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THE OPERATIONAL MODEL FOR *Modular Construction*

In the modular and industrialized environment, the four steps of data quality management (DQM) – collecting, recording, reporting, and presenting – can help both accounting and operations more accurately predict and prevent construction risks.

Tracking work, effort, time, and money as independently dependent variables is how other industries have moved to increased productivity and efficiencies.

This article will help CFMs understand and apply the skills needed to navigate the rough seas of this inflection point and get your company to a safe harbor of modular and industrialized construction. Some of the parallels to other industries are illustrative; only when these parallels are applied can they become explanatory. In other words, you cannot simply copy and paste a production system, but rather you must apply the principles and work through the process.

The Current Environment

The Industrialization of Construction® will bring an industry-wide transition from prefabrication to modular construction and, ultimately, to completely externalized work. Prefabrication will move from being an operational process used as a competitive advantage to a threshold of entry into the industry.

To lay out the operational model for modular construction, the lessons learned from industries that have previously gone through this transformation must be applied. The most important piece of this layout will be *reliance on data for management and decision-making*, which is, at this stage in the construction industry, a rarity except for the lagging indicators of financial reports. The factual requirements of the intent of this process will enable the passage of this transformation to be shared with the involved internal teams and external partners.

Contractors currently have two traditional, predominant operational models from which to select prefabrication:

1) *The Prefabrication Catalog* – A contractor creates or copies a prefabrication catalog from another contractor and asks their project teams to select prefabrication assemblies from this catalog. The prefabrication manager may also pick for the project team and build/ship the parts out to the site.

2) *Planning Prefabrication* – Project teams plan the work prior to the project start and identify what can be prefabricated. They then coordinate with the prefabrication shop to have it built, potentially undergo quality assurance/quality control (QA/QC), and shipped to the site.

Both of these operational models are advantageous over *not* doing prefabrication work, but they limit application and the full benefits of prefabrication are not realized (see "Jobsite to Garage: Changing the Mindset of Prefab & Modular Construction" from the March/April 2020 issue of *CFMA Building Profits*[1]).

Spheres of Influence

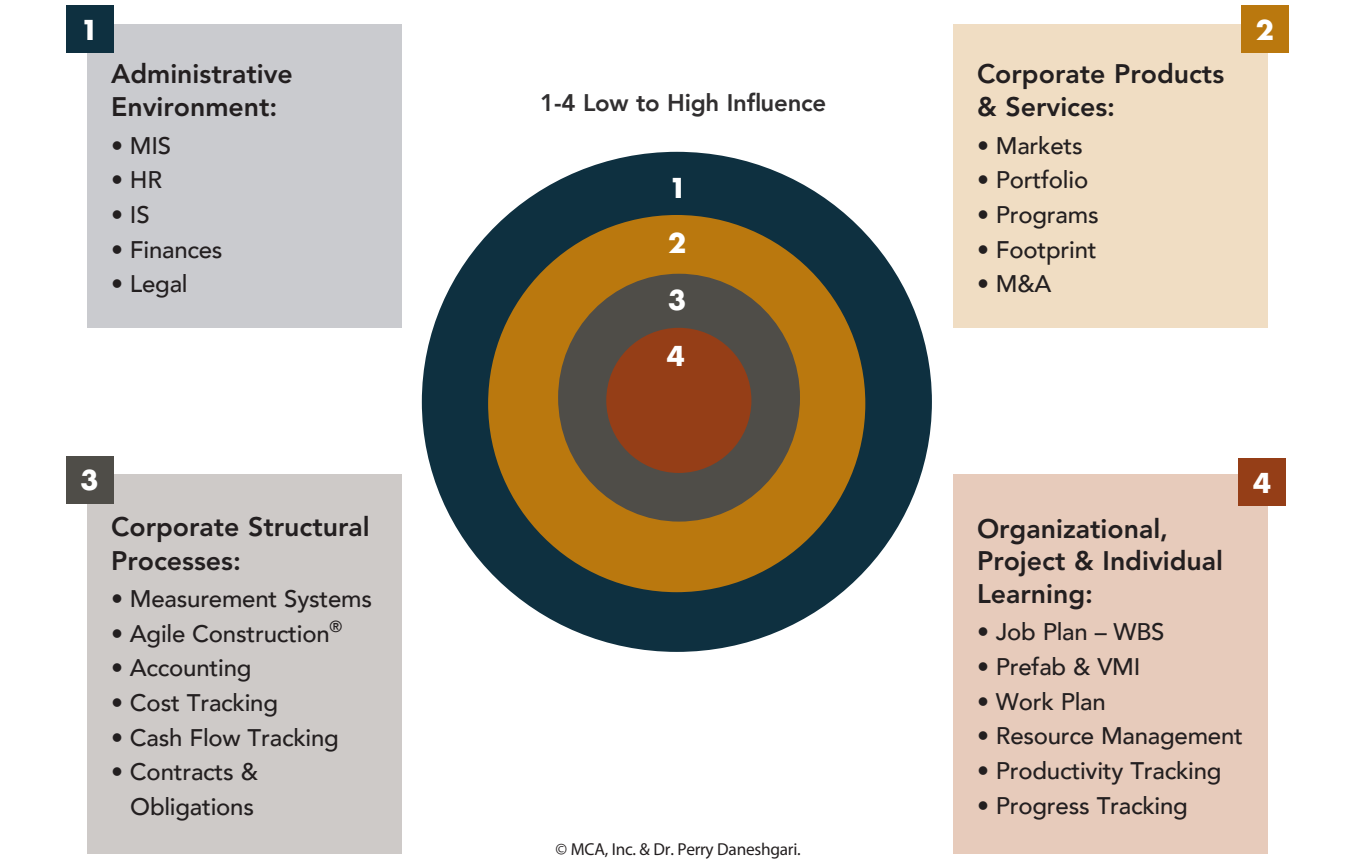
The operational model for modular construction will require contractors to work in all four spheres of influence. As shown in Exhibit 1, the outermost sphere is where companies have the least influence. As the spheres progress toward the core, the influence grows, and the business and the people within each sphere can design the operational model to work within the outer layers.

