Reducing Scale-Up Risk: A Case For Modular Construction

Liz Moore ▪ RAPID Manufacturing Institute®

Circular economy, net-zero, supply-chain uncertainty: all phrases that went from being buzzwords to front and center in just a few years. Whereas traditional product development and approval cycles have been measured on the scale of years to decades, the UN Climate Change Conference in Glasgow (COP26) called for an immediate need to reduce industrial emissions. These factors make it all the more challenging for process developers and chemical engineers to implement new strategies that will make the best use of resources and continue to meet the changing needs and wants of consumers around the world. It stands to reason that these dynamic conditions will drive the need for new technologies and processes to be developed quickly. Modular construction is one strategy to accelerate progress within aggressive timelines.

After that "eureka!" moment happens in the lab, a whole new adventure begins. Finding an application for a technology, understanding the market potential, receiving regulatory approvals, and identifying and assessing any other necessary upstream and downstream technologies to complement the process and facilitate the development of a commercially viable system can be just as much, if not more, of a challenge than realizing the initial discovery. Technical and nontechnical parameters need to be understood.

Many factors can make or break deployment of even the best ideas, for example, the nuances of supply chain logistics when sourcing raw materials in relation to the chosen market. The reality is that we don't, and can't, know everything. Whether out of necessity or convenience, every scientific or engineering endeavor comes with its own set of assumptions. These assumptions have a tendency to reappear later in the project as risks that must be mitigated.

Identifying and implementing industrially relevant conditions and materials in the technology development process as soon as possible is one best practice that can be used to address these risks. It is critical to take a conscious inventory of differences in the technology development environment compared to the intended industrial environment, ranging from ambient temperature swings to differences in altitude and therefore boiling points. Although some field engineers will tell you that the best tool for the job is whatever is within reach, more thoughtful consideration is needed before identifying what to scale up and how.

Determining the applicability of a known tool in an unknown environment should be considered before incorporating it into a new system. From power requirements to materials of construction, a myriad of decisions must be made. A process that is mass-transfer dominated at one scale or in a certain geometry may be heat-transfer dominated in other configurations; thus, it is important to remember fundamentals when considering scale-up options. Impacts of wall effects in small-scale fluid flow will be negligible at larger scales. Be aware of which correlations hold in which regimes, and when you are beyond those conditions.

Many of the products we use in our day-to-day lives have evolved from a batch experiment to a batch process, and in some cases to an industrial-scale continuous process. Skipping steps in process scale-up is a known risk, so finding ways to accelerate through these steps is one strategy to meet society's changing needs.

Process scale-up must be done thoughtfully in order to develop a robust industrial process. By targeting a lower process throughput, the orders of magnitude that a process needs to be scaled up can also be reduced. Multiple trains at a reduced throughput, also known as "numbering up," can bring a process up to its intended throughput quicker than constructing a single larger facility. Additionally, decreasing the size of each piece of equipment helps to relieve constraints that are often found when trying to source large items that can only be fabricated by a few companies worldwide.

The logistics around transporting these smaller modules, not only from the vendor to the site but even from a truck or train to its final installed destination, may be very challenging. However, altogether avoiding the need for large quantities of raw materials, over-dimension ground transportation, and tower crane availability are just a few of the many constraints that can be mitigated by modular construction. Additionally, being able to isolate single trains during (intended or unintended) outages, or to maintain ideal operating conditions by bringing trains on or offline depending on demand, are just a few of the many inherent benefits of this numbering-up strategy. In order to continue to make the best use of our resources, new strategies such as modular construction must be considered. CEP