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# DEALING WITH WEATHER-RELATED CLAIMS IN CONSTRUCTION CONTRACTS: A NEW APPROACH

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Project execution is often delayed by extreme and unforeseen weather conditions. This is because extreme weather usually causes work disruption, waste of resources, significant project delays and, eventually, financial losses for both the contractor and the project owner. Construction contracts generally include weather-related clauses addressing when, and to what extent, the responsibilities and consequences of adverse weather are to be shared or compensated. However, setting clear and objective limits for abnormal weather is problematic, starting with the lack of agreement about which weather conditions can be considered as "normal" or "average". Research on the influence of weather on construction productivity is scarce and underdeveloped. Therefore, practitioners cannot count on sound methods to mediate in and evaluate weather-related contract disputes. In these situations, claims are likely to arise and escalate. A stochastic model for objectively evaluating the weather influence during the execution stage is proposed. This model allows actual weather to be compared to historical data in a way that provides an objective assessment of the extent to which the adverse weather was (or not) exceptional. A case study of a fictional project is used to show its implementation. This is the first tool of its kind to address this concern with a straightforward, holistic and quantitative approach.

*Keywords*: Productivity, Delay, Stochastic, Prolongation, Disruption, Compensation.

## 1 INTRODUCTION

Extreme and unforeseen weather conditions generally have an adverse impact on the execution of construction projects. Extreme weather also threatens both the contractor's and project owner's interests. This happens because adverse weather usually causes productivity decrease, waste of resources, project delays and, eventually, financial losses for both parties (Ballesteros-Pérez *et al*. 2010, González *et al*. 2014). These are ubiquitous phenomena and affect construction works that are either totally or partially carried out outdoors.

Construction contracts generally include weather-related clauses addressing when and to what extent the responsibilities and consequences of adverse weather are to be shared. Particularly, these clauses try to set clear, objective and, generally, also fair conditions to distinguish when the effects of unusual weather episodes are to be absorbed by the contractor entirely or, conversely, when the project owner must provide the contractor with some compensation (Society of Construction Law 2002). However, setting clear and objective limits for abnormal weather episodes is quite problematic, starting with the absence of agreement on what can be considered as "average" or just "expected" weather (Palaneeswaran and Kumaraswamy 2008, Yogeswaran *et al.* 1998).

Multiple weather variables, isolated or combined, as well as different intensity levels of these, are likely to affect differently different construction operations. Research on the weather influence on construction productivity is relatively scarce and predominantly less than ten years old (Ballesteros-Pérez *et al.* 2017). Hence, practitioners have not been able to count on sound methods to mediate and evaluate when weather-related conflicts arise during project execution, and, in the absence of agreement, claims are likely to arise and escalate.

A new stochastic model for objectively evaluating the influence of the weather during the execution stage is proposed. This model will be applied retrospectively, that is, from the as-built project schedule backward, identifying to what extent the weather has impacted the project execution. Implementation of the model will be materialized through a case study in the UK.

## 2 BACKGROUND – CLAIMS AND WEATHER

The impact of contract clauses is a significant contextual issue. British standard-form contracts form the basis of many international standard forms (Society of Construction Law 2002) and provide a useful basis for thinking about specific clauses. There is no substitute for reading the contract that applies to a particular project. However, the key thing about claims in many contracts is the separation of disruption from prolongation. Disruption may enable the contractor to claim more money and prolongation may enable the contractor to claim more time. A claim for one does not necessarily justify a claim for the other (Hughes *et al.* 2015).

The test for each is different. Contracts typically identify a list of circumstances under which claims for each might be awarded, and these lists (disruption and prolongation) are usually not identical. However, they must be specific. In English law (for example), a client (normally the project owner) who awards more time to a contractor still retains the right to deduct damages for any further delay that is the contractor's responsibility. Hence, the preservation of a precise completion date, even an extended one, requires explicit clauses about the circumstances in which the completion date may be changed. The way that contract clauses are drafted often results in a contractor being able to claim more time for excessively adverse weather, but not more money. Hence, if there is a possibility, clients will prefer to attribute excusable contractor delay to weather, because it carries little possibility of consequential financial claims by the contractor, unlike some other excusable reasons for contractor's delay. Perhaps, paradoxically, on the other hand, the contractor's team may try to get excusable delay attributed to adverse weather. This would happen when the contractor cannot attribute delays to other causes that might be more difficult to prove, even though they carry financial compensation in addition to prolongation. For these contractual reasons, the importance of weather-related claims may be overstated in many practical situations, as well as in many research papers and reports. This is simply because it is expedient for both the contractor and client to attribute some excusable delays to the weather, rather than other causes.

