PolymerOhio, Inc.

Technology Roadmap of Plastics and Rubber Molding in Ohio

A final report and roadmap presented to:

Ohio Advanced Manufacturing Technical Network

and

Ohio Manufacturing Institute

10/15/2014

Purpose

Previous studies by the Ohio Manufacturing Institute (OMI) showed a vast network of technical resources in Ohio to support manufacturing companies. These resources are operated by universities, academic institutions, technical organizations, industry organizations and non-profit entities. However, utilization of these resources varies considerably by type of manufacturing organization, industry segment and strategic intent. OMI proposed formation of the Ohio Advanced Manufacturing Network to provide a range of support services to manufacturers of all types, sizes, and markets to help them grow and expand. This network would develop and implement an industry-driven strategy to:

- Develop mid and long-term technology roadmaps
- Develop proposals for collaborative research
- Evaluate the statewide technical support structure and resources, and
- Propose future technical support additions and enhancements.

The Ohio Advanced Manufacturing Network took a novel approach to analyzing the manufacturing industry by choosing to examine key processes rather than industry verticals (as defined by industrial segments).

The first step is development of mid and long-term technology roadmaps to develop a collective and clear industry-driven strategy and message. The roadmaps would be generated with broad industry input and validated by a broad range of industry participants. It is anticipated these roadmaps will improve alignment between industry needs and state technical resource offerings; and inform and influence government funding for pre-competitive technologies. This report presents the findings from preparation of the Molding roadmap.

Plastics and rubber molding is one of the most common manufacturing processes in Ohio's industry. Depending upon the measurement scale, e.g., employment, industry revenue, pounds of material processed, Ohio is one of the largest polymer processing states in the USA, consistently ranking first, second or third. Therefore, maintaining the health and well-being of Ohio's molding industry is a key to Ohio's continued economic health.

Scope

Molding is the process of manufacturing by shaping liquid or pliable raw material, generally by using a rigid mold. While molding processes are utilized in a variety of materials including ceramics, concrete, metals, etc., the most commonly considered molding processes are associated with polymeric materials including thermoplastics, thermosets and rubber. Figure 1 shows the wide range of molding activities conducted by Ohio manufacturers by material, process and industry sector.

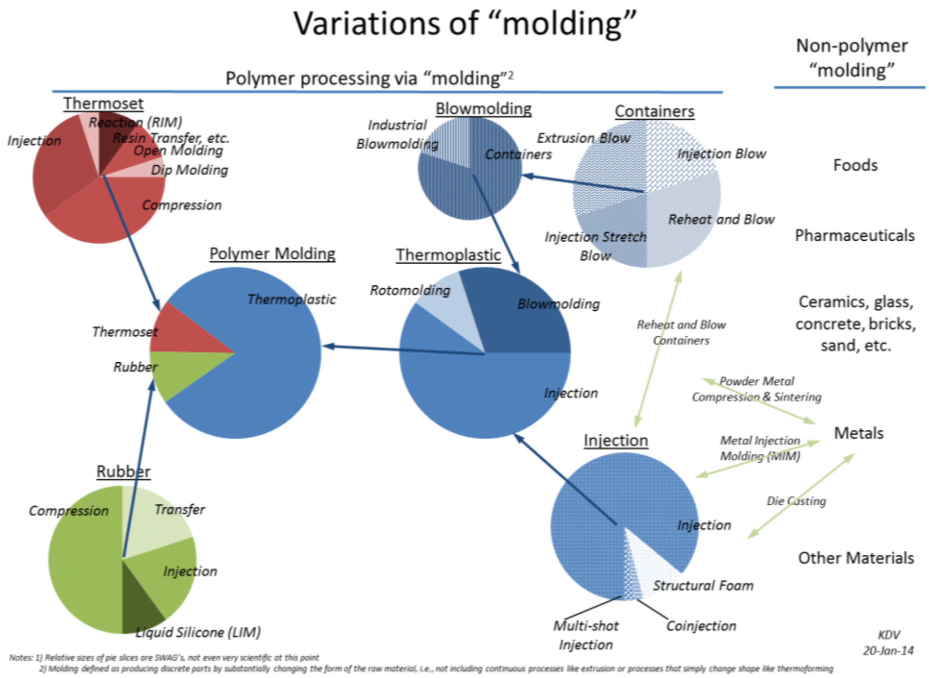

Figure 1 - The universe of "molding"

