A Practical Path Forward for Offsite Manufacturing

Strategies to Scale Capacity and Succeed with Industrialized Wood-Based Construction

Wood Works

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Executive Summary

This report is a valuable resource for small to medium-sized enterprises, start-ups, and builders transitioning to offsite construction. It specifically focuses on prefabricated elements and modules, offering guidance to existing manufacturers who are considering expanding or upgrading current processes. The document addresses essential aspects such as business planning, transformational change, financial efficiency, design for manufacturing and assembly (DfMA), and technology adoption.

Improving the likelihood of success for offsite construction ventures requires more than technical know-how; it calls for critical insights into planning, execution, and the ability to navigate industry-specific challenges. Many initiatives in this space falter due to poor upfront planning, cultural resistance to change, rushed start-up phases, and ill-timed investments in technology. Long-term success depends on a disciplined approach that emphasizes thoughtful preparation, organizational adaptability, and well-aligned strategic investments.

The key insights of this report are organized into the following themes:

Business Planning:

- Objectives and Priorities: Prefabrication should be viewed as a way to achieve business goals, not the goal itself. Companies must define clear, quantifiable objectives and prioritize them to align prefabrication methods with their unique needs.
- Prefabrication Methods: Panelized construction (PC) and volumetric modular construction (VM) are the primary methods. PC offers flexibility and cost-effectiveness, while VM excels in speed and integration but is bulkier and costlier.

Transformational Change:

- Adopt a Manufacturing Mindset: Transitioning to a manufacturing-centric model requires significant cultural change, focusing on efficiency, throughput, and waste elimination.
- Manage Perception: Prefabrication often forces vertical integration, reshaping relationships with suppliers, customers, and trade partners. Companies must carefully manage these changes to avoid resistance.

Financial Efficiency:

- Start-ups often fail due to poor utilization of resources and premature investments in technology. Companies should hire key technical staff early, defer capital investments until processes are optimized, and stagger deployment to maximize efficiency.
- Decoupling Strategy: Breaking operations into separate business centres or distribution channels can reduce risk, accelerate learning, increase revenue, and provide flexibility during market shifts.

Design for Manufacturing and Assembly (DfMA):

- Start with field assembly plans since they inform product design and manufacturing processes.
- Avoid complexity in design decisions that increase indirect costs, such as technical resources and material handling systems.
- Factory certification is essential for achieving high levels of completion but requires significant investment and operational discipline.

Technology as an Option:

- Technology should enhance a sound manufacturing process, not define it. Companies should strategically inject technology where needed, calculate ROI for each investment, and deploy it at a pace aligned with organizational readiness.

Success in offsite construction requires more than innovation – it demands strategic planning, cultural adaptation, disciplined investment, and a thoughtful approach to technology. This report underscores the value of a deliberate, methodical path to growth, where continuous learning, operational flexibility, and organizational resilience are essential to navigating the complexities of this evolving industry.

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1 Objective

The objective of this report is to increase the odds of success for start-up companies launching a new venture in offsite construction and builders making the transition from stick-built structures to prefabricated elements or modules. It will also provide guidance for existing practitioners and component manufacturers considering an expansion or upgrade to current operations. It will explore the concepts, methods, and mindset required to successfully overcome the obstacles in this challenging industry and will hopefully provide some critical insight for all industry stakeholders.

2 Introduction

The building industry in North America has a history of failed ventures and unsuccessful attempts at launching or adopting various methods of prefabrication. The good news is that most of these unfortunate events could have been avoided. Failure occurs for a variety of reasons, but the most common are poor planning, underestimating the importance of organizational culture, rushing the start-up phase, and misguided investments in manufacturing technology. Let's spend a few minutes to expand on each one.

Some companies simply don't commit to a formal business planning process. This is a critical error, and recent history tells us that an abundance of capital, confidence, or clever marketing is no substitute for proper planning. Other companies may create a plan, but without a framework or structure to guide them, their plan may be incomplete, missing critical pieces of information. Finally, even with the best of intentions, and a solid planning framework, it can be extremely difficult to find accurate, practical information. This is where education, benchmarking, and innovation come into play.

A sound business plan is essential, but it doesn't guarantee success. Many companies fail to plan, but most companies fail to execute. This is not necessarily a project management issue. It's typically about culture. Construction companies tend to underestimate what it takes to become a high-volume, capital intensive, manufacturing organization. Offsite construction is more than a production system, it's a mindset. Deep cultural change is a critical factor in the successful transition from the stick-built environment to an efficient manufacturing organization. Companies need to prepare to become manufacturing-centric.

Why do so many companies rush the start-up phase? Perhaps it's a fear of missing out that motivates them to race to the finish line. Or maybe they've made significant capital investments and need those assets to start generating revenue as soon as possible. Either way, compressing the start-up phase is a mistake. It prevents the organization from learning and developing critical operational skills. It kick-starts the depreciation schedule on expensive assets before we fully understand how to use them. Finally, it eliminates the possibility of refining the product and process as we discover opportunities for improvement through real-world production trials.

Purchasing manufacturing software and equipment prior to product optimization and process development is a common mistake made by new entrants. Technology selection should not define the process, but in this scenario, that's exactly what happens. And, over time, as product design evolves and the manufacturing process takes shape, companies are often faced with the realization that the original software or equipment selection is no longer suitable. This is quite a predicament, and sadly ironic, as the manufacturing assets that were meant to enable production are now the constraint.

