GOING LEAN:
TOWARD WASTE-FREE BUILDING

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BUILTWORLDS INSIGHTS + Skender

INTRODUCTION

A recent report produced by Transparency Market Research projects that the world will generate nearly 2.2 billion annual tons of solid waste by the year 2025, up from 1.3 billion tons in 2012. Astonishingly, it is estimated that nearly **half of that waste is generated on the construction job site**. What's more, solid waste is only the tip of the iceberg; inefficiency in the built industry runs much deeper than the billions of tons of wood, asphalt, concrete, and other physical byproducts from the construction of our homes, office buildings, schools, and roads.

Waste permeates throughout the entire construction lifecycle, taking the form of time delays, rework to address defects, unnecessary processing of materials, idle equipment, and more. Wasteful production, in any form, carries significant consequences not only for the profitability of the AEC industry, but also for the productivity and safety of our construction workforce, for the supply-and-demand chains that drive our economy, for the efficacy of our transportation networks, and for our collective environmental well-being.

Why is the construction industry particularly susceptible to wasted resources and time? By nature, the building process is a complex, context-specific endeavor. Different types of projects require their own set of workflows, stakeholders, and schedules. For that reason, it can be difficult to establish consistent procedural workflows within construction, design, and engineering companies.

Each step of the building process is dependent on its preceding step, and any changes to schedules or plans requires intricate planning and communication between owners, developers, architects, engineers, general contractors, subcontractors, workers, suppliers, transportation service providers, field service technicians, and municipal building departments. Damaged materials that require rework, inefficient processing and transport of those materials, disjointed coordination with material and equipment suppliers, and other delays can lead to a build-up of excess inventory and an overall inefficient allocation of worker hours. In short, if anything goes wrong on a given project (and we all know that something always goes wrong), the domino effect is costly.

The construction industry also faces new pressures. Rising cost of materials, trade tariffs, and an acute labor shortage have exacerbated the consequences of wasteful project delivery. To make matters worse, the industry has been comparatively slow to adopt the emergent technologies that can help to 'trim the fat' from internal processes (check out another BuiltWorlds research report, The Key to Construction Productivity, to learn more about digitization in construction, and how software platforms are evolving to improve communication and collaboration within construction companies). In this report, we will explore how some of those digital tools fit into the broader practice of **lean construction**, a set of principles born from the manufacturing sector that is helping to eliminate waste from the end-to-end design and construction lifecycle.

WHAT IS LEAN THINKING?

The concept of lean production originally stemmed from the notion that 'science' should be applied to the management of the manufacturing production line. In other words, firms should take more explicit care in considering how the specific actions and motivations of their workers affect their processes, and in turn how those processes affect the outcomes of their businesses. By standardizing how employees go about their tasks, not only could managers gain a more clear and granular understanding of how their production lines function, but they could also identify and eliminate any unnecessary, repeated, or otherwise wasteful steps in production. This line of thinking was famously, albeit somewhat imperfectly, applied on Henry Ford's automobile production line in the early 20th century.

Ford's early approach to lean production in the manufacturing sector was further refined over time, and notably shaped the renown Toyota Production System (TPS), a model that would later come to set the standard for lean principles. TPS was based on the idea that continually refining project delivery would eventually produce optimal results. It set out to reduce the burden on workers, eliminate inconsistency, and minimize wasted resources, and it accomplished this by three primary means: transitioning from a 'push' to a 'pull' inventory approach, leveraging automated technology, and maximizing human capital.

Traditionally, production is based on 'pushing' inventory that has already been produced; TPS signaled a shift toward production based on the 'pull' of actual consumer demand. In other words, "making only what is needed, only when it is needed, and only in the amount that is needed," (this concept is known as 'Just In Time Production' within TPS). Additionally, Toyota championed the idea of "automation with a human touch," allowing for simple, repeated tasks to be expedited using technology without sacrificing the value of hands-on supervision from a quality control standpoint. Lastly, TPS thrived on continual input from the people who actually worked on the production line; collaboration was a key tenet of the program.