Development of a roadmap for such a diverse population of manufacturing entities would be problematic. Thus, the scope for this technology roadmap was narrowed to polymer molding and on the following particular segments of polymer molding:

- Injection molding of thermoplastics
- Blow molding of thermoplastics
- Molding of thermoset materials in a variety of methodologies
- Molding of rubber in a variety of methodologies

Therefore this roadmap excludes continuous polymer processing such as extrusion or pultrusion, shape-changing processes like thermo- or vacuum-forming, and specialty processes like rotational molding. Although these other processes are not specifically included in this roadmap, they all share many of the same issues as the primary polymer molding processes.

Situation Analysis

Besides the dimensions of materials and process, molding businesses, or "molders", are often divided into two major categories – captive or proprietary molders and custom molders. Captive or proprietary molders are those processors who primarily produce plastic or rubber parts for their own sale or use, either internally or corporately. For example, the Whirlpool molding plant in Clyde producing appliance components or the Step 2 operations that mold toys for the retail consumer market are captive or proprietary molders. These molding operations own the molds and control the design and specifications of the parts produced. Often these captive operations produce only a portion of their needs, relying on outside molders to provide the balance and absorb the ebbs and flows of economic fluctuations. By

PolymerOhio estimates, captive or proprietary molders represent 20-30% of molding operations. Captive operations tend to be larger in terms of production volume than custom molders.

Custom molders, on the other hand, produce plastic or rubber components for the use of industrial customers, typically OEM's or original equipment manufacturers. The level of service or involvement of custom molders varies but typically their customers control the design and specifications of the parts and own the molds. In some cases customers even purchase and supply the raw materials, plastic resin or pellets. These custom molders simply provide the service of converting plastic pellets into formed parts.

The business of custom molding is highly competitive since there are a great number of them, in the range of 5-10,000 custom molding businesses in the USA. (Some sources cite a number of about 15,000 when including compounders, extrusion, and others.) The business of custom molding can be very much a commodity business in the cases where customers own the molds and the design. With the large number of potential suppliers, competition on price is often cutthroat. The more successful custom molders are most often those that have focused on providing a well-defined value offering and are able to differentiate themselves from the mass of commodity custom molders. Some examples of these differentiated custom molders would be the molder focused on providing components to aerospace customers using ultra-high performance polymers, the molder focused on providing automotive customers' under-the-hood air handling systems, or the molder focused on providing high-quality large, flat parts for short-run, quick-turnaround applications. These differentiated molders still face competition but a much smaller subset of the custom molding universe and they are able to demonstrate value and to be reasonably compensated for that value. Naturally these differentiated custom molders are on the higher end of the spectrum of technical capability, often having more unique processes, equipment and capabilities.

Unfortunately, only a small percentage, perhaps 10-20%, of the custom molders have made the effort and been successful at identifying and developing a unique competency that would differentiate them from the mass of custom molders. The bulk of the custom molders are, therefore, commodity custom molders and are stuck in the squeeze of pricing, since their customers have many similar choices. Customers for these molders want a certain level of quality and service but are continually squeezing prices paid for molding by playing off molders against each other.

These commodity custom molders tend to have a similar profile. They tend to have a very short-term focus, concentrating on today's customers and orders. They do little planning and are stretched financially, so that they do not have the resources to invest in new capabilities for tomorrow's possibilities. Any development effort that they undertake is focused on today's problem on the shop floor. They are driven by requests or demands of current customers and current business.

Molding companies are often entrepreneurial, managed by the owner. They are generally small companies with 30-40% of them with less than 50 employees or around 75% with less than 100 employees. This is another reason for the constraint on resources.

Plastic molders are a part of an extensive value chain that converts raw materials, typically petrochemicals, into components for OEM's or products for consumers. Figure 2 illustrates the typical supply chain used by a molder to gather together the necessary materials and capability to produce molded parts. Molders typically purchase their primary raw material, plastic resin or rubber compounds, from a compounder who prepares the materials with the proper additives. Sometimes additives are mixed during the molding process.