While the elements in each of the four spheres apply universally, there are specific elements related to prefabrication. Key elements of the administrative environment sphere were mentioned in "Industrialization: Is Construction Next?" from the January/February 2020 issue of *CFMA Building Profits*.[2]

Revenue Recognition to Account for Prefabrication Progress

Prefabrication has significant advantages for contractor revenue recognition and cash flow but requires a stronger reliance

EXHIBIT 1: **Influence Boundaries of Corporate Governanace & Operations**

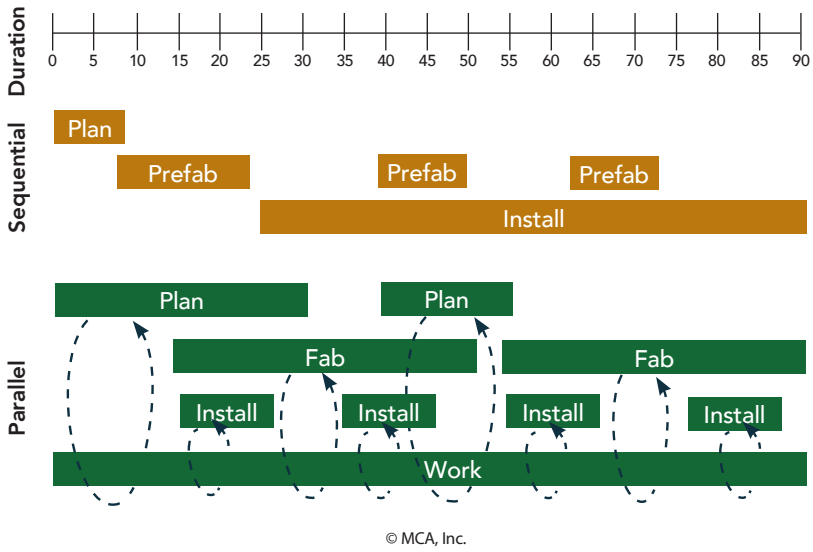


on data and data quality. Revenue can be recognized based on fulfilling performance obligations (per the FASB's ASC 606);[3] however, the work plan and schedule of values must be structured so that off-site work is traceable and visible.

Take an HVAC contractor that fabricates a ductwork system in its shop. The percent completion of the prefabrication must be tracked and incorporated into the schedule of values to calculate the fulfillment of a performance obligation and facilitate progress billing. If this is not correctly accounted for, then the prefabrication shop activities will incur cost, and the contractor will be cash negative and potentially underbilled for most of the project.

For contractors, the advantages come when they identify the prefabrication work as part of the schedule of values and as contributions to the contract's performance obligations. Due to being able to conduct more work in parallel for a particular jobsite, contractors are able to recognize progress associated with fulfilling obligations that are productive rather than front-loading the job based solely on cost.

