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Factors Affecting Productivity

Key Points

- Factors impacting productivity on engineering and construction projects are segregated into internal and external factors and are delineated.
- Concept of "phantom productivity" – productivity for activities not on the critical path is introduced.
- Loss of productivity with overtime is presented.
- Impacts of disruption on productivity are presented.
- True productivity is associated with activities along the critical path, which is the overall driver of project schedule.

Introduction

Previously, an Executive Insight entitled Barriers to Productivity provided a view on some of the barriers to productivity that exist, especially in large complex projects. More granular, field-level viewpoints on productivity were not covered in that Executive Insight and instead are the subject of this Executive Insight, which enumerates many factors impacting productivity on engineering and construction projects. No treatment of such factors will ever be exhaustive and the factors applicable will vary project by project.

Table 2 (beginning on page 5) provides an organized listing of factors based on the author's experience and observations. The first column broadly organizes factors affecting productivity into four categories encompassing internal and external factors.

- Internal factors
  - Human factors
  - Client factors
  - Management
- External factors

Each of these categories is further subdivided as reflected in the second column and additional granularity provided in the third column.

Before reaching Table 2, it is worthwhile to briefly look at productivity and a couple recurrent factors that affect it.

What Is Productivity?

Productivity is a measure of efficiency in completing a task. As it is measured, there must be some assurance that what is getting done are the essential elements of a project, those activities along its critical path. While industry practice is often a measurement of overall project productivity (or individual

trade productivity), true productivity is associated with activities along the critical path and in complex projects, near critical path activities. Everything else is "phantom productivity."

Phantom Productivity

Phantom productivity can be seen in both value-based measures of progress as well as in labor-based measures. For example, receipt of equipment and materials at the site from manufacturers and suppliers represents a key progress milestone and is often linked to payments to suppliers and subcontractors. On some projects, materials are expedited to the site in advance of project requirements, accelerating project completion statistics but often leading to inefficiencies in materials management. In one instance, the early arrival of specialty piping and equipment, coupled with inefficient and inadequate material management, led to high damage levels and materials already counted towards overall project productivity having to be replaced at considerable cost and no subsequent improvement in project progress.

Phantom productivity is also present when work is completed (manufactured, assembled, or installed), but subsequently must be reworked, at high levels, due to quality breakdowns in the overall construction process.

Phantom productivity may also be seen in under-utilization of site labor often represented by high indirect-to-direct labor. Similarly, performance of activities well off the critical path may improve project performance statistics but not contribute to overall project completion. Even worse, out-of-sequence work may expose the project to future rework if critical path activities change or are impacted by refined, already performed non-critical path activities.

Addressing phantom productivity requires a very granular analysis of critical path, and near critical path, execution performance.

One example is where the critical path calls for completion of mechanical piping and process systems to facilitate plant commissioning and startup. Assume the systems consist of three activities—installing the pipe (hanging it); edge prep and pipe cleaning; and welding. Accelerating, say doubling, the rate at which pipe is installed and edges prepped and pipe cleaned would tend to give an indication of overall productivity improvement even while completed systems are still paced by shortages of welders. This is "phantom productivity." Productivity along the critical path, however, has not improved, not at least until the constraint is relieved.

Productivity is typically measured in terms of dollars of output (installed cost) divided by either total labor cost or work-hours. This corresponds to measures for overall project productivity and over-reliance on total productivity without a closer examination of unit or critical path productivity. This has been the source of delayed recognition of many failing projects

Labor time (work-hour) measures of labor productivity need to include both productive time (time on tool) and unproductive time. Strategies for improvement exist in each area and segregation of the labor time measures improves the chances for increases in productivity for each.

Recurrent Factors Affecting Productivity

Table 2 lists many factors affecting productivity that project, construction management, and construction professionals will recognize. This section takes a closer look at two:

- Loss of productivity with overtime
- Effect of interruption

Loss of productivity with overtime is a regular occurrence in construction. Similar losses also arise with shift work and work schedules. Table 1 summarizes the loss of productivity with overtime as a function of daily and weekly hours and the duration of the overtime period. Several studies over the years arrive at similar factors, sometimes stating the factors as reciprocals of the numbers shown in Table 1.

Extended overtime schedules and persistence have measurable and significant impacts on construction productivity and underscore why it is critical to identify productivity issues before overtime becomes the solution and the source of claims.

Table 1
Productivity Inefficiency with Overtime

			Inefficiency Factor			
Days/Week	**Daily Hours**	**Weekly Hours**	**7 Days**	**14 Days**	**21 Days**	**28 Days**
5	9	45	1.03	1.05	1.07	1.1
5	10	50	1.06	1.08	1.12	1.14
5	11	55	1.1	1.14	1.16	1.2
6	9	54	1.05	1.07	1.1	1.12
6	10	60	1.08	1.12	1.16	1.21
6	12	72	1.13	1.2	1.26	1.32
7	8	56	1.1	1.15	1.2	1.25
7	9	63	1.12	1.19	1.24	1.31
7	10	70	1.15	1.23	1.3	1.38
7	12	84	1.21	1.32	1.42	1.53

Similar to suffering from the loss of productivity effects from overtime described above, many projects also suffer one or more disruptions to planned execution. The impacts of disruption can be seen in the following figures. Figure 1 shows the saw-tooth effect on productivity from interruption. The learning curve must be re-established after each interruption. Quality supervision and utilization of well-

established labor pools will aid in the retention of some knowledge. The duration of disruptions are a key factor here.