## 3 METHOD

Irrespective from its possible overstatement in the real practice, unusual weather conditions are still frequently cited as one of the factors causing construction project delays (Głuszak and Lešniak 2015). However, no method has been developed that can quantitatively evaluate the extent to which the weather during the construction phase were exceptional (or not) (Ballesteros-pérez *et al.* 2015). Most weather-related research from the construction perspective has been published in the last decade (Ballesteros-Pérez *et al.* 2017) but has focused on the particular influence of a small subset of weather variables (e.g., rain, wind, snow) in a small subset of construction operations. Also, most international construction regulations and codes of practice (e.g., Ministerio de Obras Públicas 1964, National Cooperative Highway Research Program 1978, United States Army Corps of Engineers 1999) do not address the weather with a quantitative approach, thus proposing guidelines that are generally too loose to be applied in real contexts.

In this paper, a stochastic model is proposed that, despite its simple and still imperfect approach, offers a first straightforward, holistic and quantitative procedure for dealing objectively with weather-related claims in construction contracts. This model is only briefly outlined here, leaving a more thorough treatment for a future paper.

### 3.1 Weather Influence in Construction Activities

Recently, Ballesteros-Pérez *et al.* (2017) compiled common combinations and intensity levels of weather variables that condition the execution of some frequent construction operations. Their work addressed the construction of buildings in Spain using weather data provided by the Spanish weather agency AEMET. A summary of their conclusions, with adaptations to the format in which the British weather agency (UK met Office) issues the weather data, is shown in Table 1.

Table 1. Summary of weather variable combinations and thresholds causing significant productivity decrease in standard construction operations (modified and extended from Ballesteros-Pérez *et al.* (2017)).

| **Weather var.** *(daily value)* | **Earthworks (E)** | **Formworks (F)** | **Concrete (C)** | **Steelworks (T)** | **Scaffolding (S)** | **Outdoor paint. (O)** |
|---|---|---|---|---|---|---|
| Minimum temp. ≤0ºC | | | × | | | |
| Mean temperature ≤0ºC | × | | | × | | × |
| Maximum temp. ≥40ºC | | | × | × | | |
| Precipitation ≥1mm | | | | | | × |
| Precipitation ≥10mm | × | | × | | | |
| Precipitation ≥30mm | | | | × | | |
| Hail precipitation | | | × | | | × |
| Snow precipitation | × | | × | | × | × |
| Electrical storm | | × | | × | × | |
| Wind gust ≥30knots | | × | × | × | × | × |

However, it is worth noting that these combinations and levels of weather variables are not immutable. Different countries, construction practices and types of project might consider some degree of variation and adaptation. Also, Table 1 only represents the influence of weather in technological construction operations, i.e. the human factor is not considered. Here, the thresholds expressed in Table 1 will be the ones used for the sake of consistency with previous studies but, eventually, it is up to the contractor and project owner (client) to adopt a specific combination that suits both stakeholders' points of view.

### 3.2 Case Study

For the sake of clarity, the model proposed will be explained along with its implementation in a case study. The case study involves the analysis of weather-related delay during the construction of a fictional 5-storey Reinforced Concrete (RC) structure building located in Heathrow (UK).

A simplified Gantt chart representing the actual execution times of the major construction activities of this building is shown in Figure 1. The project execution started on January 1, 2016 and the weather-sensitivity of some activities as in Table 1 is represented with different activity colors (mostly the outdoor activities). These are supposed to represent the combinations of weather variables that this contract's fictional contractor and owner agreed on as most reasonable for this project, normally before the project started.

One of the advantages of the proposed model is that the analysis can be performed retrospectively, that is when the project has been totally or partially executed. Therefore, ‘actual’ activity durations are being used. Now, it is necessary to calculate how long each activity would have taken to complete if they had enjoyed perfect weather conditions. Those durations are named ‘Weather-less durations’ as in column 4, Figure 1 and for its calculation, it is necessary to resort to weather data from the closest weather station, Heathrow airport in this case.