EXHIBIT 2: **Sequential vs. Parallel Work**



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Tracking Prefabrication with Cost & Labor Codes

Accounting should set up a codification structure to collect costs in order to treat prefabrication as a cost or profit center. As a cost center, one separate cost code can be established to track all prefabrication work that needs to be job costed. As a profit center, it should have its own cost codes established – independent of the job – and should be measured and managed as a separate business entity. While using a profit or cost center is not a new concept for most contractors, existing models such as yard-operations, tool-room, vehicles-fleet, equipment, etc. are all examples of ancillary operations that have their own cost structure and are treated either as a cost center or profit center as an indirect cost.

In either case, for revenue recognition purposes, the work also needs to be reported to a job/job number so that the prefabricated work contributes to the performance obligations of a job. The way work occurs in prefabrication is different than how it happens on the jobsite. Using the same labor codes that are used on the job will not provide accurate or useful information (to the job or to the prefabrication shop operation). Typical prefabrication cost codes could include the assemblies or assembly types tracked for overall production and productivity measurement in the prefabrication shop.

The following data can also be collected for eventual feedback to estimating on assembly costs:

- Design and layout
- Planning
- Procurement
- Production
- QA/QC
- Packaging
- Delivery

Once a contractor starts doing modular construction (or even prefabrication), then it can incorporate that work into its portfolio (sphere 2 in Exhibit 1). Our company, MCA, Inc., is researching how to price prefabrication for estimating projects, which will result in a new costing and pricing model to help contractors estimate with prefabrication in mind.

For contractors just beginning prefabrication work, changing the overall estimating approach for labor units may be detrimental. Rather, these companies should utilize the composite rates, which can be measured and verified as a result of doing prefabrication.

The Operational Model for Modular Construction

Going from just prefabrication to a full operational model for modular construction starts at the core (sphere 4 in Exhibit 1)

with organizational learning elements and is supported with corporate structural processes (sphere 3 in Exhibit 1 a few pages back). Some of these key components were covered in "Jobsite to Garage: Changing the Mindset of Prefab & Modular Construction,"[4] which includes the critical work breakdown structure (WBS) process.

Work Breakdown Structure

The WBS is the first place to identify opportunities to externalize work beyond using prefabrication to simply build assemblies. The WBS is created during the planning phase of a project, but it must be referenced and revised throughout the project as the real-time representation of the "work" bus so that additional opportunities for prefabrication can be identified.

The major opportunity for externalizing is material handling, which can only be managed and tracked if it is identified as part of the WBS. Real-time referencing and revising the WBS will move a business into the operational model of modular construction. Exhibit 2 on the previous page shows a comparison of the sequential vs. parallel approach to the work.

In the sequential approach, which matches most current operational models, planning and prefabrication are a focus prior to the job startup, followed by installation and periodic check-ins to see what *can* be prefabricated throughout the job. In the parallel approach, the work is always visible and available for externalizing via the WBS. Installations and manipulations onsite are minimized because the model changes the question to, "What *can't* be prefabricated?"

Process of Prefabrication

The process of prefabrication (Exhibit 3 below) outlines the steps for planning, producing, delivering, using prefabrication, and most important, learning and improving. This process should be the backbone for the operational model of modular construction and can apply at any level of scale.

EXHIBIT 3: **The Process of Prefabrication**

Risk Identification

Plan for externalizing work

Step 1

- Input from estimate
- WBS
- Identifying externalizing opportunities
- Failure Mode Effect Analysis (FMEA)

Planning

Products & process development

Step 2

- Select type of prefab per opportunity
- Develop spec for Type 2 & 3 prefab[1]
- Make/buy decision
- Design for Manufacturability (DFM) & Design for Assembly (DFA)
- Translate project budget to prefab budget
- High-level prefab build schedule
- Project-specific needs and requirements

Prefab planning

Step 3

- Translate field spec into design spec
- Prototype and testing plan
- Prefab WBS
- Schedule manpower, money, material (3Ms)
- Integration planning at jobsite interfaces
- Plan quality assurance/quality control (QA/QC) process checks

Execution

Prefab production

Step 4

- Production scheduling
- Build
- Delivery
- QA/QC checks
- Adjustments to process & product based on prototypes
- Job feedback
- Production tracking
- Production documentation

Lessons learned

Step 5

- Good/bad
- Feedback to catalogue
- Feedback to process
- Measurements
  - Prefab
  - Project integration
  - Expected vs. actual

[1]*Prefab Types:*
Type 1 = common items (non-job related)
Type 2 = work-specific items (job related)
Type 3 = build-to-order (job specific)

There is only one step dedicated to actually *producing* the prefabrication (Step 4).