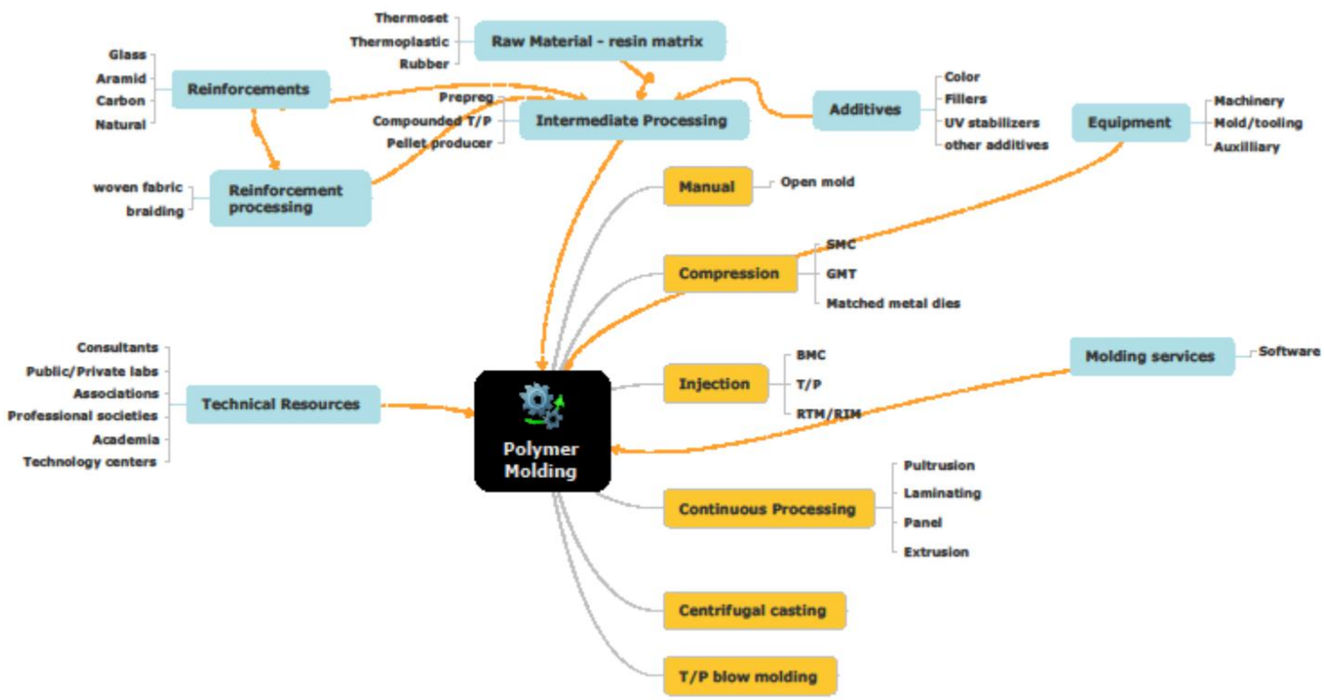

Figure 2 - Supply chain for polymer molding

Depending on the capability of the molding operation, tooling (molds) might be designed and built by a molder. More typically the molds are designed as an extension of the part design, and molds are procured and owned by the customer. This industry structure is a part of the leverage that results in price pressure on the commodity custom molder as business and molds can be easily pulled from one molder and sent to a lower-priced source at little cost when the molds are owned by the customer.

At the same time that molders are being squeezed for price they are placed under demand for more capability and services. Customers of molders are trying to be lean and cut costs, so they are pushing molders to for shorter production runs and to provide more services such as inventory control, testing and quality management and documentation, design services, etc. Customers are also demanding higher levels of quality and more variety in parts, all of which increases the complexity and processing demands on the molder.

Most molding operations have some focus as they typically are centered around one process or a narrow range of processes and one family of materials, i.e., either thermoplastics, thermosets or rubber. This focus is a result of limitations on the range of knowledge and the high capital costs associated with molding equipment. Equipment is designed and dedicated specifically for one process and very seldom can cross over between the families of materials.

