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Computing construction logic in a multi-calendar environment using the Chronographic Method

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Abstract

The construction industry operates in a multi-project environment. When planning a construction project, resources and activities may present their own specific constraints. It may be noted, for example, that: i) performance of outdoor activities depends on weather conditions; ii) the allocation of subcontractors depends on both the contractors' specific obligations to the current project as well as their commitments on other projects with which they are involved. To this end, the use of a multi-calendar environment is essential in order to produce realistic project planning. However, project management software may generate incorrect computations when using some types of precedence relationships and lags in an environment of multi-calendars. This paper demonstrates how these issues can be solved by computing logic using the Chronographic Method since, as demonstrated in the examples provided, it is shown that these errors are not related to the use of multi-calendars, but rather to the precedence logic used with these precedence relationships and lags. The results are several cases for computing the relationship types using Chronographical logic in the multi-calendar environment. The Chronographical logic is thus validated using these examples.

Keywords: Planning, Scheduling, Chronographic Modeling, Time-Scaled, Precedence diagram, Construction Project, Multi-calendars.

1 Introduction

The variability (Campinos-Dubernet, 1984) and instability of the site location (Kundig, 1984) and the extensive use of subcontracting (Rubery et al. 2002) affect the production conditions of the construction sector. This sector operates in a multi-project environment. The subcontractors' allocation and availability depends on the specific obligations to the current project as well as their commitments on other projects with which they are involved. For that purpose, a schedule using a multi-calendar environment is necessary to produce realistic project planning.

Existing project management software may generate incorrect data when using multi-calendars. Kim and Garza (2005) have presented an interesting analysis of the scheduling calculation using multi-calendars which shows in detail how P3 operations with two calendars may generate wrong or inconsistence answers with some types of precedence relationships and lags. In conclusion, they recommend the avoidance of some type of lags and relationships, or taking precautions in their utilization, if the project employs a multi-calendar system.

However, the authors disagree with this conclusion, and maintain that the errors generated using the traditional precedence network are not related to the usage of multi-calendars, but rather due to the limitations of the different types of relationship used by precedence (Francis and Miresco 2006a). These situations have been discussed in detail in previous papers which presented the scheduling theory using the Chronographic Method (Francis and Miresco, 2006b).

2 Discussion on Relation Types

The schedule logic for construction processes is usually modelled through precedence relationships and constraints between project activities. The Precedence Diagram Method (PDM) utilises four types of relationships; PDM allows overlapping by using lags that simulate partial start or finish dependencies, without the obligation of splitting activities. Moreover, the most commonly used scheduling software usually features a bar chart diagram which shows precedence dependencies between activities.

However, some authors assert that the precedence relationship types and lags are insufficient to ensure an accurate computation of the schedule. One example of this is the reverse critical path (Wiest, 1981; Badiru and Pulat, 1995), in which the project duration increases when one diminishes the duration of a critical activity. Another example is the erroneous results produced with some types of relations and delays when using multi-calendars (Kim and Garza, 2005). In addition, Francis and Miresco (2002; 2006a) show that the incorrect use of lags employed with precedence relationships is the basis of these anomalies and that these lags should therefore be replaced by realistic relationships between activities. We should also note that activities depend on each other during their execution. A relationship that limits only the start or the finish of the successor activity is considered insufficient for making an appropriate assessment of project progress. If some changes take place after the relationship’s effect, the successor activity will not be affected and the planner will be forced to make modifications manually.

The shortcomings of these precedence point-to-point external relationships for representing interdependencies and overlapping have, in the past, endorse the study of the impact of upstream activities upon downstream activities. Eppinger (1997) and Peña-Mora and Li (2001), have used the concepts of concurrent engineering to address this problem. They have proposed an overlapping framework based on the activity progress rate, upstream task reliability, downstream task sensitivity and task divisibility.

Allen (1984) describes the logic based on temporal intervals rather than time points, defines thirteen possible temporal relationships and describes situations from either a static or dynamic perspective. Song and Chua (2007) present a temporal logic intermediate function relationship based on an interval-to-interval format. The temporal logics residing in the intermediate relationship functions from three perspectives: the construction life cycle of a single product component, functional interdependencies between two in-progress components, and availability conditions of an intermediate functionality provided by a group of product components.

