NAC Executive Insights

# Construction Productivity

## Key Points

- Productivity is a measure of the rate at which work is performed.
- The appropriate measurement of productivity has been an industry challenge for decades.
- The first challenge created in construction productivity management is in establishing how productivity will be measured.
- A second challenge relates to systematic over estimation of productivity.
- Productivity challenges have grown with scale.
- Broader adoption of digital planning tools, including 4D BIM, provide granularity that good productivity management requires.
- Introduction of artificial intelligence (AI) into digital models offers further promise of optimization and risk assessment.
- Strategic and tactical actions to improve productivity are suggested and segregated into six categories—labor, equipment, materials, means and methods, technology, and management.
- Select factors influencing construction productivity are quantified.
- A strong link exists between safety and productivity.

## Introduction

Construction productivity has been a perennial problem faced by the construction industry. In this Executive Insight the following topics will be addressed:

- What is productivity?
- What are the challenges productivity creates and how have those challenges changed?
- What are strategic actions to take to improve productivity?
- What are tactical actions to take to improve productivity?

## What Is Productivity?

Productivity is a measure of the rate at which work is performed. It is the ratio of “outputs” divided by “inputs.” Outputs are usually expressed in terms of volumes, weights, or other quantitative measures such as length, equipment, or other “units.” Inputs may be measured either in financial terms or units of work (labor-hours).

Productivity is a relative measure of efficiency compared to established norms.

Recent efforts by the U.S. Bureau of Labor Statistics (BLS) are promising with regard to how to appropriately measure productivity.

## What Are the Challenges Productivity Creates?

The first challenge created in construction productivity management is in establishing how productivity will be measured and which measurements will be used. Productivity measurement can be conducted against established benchmarks, other similar projects (especially any used as part of a reference class forecasting approach), and rates and efficiencies in accepted bids, plans, or estimates. In developed claims, a "measured mile"[1] approach is often used to compare actual performance with performance in an unhindered or impacted period.

A second challenge that productivity creates relates to systematic over estimation of productivity due to construction planning that is not granular enough[2]. Also, this second challenge includes failures to fully account for the added complexity associated with large projects, such as scale, uncertainty, and emergent behaviors, requirements, and circumstances.

## How Have Productivity Challenges and Perceptions Changed?

Productivity challenges have grown with scale, with over a third of projects experiencing major changes. These changes result in rework, shifting of work to less productive periods, and added stand-by time as crews wait for information, equipment, materials, and direction.

Perceptions of the construction industry's failure to improve productivity, however, are being ameliorated to some degree by recent efforts of the U.S. Bureau of Labor Statistics (BLS) to better measure productivity. Variations in performance between different construction sectors noted by the BLS suggest opportunities exist to learn from the practices of the better performing sectors. Much remains to be done despite the BLS improvements in measurement approaches.

Broader adoption of digital planning tools, including 4D BIM, offers the potential to have the required granularity that accurate productivity management requires. The introduction of artificial intelligence (AI) into these digital models offers further promise of optimization and risk assessment.

[1] The Measured Mile is a method that is designed to create a control period drawn from when labor/material production on the project was at its normal rate. Then, compare that against the time period(s) when the contractor was being negatively affected (delayed, disrupted, suspended).

[2] This problem usually occurs when the CM or GC develops the construction schedule and doesn't include sufficient durations or detailed activities to complete the given task. Productivity data is insufficient and obtaining reliable subcontractor input is best obtained from historical data.

## Strategic Actions to Take to Improve Productivity

1. **Labor**

- Minimize holiday work, which has added cost, lower productivity, and a lingering negative morale factor.
- Account for seasonal variation (temperature, dry/rain, seasonal light levels) in labor performance in resourcing levels and planned schedules.
- Account for local or craft practices (breaks; customs, including religious) in planning.
- Choose work schedules that optimize labor productivity for the particular project and site (alternate Fridays off; 4 days x 12 hours/day with two crews; week on/week off with two crews).
- Avoid extended work weeks for an extended period of time (productivity has shown to drop as extended work weeks persist).