Molding operations often do not self-identify as such, presenting some difficulty in defining and counting molders. Often a molder might identify as a producer of parts in the primary industry served. For example, many molding operations that produce primarily for the automotive industry identify themselves as auto parts producers rather than as plastic or rubber parts producers. This is often the case for molders serving other markets such as appliance, toys, housewares, etc. This is the case even when the primary process utilized is plastic or rubber molding. Therefore, using data such as census data to estimate the size of the molding industry is erroneous, as companies identified as plastics or rubber producers are only those that are custom molders serving a broad market.

In Ohio there are estimated to be in the range of 1,500 (+/-) polymer molding operations. Of these, several hundred companies are strictly compounders, part of the supply chain serving the product-producing polymer processors. Several hundred of the polymer processors are involved in continuous production processes such as extrusion or pultrusion. There are estimated to be 1,000-1,200 molders in Ohio in the categories defined for this roadmap. Of these, there are estimated to be about 50-75 blow molding operations, 200 +/- rubber molders, 250 +/- thermoset molders, and 500-600 thermoplastic injection molders.

The technology of molding is embodied in two areas - materials and process, neither of which develop nor advance quickly as compared to some other industries. The materials technology is largely polymer chemistry, much of which is developed and controlled by the large materials companies. The process technology is a combination of the technology embodied in machinery and equipment and the know-how of the molding operation. The technology embodied in machinery and equipment (mainly process control capability) continuously evolves, however it tends to move into the industry slowly. The progressive and profitable molding operations replace machinery on a rolling cycle that might be five to seven years in length. More typically, the resource-constrained majority of molders have equipment in place that could be twenty or more years in age. Thus these molders are slow to see new processing or control technology.

Overall, the community of molders is not an aggressive seeker of innovation and technology developments, rather they respond to immediate or short term needs. It is the exception that forms a subsidiary to develop and offer new molding technology, such as additive manufacturing services, or pursues cutting-edge materials or processing technologies. When molders due pursue technology needs, they generally find assistance from the following, in order of preference:

1. Material supplier – often the challenges that is faced has to do with processability or with material properties. The larger material supplier, especially, are quick to provide advice as part of the value that they provide to molders.

2. Equipment suppliers -for certain processing issues and for many new molding processes, the equipment suppliers provide advice and assistance. This might be “hand holding” during the start-up of two-shot molding or in-mold labeling, for example.
3. A network of contacts – molders will frequently have a list of contacts that they have gathered over the years who they believe to be knowledgeable. These might be consultants or service providers but are frequently a contact at another molding shop.
4. Academic institutions or technical centers – generally molders are looking for quick, practical advice and not a development program so they are not likely to consider academic institutions as a source of assistance.

Our survey of molders confirmed these practices. When asked to rank on a scale of 1 to 6 the most important sources of technical assistance, molders ranked the sources as follows:

	Technical assistance source	Average ranking	% ranking #1 or #2
1.	Material supplier	2.282	67%
2.	Equipment supplier	3.051	39%
3.	Friends and business associates	3.462	36%
4.	Consultants	3.692	23%
5.	Trade and professional associations	4.231	18%
6.	Academic institutions	5.205	5%

Technology Gaps and Barriers Analysis

Successfully operating a molding business requires a core of knowledge and experience in many areas but especially in polymer chemistry and in machinery operation (processing) and maintenance. The technology challenges and opportunities for molders can be divided into four main categories, as follows in priority order.

1. Efficiency
2. Workforce
3. Speed
4. Niche or Specialized Technologies

Based on industry interviews, focus groups and industry surveys the priority of these technical needs have been established as shown below. (For more detailed results from the survey of molders, please see the appendix.) All four of these major categories show up as challenges for most molding operations, but they present themselves in different ways. The first three categories – efficiency, workforce and speed - are generic challenges faced by most industrial companies. The fourth, niche technologies, is dependent upon the focus of the molding operation, often driven by demands of the molder’s customers and their applications. Our industry survey confirmed these findings. When asked to rank the most important of these items, the industry responded as follows:

	Issue	Ranked as top priority
1.	Efficiency of operation	28.2%
2.	Qualified workforce	35.9%
3.	Speed of response	30.8%
4.	Specialized technology needs	5.1%

These challenges and opportunities typically present themselves in the following ways.