Many studies (Hendrickson, Martinelli and Rehak, 1987; Pultar, 1990; Chehayeb and AbouRisk, 1998)) have discussed the utilization of time as the only constraint required for the relationship between activities, and have used simulation models to provide production-based linking structures.

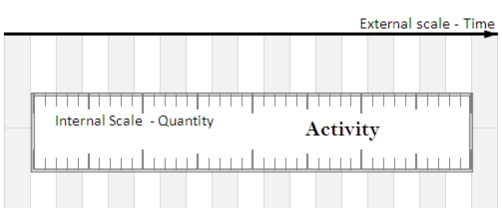

Figure 1. Time-scaled quantifiable activity.

In order to provide an accurate representation of the project constraints, the Chronographic Model (Francis and Miresco, 2006b) introduces the internal division concept and internal measurement as a function of production; we refer to this as the Temporal Function. This paper reviews and analyses the roles of Temporal Functions and uses an approach based on time-scaled quantifiable activities. This means that the approach uses time as an external scale and quantities of workload as an internal unit of measurement for the project activities (figure 1).

3 Chronographic Method and Multi-calendars

The incorrect utilisation of lags is considered as the principal reason for generated errors when using multi-calendars. It is important to distinguish between two types of lags:

1. Lags that presents some technical constraints, such as concrete curing, and always use a continuous working period calendar. These lags should not be affected by non-working days (Figure 2).

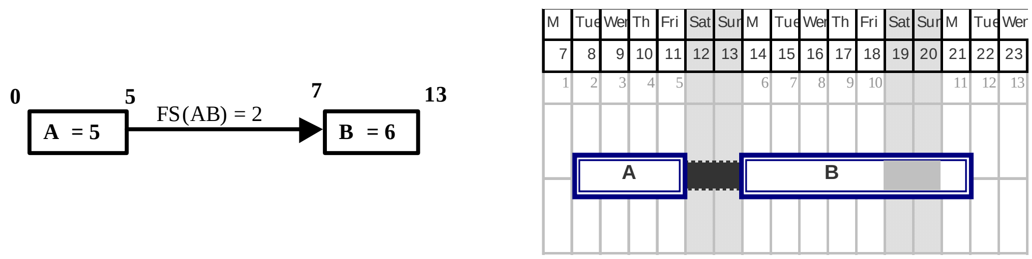

Figure 2. Scheduling and non-working days

2. Lags used as a replacement for an imposed quantity of workload, before the start or the finish of the successors activities. These lags are actually simulated with partial start or finish dependencies. These simulations are insufficient to ensure an accurate calculation of the schedule and could possibly generate wrong answers.

The Chronographic Model converts these types of relationships into internal divisions and internal relationships related to a quantity of workload, thus delaying or anticipating the start of the second activity in order to respect the predecessor production. The utilization of lags as a replacement of an imposed quantity of work is always avoided, solving the discussed problem.

In addition, in real situations, activities depend on each other during the processes of project execution. A relationship that limits only a start or a finish of the successor activity is considered insufficient to make an accurate assessment of the project's progress. If some changes take place after the relationship's effect, successor activity should not be affected and the planner will be forced to make modifications manually.

In order to address the internal flow of work progression, the Chronographic Model proposes the utilization of more than one relationship. Each section of the successor's activities is related to the correspondent section of the predecessor's activity permitting the tracking of interdependencies between two in-progress activities. Thus, any changes in predecessor productivity could affect the corresponding successor section. Figure 3 shows the internal production rate and the internal relationship between two activities.

To address a practical solution, the internal interdependencies between any two activities can be represented by a mathematical function, associated with the first Temporal Function. This relation will contain the rules that manage the interdependencies between the two in progress activities.

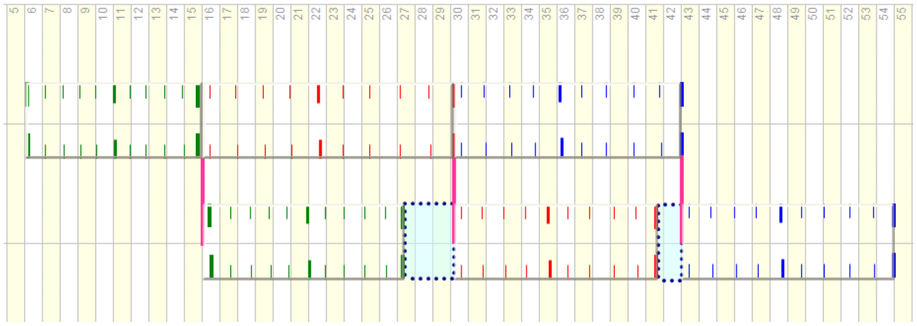

Figure 3. The internal relations between two activities

4 Computing the construction logic in a multi-calendar environment

4.1 Template Chart

The template chart shows two related *time-scaled quantifiable activities* A and B on a background that illustrate two different calendars.