### *Do Not Crunch*

***Long-term use of extended work weeks has diminishing returns.***
***Output of 8 x 60-hour work weeks = Output of 8 x 40 hour-work weeks.***

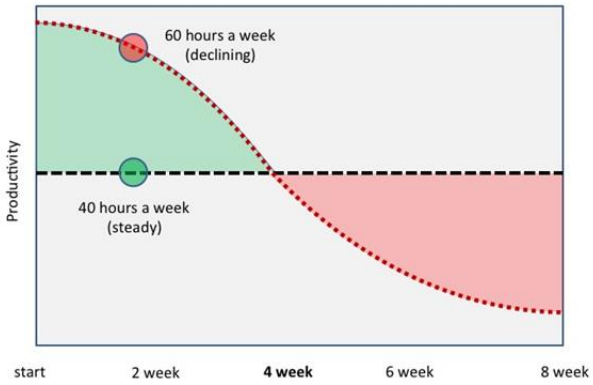


*Figure 1. Use of extended work weeks does not increase productivity.*

- Estimate labor requirements and productivity by work package, considering both the nature of the work and environmental variations (temperature, wet/dry, day/night, seasonal light levels).
- Shift as much effort to prefabrication or module yards as possible to capture higher productivity in a more manufacturing-like setting.
- Evaluate and address craft training needs at both final project site as well as at any module or prefab location.

2. **Equipment**

- Have strong schedule management of any owner-furnished equipment to eliminate any labor stand-by time.
- Develop a master equipment schedule keyed to workface requirements. Recognize that waiting for equipment is a major productivity destroyer.
- Develop an equipment maintenance plan and ensure required facilities and equipment for both routine and periodic maintenance are present and available.

3. **Materials**

- Use high quality supply chain surveys to provide for any likely constraints or extended delivery timeframes that would impact project execution efficiency.
- Assure rigorous logistics planning, including options analysis.
- Identify alternative sources of supply as a contingency for inadequate selected supplier performance.
- Inspect materials on receipt for conformance to specifications. Establish maximum rejection rates without penalty in the contract.

4. **Means and Methods**

- Match to labor skills and capacities.
- Limit/eliminate work at heights.
- Limit/eliminate work in confined spaces (added access/egress times; lower unit productivity in this work environment).
- Create a project means and methods library to share best practices. Take advantage of any industry or corporate means and methods libraries.
- Maximize off-site prefabrication and inspection.

5. **Technology**

- Improve construction planning and optimization.
- Integrate equipment and materials needs into construction plans by work package.
- Utilize 4D BIM to highlight potential trade and crew conflicts as well as congestion or need to share resources (equipment, scaffolding). Ensure productivity allowances for beneficial occupancy are provided.

6. **Management**

- Put in place a strong safety culture before anything else.
- Basis of Design (BOD) includes consideration of a Construction Basis of Design (CBOD) and waste minimization (supports increased productivity).
- Secure scope completeness, including consideration of impacts on labor productivity (need to work at height; second and third shift operations).

- Align the project team (includes owner, contractor and others), the culture (open, transparent, bias to action, with safety focused on zero accidents), and project morale.
- Monitor and support labor morale and motivation. Create a climate for motivation (see Table 1).

| **Table 1**<br>**Motivators** |
|---|
| |
| e some controls while retaining accountability. |
| e accountability of individuals for their own work. |
| each person a complete natural unit of work. |
| dditional authority to an individual in his or her activity. |
| eriodic reports directly available to all workers (transparency). |
| ce new and more difficult tasks. |
| individuals specific or specialized tasks to enable them to become s. |
| |
| *Frederick Herzberg, renowned researcher of human behavior, proposed rinciples as a means of enhancing motivation.* |

- Have rigorous site characterization to minimize disruptions from unforeseen site conditions.
- Quality and completeness of design documents are essential. Constructor must be engaged before drawings issued for construction. Timely engineering support during construction (preferably field-based) also is essential.
- Establish RFI (request for information) performance criteria (timeliness; completeness of response; clarity of response).
- Understand productivity impacts of any beneficial occupancy.
- Eliminate mobilizations and demobilizations in a craft, subcontractor, or project area. Start and stop execution is a productivity killer.
- Ensure any required access control provisions have been accurately reflected in productivity assumptions (extensive security checks).
- Ensure adequate transport for on-site labor have been provided for and accounted for in productivity estimates. This is especially important on large or remote sites.
- Be cognizant of the true extent and impacts of any disruptions to the project plan.
- Seek to limit portions of the site deemed to be hazardous work areas (added precautions; special equipment).
- Ensure site layout supports labor's needs by avoiding long distances between tools, breaks, and comfort areas. Site layout of these supporting facilities may be required to evolve with site development. Develop multiple site layout plans.

