Analysis of Job-sites in San Luis Obispo County Adapting to Unforeseen Wet Conditions

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Wet conditions are unpredictable factors that nonetheless, are estimated and incorporated onto a long term project schedule. Effective scheduling does mitigate the productivity of a job-site, however, when you factor in unforeseen wet conditions, it could result in schedule delays, material damages, and a discontent client. This paper presents an analysis on how job-sites adapted or were affected by the unpredicted amount of rain received in San Luis Obispo County. The initial findings, based on qualitative attitudinal research, are presented to show if schedules accounted for the amount of rain received, if their schedules were delayed, if material was damaged on the job-site, if they missed out on financial opportunities, and if they adapted to unforeseen wet conditions. Further discussions, based on qualitative exploratory research, are presented to identify strategies used by general contractors who mitigated the delays associated with rain days. The survey results indicate general contractors in San Luis Obispo County struggled to adapt during unforeseen wet conditions. The interview results analyzed common or successful strategies used by five different general contractors. With the identification of proper strategies, one could improve the productivity on the job-site during unforeseen wet conditions.

Keywords: wet conditions, job-site, schedule delays, productivity, strategies

Introduction

Delay is generally acknowledged as the most common, costly, complex and risky problem encountered in construction projects (Ahmed, et al. 2002). It is a critical problem in the construction industry which many have linked with weather conditions. Out of the 17 different reasons for delay in which they investigated, the three major causes of construction delay were weather, labor supply, and subcontractors (Rothbart 1970). Construction productivity is typically exposed to and contingent on weather conditions (Nguyen et al. 2010). Of the many weather conditions affecting construction projects, wet weather conditions have been identified as a prominent cause of delay (Crissinger 2005). According to Joseph L. Crissinger, wet weather is frequently the reason contractors use to request increased contract time or money (2005). Delays as a result of weather conditions are therefore significant risk factors in the contract delivery process, and construction managers are often unable to reliably predict delays as a result of them (Thorpe & Karan. 2008, p.810). Ideally, the effects of normal weather on construction works should be routinely taken into account (Ballesteros-Pérez et al. 2017, p. 3). Ballesteros-Pérez et al, have shown that, unfortunately, and despite its inherent simplicity, few projects take account of the weather factor systematically in the planning and execution stages (2017).

Nonetheless, you can control how you manage a job-site but you cannot control the external factors such as wet conditions. Although there is extensive research where job-site productivity is contingent to wet conditions, there is not enough literature research to mitigate such delays. Recently, there has been unforeseen wet conditions in San Luis Obispo, County. According to Lindsey Holden, all regions of the [San Luis Obispo] county have received more precipitation than usual during this year’s rain season, which began on July 1 and will end on June 30 (2019). This research paper focuses on job-sites located in San Luis Obispo County to discovery how many were affected by unforeseen weather conditions and to identify the strategies used to mitigate delays associated with rain days. A background on the County of San Luis Obispo’s wet weather and the impacts that wet conditions have on construction projects will help understand the necessity for improvements.
Explanation of Unforeseen Wet Conditions

Foreseeable, or just “normal” weather can be relatively easily inferred from historical weather data which is typically processed as a monthly average of severe weather days (Kim & Augenbroe. 2012). This can be used to anticipate the average number of days in which a specific construction activity cannot be carried out (Jung et al. 2016). The presence of unfavorable and unpredicted weather conditions can only have two possible outcomes from the execution point of view. The first is work that is suspended until the adverse weather subsides (prolongation) (Ballesteros-Pérez et al. 2017, p. 2). The second is the need to apply extra costly measures to counteract the influence of the weather and continue carrying out the works (disruption) (Ballesteros-Pérez et al. 2017, p.2). Either outcome irremediably leads to extra time, the need for more resources (lower productivity) and, eventually, financial losses. Any of these consequences may cause disputes among the contractor and the client because, eventually, someone has to pay (Ballesteros-Pérez et al. 2017, p.2).

Background of Wet Conditions in San Luis Obispo County

Official weather observations at San Luis Obispo began in 1869 by the U.S. Army Signal Service, which established a nationally standardized weather observing program at about the same time (Ryans 1994). On 29 September 1927, responsibility for monitoring temperature and precipitation in San Luis Obispo was assumed by Cal Poly (Ryans 1994). Ryan states that wet seasons begin in late October and last through April. The San Luis Obispo weather record extends back for over 100 years (1994). Statistics indicate that the last 30 years have been warmer and wetter than the 100 year normal (Ryans 1994).