- Activity A: 20 working days (5 sections of 4 days each)
- Activity B: 15 working days (5 section of 3 days each)

However, we substitute A and B with the two activities A' and B', with a shorter duration, when the relation condition forces one of them to exceed the length limits of the template.

- Activity A': 16 working days (4 sections of 4 days each)
- Activity B': 12 working days (4 sections of 3 days each)

Each activity uses a different calendar. Several examples are studied. Each example employs two calendars from the following:

- Calendar 1: five working days from Monday to Friday (Saturday and Sunday are non-working days)
- Calendar 2: four working days from Monday to Thursday (Friday, Saturday and Sunday are non-working days)
- Calendar 3: three working days from Monday to Wednesday (Thursday to Sunday are non-working days)

The computation process is based on the chronographic formulas detailed in Francis and Miresco, (2002, 2006b). In these formulas, computation is related to the connection points and not to the entire activity.

4.2 Different example using multi-calendars

To address these shortcomings, the chronographic modeling operating process uses production-based linking time-scaled activities. This section presents sixteen (16) cases in order to validate the chonographic logic when using multi-calendars. The result is an error-free scheduling model. Therefore, it is possible to model any encountered situation without restriction.

Each case presents two linked activities as predecessor and successor. Each activity possesses a different calendar. Two operating situations are demonstrated:

1. No Interruptions are Permitted (NIP): meaning that the operating process does not permit interruptions to the predecessor activity.
2. Free Float is equal to zero (FF0): meaning that the operating process permits interruptions, but imposes a zero Free Float between each predecessor section and the linked successor.

The coding is as follows:

Predecessor/Successor - Predecessor calendar/Successor Calendar - One of the two operating situations
As example: A/B – 1/3 - NIP

The first eight cases present situations in which the predecessor has the longest duration; in the other eight cases, the predecessor possesses the shortest duration.

4.2.1 The predecessor possesses the longer duration

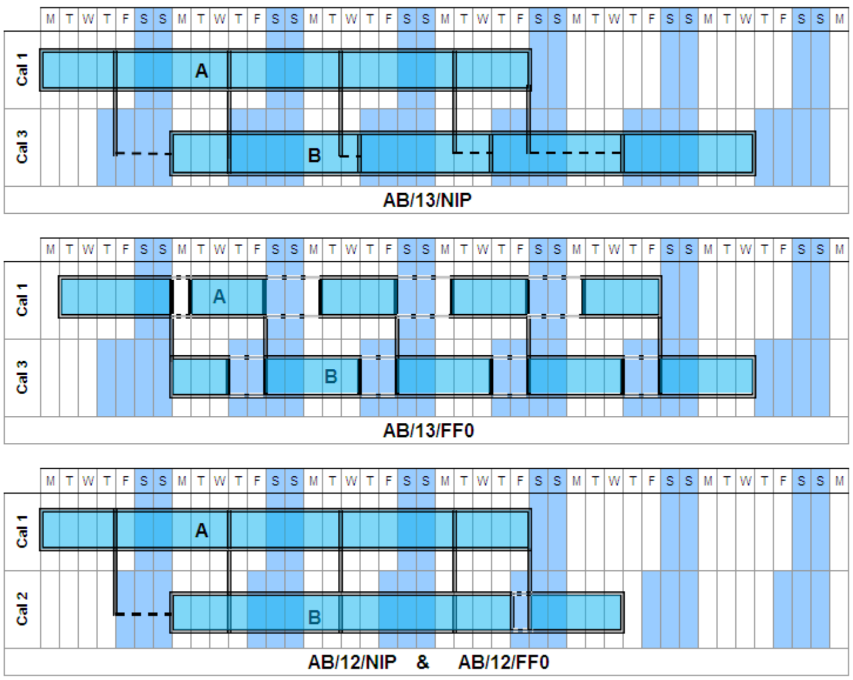

Figure 4. The predecessor uses the calendar that possesses fewer non-working days per week