3 Business Planning

3.1 | Objectives, Priorities, and the Development Phase

Prefabrication is not the goal. It's not a business outcome. It has no intrinsic value. It's simply a means to an end. So, the critical question is, what are we trying to achieve and is offsite construction the most cost-effective path to a successful outcome?

Let's start with a word of caution on prefabrication. *Do not assume* that offsite construction is a requirement for your business. This may seem counter-intuitive, but it will ensure that you remain objective in the planning stage. With respect to goal setting, there are two important steps to take in defining an objective: set clear, distinct, quantifiable goals and prioritize them in order of importance. Finally, the list of objectives, performance targets, and business priorities will be different for every company. As such, the prefabrication method and options employed must be developed to suit your specific set of objectives. We are not simply selecting a prefabrication method; our task is to develop a tailor-made solution. We will now explore each of these items in detail.

The decision to adopt offsite construction *should not* be the first step in the business planning process. The first step is to identify, define, and quantify financial and operational objectives. This exercise should be separate and distinct from the second step, which is to create action plans that will achieve these objectives. The second step is where prefabrication can be rigorously evaluated as a viable solution, not before. If offsite construction is mandated, as opposed to selected, it will immediately rule out the possibility of better solutions. It may also force the company to focus their energy on finding a way to make offsite construction work, instead of having the offsite solution work for them. This scenario invariably leads to poor performance and many businesses that make this fundamental mistake end up in financial distress.

Business objectives must be clear and distinct. More importantly, they must be *quantifiable, in dollars*. Performance targets may be measured in units, days, or percentages, but dollars are the unit of measure for a business, and they are a requirement when creating a financial profit and loss statement. Converting performance targets into dollars can be tricky. The most elusive of these is the value of time. Most companies that are considering prefabrication will undoubtedly have cycle time reduction as one of their main objectives, so calculating the value of time is important. A reduction in direct labour or material has a fairly consistent value for most businesses, but the value of time varies widely. As an example, a highly-leveraged builder in the rental market will likely attribute a relatively high value to early completion because it reduces the carrying cost of inventory and accelerates the start of a rental revenue stream. Conversely, a debt-free builder selling single-family homes has minimal carrying costs and no rental revenue, so the value of time is negligible. This is just one example of how two different businesses can place a radically different value on the same prefabrication benefit. It emphasizes the importance of quantifying the financial value of each performance target, based on your unique business model.

A final point on business objectives is the need to *prioritize*. As an example, if we have six business objectives, which one is the most important? Which one is second, and so on. You will encounter numerous problems on the journey from concept to production, and each problem may have a variety of potential solutions. Quite often, several solutions will adequately solve the problem, with the only difference being that one may be slightly stronger in a specific area. If that area is aligned with the most important business objective, then that's the best solution. Prioritization is a decision-making filter, and companies that fail to prioritize can lose momentum in the planning stage as they attempt to evaluate multiple similar options. This is especially true in software and equipment selection. Without prioritized objectives, decision-making is simply less effective. This is not a trivial point. The effect of decisions made in the planning stage will be amplified in operations, and once production starts, it can be extremely difficult and costly to change course.

Developing an offsite solution that is precisely aligned with operational and financial objectives is what ties the business plan together. This is the *development phase*. Selecting prefabrication methods and options can be a daunting task. There is a seemingly endless list of choices to make, and each decision has the potential to affect multiple areas of the business. It's a challenging, time-consuming exercise that includes education, benchmarking, product optimization, manufacturing engineering, and, occasionally, process validation trials.

The development phase can be more or less intense, depending on the scope of work, but it cannot be avoided. Some companies will attempt to copy a production system observed during a benchmarking tour. This is highly problematic and usually results in a poor outcome. That's because the most important elements of an effective manufacturing system are not what is observed in operation but rather the development and integration of product, process, technology, and culture. Benchmarking is useful, but context is critical. World-class operations understand this all too well. That's why they open their doors to the public without fear of duplication.

Aside from a sense of urgency or excitement, most companies that rush towards a solution simply don't understand the importance of the development phase. This is where organizational learning occurs. This is where intellectual property is created. And this is where competitive advantage is crafted. Successful businesses spend a lot of time in the development phase. They don't choose an offsite method; they develop offsite solutions.

3.2 | Prefabrication Methods, Benefits, and Options

In order to develop an offsite solution, we need to start with a basic understanding of the methods at our disposal. We also need to be able to assign a value to the benefits that they provide. If the business objectives are clear, choosing a method is relatively simple. The next step, selecting options, is where the challenge lies. Options can vary from minor process decisions to radical changes that alter the method, sometimes creating a hybrid solution. Let's expand on each of these items and provide some context.

There are three main prefabrication methods in the timber building industry: mass timber structural elements, panelized construction (open-wall or closed-wall), and volumetric modular construction. The focus of this report is light wood-frame structures, so we'll save mass timber for another day. Closed-wall panels are prefabricated elements that have all systems installed in the factory, from drywall through to exterior cladding. This method is highly sophisticated and has struggled to gain momentum in North America. That leaves us with panelized construction (open-wall) and volumetric modular construction, the predominant methods in North America, and the focus of our benefit analysis.

Panelized construction (PC) and volumetric modular construction (VM) are both forms of prefabrication, but their inherent strengths and weaknesses are quite different. Understanding the specific benefits associated with each method is essential in selecting the one that is best suited to produce superior results. There are countless iterations of each method, so an overview of each one in its basic form is the best place to start. In simple terms, VM increases the speed of construction while PC increases framing capacity. The four main benefits generally associated with each method are listed below.

