Automation in Construction 84 (2017) 81–95

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Weather-wise: A weather-aware planning tool for improving construction productivity and dealing with claims

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ARTICLE INFO

Keywords:
Building
Productivity
Weather
Climate
Claims
Delays

ABSTRACT

The influence of unforeseen, extreme weather in construction works usually impacts productivity, causes significant project delays and constitutes a frequent source of contractor's claims. However, construction practitioners cannot count on sound methods for mediating when weather-related claims arise, nor harnessing the influence of weather variability in construction projects. Building on the few most recent quantitative studies identifying those key weather agents and levels of intensity that affect some standard building construction activities, a new stochastic model that processes and replicates the spatio-temporal variability of combined weather variables is proposed. This model can help anticipate weather-related project duration variability; improving construction productivity by selecting the best project start date; and objectively evaluating weather-related claims. A two-building construction case study using different Spanish locations is used to demonstrate the model. The results showed that ignoring the influence of weather can lead to an extension of 5–20% longer project duration compared to planned.

1. Introduction

Construction projects consist of numerous technological operations that can generally be structured in multiple alternative ways. The work breakdown structure (WBS) and the activity precedence relationships have a big impact on the actual project duration. However, the sensitivity of technological operations to adverse (local) weather conditions is also frequently recognised as one of the factors causing noticeable project delays, cost overruns, and contractual claims [1].

According to Mentis [2], projects may take significantly longer, cost more and foster a larger number of conflicts partly when threat identification is inaccurate, its scope is too narrow or its assessment is not satisfactorily incorporated into the project contract, planning and execution stages. Overall, the lesson from Mentis, involving construction projects from several developing countries, is that “almost by definition, what is poorly known is likely to cause problems”. Maybe not that surprisingly though, adverse weather conditions stand out as one of the most recurrent threats in half of the projects discussed in his analysis.

The presence of unfavourable 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). The second is the need to apply extra costly measures to counteract the influence of the weather and continue carrying out the works (disruption). 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.

Accordingly, the influence of weather in construction projects is recognised by both researchers [3–5] and practitioners [6,7] but with two very different interests and motivations. Researchers are mostly focused on work that systematically addresses the influence of poor weather conditions in planning project execution or modelling building performance (e.g. [4,8–12]). Practitioners mostly focus on issuing recommendations for preparing weather-proof construction systems [7] or drawing up contracts that can deal with weather-related and delay-related claims [6,13]. In both cases, despite the different aims of each group, it is clear that regular practice has subdivided the weather into two categories: foreseeable and unforeseeable.

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http://dx.doi.org/10.1016/j.autcon.2017.08.022
Received 21 December 2016; Received in revised form 12 June 2017; Accepted 10 August 2017
0926-5805/

Foreseeable, or just “normal” weather can be relatively easily inferred from historical weather data [5], which is typically processed as a monthly average of severe weather days. This can be used to anticipate the average number of days in which a specific construction activity cannot be carried out [14].

Ideally, the effects of normal weather on construction works should be routinely taken into account. Ballesteros-Pérez et al. [15] have shown that, unfortunately, and despite its inherent simplicity, few projects take account of the weather factor systematically in the planning and execution stages. There are two reasons for this: compressed tender periods and availability of data for a specific site. Tender periods are frequently too short, as discussed by Hughes et al. [16]. Moreover, a lot of information needed for preparing a bid is simply missing at that stage. Thus, estimating and planning may be far less reliable and organized than it should be. This can be exacerbated by the, sometimes, large differences between the weather on a specific site and the weather at the nearest meteorological station. However, even if normal weather data were regularly used, three problems arise. First, the weather involves the confluence of multiple phenomena (wind, rain, heat, etc.) and those phenomena, contrary to expectations, do not involve a clear correlation of occurrence with each other. This will be proven later in this paper. Second, each weather agent has variability, and that variability has been addressed by very few studies [4], generally combining only up to two or three phenomena (see Table 1). Third, weather data are generally measured at a ground level, probably quite far away from where the construction works will be located [14], and, perhaps, with a different topography [17].

Concerning unforeseeable or abnormal weather, it is, paradoxically, brought up more frequently in the daily practice of projects, as most construction contracts usually include clauses stating that the contractor may be entitled to a time extension or cost compensation due to the occurrence of unusual severe weather conditions [18–20]. Yet, the problem is that normal weather conditions, or rather their interaction in relation to productivity decrease, are not properly known or registered somewhere (e.g. in the contract itself). Hence, how is it possible to compare a severe weather episode or its effects versus an inexistent baseline? In other words, how is it possible to state that something is abnormal when normal weather is neglected by default?

