Productivity: Measurement, Improvement and its Role in Mitigating the Risks of Dispute in Construction Projects

Dr. Rashad Zakieh (PMP)

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Why Productivity?

Measuring and Identifying Causes of Productivity Variations.

Improving Productivity in Practice

The Role of Productivity in Mitigating the Risks of Disputes
Higher Productivity Means:

<table>
<thead>
<tr>
<th>Client</th>
<th>Contractors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Costs</td>
<td>Increased Profit ($)</td>
</tr>
<tr>
<td>Shorter Schedules</td>
<td>Higher Projects Turnover</td>
</tr>
<tr>
<td>Higher Return on Investment</td>
<td>More Competitive Edge</td>
</tr>
</tbody>
</table>
Agenda

• Why Productivity?
• Measuring and Identifying Causes of Productivity Variations.
• Improving Productivity in Practice
• The Role of Productivity in Mitigating the Risks of Disputes
What is Productivity?

Productivity = Output (Quantity of work) / Input (Time in hours)

Available Time

- Planned Breaks
- Interruptions
- Other Breaks / Interruptions < 15 Minutes
Why Measure Productivity?

- Evaluate performance
- Provide feedback to planners and estimators
- Establish a strategy for productivity improvement
Why Do We Not Measure Productivity?

- Time consuming
- Difficult to start something new
- Benefits are not recognized immediately
- We do not know how to do it
General Facts About Productivity Measurement

- Never too late to start
- Can be conducted using simple forms
- Has an accuracy of +/- 15% at best
How to Measure Productivity?

Productivity = \frac{Output (Quantity of work)}{Input (Time in hours)}

- Total Time (Paid Time)
- Available Time
- Productive Time
- Interruptions
- Planned Breaks
- Planned Breaks
**Data Collection Form**

**Date:** 06/08/05  
**Form Checker:** JAA  
**Project Name:**  
**Temperature:**

<table>
<thead>
<tr>
<th><strong>GANGERS NAME:</strong></th>
<th><strong>OPERATIVES NAMES</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TYPE OF WORK:</strong></td>
<td>Welding Pipes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>ACTIVITY INFORMATION</strong></th>
<th><strong>HOURS WORKED BY EACH OPERATIVE IN EACH AREA</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>AREA: Process Area 1</td>
<td>10 10 10 10 10</td>
</tr>
<tr>
<td>LEVEL/HEIGHT:</td>
<td></td>
</tr>
<tr>
<td>ORG. No.</td>
<td></td>
</tr>
<tr>
<td>AREA:</td>
<td></td>
</tr>
<tr>
<td>LEVEL/HEIGHT:</td>
<td></td>
</tr>
<tr>
<td>ORG. No.</td>
<td></td>
</tr>
</tbody>
</table>

**TYPE OF STOPPAGE > 15 Mins**  
- Design related  
- Sequencing related  
- Materials related  
- Lack of Instructions  
- Weather  
- Inspection related  
- Machinery break out related  
- Inappropriate tools/materials  
- Awaiting permits  
- Others (specify on reverse of sheet)

<table>
<thead>
<tr>
<th><strong>WHY IS WORK SLOWER?</strong></th>
<th><strong>NUMBER OF HOURS WHEN WORK HAS BEEN SLOWER</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Design related</td>
<td></td>
</tr>
<tr>
<td>Information related</td>
<td></td>
</tr>
<tr>
<td>Approaching end of day/ job</td>
<td></td>
</tr>
<tr>
<td>Weather</td>
<td></td>
</tr>
<tr>
<td>Materials related</td>
<td></td>
</tr>
<tr>
<td>Others (specify on reverse of sheet)</td>
<td></td>
</tr>
</tbody>
</table>

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*Provide more information on specifics of work completed on a separate sheet or more details.*

- Work stopped because of shortage of spool
  - New rev. ORS arrived after the spool fabricated
  - Cut the welding, re-beveling the joint
  - Inspect the fit-up of spool
Daily Productivity Variations

Productivity Index vs. Work Day

- The graph shows variations in productivity index over the course of a work day.
- The index values range from 0.4 to 1.3.
- There are fluctuations throughout the day, with some peaks and troughs.
- The horizontal line at 1.0 indicates the baseline productivity index.
What Causes Productivity Variations?