The prior steps incorporate lessons learned from other industries that have gone through industrialization and have moved toward a production and operator-driven environment. Steps 1 and 2 are critical for identifying all of the work that can be done through prefabrication, and how to prepare the identified work for productive prefabrication. Translating ideas into production requires product development and design for assemblies and subassemblies.

Setting up the physical prefabrication environment is an easier part of the transition than changing the overall company environment because the latter requires leadership (covered in "Industrialization: Is Construction Next?"[5]), support, and training for the workforce (covered in "Jobsite to Garage: Changing the Mindset of Prefab & Modular Construction"[6]). Once these challenges are met, setting up the prefabrication shop requires attention to three flows: material, information, and work.

Material Flow

Off-site prefabrication must be job-independent and contribute to the reduction of labor cost in material handling and labor waste on the jobsite. Material flow must be mapped from the vendors to the shop, within the shop itself, to the jobsite, and within the jobsite.

Without planning for this, all of the hard work identifying and producing prefabrication can be lost with one late shipment or one piece of the assembly being left off the delivery truck.

Exhibit 4 on the following page shows an example of this type of layout, which considers inbound/outbound material flow to and within the prefabrication shop.

The material flow should be designed and quantified to avoid inventory buildup and should ultimately lead to standardization of material – a key advantage for prefabrication. Material distributors and vendors may also have the ability to support the prefabrication shop material flow by managing it as a subset of their branch. They can also provide vendor-managed

COVID-19 IS A CATALYST FOR INDUSTRIALIZATION:
Accelerating the Need for Modular Construction

Socioeconomic catalysts build on preexisting conditions and accelerate the tectonic shifts caused by market and social needs. Such disturbances and disruptions cause irreversible ecosystem shifts. Examples of comparable catalysts as COVID-19 are Industrialization, Depression, WWII, Oil Crisis, and September 11.

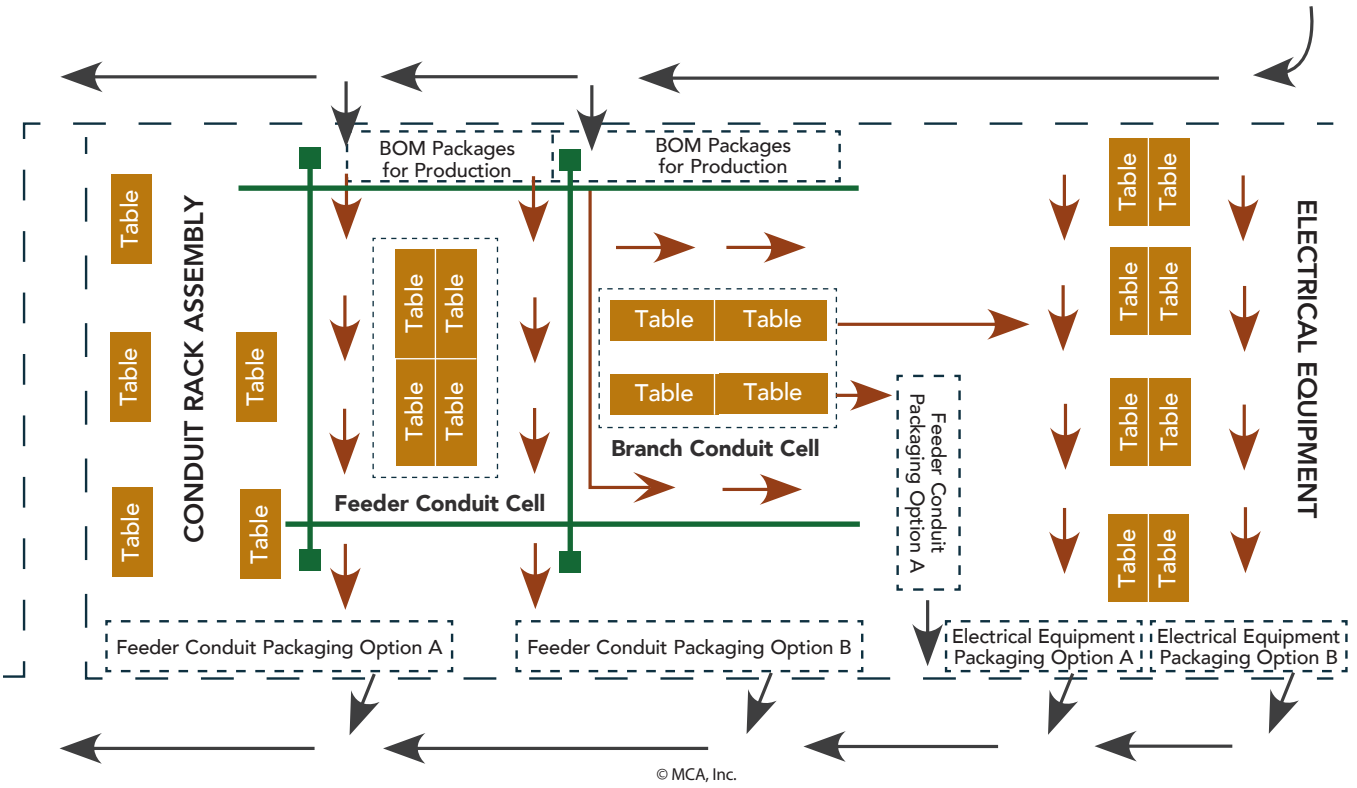
Although it seems like the COVID-19 pandemic and its impact is a new and unique situation, its historical parallels take that uniqueness away. We must prepare ourselves to go from current smooth sailing toward Industrialization and navigate the rapids for a while. The solutions will most likely lay in Modularization and Construction Industrialization®.