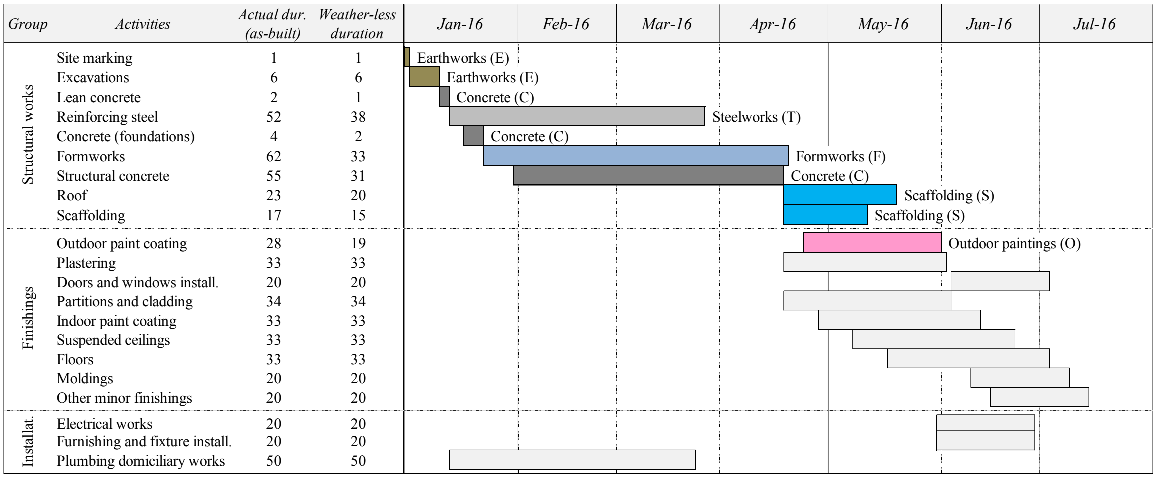

Figure 1. As-built schedule of a 5-storey RC building starting on January 1, 2016 (in working days).

### 3.3 Weather Data Analysis

For this case study, a 30-year series (1986-2015) from the Heathrow airport weather station was retrieved. Another 1-year series (2016) involving the same location during the year in which the building was executed was also retrieved, but processed separately as explained later. The weather data consisted of daily measurements of the weather variables registered in the first column of Table 1. For each construction operation (E, F, C, T, S, and O) it was calculated, by means of a simple spreadsheet, in how many of those days, no weather variables exceeded the thresholds of each construction activity. For instance, for Earthworks, a day was considered as ‘workable’ when the daily mean temperature remained above 0ºC, there was no snow, and precipitation did not exceed 10 mm. A workable day was computed as ‘1’, and a nonworkable day as ‘0’.

Table 2. Proportion of workable days per const. operation before the project starts (Heathrow 1986-2015).

| Month | Earth. (E) | Form. (F) | Concr. (C) | Steel. (T) | Scaffold.(S) | O. paint.(O) | Asp. pav. (P) |
|---|---|---|---|---|---|---|---|
| January | 0.862/0.107 | 0.736/0.142 | 0.522/0.161 | 0.697/0.130 | 0.680/0.149 | 0.476/0.158 | 0.461/0.122 |
| February | 0.824/0.166 | 0.752/0.192 | 0.459/0.187 | 0.708/0.210 | 0.624/0.178 | 0.472/0.178 | 0.427/0.163 |
| March | 0.936/0.086 | 0.811/0.104 | 0.679/0.171 | 0.809/0.105 | 0.766/0.101 | 0.599/0.148 | 0.610/0.197 |
| April | 0.940/0.053 | 0.837/0.088 | 0.768/0.099 | 0.837/0.088 | 0.807/0.109 | 0.589/0.166 | 0.620/0.146 |
| May | 0.969/0.030 | 0.855/0.083 | 0.861/0.081 | 0.855/0.083 | 0.855/0.083 | 0.696/0.146 | 0.750/0.124 |
| June | 0.957/0.040 | 0.865/0.077 | 0.899/0.069 | 0.863/0.078 | 0.865/0.077 | 0.675/0.176 | 0.712/0.156 |
| July | 0.967/0.035 | 0.900/0.058 | 0.915/0.056 | 0.900/0.058 | 0.900/0.058 | 0.726/0.094 | 0.765/0.089 |
| August | 0.953/0.041 | 0.880/0.067 | 0.914/0.068 | 0.880/0.067 | 0.880/0.067 | 0.740/0.136 | 0.765/0.134 |
| September | 0.954/0.051 | 0.890/0.084 | 0.888/0.090 | 0.890/0.084 | 0.890/0.084 | 0.691/0.148 | 0.732/0.132 |
| October | 0.944/0.052 | 0.824/0.087 | 0.800/0.096 | 0.820/0.092 | 0.824/0.087 | 0.578/0.141 | 0.637/0.130 |
| November | 0.938/0.059 | 0.868/0.095 | 0.762/0.128 | 0.866/0.095 | 0.860/0.097 | 0.587/0.161 | 0.554/0.117 |
| December | 0.880/0.120 | 0.780/0.151 | 0.583/0.174 | 0.759/0.149 | 0.712/0.161 | 0.503/0.171 | 0.489/0.158 |

Table 3. Proportion of workable days per const. operation during the project execution (Heathrow 2016).