Panelized Construction

- Increased Framing Capacity
- Complete Design Flexibility
- Standard Freight Cost
- Small Manufacturing Footprint

Volumetric Modular

- Increased Speed of Construction
- Total System Integration
- Minimal Onsite Trade Requirements
- Weather Resistant

Panelized Construction photo courtesy of Auto Construct Incorporated
Volumetric Modular photo courtesy of Eastcut Wood Building Solutions

PC is compact, flexible, and cost-effective. It is easy to start and scale in a small manufacturing space and can rapidly increase framing capacity. Most anything that can be stick-built can also be panelized, without additional engineering or permits. Flat stack bundles and standard freight dimensions minimize shipping costs. PC is borne out of the component manufacturing industry, so there is a wealth of standard equipment and automation on the market to help boost efficiency.

VM, by comparison, tends to be bulky, rigid, and costly, but the advantages are significant. A weather-tight box allows the module to be fully completed in the factory, which also sets the stage for vertical integration of the entire trade base. With minimal onsite work and a weather-tight enclosure, VM is perfect for locations that are remote or subject to inclement weather, but the single biggest draw to VM is the unparalleled speed of onsite construction.

It is generally true to assume that each strength is, by default, a weak point for the other method. As an example, PC has virtually no design restrictions or additional engineering requirements, whereas VM is a heavily engineered structure with obvious architectural limitations. This is an important point. PC and VM are both forms of offsite construction and are generally regarded as having similar benefits such as speed of construction, production capacity, and waste elimination, but, in practice, they diverge in meaningful ways. Understanding the key differences, and the operational costs associated with each method, are critical factors in aligning methods with objectives.

At this stage, there is likely enough information to firmly place a company in one of two camps, PC or VM; however, at the risk of overcomplicating this topic, we're going to go one level deeper and explore the idea of options. As you can see by the pictures illustrating the two methods, the PC examples include a roof module, a stair module, and a wall panel with a window installed. And, although it's not apparent in the picture, the VM box was assembled using wall panels and floor cassettes built on a component manufacturing line. This is not intended to blur the lines, but rather to illustrate the possibility of options.

Options are a series of small decisions that configure, customize, and refine the manufacturing process to precisely fit a specific set of objectives. Here are a few examples of what may be considered options in the process development phase. These examples are relevant for both PC and VM.

- Product Design: build up or break down sub-assemblies and modules to maximize standardization
- Process Design: select batch processing or one-piece flow for each work cell, station, or production line
- Manufacturing Technology: select a manual, semi-automatic, or fully automatic process for each station in the production line
- Vertical Integration: increase or decrease the level of completion (value-add) for wall panels, floor cassettes, and modules

These decisions can be extremely difficult for new entrants because they force companies out of their comfort zone. This is no longer about building structural timber elements offsite, it's about manufacturing. The level of manufacturing expertise required in the development phase can be daunting for a traditional construction firm. Fortunately, knowledge can be transferred. Aptitude and attitude, however, are far more difficult to teach. This brings us to the most important aspect of a successful launch. It's also a topic that most builders struggle with – culture.

4 Transformational Change

The greatest challenge in the conversion from stick-building to prefabrication is anticipating and managing transformational change. This topic is not well understood, and it's likely not on your radar, but it should be. Without a clear understanding of the cultural and business changes required, and a willingness to embrace them, you will fail to execute or generally underperform. There are two main areas where transformational change is required: organizational culture and redefining your position in the value chain. Let's explore each area separately.

4.1 | Adopt a Manufacturing Mindset

As companies move from general contracting and project management to a manufacturing-centric business model, the underlying business assumptions change dramatically. In most cases, new priorities and a heightened sense of urgency render the existing organizational culture ineffective. To explain *why* priorities change and to emphasize *how impactful* those changes are on organizational culture, let's consider a typical home builder incorporating the manufacture of prefabricated elements.

Home builders acquire and create assets. These assets generally appreciate in value over time. As a general contractor, fixed overhead is kept to a minimum, and direct costs (hard costs) are made variable through piece work; builders only pay for work performed. Appreciating assets, relatively low fixed overhead, and variable hard costs, mean that there is minimal risk in sacrificing speed of construction to achieve or maximize profit per unit. With the exception of inventory carrying costs or expedited customer deliveries, the cost of wasted time is relatively low.

Incorporating the manufacture of prefabricated elements as part of the production process turns each one of these critical business factors on its head. The assets associated with manufacturing depreciate rapidly. Fixed overhead costs grow exponentially with a factory set-up, and direct labour becomes a fixed hourly cost that is incurred *regardless* of output. In this scenario, speed and efficiency are of paramount importance. And what about the value of time? In a manufacturing environment, every hour of lost production is not simply a loss of revenue but a staggering, compounded expense. With overhead growing exponentially, *fixed* direct labour costs, and rapidly depreciating assets, the cost associated with wasted time becomes a game-changer.

This is a radically different business environment, and organizational culture must change accordingly. The entire company is now geared towards three primary objectives: labour efficiency, throughput per hour, and waste elimination. If you're highly leveraged, based on your investment in manufacturing equipment, throw equipment uptime into the mix as a fourth objective. In short, the organization needs to adopt and embrace a manufacturing mindset. Welcome to the world of lean manufacturing, factory workflow, equipment effectiveness, workplace organization, visual management, and the relentless pursuit of waste elimination. Expect this cultural transformation to be an extremely challenging, and sometimes painful exercise, but don't avoid it. Without a manufacturing mindset, you won't realize the full value of your investment in manufacturing and will struggle to compete in a high-volume commodity market.