Over the past two months, we have been asked, "What impact will COVID-19 have on the construction industry?" Here is what we expect to see, which we will be studying and then publishing in the September/October 2020 issue of *CFMA Building Profits*:

- Up to 12% of labor time is unrecoverable due to additional work required to comply with guidelines and site-specific policies from the Centers for Disease Control and Prevention (CDC).
- Productivity increases (while work sites have limited crew size, reducing interferences to completing work productively) followed by severe decreases when jobs reopen, and scheduled completion dates must be met.
- Increased supply chain shortages, which add stress on jobsite productivity as material and equipment delays cause schedule slippage.
- Personnel impacts, including absenteeism worse than the industry-wide average of 12-15%, which further exacerbates the workforce shortage problem that existed before COVID-19.

Two ways to address these challenges is through Externalizing Work® and "flattening the curve" of the work and manpower needed onsite. Construction companies need to complete work to keep the construction projects moving in order to maintain their revenue stream independent of the short-term government lending programs such as the Small Business Administration's Paycheck Protection Program (PPP). We expect the need for modular construction and beyond to be imminent and the pace of Industrialization of Construction® to increase.

EXHIBIT 4: **Prefabrication Shop Material Flow Layout**



inventory services to stock, monitor, and replenish common materials (even down to the consumables and tools) used for prefabrication production.

Information Flow

The information flow needed to support prefabrication is similar to the material flow in that it requires design of information into, within, and out of the prefabrication operation.

The most critical information is the translation of work and the installation into an assembly that is produced, shipped, moved into place, and installed correctly. Without this, prefabrication can quickly turn into "refab" (reworked prefabrication) because doing the work off-site cannot replace the accuracy and ease of installation.

The projects using prefabrication need a tight connection between the onsite foreman and the prefabrication shop manager for the transfer of information. Quality is the responsibility of both parties and must be managed by translating the onsite "eyes and ears" for perfection into a build process away from the site.

The prefabrication request form and corresponding process is one of the most critical elements of information flow. The technical element of the request can be informal at first, including a sketch, a drawing with markups, etc.