The County of San Luis Obispo Public Works Department has a Rain Accumulation site where one can identify rain accumulation averages which started count since July 1st [2018] (2019). There are 26 sensor sites, all located in San Luis Obispo County (2019). Not all major cities [Arroyo Grande, Atascadero, Grover Beach, Morro Bay, Paso Robles, Pismo Beach, and San Luis Obispo] have direct sensor sites. Figure 1 identifies rain accumulation in average percentages scattered through San Luis Obispo County, from July 1, 2018 - June 1, 2019.

Figure 1: Map of San Luis Obispo County for rain accumulations in average percentages
So far this rain season, which runs from July 1, 2018, through June 30, 2019, gauges throughout the Central Coast have recorded roughly 134 percent of average rainfall for mid-February (Lindsey 2019). Typically, by this time, both the Paso Robles and Santa Maria airports would have recorded over 8 inches of precipitation (Lindsey 2019). However, this season, the weather station at the Paso Robles Municipal Airport has recorded 11 inches or about 138 percent of normal (Lindsey 2019). The Santa Maria Public Airport has seen 10.5 inches or 123 percent of average for this time of the year (Lindsey 2019). Cal Poly (official home of climatology for San Luis Obispo) has measured 18 inches of rain or 141 percent of typical, while SLOWeather.com in western San Luis Obispo reported 138 percent of average rainfall (Lindsey 2019).

San Luis Obispo County has had a wetter winter than average — and some areas have gotten way more rain than normal — but this year’s weather isn’t likely to set records (Holden 2019). As of Thursday [February 21, 2019], all regions of the county have received more precipitation than usual during this year’s rain season, which began on July 1 and will end on June 30 (Holden 2019). Some areas have gotten up to 10 inches more rain to date than average, according to information compiled by John Lindsey, a PG&E meteorologist (Holden 2019). Rocky Butte near San Simeon, known as the rainiest spot in the county, has typically received 26.4 inches of precipitation by this time of year. It’s gotten 37.11 inches so far this season (Holden 2019).

Problems Related to Wet Conditions

In the rainy season [of] construction, the biggest factor is the weather conditions, in the event of a heavy rain, it is likely to delay the duration (Zhao et al. 2018). In general, the rainy season will have a greater impact on outdoor construction, such as:

1. Foundation wall irrigation: due to the construction of the bottom of the tank water, will lead to corrosion of the template and the bottom plate, affecting the construction quality.
2. Tower crane tilt: the rainy season when the storm comes, due to no wind control measures, resulting in tower crane tilt.
3. Slope: in the deep foundation construction, due to a large number of water tank, the pump cannot quickly discharge the water, resulting in a large area of landslides, and some projects even affect the tower crane base stability, resulting in downtime.
4. Pile collapse: in the construction of deep foundation, the pile is more, due to improper measures, artificial digging pile into the hole, the drill pile after drilling is not timely pouring concrete, after the storm collapse, if not found, will cause downtime, increase the workload.
5. Brick wall collapse: brick and concrete structure of the brick masonry, due to rain washed sand brick wall is not consolidated masonry mortar, prone to collapse.
6. Human defense channel irrigation: a short period heavy rainfall to the municipal drainage system caused great pressure, heavy rains cannot be ruled out, the rain will be poured into the construction of the basement, which into the air defense channel (Zhao et al. 2018).

Construction projects are executed usually in an outdoor environment, and therefore, are affected by various weather conditions (Moselhi & El-Rayes, 2002, p.1). Highway construction operations are sensitive to rainfall, which often leads to significant losses in productivity and, in some cases, complete suspension of construction operations as a result of saturated and unworkable soil and paving conditions. Many cases in the literature document significant delays in construction schedules due to excessive rainfall (Moselhi & El-Rayes, 2002, p.1). For example, the scheduled completion date of a highway construction project was delayed by 4 months as a result of losing 105 working days to excessive rainfall (Moselhi & El-Rayes, 2002, p.1).