- Establish strong document flow and document management systems and practices early to minimize time waiting for information. Ensure crews and supervisors have wireless digital access to information they require to perform their work.
- Provide supervisory staff with conflict resolution training.
- Thoroughly review quality and completeness of engineering drawings prior to release to work crews. Provide schedule buffer so work crew generated RFIs and field holds are minimized or eliminated.
- Minimize manual and paper-based processes that may delay information flows or create unintended information gaps (the missing notes page for a drawing set).
- Establish a data-centric management culture.
- Celebrate performance.
- Ensure proper sequencing of trades.
- Strive for repetition (improved experience curve), standardization, and simplicity in construction planning.
- Process change orders in a timely and effective manner[3].

### *Learning Curve vs. Experience Curve*

***Learning curve – productivity increases as an apprentice or worker new to a task learns their trade and required skills.***

***Experience curve – productivity increases as a skilled worker repeats a task a number of times.***

- Include a cleaning clause in all subcontracts linked to payments (supports site housekeeping).
- Require equipment suppliers to take back shipping and packing materials as part of their contracts (supports site housekeeping).
- Include penalty clauses for late delivery of equipment and materials. Similarly include penalty for late mobilization of select subcontractors.
- Conduct routine (weekly) inspections on a fixed schedule to eliminate unplanned disruptions from routine inspections.
- Prepare summary of base bid requirements and review with all supervisory personnel. This is more than just a scope review and should include estimate assumptions, including assumed means and methods and productivity factors.
- Identify coupled constraints in master schedule (labor, materials, equipment, and logistics).
- Use prototyping of highly repetitive modules or key program elements.
- Utilize look-ahead reports for upcoming training and tool needs.

[3] Oftentimes, subcontractors are left to finance a project because the CM or GC and owner do not process the simplest of cost changes as well as major bulletin changes. A happy subcontractor, defined as one that is taken care of by the CM and GC financially, is more likely to be motivated to meet schedule and other project demands.

- Seek to establish dates for scope and design freeze.

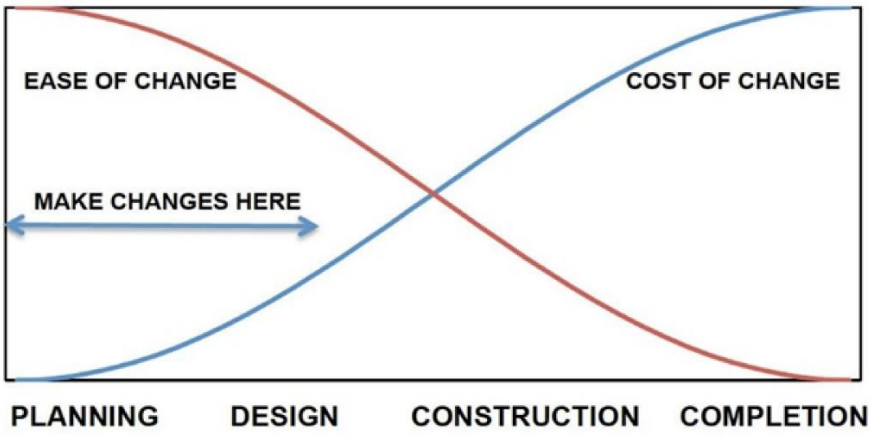


*Figure 2. Cost Influence Curve: Changes made earlier are easier and less expensive.*