- Interruptions (>15 minutes)
- Competence
- Overtime Working
- Planned/Unplanned increase in size of labor force
- Day of the week
What Causes Interruptions?

- Waiting for information or instructions
- Waiting for materials
- Waiting for equipment
- Waiting for inspection or issuance of permits
- Waiting for preceding trade to complete work
- Weather
Impact of Interruptions

Productivity Level

Start

Re-Start

Stoppage/ Interruption

End

Interruption
Effect of Duration of Interruption

Productivity Loss vs. Duration of Interruption

Who Causes Interruptions?

- 90% are the responsibility of management
  - Client
  - Engineering
  - Procurements
  - Contractor

- The root cause may be on-site or off-site
Interruptions Example 1: Site Preparation

Productive Time, 77%

Interruptions, 23%

Planned Breaks

Productive Time

Materials/Equipment, 17.0%
Machinery Breakdown, 2.5%
Inspection, 2.1%
Permits, 0.9%
Sequencing, 0.5%
Example 2: Piping

Interruptions, 36%
Productive Time, 64%
Sequencing, 1.4%
Weather, 1.8%
Materials, 9.7%
Design, 7.6%
Permits, 3.6%
Inspection, 11.9%
Interruptions
Example 3: Steel Frames

Productive Time, 57%
Interruptions, 43%
Materials/Equipment, 32.1%
Machinery Breakdown, 7.4%
Sequencing, 3.0%
What Causes Productivity Variations?

- Interruptions (>15 minutes)
- Competence
- Overtime Working
- Planned and Unplanned increase in size of labor force
- Day of the Week
Productivity Variations Among Crews

Crew A
PI = 1.02

Crew B
PI = 0.8

Selecting workers of Crew A capabilities, or training and motivating Crew B to perform like (A) would improve productivity by 30%.
What Causes Productivity Variations?

- Interruptions (>15 minutes)
- Competence
- Overtime Working
- Planned and Unplanned increase in size of labor force
- Day of the Week
Effect of Overtime Working

- Working hours increased from 60 to 72 (20%)
- Production increased by 6% during this period
- Productivity decreased 9% during this period
On average, 5% loss in productivity for every 5 hours increase in the length of the working week (beyond 40 hours)

What Causes Productivity Variations?

- Interruptions (>15 minutes)
- Competence
- Overtime Working
- Planned and Unplanned increase in size of labor force
- Day of the Week
Unplanned Increase in Size of Labor Force

![Graph showing the relationship between Increase in Size of Labour Force (%) and Productivity loss (%). The graph illustrates a positive correlation, with productivity losses increasing as the size of the labor force increases.](image-url)
What Causes Productivity Variations?

- Interruptions (>15 minutes)
- Competence
- Overtime Working
- Planned and Unplanned increase in size of labor force
- Day of the Week
Effect of the Working Day Average Curve

Productivity Index

SAT SUN MON TUE WED THU
Summary of Study Findings

1. **Over 60% of working days suffer from avoidable interruptions**, causing average loss in man-hours of 30%.
2. Daily productivity varies by up to 400% within same crew and over 25% amongst crews performing similar activities.
3. Overtime causes loss in productivity, so does over-manning.
4. Productivity trend shows a decline towards the weekend.