4.2 | Manage the Perception

Adopting a manufacturing mindset is driven by an internal need for efficiency, but what about external forces? How do they change the way we operate? Of all the market factors that are in play when adopting offsite construction, vertical integration is the most consequential.

Vertical integration is more than a means to increase revenue and margin, it's a bold strategic move. It represents a major step in the evolution of a business. Integration can occur with vendors or customers and, depending on the scale of the initiative, it can reshape the structure of your operation, redefine your position in the value chain, and change critical relationships with customers and trade partners. Vertical integration has the potential to transform a business and, as you would expect, companies spend a considerable amount of time deliberating before launching this type of initiative.

The key takeaway here is that, in most cases, prefabrication actually *forces* vertical integration to occur. It does so by blurring the lines that exist between suppliers and customers. Vertical integration downstream affects suppliers and trade partners. Moving upstream, we encroach on our customer's territory, developing core competencies that already exist in their organization. At what point do we cross the line from supplier to competitor? Are we partnering with our trades or replacing them? A prefabrication strategy can be a value proposition or a competitive threat. It's a matter of perception, and it needs to be carefully managed.

If vertical integration is simply a byproduct of your prefabrication plan, an unintended consequence, it will not get the time and attention it deserves. Here are a couple of important points to remember as you develop your product offering. First, it's imperative that you understand whether or not your product strategy affects the structure of your ecosystem. Does your new product offering automatically redefine your status as a supplier, customer, or competitor? Second, it's a safe bet to assume that most of the stakeholders in your ecosystem see vertical integration as a zero-sum game, so expanding your product offering invariably reduces the scope of work for another stakeholder, either upstream or downstream. Blowback from trade partners or customers, especially unexpected resistance, is the opposite of what we're trying to achieve, so pay attention and tread carefully. Instead of simply operating within an existing ecosystem, recognize that you, and others like you, are actively reshaping it.

5 The Bottom Line

Expenses skyrocket in the absence of revenue, technical resources are either absent or ineffective, start-up takes far longer than anticipated, and all while the full complement of capital equipment is sitting dormant on the factory floor. Sound familiar? Start-ups are notoriously difficult, but mature companies can also fall victim to financial distress. For an existing business, it may be an economic shock, a new competitive threat, or a change in customer requirements that threatens their financial viability.

With all of the attention given to labour and factory efficiency, it's astounding that there isn't more robust discussion around financial efficiency. After all, the goal is to make money. In this section, we will provide some insight into the pitfalls that make start-ups vulnerable and offer a framework for mature businesses that will help them to become more resilient.

5.1 | Focus on Financial Efficiency

Start-up companies, and those that are expanding or upgrading, are all susceptible to financial distress, especially during the launch phase of their new venture. New ventures can fail for a variety of reasons, not the least of which may be a lack of financial due diligence, an ill-conceived product offering, or an inefficient manufacturing process. However, if we sweep aside the wide range of project-specific technical errors, a common theme emerges. Quite often, poor financial efficiency is to blame for financial distress or outright failure. For the sake of this exercise, we'll define financial efficiency as maximizing the utilization of resources and assets in a timely manner. Let's take a moment to unpack this concept.

Simply put, companies run into trouble when the resources they employ and the assets they purchase are not fully utilized. Companies are particularly vulnerable in the start-up phase because *new* manufacturing systems are predictably inefficient during launch. This is often compounded by a lack of technical resources, such as engineers, designers, technicians, and carpenters. Why does this matter? Because competent, technical resources are *required* to make manufacturing assets productive. They're not separate and distinct, and they're not optional. Therefore, if we fail to establish our technical resources in advance of equipment installation, we unnecessarily extend the launch period, further eroding our working capital. So, maximizing the utilization of resources and assets is not just a technical issue, it's a *timing* issue.

And why do we fail to get the timing correct? It boils down to two major issues. First, there is a gross misconception about the role technology plays in profitability. Second, companies tend to underestimate the time it takes to learn their craft. We'll explore each one in turn.

Our industry needs to stop the love affair with technology. We consistently overestimate its value. Technology is a tool, and it has its place. It enhances our performance, but it does not negate the need for skill and ability. The popular belief that technology alone is the enabler creates a false sense of urgency around the purchase and installation of equipment. Start-ups tend to order manufacturing equipment before they truly understand what they need and install it before they're ready to operate. They also have a bad habit of ordering all of the equipment at once. Purchasing equipment commits capital and, depending on payment terms, depletes our cash reserves. Once equipment is installed, we start incurring depreciation and interest expenses. At this point, we bear the full financial burden of the asset, and we should be ready to make full use of it. This is seldom the case, which leads us to the next issue, learning our craft.

Technology does not eliminate the need for skill and ability in the workplace. In fact, there's an entirely new level of technical expertise required when we employ sophisticated manufacturing technology. Unfortunately, businesses that adopt offsite construction often fail to recognize, or fully understand, the technical resources required to support a manufacturing operation. This means that the critical resources required to make full use of expensive assets are either non-existent or ill-prepared to do their job. To make matters worse, our industry is still in its infancy. Qualified, competent technical staff are scarce. So, once we identify the need for a resource, it takes far too long to secure talent. If we can't find experienced staff, we must then set aside ample time to onboard and train inexperienced candidates. Either way, the clock is ticking.