Methodology

The preliminary data for this research paper was conducted in four phases:

Phase A: Selecting Potential Candidates for Evaluation
Phase B: Surveying General Contractors
Phase C: Identifying Potential Candidates for Data Analysis
Phase D: Interviewing General Contractors
Selecting Potential Candidates for Evaluation

In order to conduct a critical assessment, it was necessary to set a list of criteria for potential candidates to evaluate. During the process of reaching out to general contractors, many wanted to talk about multiple job-sites, projects out of the county, and projects who had already been completed. To select candidates which would improve the accuracy of the results, there was a set of three requirements to carry on with the survey. For instance, general contractors had to agree to focus on one job-site. That one job-site had to be in cities located in San Luis Obispo County: Arroyo Grande, Atascadero, Grover Beach, Morro Bay, Paso Robles, Pismo Beach, and San Luis Obispo. To narrow down the range of job-sites, they had to be active job-sites such as breaking ground before April 1, 2018 and still in progress during April 1, 2019. Of the 38 general contractors who went through the evaluation, 17 general contractors fit the criteria and had agreed to be survey.

Surveying General Contractors

A survey was designed to assess the effects of unforeseen wet conditions imposing on job-sites located in San Luis Obispo County. Of the 17 general contractors who agreed to be surveyed, 3 filled out the survey through email, 13 had their survey through phone interviews and 1 had their survey in person at their job-site. Respondents answered the same questionnaire where only open ended questions had some detail variances.

Identifying Potential Candidates for Data Analysis

Once the data from the survey was collected, another evaluation was set in order to identify which general contractors utilized strategies during unforeseen weather conditions. The evaluation depended on which general contractors responded yes to question number 11 -- Did your job-site utilize any strategies that would allow you to adapt to the consecutive amount of rain days? In other words, did you attempt to work during the raining days? From the general contractors who answered yes, respondents who either had a confident strategy or a repeated strategy were asked to participate in a follow up interview. A confident strategy is an answer in which the respondent claimed their actions to have helped their job-site. A repeated strategy is an answer where more than one general contractor utilized the same or similar strategy.

Interviewing General Contractors

The follow up interview were conducted in person to gather detailed information on the strategies they used. Of the general contractors who answered yes and fit the criteria, 5 general contractors agreed for a follow up interview. They are identified as followed:

C-1: SAN LUIS OBISPO A
C-1.1: SAN LUIS OBISPO B
C-2: ATASCADERO
C-3: PASO ROBLES
C-4: PISMO BEACH

They were either conducted in their job-site trailer, at their office which was located outside of their job-site, or at a mutual agreed location. Each participating candidate was asked to provide more in depth detail about their strategies used. To eliminate variance, they were asked to focus on one prominent strategy. From there, they were asked to defend their strategy. These interviews were left open ended in order to explore their choice of strategy.

Research Results

There were 8 different titles/roles out of the 17 general contractors who were surveyed. Titles/roles varied between (6) project manager, (3) assistant project manager, (3) superintendent, (1) assistant superintendent, (1) project executive, (1) owner/manager, (1) safety manager, and (1) owner/CFO/manager/estimator.
**Survey Results**

In regards to the results, Appendix A contains the survey questions that will help understand the following results. A majority, 15 respondents, said yes to an overly disruptive amount of rainfall from April 1, 2018 - April 1 2019 whereas only two respondents said no. Very few said their schedule accounted for that many day of rain whereas a majority claimed their schedule did not account for that many days of rain. 70.59% said their job-site schedule was delayed due to the rain whereas 11.76% said no. Although I didn’t have “unsure or I don’t know or can’t say” as an option, 17.65 % did not claim either yes or no due to other dominant delays. 58.82% of the project owners were considerate or understanding about the delayed schedules due to the rain whereas 41% of the project owners had different expectations. 64.71% respondents claimed that the rain damaged material on their job-site whereas 35.29% said no. 58.82% respondents claimed that the rain caused them to miss out on financial opportunities whereas 23.53% said no. Although I didn’t have an “other, not sure, or I don’t know” option, 17.65% did not claim either yes or no due to dominant delays. 58.82% respondents claimed to have utilized any strategies that would allow their job-sites to adapt to the consecutive amount of rain days. The other 41.18% claimed no.