<table>
<thead>
<tr>
<th>Interruption Reason</th>
<th>Client</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Information</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Scheduling</td>
<td></td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Materials</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Inspection</td>
<td>✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Instructions / Supervision</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Equipment / Tools</td>
<td></td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Permits</td>
<td>✓ ✓ ✓</td>
<td>✓</td>
</tr>
<tr>
<td>Weather</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Agenda

- Why Productivity?
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- Improving Productivity in Practice
- The Role of Productivity in Mitigating the Risks of Disputes
Barriers to Improving Productivity

1. Lack of Alignment of Goals.
2. Contractual Conflict.
3. Difficulties in Measuring Productivity.
5. Weak Commitment to Continuous Improvement.
How to Improve Productivity in Practice?

- Factors Related to the Organizations’ Culture
- Factors Related to the Site/Project
Organizations’ Cultural Factors

• Obtain commitment to productivity improvement at all management levels
• Create a blame-free environment. Focus on predicting and resolving potential problems
• Develop a culture of continuous productivity improvement
• Involve all those who can make a difference (sub-contractors, suppliers, etc.)
Commitment to Productivity Improvement

- Committing to well-defined productivity goals
- Stake holders to create a blame-free culture
- Continuously improving productivity
- Measuring performance and getting feedback at crew, activity, and site/project levels
Creating Blame-Free Environment

• Cause of delay is exchangeable
• Everyone takes a turn to resolve problems
• Blame causes the temptation to suppress the truth and hence no evidence of real cause of poor productivity
• Reward superior productivity performance
Continuous Productivity Improvement

- Senior management commitment to improving productivity must be visible at all times
- Productivity measurement must be conducted regularly
- Suitable tools must be used to analyze the root of all problems hindering progress
- Blame-free environment should prevail
- Willingness to accept more difficult goals should be encouraged
Site/Project Related

- Measure productivity performance simply and frequently
- Provide on-the-job feedback to working crews
- Hold weekly meetings dedicated to previous barriers
- Plan the next two weeks to identify potential barriers
- Set clear production goals and reward high performers
- Find the root cause of inadequate performance
- Avoid overtime work as much as possible
- Minimize the size of the labor force
Productivity Improvement Process

- Identify
- Develop/Implement
- Collect/Measure
- ROI
- Analyze
- Awareness Sessions
- Remeasure
Source of Data

Projects:
• Residential & Recreational Complex
• Industrial Support Facilities

Two Major Contractors:
• Multi-million dollar projects with a total duration of 22 months
• Activities include excavation and backfilling, piping and sanitation work, mechanical, civil & electrical work, and building and other external work
Awareness Sessions

• Conducted Six Productivity Improvement Awareness Sessions (Client & Contractors)
• Sessions are Conducted at Construction sites
• Sessions Attendees from (PM, Sr.Eng, Eng, Site Foreman, Planners, Safety Eng, Inspection, etc.)
Productivity Measurement

- Selected significant activities per contractor
- Selected 2-3 crews per activity
- Measured daily Productivity (3-6 weeks)
- Daily data collection involves measuring:
  - Nature and duration of interruptions lasting > 15 min
  - Quantity of work completed
- Used earned value principle to calculate productivity index
Main Causes of Low productivity

- Major Interruptions
  - Weather
  - Lack of Materials at work place
  - Sequencing related (lack of coordination
- Manpower Related
  - Lack of Supervision
  - Unskilled Manpower
  - Lack of Certified Operators
Productivity Improvement Strategy

- Met with Client/Contractors personnel
- Shared measurement results
- Identified Improvement Strategy by taking into accounts the study’s results
- Proposed and agreed on action items
- Conducted weekly Productivity Improvement meetings
Productivity Improvement – Example: Sand bedding Activity

Productivity Index.

Day

BEFORE
AFTER

Cumulative day 1-50
Cumulative day 25-50
Productivity Improvement
Overall Contractor Work

Productivity Index.