A BRIEF HISTORY OF LEAN PRODUCTION + THE LCI:

1910 — *Henry Ford creates the first comprehensive manufacturing strategy, arranging people, equipment, materials, and tools in a continuous system to produce the Model T.*

1948 — *Taiichi Ohno and Eiji Toyoda begin developing the Toyota Production System, a comprehensive, waste-minimizing plan for Toyota's manufacturing and logistics.*

1990 — *James Womack's book "The Machine the Changed the World" provides the first comprehensive description of Toyota's system and the principles of lean production, introducing these concepts to American manufacturers.*

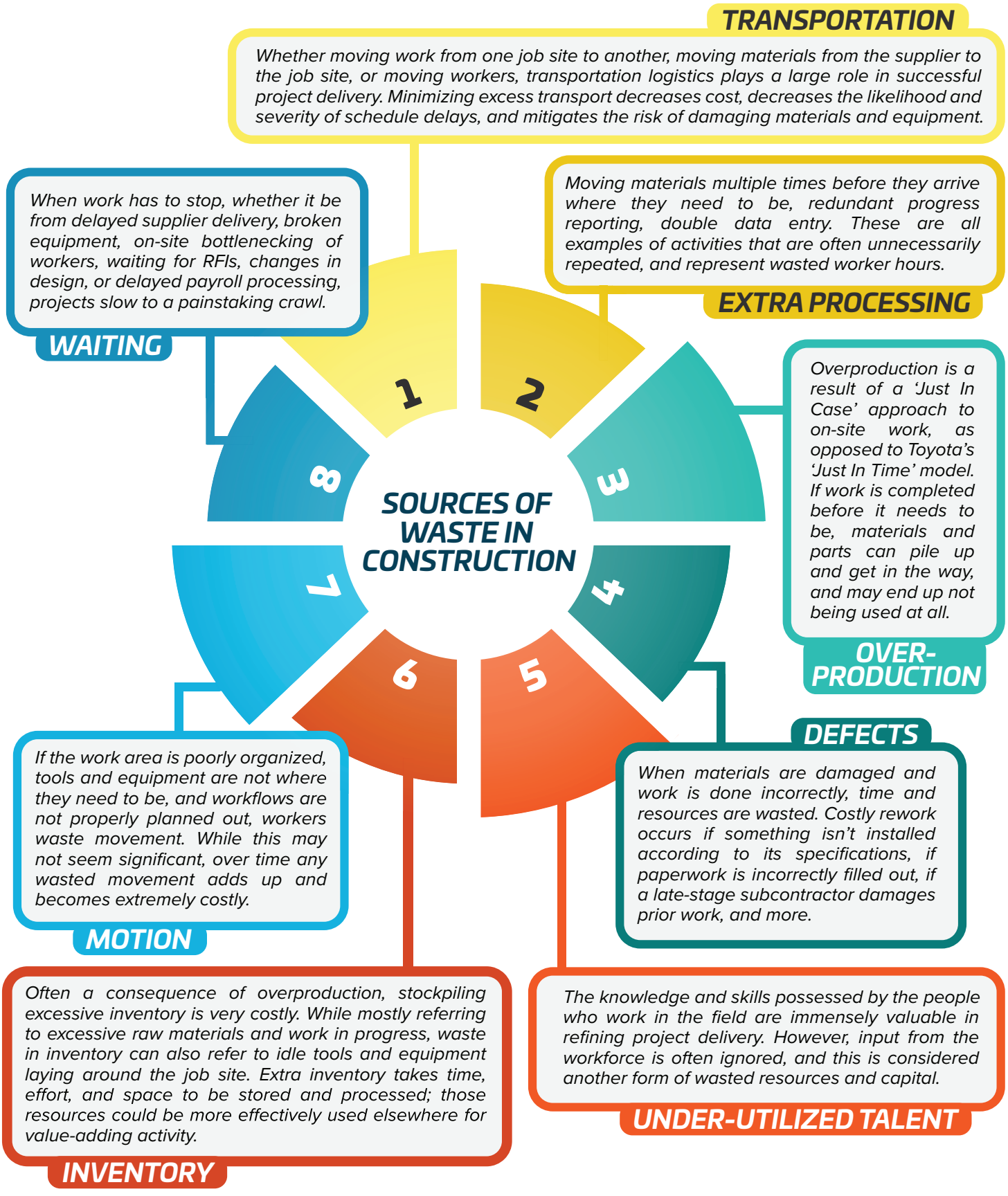
1993 — *Greg Howell and Glenn Ballard develop the Last Planner System (LPS), a collaborative system for producing predictable and consistent workflows in construction projects.*