Here we have a striking imbalance. Expensive, depreciating assets are installed prematurely and the technical resources required to make use of those assets are late to the party. Add a lack of revenue, weak margins, and a variety of unexpected issues that delay the launch, and we have a perfect storm. There are three things that we can do to avoid this dire situation.

First of all, hire, train, and deploy technical resources *in advance* of operations. This is the most important piece of the puzzle. Ironically, it's also the least expensive. Second, *defer* capital investment in accordance with these two rules. Don't select equipment and options until you have optimized your product and developed your manufacturing process. Next, do not order equipment without confirmation that the appropriate technical resources will be in place to support the installation, start-up, and ramp plan for the production asset.

The third recommendation is far more complicated because it ties the first two together. Simply put, we need to pair resources with assets and deploy them in conjunction with each step in the manufacturing process. Here's how it works. Start by developing an implementation plan that mirrors the actual manufacturing process, from design through to shipping. Break this plan into sequential steps, with each step representing a *production centre*. A production centre is any functional step in the manufacturing process, such as design, component cutting, or wall panel assembly. Next, we identify the technical talent and manufacturing technology required for each functional step and allocate them to a production centre. Finally, we set a target date for the creation of each production centre, which now dictates the deployment of the associated resources and production assets. This approach defers and staggers capital investment in equipment until it is absolutely needed and ensures that the appropriate technical resources are in place to make those assets productive.

Diving further into this exercise is well beyond the scope of this report, but the concept is clear. We're creating an implementation plan with milestones that are based on maximizing financial efficiency at every stage of the start-up, reducing the risk of overextending ourselves and ensuring that each step we take is solid and productive. This approach will minimize the potential for financial distress and buy you the time you will need to manage the inevitable challenges you will face in the launch phase.

5.2 | Be Flexible and Resilient

Imagine, for a moment, that each production centre is more than simply a functional step in the manufacturing process. What if they were separate business centres or distribution channels, the output of each being a commercially viable service or product? Let's call this strategy *decoupling*. Is this an unconventional approach? It depends on who you ask. Small, privately-owned companies that bootstrap new ventures take this approach out of necessity. They need to be profitable at each stage in the evolution of their business, from design services to the manufacture of prefabricated elements. Large, well-funded corporations have the working capital required to take the long view, absorbing losses and forgoing revenue on the journey to their desired end state. However, just because they can afford to accelerate towards the end goal, doesn't mean that they should. Ironically, *decoupling* is even more important for the major players in this space.

Large corporations with lofty goals rarely consider *decoupling*. Perhaps it hasn't occurred to them. Or maybe they would argue that establishing multiple, separate business centres along the way will simply delay the outcome. It may, but this is where our paradigm needs to shift. Speed is *not* the objective. The objective is *certainty*. We want to be certain that we will succeed, both as a start-up company and as an enduring enterprise. *Decoupling* provides certainty in four important ways.

First, as described in the previous section, *decoupling* reduces the risk of failure in start-up situations by maximizing financial efficiency.

Second, it prioritizes and accelerates learning. There's no better motivation to learn your craft than trying to sell it in the marketplace. The pressure to learn becomes intense because it's tied directly to a revenue stream. Efficiency is required to be competitive, and attention to detail is assured because we cannot afford to ship defects to our customer. Conversely, if each sequential step is an internal function, we simply don't have the same pressure to perform.

Third, having multiple distribution channels increases revenue. As an example, if a company sells open-wall panels and floor cassettes, it has, by default, the internal capability to engineer structures and create permit drawings, design elements and produce shop drawings, cut and kit component packages, and assemble wall panels. The saleable product may be wall panels, but there is clearly a market for structural design and the sale of component packages. Offering a range of products and services allows a business to sell to wider variety of customers with varying levels of sophistication.

Finally, *decoupling* can provide options in the face of adversity. Using our previous example, if the only way to monetize your value proposition is in the form of a wall panel, you're relying on one revenue stream. If you can sell the product or service produced at each step in the process, you have options. In trying times, when your customer may be making structural changes to their business, you have room to manoeuvre. Creating and maintaining multiple revenue streams is always a smart play, but it's especially valuable when the market shifts beneath your feet.

6 Design for Manufacturing and Assembly

Design for Manufacturing and Assembly (DfMA) is a methodology that is becoming a regular topic of conversation in the offsite construction industry. The basic premise of DfMA is to simplify and standardize product design in order to reduce the cost of manufacturing and assembly. DfMA is often described as an engineering methodology. This may give you the impression that it's predictable, tedious, and narrow in scope. That's not the case. In reality, the exercise can be extremely creative and dynamic. With this in mind, let's explore a few aspects of the DfMA process that are probably not on your radar. In the next three sections, we'll provide some insight on where to start, explore the cost of complexity, and offer a few words of caution before you dive into the deep end.

6.1 | Don't Start with Design

If we don't start with design, where exactly do we start? It sounds like a radical statement; after all, the order of operations is clear: design, manufacturing, and assembly. This is the sequence of events, but are they listed in order of priority? If so, DfMA would suggest that design is the most important factor, followed by manufacturing, and then assembly. Assembly is third. Does that make sense? Let's take a look.