Of the 15 respondents who answered yes to question number 3, many didn’t provide a confident estimate for question number 4 to state how many days, weeks, or months it rained during their job-site. One superintendent, during an in person interview, claimed he had 29 calendar days of rain. However, that superintendent replaced the superintendent before him and had only tracked the number of rain days since January 1, 2019. One owner/CFO/manager/estimator claimed he did not keep track of the rain days, however, he estimated 4 weeks. Another superintendent claimed his jobsite received minimal rain, however he still claimed yes about his job-site receiving an overly disruptive amount of rainfall from April 1, 2018 - April 2, 2019. Nonetheless, others (Table 1) did provide a confident estimate such as keeping track of the number of rain work days and comparing them to the number of rain days accounted for their schedule.
Table 1

Comparison of schedule estimate and delays

<table>
<thead>
<tr>
<th></th>
<th>Rain Work Days (WD) from April 1, 2018 – April 1, 2019</th>
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<tbody>
<tr>
<td></td>
<td>Scheduled Rain (WD)</td>
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<tr>
<td>Respondent A</td>
<td>38</td>
</tr>
<tr>
<td>Respondent B</td>
<td>45</td>
</tr>
<tr>
<td>Respondent C</td>
<td>30</td>
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<tr>
<td>Respondent D</td>
<td>25</td>
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</tbody>
</table>

Of the 12 respondents who answered yes to question number 6, many didn’t provide a confident estimate for question number 7 to estimate how many days, weeks or months they were behind schedule. Much like question number 4, there was unreliable information. For example, one project executive claimed they were about 2 months behind schedules but the information provided wasn’t based on a comparison of scheduled rain work days and tracked rain work days. Therefore, respondents (table 1) from question 4, provided more accurate data. Respondent A estimated that they were 26 work days behind schedule and Respondent C claimed they were 20 days behind schedules.

Interview Results

Table 2

Contractors in San Luis Obispo County who utilized strategies that allowed their job-sites to adapt to the consecutive amount of rain days

<table>
<thead>
<tr>
<th>General Contractor Results</th>
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</thead>
<tbody>
<tr>
<td><strong>Entity</strong></td>
</tr>
<tr>
<td>C-1</td>
</tr>
<tr>
<td>C-1.1</td>
</tr>
<tr>
<td>C-2</td>
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<tr>
<td>C-3</td>
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<tr>
<td>C-4</td>
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</table>

Site Preparation

Site preparation was an identified strategy in which two general contractors highlighted the use of pumps and tarps as a strategy. Respondent C-1 emphasized the need for multiple pumps in order to monitor the proper drainage on-site. He claimed that job-sites should establish a strategy where they have prompt access to more pumps in order to increase water drainage. Respondent C-3 emphasized the need for proper tarps in order to avoid rework. He claimed that you need strong plastic, tape or some sort of waterproof adhesives to secure areas the moment it starts to rain. Although he acknowledges that covering earthwork with plastic won’t fully seal the area, he claims that it still minimizes the amount of flooding.

Enforced Attendance

Enforced Attendance during rainy days was a common strategy from two general contractors that increased productivity. Respondent C-1.1 emphasized how constant communication with their subcontractors resolved confusion on coming to work when it was raining. He mentioned how most subcontractors automatically assumed not to show up during rainy days and that many claimed how they would speed up their productivity when the weather got better. As a result of continuous wet conditions, he set up meetings, made phone calls, and clarified attendance by enforcing them to work during rainy days unless told otherwise. Respondent C-4 emphasized how he
enforced attendance during rainy days from the start. He claimed that subcontractors in area experience the slightest precipitation during outside work and want to head home. However, he did claim that he wouldn’t encourage them to work if it jeopardized their safety.

**Protective Equipment**

Protective equipment was a notable strategy which endorses the productivity on one job-site. Respondent C-2 emphasized how providing protective equipment to workers made them feel valued and appreciated for their safety concerns. He explained how equipping them with basic rain gear, regulating proper tools, and being cautious of their safety reinforces the idea that they are working under safe conditions. They are less inclined to slow down or provide excuses as to why they cannot perform under rain. He claimed that protective equipment should be a strategy where one adopts under any weather condition to address the concerns of workers on the job-site. Although he acknowledges that investing in such equipment could become pricey, he still endorses such investments.