Challenge	Discussion
1. *Efficiency* 1.1. Ability to control or reduce cost of material 1.1.1. Cost of material 1.1.2. Scrap rate / material loss in process 1.1.3. Recycling (especially in rubber and thermoset molding) 1.2. Ability to schedule production effectively to meet customer requirements 1.3. Ability to improve cycle times or molding process efficiency 1.4. Ability to effectively apply automation 1.5. Ability to control overall manufacturing process and costs	Due to the industry structure, the number of competitors and the fact that so many molders are custom, commodity molders, they are faced with tremendous price pressures. Therefore, the need to continually seek improvements in efficiency and cost reduction is highest on their list of priorities.
2. *Workforce* 2.1. Lack of qualified process technicians 2.2. Lack of workers (e.g., entry-level machine operators) with basic STEM (e.g., math) skills 2.3. Lack of workers with soft skills and willing to work in manufacturing 2.4. Lack of qualified multi-craft maintenance workers 2.5. Shortage of qualified toolmakers	As is the case with much of manufacturing, there is great difficulty in finding qualified and capable workers ready to work in manufacturing. Experienced and knowledgeable workers are reaching the age of retirement and not being replaced through training programs.
3. *Speed* 3.1. Ability to respond to and ship orders more quickly 3.2. Ability to develop products and prototypes more quickly 3.3. Keeping a short supply pipeline 3.4. Designing new parts more quickly	Customers of molders are demanding more capability and quicker turnaround from molders. This pressure shows up in product development, in manufacturing startup and in on-going production
4. *Niche or specialized technologies* (some typical examples but not exhaustive) 4.1. Developing new materials and material capabilities 4.1.1. Developing lighter weight, stronger materials / components 4.1.2. Developing or incorporating multi-functional materials 4.1.2.1. Incorporating or improving	All molders face specific technical challenges unique to polymers and polymer processing and their particular customers and applications. Because of the broad diversity in molding, many of these niche technologies apply only to a

conductive or insulating properties

4.1.2.1.1. Electrical

4.1.2.1.1.1. Electrically conductive

4.1.2.1.1.2. Electrically insulating

4.1.2.1.2. Thermal

4.1.2.1.2.1. Thermally conductive

4.1.2.1.2.2. Thermally insulating

4.1.2.1.3. EMI shielding

4.1.2.2. Photonic, thermal, etc. properties

4.1.2.3. Improving physical properties such as durability, resistance to dirt, etc.

4.1.3. Bio-materials & sustainability

4.1.3.1. Incorporating bio-derived materials

4.1.3.2. Utilizing compostable materials

4.2. Process development or evolution

4.2.1. Developing or utilizing in-mold decorating or in-mold labeling capabilities

4.2.2. Developing or utilizing multi-material molding capabilities

4.2.2.1. Over-molding or multi-shot molding

4.2.2.2. Co-injection

4.2.3. Incorporating molding into assembly process

4.2.3.1. Electronics encapsulation

4.2.3.2. Expanding use of insert molding

4.2.4. Implementing micro-molding capability

handful of molders that serve a particular niche application.

Molding Technology Roadmap – Action Plan

The potential solutions to these technology challenges and opportunities are widely varied. In many cases the solutions are not new technology but rather awareness and application of existing technology by molders. Molders are often constrained by lack of resources, either financial or manpower, from discovering or implementing new or improved technologies. Following is a list or proposed approaches (indicated by alphabetical bullets and *italic text*) to each of the numbered challenges shown above.

1. Efficiency

1.1. Ability to control or reduce cost of material

1.1.1. Cost of material

A. Development of new polymer materials with lower raw materials or process costs

B. Negotiate lower material pricing with buying groups, etc.

C. Part redesign for material reduction e.g. thinner walls, etc.

1.1.2. Scrap rate / material loss in process

A. Increased training of process technicians.

B. Improvements in processing capability of equipment

1.1.3. Recycling (especially in rubber and thermoset molding)

A. Development of processes to utilize rubber or thermoset scrap

B. *Development of de-polymerization process for rubber and thermoset materials*

1.2. Ability to schedule production effectively to meet customer requirements

A. *Development and utilization of more advanced information systems and modeling softare to improve management control and decision making*