The main operational objective for most prefabrication companies is speed of construction. Speed is measured in the field, during assembly. This is where the customer observes and monitors your performance. This is where our value proposition is delivered. One might argue then, that a thoughtful, well-conceived assembly plan, successfully executed, is the most important part of the equation. It's a sound argument, and here's the key point. Assembly informs product design. Product design is critical, but it can't be optimized without a clear understanding of what must be accomplished in the field. So, the sequence is fine, but the start point should be the assembly plan, not product design.

Here's another reason why this argument holds water. Consider the idea of constrained and unconstrained events. An event that's constrained is one that must comply with multiple requirements, leaving little room for error or imagination. In the development phase, field assembly is the most constrained event. It's performed outside, on your customer's jobsite, under their watchful eye, on a tight timeline, in an uncontrolled environment, and in conjunction with the other trades. Product design, by comparison, has the same technical and financial guardrails as assembly, but it has no physical constraints. We design in our own space, with our team, and our resources. Finally, manufacturing is where we are almost completely *unconstrained*. The customer doesn't generally care how or where we manufacture our prefabricated elements and modules, as long as the final product and service meets their specifications. Faced with a series of interdependent, sequential events in the development phase, where do we want to start? At the choke point – the most difficult event. That's field assembly. This gives us an ever-widening funnel of options as we continue the development process through design and manufacturing.

In summary, everything we do in design and manufacturing is a means to an end. That end is success in the field. It's what the customer pays for, so we have to get it right. It's the most constrained and difficult event to execute, so that's where we start. Field assembly informs design, and design then controls manufacturing, which makes manufacturing the *easiest* and *least important* step. Least important? Yes. That's counter-intuitive for most new entrants and the reason why so many get into trouble.

6.2 | The Cost of Complexity

As we develop the design of our prefabricated elements, it's important to understand and anticipate how our design decisions impact the cost of manufacturing. Some decisions are more consequential than others. Those that increase direct costs, without affecting our level of completion, are relatively simple. The cost calculation is straightforward, and impact is measured on a per unit basis, so costs vary *proportionately* with volume. This makes the change predictable and easy to manage. In comparison, design decisions that increase our level of completion are more complex. While direct costs are still affected, *indirect* costs now take centre stage with the potential for substantial increases in manufacturing overhead and infrastructure. These costs are *not* tied to volume and, if we're not careful, can quickly outweigh the intended benefits. Let's focus our attention on this scenario as the costs can be quite significant and may come as a surprise to new entrants.

Increasing the level of completion for a prefabricated element or module drives cost in two key areas: internal technical resources and material handling systems. Adding purchased components and systems to our product offering increases the need for technical knowledge, but it also creates a knock-on effect for panelized construction, increasing the size and scale of material handling systems. Following the design evolution of a prefabricated wall, from an open-wall panel (its most basic configuration) to a closed-wall element (complete system integration from drywall to cladding) will help to illustrate how and why our cost structure may change.

Here's our baseline. Open-wall panels do not include anything other than basic structural framing components, such as plates, studs, and sheathing. Aside from a carpenter's skill set and their inherent knowledge of local building codes, there's no additional technical knowledge required. Open-wall panels are manufactured in a horizontal position, flat-stacked in bundles, and shipped to site. Horizontal, flat-stacked bundles make good use of a standard flatbed trailer, maximizing volumetric load capacity and product pack density, thereby minimizing freight costs. A small jib crane with a panel clamp and a forklift are required in the shop. Add a telehandler onsite to offload trailers and lift bundles into position for manual installation, and our material handling system is complete.

From our baseline, the first step towards closed-wall elements is the addition of factory-installed windows. Installing windows in a clean, dry, climate-controlled environment, at ground level, with ergonomic lift devices, will reduce the cost of labour and improve the quality of installation. It also gets the building closed-in from the weather much faster. It's a good idea, but how much of an impact will this simple addition make to our cost structure? You'd be surprised. Let's review the technical and material handling changes required to facilitate this product enhancement.

Adding factory-installed windows expands our scope of work, which now includes the building envelope. As such, we need to install an apron and flashing tape for the sill plate. We also need to install flashing tape on all four corners of the rough-size opening (RSO). Weather barrier material must be added to the perimeter of the RSO, being careful to layer each strip correctly to avoid water intrusion. After the window is shimmed, levelled, and fastened, we need to add flashing tape to seal the envelope between the weather barrier strips and the nailing flange on three sides of the RSO. The installation procedure will vary based on the type of window, the homebuilder, the window manufacturer's specifications, and the installer's preference, but you get the idea. This is the technical component. It's the easy part. The concern lies in how this seemingly small addition can alter our entire material handling system and cost structure. Let's follow the wall panel through the process, step by step.

Windows are installed vertically, so each wall panel must be tilted to a vertical position prior to installation. Plan on adding a tilt-table or overhead crane for this operation. And don't forget to increase your manufacturing footprint accordingly. This carries through to shipping as most window manufacturers will insist that this orientation is maintained during transit. That brings clear ceiling height into play. Imagine loading a 10' tall wall panel onto a flatbed trailer with a deck height of 5' using a 3-ton overhead crane system. Buildings with 20'+ clear ceiling heights are expensive. Try finding one with grade-level drive-in doors that can accommodate a fully-loaded trailer. Abandoning flat-stacked bundles forces us to load one wall panel at a time, so it's a good idea to have the overhead crane travel from the installation point to the loading area *and* to minimize that travel distance. Remember, we still need to keep up with the speed of the wall panel manufacturing line. Next, standard flatbed trailers must be modified, adding a steel framework to contain and secure wall panels in an upright position. Did we anticipate purchasing a fleet of expensive custom trailers? Probably not. While you're busy wrapping your head around spiralling capital and infrastructure costs, let's not forget about pack density. It just dropped significantly, increasing the freight cost per linear foot of wall panel by approximately 25%. It doesn't end here. We still need to offload, and the telehandler is not up to the task. Wall panels need to be lifted vertically, straight up and clear of the load, 26'–30' high and then boomed-in directly to the installation point. A 30- to 50-ton mobile crane should do the trick. Again, likely not in your operational budget.