**Conclusions and Discussions**

The aim of this paper is intended to help general contractors and owners to make informed decisions regarding the mitigation of schedule delays contingent to wet conditions. The survey process, based on qualitative attitudinal research, investigated how job-sites in San Luis Obispo County adapted to unforeseen wet conditions. There is high correlation between respondents who claim they received an overly disruptive amount of rainfall and those who claim that they did not account for that many rain days. Although a majority claimed that their job-site schedules were delayed due to the rain, more couldn’t associate their causes of delays with rain than those who claimed that their job-site schedules were not delayed due to the rain. Such result highlighted the limitation of assuming wet conditions to be the sole variable in schedule delays, however, the literature review considers wet conditions to be a significant delay factor. The purpose of asking how project owners felt about the delays associated with rain provided an insight on owner expectations in the area. This paper does not elaborate on project owner satisfaction but it does bring attention their expectations being addressed or redefined. Examining material damages on-site supported the thought process of general contractors evaluating their loss in financial opportunities. However, some general contractors didn’t associate their loss of financial opportunities with rain being the dominant cause of delay. This result highlighted the limitation of integrating loss in financial opportunities with rain being a factor that affects one’s job-site. Nonetheless, these survey questions allowed general contractors to evaluate the status of their job-sites to answer the strategic question. That is, more general contractors claimed to have utilized strategies that allowed them to adapt to the consecutive amount of days. The paper has limitations to quantify the accuracy of adaption considering the results is based on the overall judgment from general contractors. Although the titles/roles of general contractors vary, there was no significant correlation between their title/role and the productivity performance of their job-site. All general contractors had qualifying results with the exception of identifying eligible candidates to provide a confident estimate for how many days, weeks, or months it rained during the job-site. Therefore, Table 1 provided measurable data where four respondents share a common trend on delays associated with rain. However, more confident respondents are needed to quantify the results since non-confident estimates will decrease the accuracy of delays associated with rain. Overall, the results emphasized the need to identify proper strategies which could improve the productivity of a job-site during unforeseen wet conditions.

Since the interview results were based on qualitative exploratory research, it helped identify accessible strategies for general contractors in San Luis Obispo County. Regarding the use of automation design systems was never brought up as a strategic strategy which suggest that such approach hasn’t been attainable in the area. Instead, strategies such as site preparation, enforced attendance, and protective equipment was identified as accessible strategies for general contractor in San Luis Obispo County. Although each (the five who fit the criteria) general contractor did not provide a detailed hard copy of their strategy, through discussions they enforced the idea of manipulating a strategy that works for their job-site. For instance, the identification of a strategy that will mitigate delays associated with rain will only work if it is enforced and contingent to the size of the project. General contractors who struggled to adapt during unforeseen wet conditions should adopt these strategies and manipulate them to suit the needs of their job-sites. Although this paper only identifies strategies from general contractors in San Luis Obispo County, more research should expand on these identifications to improve the productivity of a job-site during unforeseen wet conditions.
References


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Lindsey, J. (2019, February). Getting Sick of the Rain, SLO? Well Get Used to It, We’re ‘Locked In’ to This Pattern *The Tribune*


Appendix A - Survey Questions

1. Are you currently working at an active job-site located in the County of San Luis Obispo?
   Yes or No

2. State your title/role at your jobsite.

   ______________________________________________________________

3. Did your job-site receive rainfall from April 1, 2018 - April 1, 2019?
   Yes or No

4. If yes, how many days, weeks, or months?
   ______________________________________________________________

5. Did your schedule account for that many days of rain?
   Yes or No

6. Was your job-site schedule delayed due to the rain?
   Yes or No

7. If yes, estimate how many days, weeks, or months.
   ______________________________________________________________

8. If yes, is the owner of your project considerate or understanding about the delay schedules due to the rain?
   Yes or no

9. Did the rain damage any material on your job-site?
   Yes or No

10. Did the rain cause you to miss out on financial opportunities?
    Yes or No

11. Did your job-site utilize any strategies that would allow you to adapt to the consecutive amount of rain days? In other words, did you attempt to work during the raining days?
    Yes or No

12. If yes, what strategies or actions did your job-site take? The more detail, the better.
    ______________________________________________________________
    ______________________________________________________________
13. If no, why did your job-site not adapt to the consecutive amount of rain days? The more detail, the better.


14. Do you believe job-sites that experience huge amounts of unpredicted rain should adapt to new strategies or resort to non-work days?