| Month | Earth. (E) | Form. (F) | Concr. (C) | Steel. (T) | Scaffold.(S) | O. paint.(O) | Asp. pav. (P) |
|---|---|---|---|---|---|---|---|
| January | 0.968 | 0.742 | 0.516 | 0.742 | 0.742 | 0.419 | 0.323 |
| February | 0.828 | 0.690 | 0.414 | 0.655 | 0.552 | 0.448 | 0.448 |
| March | 0.903 | 0.806 | 0.548 | 0.806 | 0.710 | 0.548 | 0.516 |
| April | 0.933 | 0.800 | 0.800 | 0.800 | 0.800 | 0.533 | 0.567 |
| May | 0.935 | 0.935 | 0.903 | 0.935 | 0.935 | 0.710 | 0.710 |
| June | 0.933 | 0.833 | 0.867 | 0.833 | 0.833 | 0.767 | 0.800 |
| July | 0.968 | 0.806 | 0.871 | 0.806 | 0.806 | 0.710 | 0.742 |
| August | 0.903 | 0.742 | 0.871 | 0.742 | 0.742 | 0.484 | 0.484 |
| September | 1.000 | 0.700 | 0.700 | 0.700 | 0.700 | 0.600 | 0.733 |
| October | 0.903 | 0.613 | 0.581 | 0.581 | 0.613 | 0.387 | 0.548 |
| November | 1.000 | 0.933 | 0.867 | 0.933 | 0.933 | 0.633 | 0.633 |
| December | 0.935 | 0.871 | 0.710 | 0.871 | 0.871 | 0.742 | 0.710 |

Table 2 represents the averages and sample standard deviations (computed with 30 years of historical data) of the amount of 'workable days' per month. Later, Table 3 represents the similar calculations but for a single year (2016), that is, the 'actual' amount (proportion) of workable days that the building project experienced during its execution. It is precisely by multiplying these factors from Table 3 by the respective 'actual' activity durations from Figure 1 (depending on which month each activity was executed), that one can obtain the 'Weather-less durations'.

## 3.3 Stochastic Analysis and Results

The 'weather-less' activity durations represent the duration each activity might have had irrespective of the weather influence (perfect weather conditions). The remaining step considers exposing the project schedule from Figure 1 with 'weather-less' durations to the type of weather conditions that the Heathrow airport weather station experienced from 1986 to 2015. For that purpose, different Beta distributions are fitted to each month and construction operation by the method of moments, that is, their shape parameters are calculated by using the average and standard deviation values stated in Table 2. Also, each Beta distribution is assumed to be independent from each other. Finally, we submit the weather-less schedule to those artificial weather conditions generated by the Beta distributions and calculate, according to the stochastically-generated changing proportions of workable days, how long the same project would have taken to complete in each iteration. The result is shown in Figure 2.

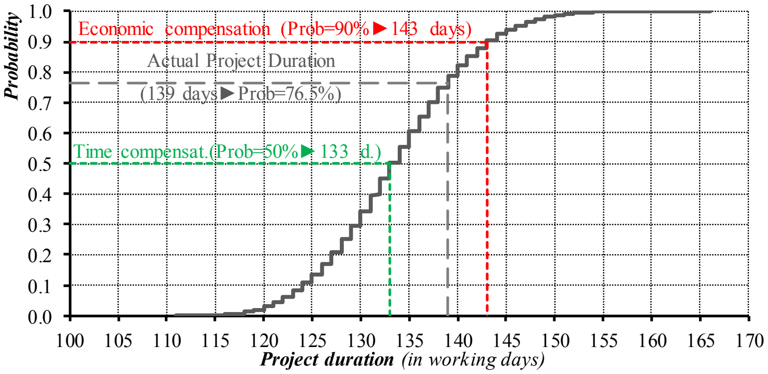

Figure 2. Stochastic project durations of the simplified RC building starting on January 1, 2016.

The S-curve represents the project duration distribution curve. It is known that the 'as-built' (actual) project duration was 139 days, whereas the weather-less duration (not shown in picture) corresponded to 108 days. This presents the intriguing possibility for our fictional contractor and client to have agreed that weather conditions above the 'average' conditions (maybe 50%) might receive a time compensation, whereas only the 10% most adverse conditions might receive economic compensation. It is easy to see that, in this example, the contractor would have received a time compensation (e.g., of 139 – 133 = 6 days), but no economic compensation.

## 4 CONCLUSIONS

This model replicates the weather conditions from current and previous years. The simple case study shows how it can be applied to mediate in weather-related discussions during the execution of a project. The case study made use of a single weather station (Heathrow), but an on-site weather station might have better represented the actual weather conditions experienced during the execution, and the data could have been compared to that of nearby weather stations.

Even though this model is a simplification, the approach presents a clear, comprehensive and quantitative treatment of the weather influence in construction contracts, an enduring problem that may now have a potential solution. This simple model enables project managers to compare the actual weather to previous weather so that an objective view can be formed in relation to whether the adverse conditions were exceptionally adverse or, maybe, just "normally adverse".

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