This is a worst-case scenario, presented in order to emphasize a point. And, while everything may not apply to your specific application, to a certain extent, most of it will. So, how exactly do we justify the incremental cost? There are two ways to offset the substantial increase in fixed and variable indirect costs: volume and value-add. In the spirit of enhancing our value proposition, let's choose the value-add route and continue our journey towards closed-wall elements.

Starting from the outside, adding trim and cladding forces us to keep wall panels separated during transit. This minimizes product damage, but it also further reduces our pack density and increases the complexity of our custom trailers. If we expand inward from the timber structure, adding insulation and drywall, we need to wrap the load, protecting it from the elements. Again, our shipping costs will increase. That leaves us with an operating zone that lies between the timber framework and the drywall layer. In this zone, there's an opportunity to pre-install mechanical, electrical, and plumbing systems (MEP). These components are installed inside the stud cavities, so there's no risk of physical damage in transit. They're also impervious to weather, eliminating the need to tarp or shrink-wrap the load. So, we've defined a value-add opportunity that leverages the incremental costs incurred for window installation. However, while our infrastructure and operating costs are contained, we've now activated the other cost driver, manufacturing overhead.

From a technical perspective, adding windows forced the business to get acquainted with one small aspect of the building envelope. That pales in comparison with the installation of MEP; this is next level. Here, we need to acquire or develop the internal technical resources required to design all three systems. Are they energy efficient, code compliant, and cost-effective? Because we're responsible for all three systems, we would be remiss if we didn't take time to integrate and optimize the installation process. Speaking of installation, each system is now broken down into a series of micro-installations in each prefabricated element or module. That's new. How are they inspected, connected, and tested in the field? Complexity grows exponentially, and vertical integration with multiple trades is in play. We've blurred the lines and accelerated the process. Technical depth, breadth, and know-how across a variety of disciplines is now part of our scope of work. That's an expensive department to staff.

The cost of complexity will appear in many forms as your product offering evolves. As your design becomes more sophisticated, the associated costs will be more substantial. They will also be wide-ranging and elusive, so the key is to anticipate where they will emerge and to address them *before* you commit to the outcome.

So far, we've touched on equipment, infrastructure, and technical resources, but there is one more cost layer to consider as we approach the endgame. Let's step away from panelized construction and spend a few minutes on volumetric modular.

6.3 | The Endgame

Unlike the evolution of a panelized construction system, the endgame for volumetric modular is clear from the start. The goal is to achieve the highest level of completion possible. This will maximize the speed of onsite assembly, minimize the need for local trade support, and minimize your freight cost as a percentage of revenue. Module size, shape, and material handling infrastructure are another set of assumptions that are typically predetermined. That's because efficiency, both in the factory and the field, will push modules to be as large as transportation routes and regulations will allow. Rolling floor beams, catwalks and mezzanines, overhead cranes, custom trailers, permits and pilot trucks, mobile cranes and tower cranes – it's all par for the course and is likely already in your business plan, as is the technical team that you will hire and deploy.

What may not be in your business plan is the *next* layer of indirect costs; those that are associated with the manufacture of fully-finished modules and closed-wall elements. We're talking about the inspection process. Volumetric modular is your best bet for unparalleled speed of construction. It's also a great solution for remote work where local trade support is scarce or nonexistent. In both cases, conventional inspection by local authorities is problematic. Critical systems and structural features are buried behind the drywall. Even if systems are partially exposed for onsite inspection, it may not be possible to get inspectors to site when building in remote locations. This brings us to the next level in the evolution of your prefabrication business, factory certification.

Factory certification is an interesting proposition. It's not a simple endeavour. It's a means to an end in our pursuit of closed-wall elements and fully-finished modules, but the costs are unique, and the process is invasive. Let's take a moment to expand on these two critical points.

Factory certification costs are unique. They will occur in both the initial certification process and the ongoing operation and maintenance of the program. Incremental overhead will appear in the form of consulting fees, technical staff, indirect labour, and administrative support. Operational costs will increase with the addition of production requirements like inspection, checklists, material certification, system testing, product reviews, and record retention, to name just a few. How are all of these costs unique? They don't generate revenue. Instead, they unlock the *potential* for revenue. Let's use vertical integration as a comparison. As we absorb the trade base, we add the technical staff required to self-perform, but we also increase our product margin and selling price. Factory certification is different. It's an arduous, expensive task that adds no value, at least not in the conventional sense. It doesn't increase our selling price or product margins. It's an *enabler*. It's a requirement that unlocks the potential for the highest level of completion, thus creating the highest value proposition for our customer. Just like investment in factory infrastructure, the start-up and maintenance costs associated with a factory certification program are substantial, and they're *not* tied to volume. Therefore, we need to have confidence in our volume projections and financial calculations before embarking on this journey.