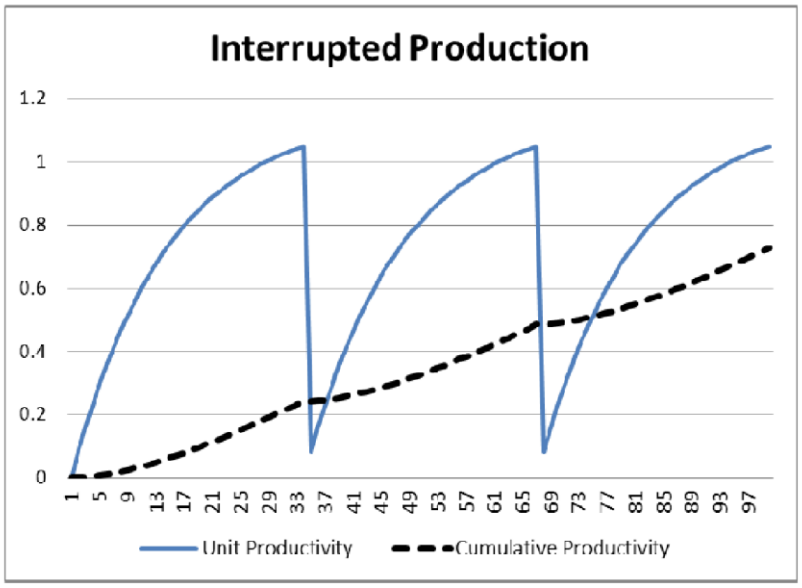

Figure 1. Interrupted Production with Serial Learning Curves

Figure 2 illustrates productivity loss as interruption durations extend. Results from two studies are shown with average productivity loss percentages reaching 40 percent after just three hours and 90 percent destroyed after six hours. The ability to undertake "contingent execution" of other tasks may help mitigate the impacts reflected in Figure 2 in the aggregate project.

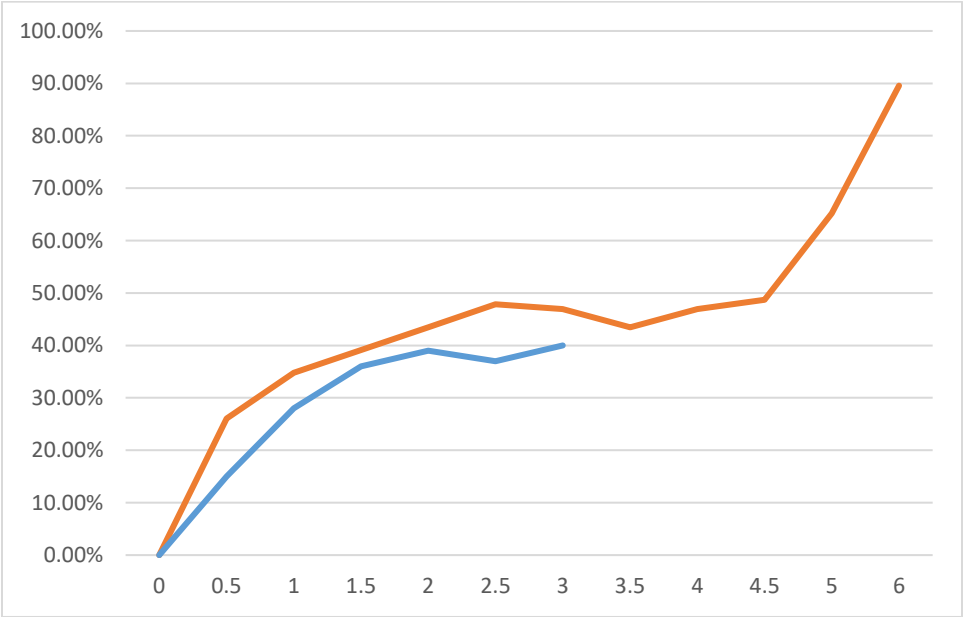

Figure 2. Average Daily Productivity Loss % vs Interruption Lengths

Factors Affecting Productivity

Tables 2A-2D provide a granular view of productivity, across the four factors listed below.

1. **Human factors** such as safety, ethics, environmental conditions, physical limitations, labor management, and labor de-motivators are recognized as human factors affecting productivity (Table 2A).