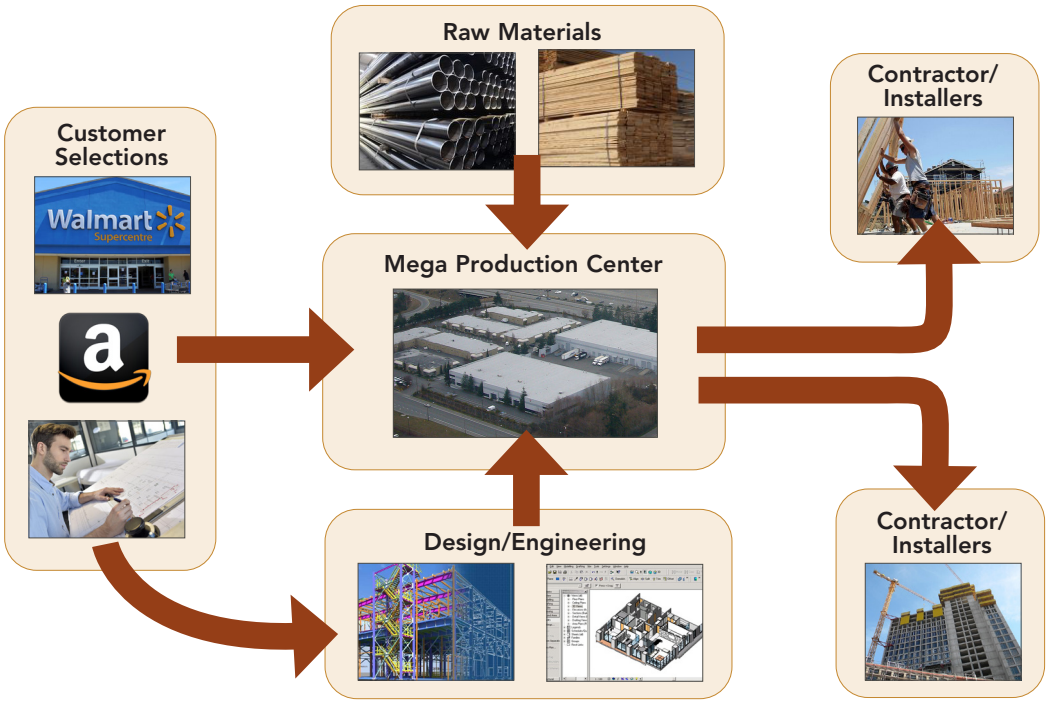
More critical information will eventually be needed to keep the prefabrication shop's efforts connected to the job, such as the project name/number, point of contact in the field for questions, date needed on the jobsite, etc.

The second most important information flow is what accompanies the prefabrication when it ships. Information about what was produced, what is included in the assembly package, assembly instructions, as well as point of contact in the prefabrication shop are all useful for the field to productively install the prefabrication.

Workflow

In addition to material and information flow, the prefabrication workspace should be laid out to accommodate the workflow, which transforms raw material into output packaged assemblies and subassemblies ready for shipping.

EXHIBIT 5: **Construction Industrialization Megacenter Scheme**



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A few simple considerations include:

- Ergonomics at individual workstations, between workstations, and material location and replacement
- Safety
- Tool utilization and uptime
- Flexibility of workspaces to accommodate changes in flow and the mix of assemblies produced
- Spaces for job planning and review with access to technology

The workflow should also be segregated into three types of prefabrication:

1) Assembly of parts common amongst all jobs in the form of a cell layout for workflow efficiency

2) Assembly of type-of-work-specific prefabrication (common within a type of work) in the form of flexible and configurable cells

3) Assembly of build-to-order project-specific parts, which are laid out for dedicated spaces with clear boundaries on availability based on scheduled production dates

Coordination Required for Modular Construction

While following the previous steps will lead a contractor toward modular construction, the full application of modular construction requires cross-trade and integrated final assemblies. For an individual contractor, this means involving and/or working with other trades to produce assemblies. This method can be driven by the GC, owner, or construction manager (CM) as well as by subcontractors.