## Tactical Actions to Take to Improve Productivity

**1. Labor**

- Establish strong site-based safety culture and practices. “Walk the talk.” Eliminate hazards. (There is a strong link between safety and productivity.)
- Control use of overtime and second-shift work, especially for extended periods. This leads to drops in labor productivity and requires a second (or third) shift to pick up from prior shifts. Gaps may occur.
- Avoid use of extra crafts that impact baseline labor planning. Avoid unplanned joint occupancy of work areas.
- Avoid overcrowding or required sharing of equipment and scaffolding.
- Build and monitor morale and team-based behaviors. Engage workforce positively and instill a sense of trust.
- Engage workforce through workface planning.
- Provide breaks commensurate with environmental conditions, period of sustained work, and level of exertion to minimize impacts of fatigue.
- Incentivize productive attendance and retention. Turnover can lead to significant productivity loss from new and unfamiliar workers.
- Limit need for extensive or frequent reassignment of labor that impacts productivity.
- Assess impact of any work slippages into other than planned time frames (Examples – work shifts from dry season to rainy season; work slips from fall pre-holiday period to winter over major holiday period).
- Ensure full complement of supervisors at project initiation. Do not let the project get off on the wrong foot.
- Recognize and account for productivity differences by day of the week (See Table 2).

| Table 2<br>Productivity by Day of the Week<br>(Ranked) | |
|---|---|
| | |
| **Highest** | Wednesday |
| | Thursday |
| | Tuesday |
| | Monday |
| | Friday |
| | Saturday |
| **Lowest** | Sunday |
| | |

- Dismiss inefficient construction workers.
- Craft-friendly work environments improve craft retention.
- Placing shelters (for crew facilities, tool maintenance, specialty tasks benefitting from a controlled environment) increase productivity and can provide added cost savings.
- Seal exposed areas each day.
- Provide adequately engineered work surface.
- Plow wet ground to accelerate drying.

**2. Equipment**

- Monitor upcoming equipment requirements to ensure correct tools in correct quantities are available.
- Provide adequate time and resources for equipment maintenance (lubrication, sharpening, and inspection).
- Minimize crane movements.
- Cutting and welding should be positioned to reduce effort and make work more visible.
- Sanders, grinders, drills, hacksaws, and similar hand tools should have weight balance and grips periodically checked.

**3. Materials**

- AI-enabled supply chain management can minimize unforeseen disruptions.
- Strengthen material management to avoid material unavailability (waiting for materials). Link to actual site performance, wastage factors, and supply chain lead times.
- Employ real-time logistics management, including equipment and materials tracking and establishment of required buffers and inventories.
- Monitor impacts on required material quantities and timing from any approved changes.
- Establish designated areas for segregated collection (and possible reuse) of waste materials and general debris.
- Store materials on pallets to keep out of the mud.

**4. Means and Methods**

- Ensure workface is adequately lighted.
- Ensure adequate protection of workers performing in operating plant areas; account for any special protective equipment required and any added time associated with access and egress.
- Establish inspection and approval points and reflect on schedules.
- Ensure acceptance or performance criteria are associated with discrete tasks and activities.
- Clear performance responsibilities linked to crews or individuals. Monitor and track.
- Use reusable formwork and standardized formwork sizes.
- Continue expansion of mechanization wherever possible (power compaction; motorized screeds, power floating, and troweling; power tools (battery and compressed air)).
- Use personnel lifts in lieu of scaffolding and ladders (improved safety, lower erection time).
- Use electronic/laser leveling and transits. Use laser scanning to confirm as-built conditions as work progresses.
- Use adhesives as substitute for certain mechanical fastenings.
- Prefab repetitive, labor-intensive components (roof trusses; stud walls; concrete floor and deck slabs).
- Use tablets to provide greater information at workface, including instructions, checklists, illustrations, and inspection/acceptance criteria; also query access to supervisor, engineer, or vendor.
- Use pre-cut and pre-spooled cable.
- Use pre-wired electrical modules.
- Use skid mounted equipment, including spooled electrical “home runs” and installed controls and control cables.
- Optimize vertical lifts of materials (consider cycle times).

**5. Technology**

- Enable visualization of problem areas and potential execution options and risks.
- Expose and characterize inherent inefficiencies in planned execution approaches.
- Populate a knowledge base of execution solutions and real-life lessons learned, supporting future use by embedded AI.
- Provide substantiation to any requests for changes or claims.

**6. Management**

- Minimize out of sequence work that leads to rework.
- Assess when approved changes are best made (now, later, punch list or commissioning stage, post-startup).
- Keep site clean, maintained, well-lighted, and orderly. (Poorly kept sites are often a leading indicator of safety and productivity problems.). Work to established plans, protocols, or performance criteria.
- Out of sequence construction, including unplanned acceleration of non-critical path scope, can lead to future rework.
- Rework can arise from inadequate supervision, including that associated with unplanned or accelerated activities.