Day

BEFORE
AFTER
• Why Productivity?
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Main Causes of Claims

- Poor Planning
- Changing Scope of Project
- Errors and Omissions
- Contract Acceleration
- Delays and Stoppages
- Late Completion of Project
Effect of Working Hours

On average, 5% loss in productivity for every 5 hours increase in the length of the working week (beyond 40 hours)

The more prolonged the period of overtime working, the greater the loss in productivity.
Reasons for Productivity Loss Due to Overtime Working

- People simply get tired
- Operatives have a pre-conceived view about what represents a reasonable week’s work, so output remains almost constant no matter how many hours are worked
- Lack of supervision during O/T period
Loss of productivity arising because big sites employ larger workforces is different from loss which arises because an accelerated program demands over-manning.

Reasons for Productivity Loss Due to Increase in the Labor Force

- More interruptions and disruptions
- More absenteeism
- Insufficient or inadequate supervision to deal with large numbers of workforces
- Lack of sufficient, detailed planning, particularly in the transition period
Case Study I (Scenario)

- Pulling 100,000m of large diameter cables
- No. of men 20, working hours per week 40, output rate from similar previous jobs 5m/man-hour. Cost is $20/man-hour. Delay cost $50,000/week
- At the end of week 10, contractor pulled 20,000m

Planned Duration = \[
\frac{100,000}{(40 \times 20 \times 5)} = 25 \text{ weeks}
\]

Weekly productivity = \[
\frac{100,000}{25} = 4,000\text{m}
\]
Case Study I (Alternative Solutions)

- Do nothing and pay penalty
- What are our options to minimize the effect of accelerating work or smooth out problems triggered by a claim?
  - Increase number of men
  - Increase working hours
  - Pay penalty
  - A mixture of 2 or all
Case Study I (Contractor’s Action)

• The contractor decided to increase weekly working hours to 50 and labor force to 30:
  1. Would this action make him finish within planned duration?
  2. What is the total man-hours lost due to accelerating his work?

Planned Duration = 100,000/(40 x 20 x 5) = 25 weeks

Weekly productivity = 100,000/25 = 4,000m
Case Study II (Man-hours)

<table>
<thead>
<tr>
<th>Period #</th>
<th>Planned</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case Study II (Man-days)

Period #
Man-days

Planned Actual

Case Study II (Man-days)
**Compound Loss in Productivity**

\[ P_T = 1 - \left( \frac{100 - P_L}{100} \right) \times \left( \frac{100 - P_o}{100} \right) \times 100 \]

- \( P_T \): Total loss of productivity as a % actual hours
- \( P_L \): The % loss in productivity arising from unplanned increase in the size of labor force
- \( P_o \): The % loss in productivity arising from an increase in working hours
Compound Loss in Productivity - Example

If the unplanned increase in the size of labor force is 60%, and the working hours are increased from 45 to 50, then:

\[ P_T = 1 - \frac{(100 - 20)}{100} \times \frac{(100 - 5)}{100} \times 100 \]

\[ P_T = 24\% \]
### Case Study II (Calculating Total Loss)

<table>
<thead>
<tr>
<th>Period</th>
<th>Maximum Average Labourforce</th>
<th>Actual Labourforce</th>
<th>% Increase (\frac{[3]}{[2]} - 1) x100</th>
<th>% Loss in Productivity (\frac{[5]}{[5] \times [3] \times 5.5 \times 4/100})</th>
<th>Number of Mandays Lost in Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>121</td>
<td>153</td>
<td>26</td>
<td>20</td>
<td>680</td>
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<tr>
<td>9</td>
<td>121</td>
<td>198</td>
<td>64</td>
<td>31</td>
<td>1335</td>
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<td>10</td>
<td>121</td>
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<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>13386</strong></td>
</tr>
</tbody>
</table>
Summary

- Productivity can be measured simply and accurately
- Productivity can be improved with significant value for money/efforts
- The Construction Industry is spending significant amount of money on claims
- Understanding the impact of delays on construction work is vital to minimize the risk of lengthy and costly claim process
- The models provided may be used to predict the amount of claims expected due to delays and accelerated working
Thank you