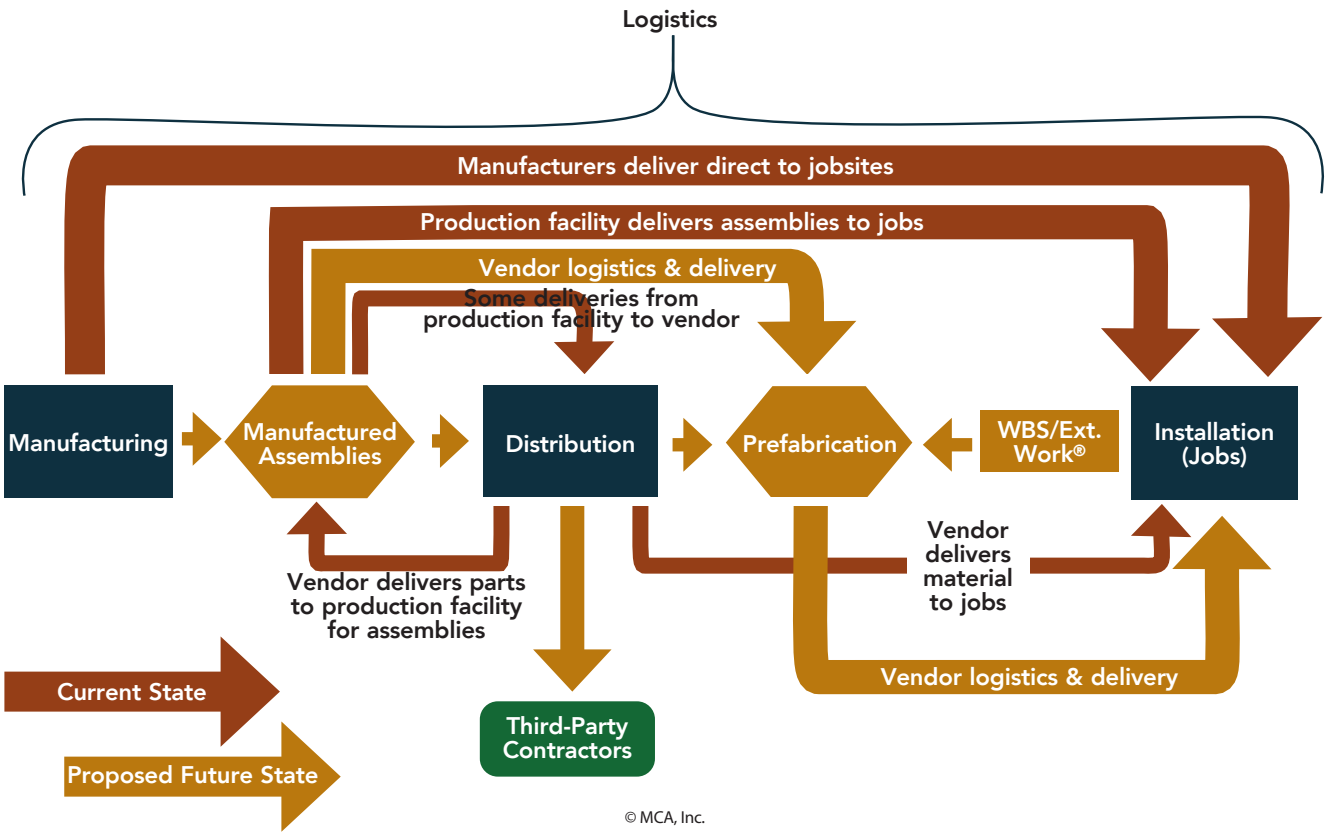
Examples include hospital headwalls with integrated mechanical, electrical, plumbing, carpentry, and steel scopes of work. Ceiling infrastructure can also involve the same cross-trade approach to building racking systems on the ground and then hoisting and supporting them only onsite.

A few key elements to this approach are covered hereafter; however, given the stage of modular construction, contractors should consult their attorneys, engineers, and CPAs for more regulatory guidance and advice.

Contract Management

The majority of contracting and subcontracting methods still separate scopes of work by trade. So, when multi-trade prefabrication is being considered, it is important to understand

EXHIBIT 6: **Construction LCM™ (Logistics-Centric Model)**



the risks and money flows associated with combining scopes amongst trades. It is important for GCs/CMs to stay informed of any scope collaboration so they can manage the impact to the contract agreements.

Integrated project delivery (IPD) includes multi-party contracting, which could allow for a more efficient modular construction approach; however, the delivery method itself has not yet been used across construction reliably.

Shared Space & Supporting Infrastructure to Build

When modular construction is driven by the GC/CM, a shared production space is sometimes established. Otherwise, trade contractors need to discuss the best location to build the assemblies.

Collaboration on Delivery, Install & Feedback

With multiple trades involved in building the assemblies and subassemblies, deciding who should do what in terms of delivery, final installation, and providing feedback to the prefabrication operation requires collaboration and communication.

Tolerance Management

Building information modeling (BIM) can and will continue to be an important technology to support modular construction. However, the technology is still utilized as a tool for the physical assembly of the building and does not incorporate the interfaces and work information on which tradespeople still collaborate at the jobsite. The interfaces of systems, subassemblies, and final assemblies need to be designed and planned together to avoid overbuilding or tolerance stacking, which is another principle that has been learned in manufacturing and will need to be translated to construction.

The Transition Toward Industrialization of Construction®

Going from modular construction to Externalizing Work® requires the mindset shift to referencing and revising the WBS throughout the job (Exhibit 2) and results in 30-50% of the work being done off-site. Only final assemblies are delivered to jobsites, and there is no movement of individual tools or materials onsite. This model requires distribution

and logistics support due to the change in how assemblies are transported and delivered to the site and final installation locations.

Material distributors and suppliers can support this to a limited capacity, but ultimately the supply chain itself will be disrupted by logistics providers that use their value and knowledge of transportation and movement more than their knowledge about product and pricing.