1997 — *Howell and Ballard launch the Lean Construction Institute (LCI) in order to develop and share information about how lean production practices could be adapted to improve the management of construction projects.*

2018 — *LCI hosts the 20th annual LCI Congress in Orlando, bringing together owners, trade partners, members of the design community, general contractors and other industry professionals to share ideas and collaborate.*

The precedent set by Ford and Toyota has paved the way for lean production practices across the manufacturing industry, and has brought attention to the value of optimizing process, prioritizing project delivery, and cutting out non-value-adding activity. As a result, since the mid-twentieth century the manufacturing industry has truly maximized the amount of output produced from its workers using lean principles, and has proven to be one of the most productive industries in the US economy. The question then arises: if the manufacturing line was made vastly more efficient and less wasteful by using the TPS model, can construction activity undergo its own processual transformation to similar ends?

If the goal of the lean construction program is to turn waste into value, a good first step is to identify the most significant waste-generating elements of design and construction. Check out the sources of waste in construction on page 5 for a few examples of tasks and activities that are potentially costly throughout the building process.


SOURCES OF WASTE IN CONSTRUCTION
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TRANSPORTATION
Whether moving work from one job site to another, moving materials from the supplier to the job site, or moving workers, transportation logistics plays a large role in successful project delivery. Minimizing excess transport decreases cost, decreases the likelihood and severity of schedule delays, and mitigates the risk of damaging materials and equipment.
EXTRA PROCESSING
Moving materials multiple times before they arrive where they need to be, redundant progress reporting, double data entry. These are all examples of activities that are often unnecessarily repeated, and represent wasted worker hours.
OVER-PRODUCTION
Overproduction is a result of a 'Just In Case' approach to on-site work, as opposed to Toyota's 'Just In Time' model. If work is completed before it needs to be, materials and parts can pile up and get in the way, and may end up not being used at all.
DEFECTS
When materials are damaged and work is done incorrectly, time and resources are wasted. Costly rework occurs if something isn't installed according to its specifications, if paperwork is incorrectly filled out, if a late-stage subcontractor damages prior work, and more.
UNDER-UTILIZED TALENT
The knowledge and skills possessed by the people who work in the field are immensely valuable in refining project delivery. However, input from the workforce is often ignored, and this is considered another form of wasted resources and capital.
INVENTORY
Often a consequence of overproduction, stockpiling excessive inventory is very costly. While mostly referring to excessive raw materials and work in progress, waste in inventory can also refer to idle tools and equipment laying around the job site. Extra inventory takes time, effort, and space to be stored and processed; those resources could be more effectively used elsewhere for value-adding activity.
MOTION
If the work area is poorly organized, tools and equipment are not where they need to be, and workflows are not properly planned out, workers waste movement. While this may not seem significant, over time any wasted movement adds up and becomes extremely costly.
WAITING
When work has to stop, whether it be from delayed supplier delivery, broken equipment, on-site bottlenecking of workers, waiting for RFIs, changes in design, or delayed payroll processing, projects slow to a painstaking crawl.