Table 2A – Human Factors Affecting Productivity

Safety	Ethics	Environmental Conditions	Physical Limitations	Labor Management	Labor Demotivators
Safety culture not present	Deceit; deception; lack of complete truths	Weather conditions (heat stress; cold weather)	Inadequate breaks and facilities	Late arrival; early departures	Late arrival; early departures
Inadequate attention to safety and resultant poor performance	Corruption	Weather variability	Proximity of lunchrooms and sanitary facilities	Extended or unplanned breaks	Extended or unplanned breaks
	Theft of materials and tools	Presence of hazardous materials or other health threats (disease; poisonous or deadly animals)		Poor labor management relations	Poor labor management relations
	Conflict of interest among team members	Excessive noise		Time off for union activities	Time off for union activities
		Excessive blowing sand or dust		Breakdown in communications	Breakdown in communications
		Poor housekeeping of site		Strikes or other labor slowdowns or actions	Strikes or other labor slowdowns or actions
		Unsafe work conditions		Lack of recognition and other positive motivation factors (compensation; benefits; safety and performance incentives)	Lack of recognition and other positive motivation factors (compensation; benefits; safety and performance incentives)
		Inadequate lighting		Lack of respect	
		Inadequate ventilation		Unfair or discriminatory work practices and assignments	
		Confined space		Poor craft cooperation	
				Inadequate labor engagement/ workface planning	
				Mismatch between responsibility and authority	
				Extended learning curve	
				Alcohol and drugs	
				Fatigue	

2. **Client factors** affecting productivity include a range of contractual factors (Table 2B).

Table 2B – Client Factors Affecting Productivity

Contractural
Disputed change orders/ delayed resolution
Extended payment of undisputed amounts
Inspection delays (client or third party)
Delayed notice to proceed
Delayed approvals
Inadequate timely access to client executives by contractor

2. **Management factors** affecting productivity include any first of a kind project aspects, quality of supervision, project management, design management, materials management, construction management, change management, equipment, temporary facilities, and information (Table 2C).

Table 2C – Management Factors Affecting Productivity

Quality of Supervision	Project Management	Design Management	Construction Management	Construction Management
Lack of required personnel at appropriate skill level	Lack of required project management personnel at appropriate skill level	Tight labor supply of required design resources	Inadequate constructability reviews and construction planning	Ineffective or infrequent communications
Inadequate crew dynamics and teamwork (engaged; valued)	Management systems and practices inadequate for project needs	Incomplete scope	Inadequate planning and scheduling	Construction site access
	Poor planning	Design and drawing (3D model) management	Acceleration	Operations interfering with one another; lack of coordination of construction contractors; subcontractors; work crews and trades
	Poor project organization	Excessive or late design changes	Joint occupancy	Unavailability of right materials, tools and equipment
	Mismatch between process and procedures and tasks to be undertaken	Incomplete design work/ high number of RFIs	Beneficial occupancy	Out of sequence work
		Errors & omissions	Means & methods mismatch with work to be accompli	Quality driven rework (inadequate quality control)
			Job site congestion	Non-compliance with specifications
			Inadequate or untimely measurement and assessment of progress	Fabrication errors require field rework
			Ineffective or infrequent communications	Change driven rework
				Inadequate protection of completed works

Materials Management	Change Management	Equipment	Temporary Facilities	Information
Excessive or late changes	Weak change management process and planning to implement change	Equipment shortages or delayed receipt/ availability	Delayed provision of adequate temporary power	Delayed receipt of information and instructions
Poorly defined material management system and responsibilities	Frequent change orders	Mis-positioned equipment	Inadequate heating and hoarding (1)	
Inappropriate or inadequate material management interfaces		Unscheduled maintenance or repair		
Incomplete or inadequate pre-planning		Extended planned maintenance cycles		
Inadequate material tracking and control (improperly located; not readily retrievable)		Poor equipment flow and/or cycle times		
Deficiencies and/or lack of timeliness in materials procurement (material unavailability when required)		Inadequate use of equipment technology		
Inefficient materials handling and site layout (logistics)		Equipment unavailability due to mis-scheduling or extended use on precedent activity		
Defective materials requiring replacement			(1) Temporary wooden fence around a building or structure under construction or repair.	

3. **External factors** include project conditions, government policy and regulations, third-party actions, and labor (Table 2D).

Table 2D – External Factors Affecting Productivity

Project Conditions	Government Policy and Regulations	Third Party Actions	Labor
Weather variability	Slow approval or out of sequence approval of permits	Slow or out of sequence relocation of utilities due to lack of granularity in required design submissions and timing	Inadequate general labor resources
		Slow or out of sequence relocation of utilities due to insufficient utility company resources	Inadequate skilled labor resources
		Inadequate engagement of stakeholders	General labor unrest
			Restrictive labor regulations or union rules

Summary

Factors impacting productivity on engineering and construction projects are segregated into internal and external factors and are delineated with granularity. This discussion complements the Executive Insight, Barriers to Productivity.

The concept of "phantom productivity" is introduced and relates to the concept of Earned Schedule presented in the Executive Insight of that title. Two recurring productivity loss factors are presented and impacts quantified. These include loss of productivity with overtime and the impacts of disruption on productivity.

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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.