- Maintain crew integrity to accrue the productivity benefits of teamwork. Ensure crews are fully staffed per plan, including timing. Avoid providing too many personnel to a task, which can create inefficiencies.
- Recognize required learning curve impacts on productivity and provide incentives for retention and well-developed onboarding, orientation, and training.
- Plan work in hazardous areas to maximize time on tool.
- Ensure adequate supervision levels at all work areas on all shifts. Concept of working supervisor reduces required supervision (not a good idea).
- Train supervisors on effective use of field productivity software and other available tools.
- Ensure sufficient technology support is available onsite.
- Encourage and recognize individual and crew-based productivity improvements.
- Strengthen use of workface planning and increase delegation to better trained line supervisors. Preplan and assign work responsibilities as part of workface planning. Invest in training. Note: Workface Planning is the organization of field execution around the creation of fully resourced packages of work that can be executed by a single construction crew in a discrete period of time, typically five to 10 days or around 1,000 hours. It is the final step in the Advanced Work Packaging (AWP) process, focused on getting the correct things to the correct people at the correct time to improve productivity and save money.
- Avoid overly complex inspection procedures. Ensure inspection frequency does not overly contribute to waiting time.
- Plan other crew activities that support future productivity improvement that can be performed if equipment or materials unavailable (work area housekeeping; materials staging; tool maintenance; training; workface planning/re-planning).
- Establish scheduled periods for incidental rework or repair of damage to works every month (scheduled and planned versus unscheduled and ad hoc).
- Focus time management on reduction of unproductive time.
- Focus supervision on initial execution of highly repetitive tasks, including use of multi-crew observation of first execution.
- Focus supervision on tasks critical to overall schedule progress and those with challenging inspection or acceptance criteria.
- Focus supervision where contract penalty clauses may come into play.
- Establish hourly, daily production goals aligned with workface planning packages.
- Ensure adequate time buffers between activities.

## Summary

Table 3 (page 11) illustrates the impacts of some select factors on labor productivity.

| Table 3<br>Select Factors Influencing Craft Labor Productivity[4] | | | | | | |
|---|---|---|---|---|---|---|
| | | **Influence** | | | | |
| **Factor** | **Sub-factor** | **A. Worst** | **B.** | **C. Average** | **D.** | **E. Ideal** |
| | | | | | | |
| **Craft Availability** | Local supply | Poor<br><40% | Fair<br><60% | Average<br><80 | Above Average<br><100% | Ideal<br><110% |
| **Craft Skill Level** | Work ethic; prior relevant experience | Poor<br><50% | Fair<br><70% | Average<br><90% | Above Average<br><100% | Ideal<br><110% |
| **Congestion** | Work area per laborer ($ft^2$) | <200<br><60% | 200 -250<br><75% | 250 – 300<br><90% | 300 – 350<br><100% | >350<br><110% |
| | Number of Weeks | | | | | |
| | | >10 | 8-10 | 6-8 | 3-6 | <3 |
| **Work Week (hours)** | 40 | 100% | 100% | 100% | 100% | 100% |
| | 50 | 70-75% | 75-80% | 80-85% | 85-90% | 90-95% |
| | 60 | 60-65% | 65-70% | 70-75% | 80-85% | 85-90% |
| | 70 | 50-55% | 55-60% | 60-65% | 70-75% | 80-85% |
| **Shifts** | Shifts per day | 3<br><70% | 2<br><85% | 1<br>!00% | | |
| **Climate** | Temperature | Extremes<br>Cold <40<br>Hot >95<br><50% | Averages<br>Cold <60<br>Hot >75<br>80% | Mild Year Round<br>60-75<br>100% | Inside<br><110% | |
| | Snow/Ice | >6 months<br><50% | 3-6 months<br><70% | 1-2 months<br><90% | Minimal<br><100% | Inside<br><110% |
| | Rain (inches per year) | >200<br><40% | 100-200<br><60% | 50-100<br><80% | <50<br>90% | Inside<br><100% |
| | | | | | | |

## About the Author

Bob Prieto was elected to the National Academy of Construction in 2011. He is a senior executive who is effective in shaping and executing business strategy and a recognized leader within the infrastructure, engineering, and construction industries.



[4] Representative values applied to baseline; weighting of factors varies by sector