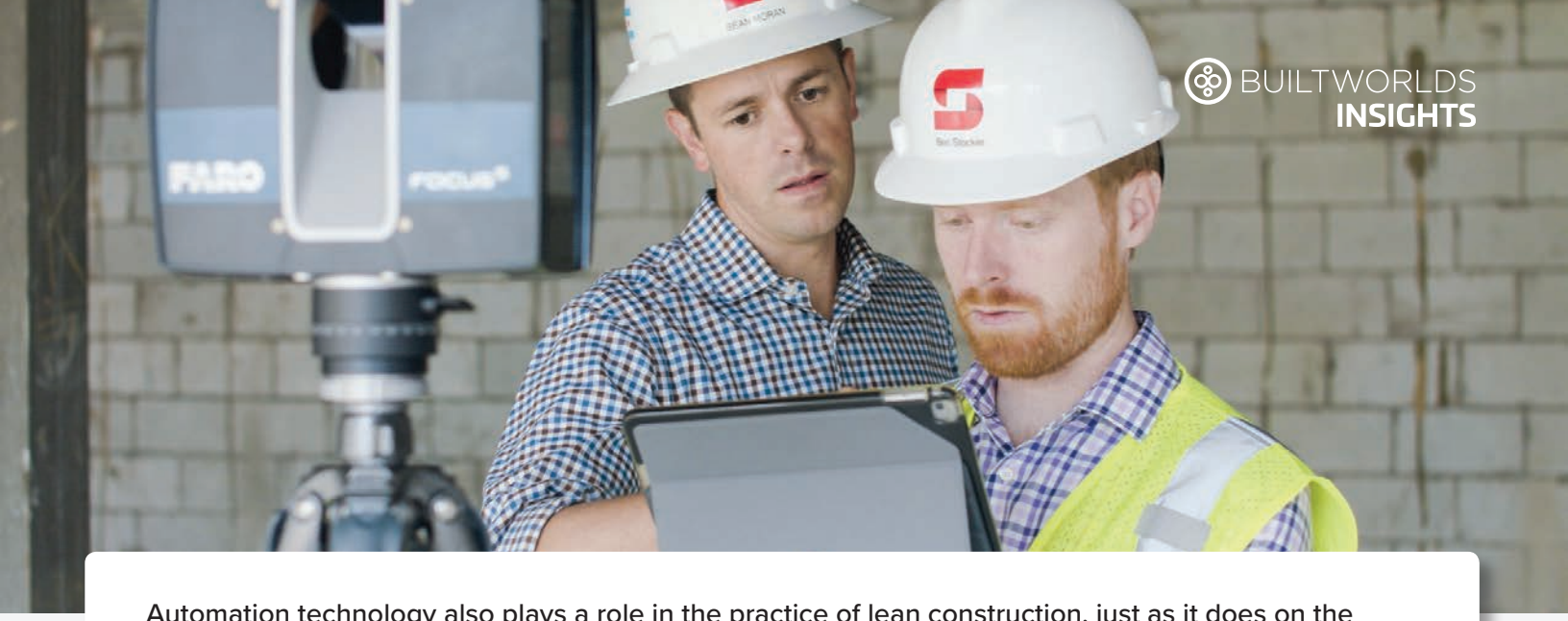
LEAN CONSTRUCTION SOLUTIONS

With the success of lean practices in manufacturing, it did not take long for construction professionals to modify that approach and apply it to the building process. The amount of non-value-adding activity that is traditionally performed on the job site makes construction a prime candidate for lean thinking, but it is worth noting that the industry's complexity means that lean practices must continuously adapt to the specific projects that utilize them. While manufacturing occurs in a closed, controlled environment whereby production steps can be repeated identically across projects, construction is subject to constant change based on the type of project and a range of external factors. That being said, implementation of lean practices can take the ever-hectic job site and turn it into a (close enough) approximation of the manufacturing line.

The trend of prefabrication and modular building is contributing to that standardization. As buildings are increasingly constructed from prefabricated modules, the amount of work completed on the job site is shifting away from actual production and toward assembly and finishing work. Not only does this decrease the amount of work done on-site, but it allows materials and parts to be processed in a controlled setting. While this may increase the complexity and depth of supply chains, it decreases overall project complexity by minimizing the 'wildcard' variable that is the job site (for example, decreasing the risk of on-site injury, minimizing the effect of weather delays, shortening project schedules, etc.). This approach to construction has been championed by contractors like **Skender** and **The Boldt Company**, among others.

" Projects with a higher lean intensity are 3 times more likely to finish ahead of schedule and 2 times more likely to finish under budget. "

– Bevan Mace, VP of National Operations and Lean, Balfour Beatty US



Automation technology also plays a role in the practice of lean construction, just as it does on the manufacturing side. With the ability to make manual, heavily-repeated tasks quicker and more consistent, automated machinery is helping developers and contractors eliminate wasted and unnecessary worker hours on their job sites. Automated bricklayers from **Construction Robotics** and **Fastbrick Robotics**. 3D Printers from **Genesis Dimensions**, **ICON**, and **MX3D**. Job site monitoring tech from **Sensera Systems** and **Triax Technologies**. Autonomous vehicle fleets from **Cooper Gray Robotics** and **Built Robotics**. These are just a few examples of automated machines that are enabling lean thinking in construction.