For example, a traditional material distributor may offer to pick up the prefabricated assemblies from your shop and deliver them to the jobsite. At the same time, they make a delivery on another truck with materials to the jobsite. This redundancy will eat up the traditional vendor's capacity to support both Externalizing Work® and the full application of Industrialization of Construction® in the form of megacenters.

Megacenters

The final stage of Industrialization of Construction® will take the form of a megacenter (Exhibit 5 at left). Construction consumers will select their desired built environment or infrastructure through retail channels, which will trigger production in a common megacenter setting with logistics packages and processing, reducing the number of final manipulations on jobsites. This is a fundamentally different model than today's typical construction but has happened in other industrialized industries and is currently happening overseas. Eventually, the U.S. could lead the effort with the amount of knowledge and experience from its aging workforce.

Exhibit 6 at left shows the Logistics-Centric Model™ approach, which is the starting point to transition to the megacenter model. The red arrows depict the current and traditional approach of the material and prefabrication movement within the supply chain and to the jobsite. The yellow arrows show the future state of the construction Logistics-Centric Model.™

In the construction Logistics-Centric Model,™ the logistics of moving material, manufactured assemblies, and prefabricated final assemblies identified through the WBS becomes the critical limiting factor of performing more work off-site.

EXHIBIT 7: **KPIs for Construction LCM™**

CONSTRUCTION LCM™ PROCESS STEP	KPI	INDICATOR ▲ = good ▼ =good
Project Management	Productivity	▲
Project Management	Obstacles to scheduled work	▼
Ordering	Cost to process orders	▼
Ordering	Ordering system cycle time	▼
Ordering	Order lead time	▲
Ordering Processing	Information availability about material & assemblies	▲
Production	First time pass	▲
Production	Number of manipulations onsite	▼
Production	Production scheduling lead time	▲
Production	Inspections/need for inspections	▼
Receiving & Movement Onsite	Number of touches	▼
Receiving & Movement Onsite	Cycle time from delivery to install	▼
Receiving & Movement Onsite	Material handling within the jobsite	▼
Remobilization	Percent of "correct" logistics outcomes	▲
Remobilization	Rate of returns	▼
Remobilization	Equipment utilization rates	▲

Distributors and vendors will need to rethink their own operational models to support this increased pace of material, work, and information flow.

From a financial perspective, the way work and jobs are measured will also completely shift with the measures of material, work, and information flow becoming more critical. A table of KPIs coinciding with the steps of the construction Logistics-Centric Model™ is shown in Exhibit 7.

Industry Transformation **Do's & Don'ts**

The do's and don'ts of this industry-wide transformation will have no background in the history of construction or your company's past successful strategies and tactics. Here are the top 10 do's and don'ts of the transformation to modular, industrialized, and lean construction:

1) *Do* start to think like Henry Ford by identifying and removing waste.

2) *Do* separate the three elements of project performance – work, effort, and time – at the highest level of the company.

3) *Do* include your workforce in breaking down the work (WBS).

4) *Do* create and track the actual field nonfinancial performance database, and integrate it as a part of financial and estimating measures.

5) *Do* include your vendors and suppliers as a part of the solution in the reduction of installation cost and logistics management.

6) *Don't* manage jobs from the top down.

7) *Don't* rely only on lagging indicators for progress measurement.

8) *Don't* confuse work with effort and time.

9) *Don't* let your labor manage the system productivity as it needs to be managed by the entire company's executives.

10) *Don't* be a single point trender; don't shoot the messenger.

Conclusion

This article has provided the nuts and bolts of establishing an operational model that can support prefabrication and, ultimately, modular construction.

The increase in prefabrication shows that, as an industry, we are on the path toward industrialization. Given our societal needs, such as the workforce shortage and our global pandemic response to COVID-19, we require buildings and infrastructure to be created faster, better, and cheaper. This three-part article series in *CFMA Building Profits* has helped draw a road map to get there. ■

Note: A Guideline for the Operational Model Transition is available at *www.cfma.org/IndConst* with all three articles in this series to help guide your company through this process.

Endnotes

1. *www.cfmabponline.net/cfmabp/20200304/?pg=37.*
2. *www.cfmabponline.net/cfmabp/20200102/?pg=45.*
3. "Revenue from Contracts with Customers (Topic 606)." FASB. May 2014. *asc.fasb.org/imageRoot/00/51801400.pdf.*
4. *www.cfmabponline.net/cfmabp/20200304/?pg=37.*
5. *www.cfmabponline.net/cfmabp/20200102/?pg=45.*
6. *www.cfmabponline.net/cfmabp/20200304/?pg=37.*

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