1.3. Ability to improve cycle times or molding process efficiency

A. *Improvements in equipment and process control systems*

B. *Implement automation to reduce cycle times*

C. *Development of faster reacting thermoset materials combined with quicker processes*

1.4. Ability to effectively apply automation

A. *Develop lower cost automation solutions*

B. *Develop more intelligent or self-learning automation controls*

1.5. Ability to control overall manufacturing process and costs

A. *Development and utilization of more advanced information systems to improve management control and decision making*

B. *Transition to servo-driven machines and other energy-saving systems and procedures*

2. Workforce

2.1. Lack of qualified process technicians

A. *Increase availability and quality of CareerTech and post high school technical training*

B. *Move to equipment with more intelligent controls*

C. *Improved recruitment tools*

2.2. Lack of workers (e.g., entry-level machine operators) with basic STEM (e.g., math) skills

A. *Improve primary and secondary education systems*

2.3. Lack of workers with soft skills and willing to work in manufacturing

A. *Change societal norms*

2.4. Lack of qualified multi-skill maintenance workers

A. *Increase availability and quality of CareerTech and post high school technical training*

2.5. Shortage of qualified toolmakers

A. *Increase availability and quality of CareerTech and post high school technical training*

3. Speed

3.1. Ability to respond to and ship orders more quickly

A. *Implement tools and procedures for quicker mold changes*

B. *Implement ERP systems across supply chain*

3.2. Ability to develop prototypes and first production parts more quickly

A. *Utilization of more advanced design and process simulation tools*

B. *Utilize 3-D printing for prototypes*

C. *Utilize 3-D printing for mold components*

3.3. Keeping a short supply pipeline

A. *Improve systems and ability to communicate with both customers and supply chain*

3.4. Designing new parts more quickly

A. Develop or implement design tools integrated with the manufacturing process

4. Niche or specialized technologies (some typical examples but not exhaustive)
   4.1. Developing new materials and material capabilities
      4.1.1. Developing lighter weight, stronger materials / components
         A. Develop or implement new materials and composites
         B. Greater use of foaming agents, gas-assist and other such processes
      4.1.2. Developing or incorporating multi-functional materials
         4.1.2.1. Incorporating or improving conductive or insulating properties
            4.1.2.1.1. Electrical
               4.1.2.1.1.1. Electrically conductive
                  A. Develop or implement new materials and composites
               4.1.2.1.1.2. Electrically insulating
                  A. Develop or implement new materials and composites
            4.1.2.1.2. Thermal
               4.1.2.1.2.1. Thermally conductive
                  A. Develop or implement new materials and composites
               4.1.2.1.2.2. Thermally insulating
                  A. Develop or implement new materials and composites
            4.1.2.1.3. EMI shielding
               A. Develop or implement new materials and composites
         4.1.2.2. Photonic, thermal, etc. properties
            A. Develop or implement new materials and composites
         4.1.2.3. Improving physical properties such as durability, resistance to dirt, etc.
            A. Develop more scientific approach to textures and surface properties
            B. Develop nano-composites with tailored properties
      4.1.3. Bio-materials & sustainability
         4.1.3.1. Incorporating bio-derived materials
            A. Develop or implement new materials
         4.1.3.2. Utilizing compostable materials
            A. Develop or implement new materials
   4.2. Process development or evolution
      4.2.1. Developing or utilizing in-mold decorating or in-mold labeling capabilities
         A. Find or develop expertise in IMD or IML
      4.2.2. Developing or utilizing multi-material molding capabilities
         4.2.2.1. Over-molding or multi-shot molding
            A. Invest in equipment, find or develop expertise
         4.2.2.2. Co-injection
            A. Invest in equipment, find or develop expertise
      4.2.3. Incorporating molding into assembly process
         4.2.3.1. Electronics encapsulation
            A. Find or develop expertise in encapsulation

4.2.3.2. Expanding use of insert molding

A. Find or develop expertise in insert molding

4.2.4. Implementing micro-molding capability

A. Find or develop expertise in micro-molding

Conclusions

The molding industry has many technical issues and challenges. The broad challenges are those faced by all manufacturing – workforce, efficiency and speed. Clearly there is a need for training programs to support the needs of the industry for a qualified workforce. In the areas of efficiency and speed there are technologies currently available that are not widely used because of the size and resources of typical molding operations. The challenges that are specific to the polymer molding industry are highly diverse and specialized to specific applications. This presents a particular challenge for industry technology development since specific technologies are often applicable only to a handful of companies and these companies are often small and resource-constrained. This does not mitigate the need for technology development in materials and process, it simply makes it more difficult to identify, prioritize and support meaningful technology development at the small molder level.