SPOTLIGHT: Skender

With more than 60 years of building experience, Skender has set the standard for optimizing process and project management practices in construction. Their roughly 20 year-long embrace of lean production principles has culminated in SkenderLean, a comprehensive and value-optimized program that guides their overall approach to building. With the goal of creating more value for their clients, SkenderLean helps them minimize risk, avoid delays, prioritize sustainability, empower decision-makers, and reduce wasted resources on all of their diverse building projects.

" There's no reason we can't apply the principles of advanced product design to buildings. Skender Manufacturing will use technology to challenge industry norms and boundaries. Our Chicago factory will be a place where the status quo exists only to be destroyed."

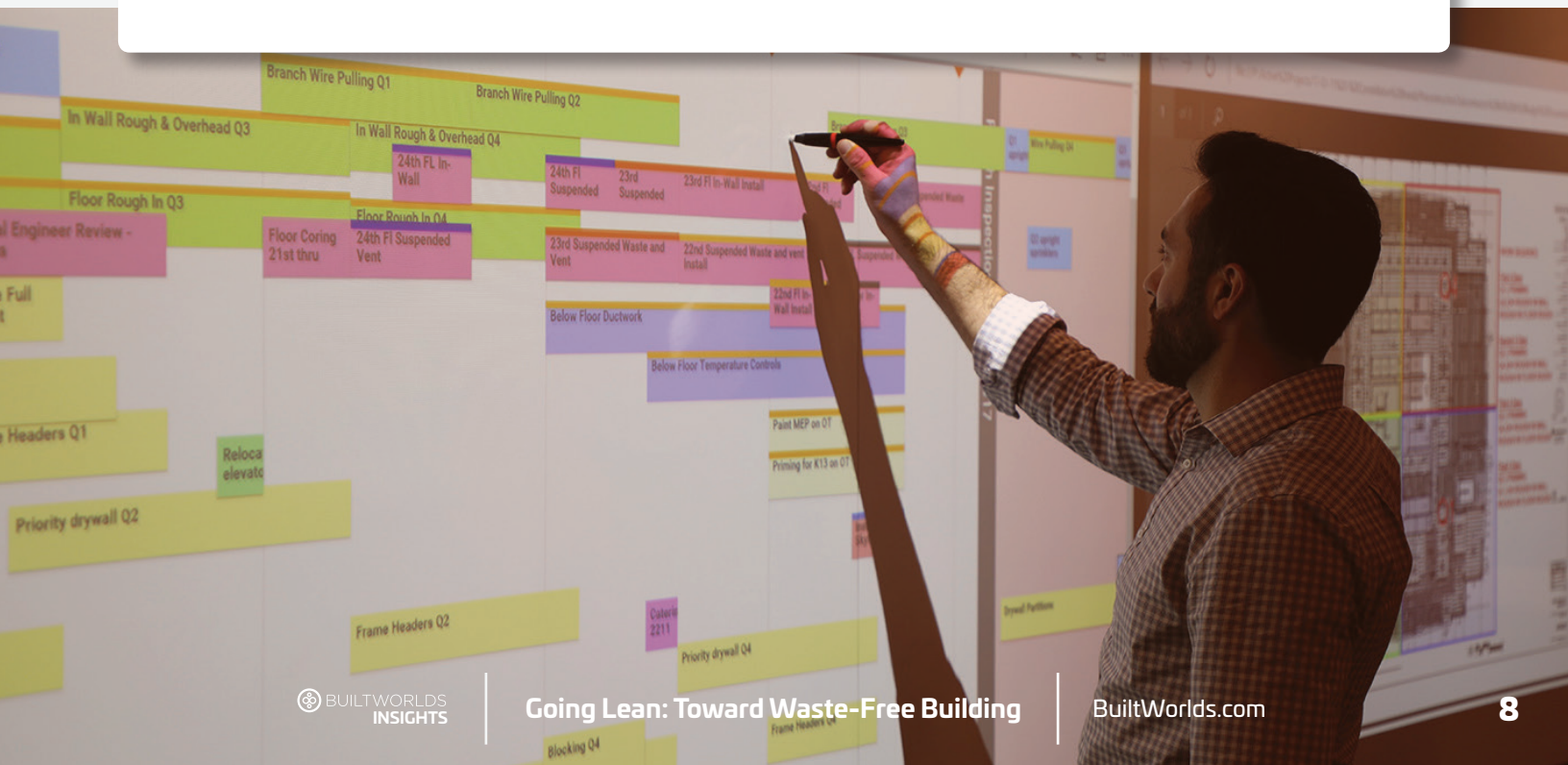
– Peter Murray, President, Skender Manufacturing

