple problem that training can solve—without the on-the-job training in tool and die build (e.g., strategy 2), it is nearly impossible to produce a journey person tool and die maker or machinist who can support tryout, launch, and production utilizing imported dies.

### ***Section III: Recommendations***

Tool and die is facing a talent crisis, and it involves issues so large that no one company can solve on its own. The automotive industry—motor vehicle manufacturers, parts suppliers, and independent tool shops—need to collaborate with each other and partner with community and technical colleges and other training providers to prepare the future skilled trades workforce.

#### ***Address Training and Apprenticeships as a Common Good***

The U.S. model where every firm invests in training its own apprentices has limitations. Smaller firms that invest in training and apprenticeships find they have difficulty retaining talent in an environment where larger firms that offer better compensation are hiring away their experienced tool and die makers. Global competition and customer pricing pressures make it difficult for these small firms to offer

more competitive compensation packages, and they cannot sustain their businesses without the ability to realize the full return on their training investments. What is more, independent tool and die shops are typically small employers, and only hire and train a few workers at a time. Going it alone in training can be costly at such a small scale. Recognizing that the entire automotive industry benefits when any firm invests in hiring and training tool and die apprentices, a collaborative approach to funding these critical investments would be beneficial. There is a role for industry partnerships and associations, as well as for federal and state governments, to support ongoing investment in apprenticeships. International models may provide insights and best practices, but are often part of a larger educational system that cannot be easily adapted or transformed for use in the United States.

#### ***Build Stronger Industry Partnerships with Community and Technical Colleges***

Skill needs are changing rapidly, and many companies and smaller shops are struggling just to keep up with training their incumbent workforce and new apprentices. Community and technical colleges are critical partners in apprenticeship programs, but colleges find it challenging to discern which future materials and processes will be in use in the industry, to hire and retain instructors who are current with the industry's technological advancements, as well as to invest in equipment required to train students. Several respondents told CAR that they see a large disconnect between industry and community and technical colleges—one so large that it would take a group of firms working in concert with colleges to address.

#### ***Strategic Direction***

Outside of the automakers' apprenticeship programs and colleges' own technical advisory

councils, there are no formal feedback loops to infuse state-of-the-art training and equipment into the curricula for training future apprentices. Industry-wide forums could be employed to convey the automakers' and suppliers' overall strategic direction to colleges, other educational institutions, and training organizations.

### *Instructors*

It is becoming more difficult to hire instructors for skilled trades training and apprenticeship programs. While pay and benefits adjustments may make the position more attractive, the whole model may need to shift to the use of adjunct professionals—relying on those currently working in the industry—to teach in these programs. This will require a commitment from industry to support these types of employment arrangements for incumbent workers.

### *Equipment*

On the equipment side, educational providers often utilize used equipment that industry has donated, or they fund purchases of new equipment with grant dollars. Used equipment may be better than what the college currently has, and the grant process introduces a delay in the acquisition; however, neither method offers a way to stay current with the pace of change in industry. One automaker that participated in this research placed their training cell for incumbent workers at a local community college site. The college's instructors have access to the most current equipment at no cost, but require some support from the automaker to design training that utilizes the cell. While industry prefers to train their workforce on the specific equipment and configurations they use in manufacturing, respondents recognize that the vast majority of equipment-specific training is transferrable to other equipment made by different manufacturers.

### *Change Industry Practices*

Current purchasing practices affect the ability to meet future demand for tool and die workers. Sourcing more tooling builds domestically will allow there to be sufficient work to utilize in training new apprentices. Since it takes up to a decade to train a journeyman tool and die maker, this would not be a short-term change. This commitment may mean higher prices for those domestically sourced tools, but without the work in-house, it is impossible to train future tool and die workers in the United States.

Second, the forecast of future tool and die build hours required to support new product launches and model refreshes would be changed if productivity improvements were made that allow the tool and die workforce to support greater output with fewer worker-hours. Productivity can be improved through intra- and inter-company standardization of processes, die inserts, fasteners, and greater process control at materials suppliers. In addition, implementation of problem solving approaches that prioritize critical adjustments to achieve dimensional tolerance of the overall part or assembly can increase throughput and reduce the number of tooling build hours required to support planned product launches and refreshes.



**CONCLUSION**

The current crisis in tool and die is only going to become more severe as the automotive industry prepares to launch record numbers of new and refreshed models over the next few years. The industry needs to attract younger people to careers in the trades, and support training for smaller firms that struggle to retain their workforces in this hot employment market.

Economic developers, community and technical college leaders, and the workforce development practitioners in automotive communities need to be aware of these issues, and work with their local industry and tool shops to address the skilled trades recruitment and training needs that could put a damper on the auto industry's future product cadence and sustained employment levels.

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