The aim of this study is to tackle preconceptions about weather-related uncertainty. This will be achieved by developing a holistic model that enables practitioners to use weather data for forecasting project durations, improving construction productivity and the settlement of contract claims. A case study is carried out involving the construction of two different buildings in different Spanish locations. This enables several applications of this model to be developed for progressively dealing with three aspects: normal weather, its multivariate statistical variability, and distinguishing exceptional from non-exceptional weather. Such applications allow the reduction of weather-related uncertainty at the planning and construction stages. They also provide an objective and independent estimate as to how exceptional the weather conditions were at the construction stage. Hence, in general, the model will allow working ‘weather-wise’, that is, in favour of the weather, instead of against it.

2. Literature review

2.1. Weather and claims

The risks of weather-related delays are generally dealt with in contracts through provisions such as weather, default, and *force majeure* clauses [19]. However, from the standpoint of the contractor, the effect of weather in construction works is materialised in two ways: work stoppage or productivity loss [14]. Severe weather conditions impact any construction work that is either totally or partially carried out outdoors because either the equipment cannot work properly, the quality of the materials is deteriorated, or workers' health and safety is threatened [21]. Regardless of the reason, the consequence is a financial loss that must be borne by either the contractor, the client or both.

From the client's perspective, the initial effects of weather issues are mostly connected to project (time) delays [19,22]. Only if the contractor tries to mitigate weather-related losses at the expense of the client, or if due to an inauguration delay the client misses a business opportunity (e.g., the timely exploitation of an infrastructure), will the extreme weather also entail financial losses for the client [23]. Unfortunately, the weather impact is almost always associated with

Table 1
Sample of recent publications dealing with the effect of weather in construction works.

Reference		Construction work	(Sub) activities	Weather agents
(Thomas et al., 1999)	[36]	(Steel) buildings	Steel structure delivery and erection activities	Temperature and snow
(El-Rayes and Moselhi, 2001)	[20]	Highways	Earthworks, Base courses, Drainage layers and Paving	Precipitation
(Jang et al., 2008)	[10]	Buildings	Generic	Temperature and precipitation
(Thorpe and Karan, 2008)	[9]	Buildings	Clearing and grubbing, excavation, foundations, structural erection, floors, interiors, roofs and HVAC.	Temperature, snow, humidity and precipitation
(Apipattanavis et al., 2010)	[31]	Highways	Concrete and asphalt paving, structures, excavations and grading	Precipitation, air and soil temperature, and wind
(David et al., 2010)	[37]	Buildings	Generic	Solar radiation, temperature, humidity, wind
(Shahin et al., 2011)	[11]	Pipelines	Clearing and grading, trenching, bedding, pipe-fusing, laying-in, hydro testing, compaction and backfilling	(Air and soil) temperature, wind, humidity and precipitation
(Duffy et al., 2012)	[38]	Pipelines	Grading, stringing, bending, welding, trenching, coating, lower-in, backfill, cleanup	Temperature, wind, precipitation
(Dytczak et al., 2013)	[39]	Buildings	Generic	Temperature and wind
(Chinowsky et al., 2013)	[40]	Roads	Generic	Temperature and precipitation
(Marzouk and Hamdy, 2013)	[41]	Buildings	Formwork	Precipitation and temperature
(Shan and Goodrum, 2014)	[42]	Buildings	Steel structure	Temperature and humidity
(Alshebani and Wedawatta, 2014)	[43]	Any	Concretes, equipment-related and workers' productivity in general	(Hot) temperature
(González et al., 2014)	[35]	Buildings	(RC) structures and finishings (e.g., partition walls, windows, and doors)	Not specified
(Shahin et al., 2014)	[44]	Tunnelling	All tunnelling process, hoisting and muck car cleaning	(Air and soil) Temperature and Wind
(Ballesteros-pérez et al., 2015)	[15]	Bridges	Earthworks, formworks, concrete and asphalt pavings	Temperature, precipitation, wind and electrical storms
(Jung et al., 2016)	[14]	(High-rise) Buildings	Generic + core wall, steel frame, deck plate, RC, curtain wall	Solar radiation, temperature, wind, dew point temperature and precipitation
(Li et al., 2016)	[45]	(RC) buildings	Steel reinforced bars	(Hot) temperature