One technology that does stand out is additive manufacturing or 3-D printing. Molders currently see the application of 3-D printing for quick development of prototypes or for economically producing intricate mold inserts. 3-D printing is also seeing some applications for very low volume manufacturing of more complex parts. As the technology develops for 3-D printing, it is likely that this process will move upwards in the scale of volume, displacing some low-volume molding applications.

Appendix

Roadmap Development Process

The research and analysis for this roadmap was largely conducted by a staff member of PolymerOhio with more than 20 years of experience studying and advising in the polymer molding industry, bringing a deep and intimate knowledge of the industry. This roadmap was developed using a multi-phase approach as follows. Between each phase, "strawman" lists of challenges and opportunities were developed to capture and communicate with the various audiences.

1) Secondary research and interviews of industry leaders – a review of articles and discussions with various industry leaders on an international basis to gather input on current topics and issues in molding
2) Interviews of molders – discussions, led by an industry expert, with a random selection of molders via both focus groups and phone interviews to gather input as to technology issues, challenges and opportunities in molding

3) Interviews of supply chain and technology sources – interviews by an industry expert with material and equipment suppliers to the molding industry and academic and research organizations involved in supporting the industry
4) Survey – a broader web-based survey of molders to confirm and prioritize the challenges and opportunities in molding
5) Publication

Summary of Industry Survey Results

An industry survey was developed to confirm and prioritize the input gathered through interviews and focus groups. Molders were invited to participate in the survey using both the PolymerOhio database and the list of molders of the accounting firm, Plante Moran. The survey was a combination of ranking questions and verbatim questions to gather information regarding technology challenges and issues. The major questions and the average rankings are shown below. Respondents were asked to rank order all options in each question.

<u>Most critical technical issues for molding operations</u>

	Average ranking	% ranking #1
1. Efficiency of operation	2.256	28.2%
2. Qualified workforce	2.308	35.9%
3. Speed of response	2.333	30.8%
4. Specialized technology needs	3.436	5.1%

As expected, efficiency, workforce and speed are the highest rank issues and are all quite close in ranking.

<u>Elements of efficiency that present the greatest challenge</u>

	Average ranking	% ranking #1
1. Ability to control scrap or recycle	2.806	19.4%
2. Ability to schedule production	2.833	27.8%
3. Ability to control or reduce cycle times	2.972	19.4%
4. Ability to apply automation	3.389	11.1%
5. Ability to control cost of energy	3.417	19.4%
6. Other elements of efficiency	5.583	2.8%

As customers of the molders attempt to reduce inventory and drive down costs, schedules change more rapidly. Small molding operations are limited in flexibility and do not have effective tools to respond to schedule changes.

<u>Greatest challenges in developing a qualified workforce</u>

	Average ranking	% ranking #1
1. Finding qualified process technicians	2.135	43.2%

2.	Finding machine operators	2.189	32.4%
3.	Finding qualified maintenance workers	2.973	8.1%
4.	Workforce turnover	3.243	10.8%
5.	Other workforce issues	4.459	5.4%

Qualified process technicians or mold set-up technicians is an especially large problem as these are the people that have the greatest impact on quality and productivity in the plant. Finding a technician with training and experience is a difficult task in the molding industry.

<u>Elements of speed most critical to the molding operation</u>

		Average ranking	% ranking #1
1.	Response to changing orders	2.432	37.8%
2.	Providing prototype or first run parts	2.514	27.0%
3.	Keeping a short supply pipeline	2.514	18.9%
4.	Designing new parts quickly	2.757	13.5%
5.	Other elements of speed	4.784	2.7%

Molders are pressed by customers to respond quickly to new orders or to schedule or production changes.