One core tenet of Skender's approach is vertical integration across the numerous phases of construction, from planning and design to preconstruction to on-site work and beyond. By bridging the gaps in the building process, they are able to minimize the cost of handoffs across project stakeholders, or even eliminate those handoffs altogether. In doing so, clients save time and money and maximize return on investment.

Staying at the forefront of innovation, Skender in 2018 took another step in their evolution by opening a state-of-the-art manufacturing facility in Chicago to produce modular components that go into multifamily, healthcare, and commercial buildings. Skender's new manufacturing arm is further evidence that prefabrication and modular construction are playing a large role in the adoption of lean thinking and vertical integration in construction.

Another aspect of the project lifecycle being transformed by lean principles is the pre-construction phase. While we typically think of waste as being sourced on-site, much of that waste can be addressed before the project even reaches the job site. The efficacy of the pre-planning process is reflected in the daily success of a given project, and touches every facet of project management. With lean construction, one tool in particular stands out: the **Last Planner System** (LPS). LPS functions on the Toyota 'Just In Time' model where actual progress (or demand) pulls production. Specifically, LPS involves planning work in greater detail as you get closer to doing that work. Another key aspect of LPS is that schedules should include input from all stakeholders, in order to give a stronger sense of ownership to the leaders of each major phase of work. With LPS and other similar tools, handoffs between phases are more easily facilitated, cutting out waste time and effort and promoting improved communication.

Similarly, the newest generation of Enterprise Resource Planning (ERP) software platforms from companies like **Penta Technologies**, **Sage**, and **Autodesk** allow managers to break down schedules by task level and type, differentiating between high-level master planning, weekly sprints, and day-to-day progress in easily-accessible digital dashboards. Further, by connecting schedules to BIM models, reporting functionalities, payroll processing, technician dispatch, fleet management, and more, these software platforms are cutting out the gaps between all phases of the building process and allowing increased accessibility and collaboration. While not explicitly born from lean programs, these platforms are still contributing to making construction a more continuous and efficient process.



CONCLUSION

The push toward lean construction and waste-free building is coming from multiple directions. From one side, the economics of construction are increasingly unfavorable to builders; in 2018, the construction labor shortage and the sharply rising price of materials have created a perfect storm, drastically increasing the cost of inefficiency in construction. Those external pressures are pushing contractors, managers, owners, and developers to take a step back and reevaluate how they approach project delivery.

From another side, emerging technology and the development of new innovative tools have made it more feasible for construction professionals to take action and transform their processes. From automated machines to scheduling and design software, efficient building is as easy as it has ever been. As more and more companies adopt emerging construction technology, the market for those solutions will continue to open up and they will only become more cost-effective and user-friendly.

" The industry needs to change the way it thinks and behaves. We need to first understand why we do things the way we do in order to adopt a more collaborative process. "

– Afshan Barshan, Executive Vice President and Partner, Skender

Perhaps the most significant driver of lean adoption in construction, however, is simply the natural evolution of our perceptions and how we, as an industry, think about production. The manufacturing process was optimized and refined over hundreds of years, and the same goes for construction. While the past several decades have witnessed a distinct reluctance to change and welcome a new paradigm, we are reaching an exciting tipping point. Construction companies at the forefront of innovation have become more agile, efficient, sustainable, and less wasteful. The precedent for lean construction has been set, the external economic pressures are rising, the technology is there, and the shift towards a more collaborative, thoughtful, resourceful built environment is following closely.

Moving forward, institutional support and infrastructure from organizations like the Lean Construction Institute (LCI), as well as schools and universities, unions, municipal governments, and others will be key catalysts in that paradigm shift. As the next generation of construction industry professionals rises, a waste-reducing approach to project management and production in line with lean principles is expected to become the norm.

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