The underlying objective of factory certification is control. What does that mean? In a previous section, we described the manufacturing process as unconstrained. Not anymore. A quality assurance program gets into the nuts and bolts of your operation *and* business systems. And, although it's largely administrative, it can be quite invasive. Some elements of the certification process are prescriptive, which means that an external organization has the authority to change the way you run *your* business. And what doesn't change, is formalized and documented, forcing consistency in how business processes and manufacturing tasks are executed. No more game-time decisions in production. Get used to inspecting, reporting, reviewing, and approving most of the critical aspects of your production process as they relate to code compliance and product quality. No matter whether it's automotive, aerospace, or offsite construction, quality assurance programs have the same prime directive, to ensure that we are both disciplined and regimented in how we design our product, run our operation, and manage our business affairs. Much like adopting a manufacturing mindset, factory certification will influence organizational culture. Is it a positive change? Yes. Is it a hurdle that must be overcome? That depends. Some organizations will welcome and embrace the discipline; others will view it as a constraint or burden and rail against it. Either way, don't underestimate it. The certification process is bound to be far more invasive and consequential than you anticipated.

As a precautionary measure, we've focused on the *challenges* associated with factory certification. In doing so, we may have cast it in a bad light. The reality is that there is far more upside than downside here. Yes, the process can be painful, but it will also make your company stronger. You will get better at planning, organizing, documenting, and controlling the critical aspects of your business. The operation will become more stable, consistent, and predictable. And, while this sounds rather boring, isn't it exactly what your customer wants? Isn't this what our industry needs? Well, if we choose to follow the same evolutionary path as automotive manufacturing, the answer is yes.

7 Technology is an Option

A manufacturing process and the equipment technology it employs are not interdependent. They're separate and distinct. Manufacturing is a requirement. Investing in technology is an option. It's an option that deserves careful consideration. That's because the outcome of a poor investment strategy is far worse than simply failing to achieve a decent return. It can threaten the viability of your business venture.

Misguided decisions on technology selection and deployment impact the business in two important ways. First, as mentioned previously, we are investing in manufacturing technology, a depreciating asset. If we fail to generate revenue or savings from our investment, we lose both the anticipated benefit *and* our capital. Second, automation and flexibility are inversely related. This is important to note because it may be counter-intuitive for some. The more sophisticated the solution, the lower the potential for product and process change. Ironically, a robotic system, which would appear to be infinitely flexible, can be the most restrictive when considering post-installation product and process changes.

Poor decisions in technology selection can impose crippling constraints on product development, operational efficiency, and financial performance. Given the grave consequences associated with making a critical error, what can we do to maximize both our return on investment and our flexibility in operations? Here is a simple system that will serve you well in both areas. It includes three major elements.

Just like construction, the first element is the foundation. No matter how robust the building structure, it will not perform if it rests on a shaky foundation. In exactly the same way, manufacturing technology will only perform if it serves to enhance a manufacturing process that is fundamentally sound. This means that the first order of business is to develop an efficient manufacturing process or baseline. The best approach, when developing your baseline, is to exclude the use of sophisticated manufacturing technology and tools. This makes the exercise relatively simple and easy to understand. Once the baseline is established, we can now assess the need for advanced technology in each separate station or operation. This approach is focused and clinical, with no broad-based assumptions on value creation. As opposed to ordering a fully automated manufacturing system from the start, we enhance the baseline, strategically injecting technology where required to meet safety, quality, and speed requirements. In the end, we may very well end up with a fully automated system. The difference is that we will understand why it is required and where it adds value, station by station. Breaking the capital investment up into a series of small, focused activities, leads us to the next element – calculating our return on investment (ROI).

The key takeaway for the second element is to avoid calculating ROI at an aggregate level. The recommendation here is to be more granular in your approach. Assess the financial benefit for each and every application where capital is deployed, no matter how small the investment. While the need to enhance an operation with technology might be obvious, configuring the technical solution can be challenging. What type of automation is appropriate? Which equipment builder should you hire? What model, options, and features should you select? In most cases, there will be a number of potential solutions that are capable of producing the desired outcome. The answer to all of these questions lies in basic financial modelling. After we rule out options that miss the mark on vendor reputation, equipment quality, and after-sales service, we need only to run the remaining options through our ROI model. Assessing the financial merit of each option in a relatively small, controlled area with minimal variables makes for a sharp and accurate analysis. Consolidate a series of ROI calculations to form an aggregate number for a production line or work cell, but work from the ground up. This systemic, granular approach will force you to become intimate with the production process at a working level and inspire confidence in your financial projections.

The third element moves away from technical and financial considerations. It addresses the organization's ability to adapt. Building on the financial efficiency theme, we must avoid deploying technology where it is either not required or where the organization is not ready to receive it. The first element of our system ensures that we don't arbitrarily purchase advanced technology. The second element optimizes the technical solution, ensuring that it meets our investment criteria. The final element sets the pace of adoption. Simply put, the pace of deployment must not exceed the *natural pace of adoption*. All organizations are unique, with varying levels of exposure to advanced technology. Some will be quick to adopt while others may be relatively slow. Whether it's a willingness to change, comfort with technology, or aptitude, each business will have an inherent, natural adoption rate. Figure out what it is and deploy accordingly. Moving beyond the organization's ability to adopt and adapt creates debilitating stress and frustration in the workplace. Launching a new venture with advanced technology is already a monumental task. Don't exacerbate the situation by pushing beyond the limitations of your team.

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