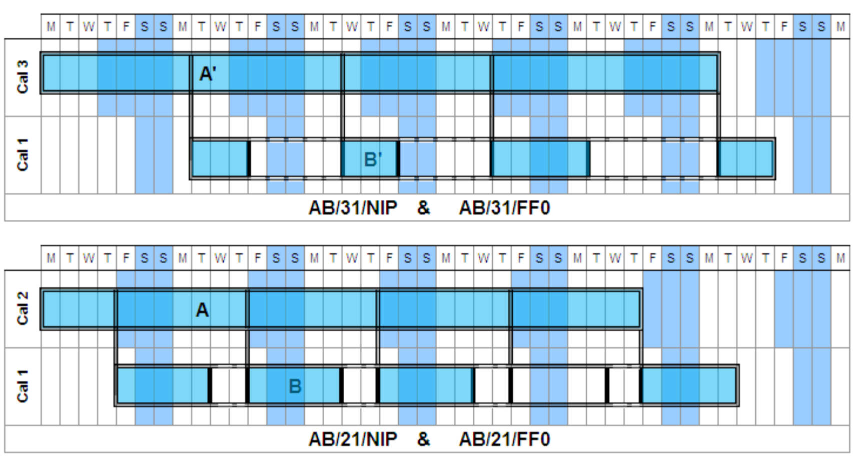

Figure 5. The predecessor uses the calendar that possesses more non-working days per week

4.2.2 Predecessor possesses the shortest duration

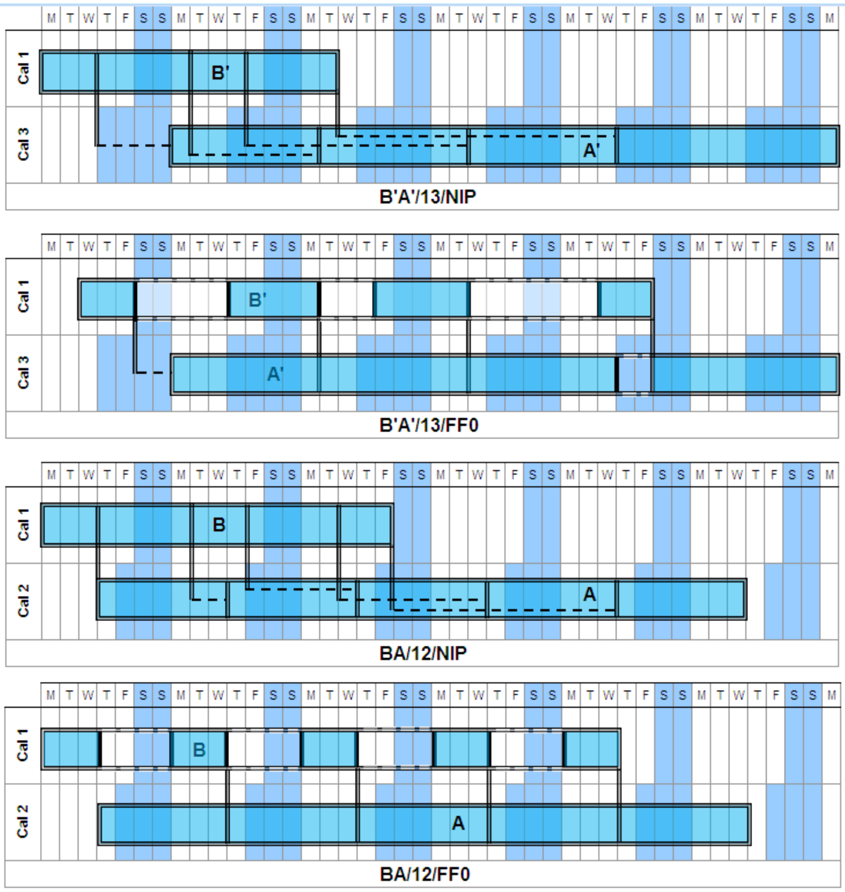

Figure 6. The predecessor uses the calendar that possesses fewer non-working days per week

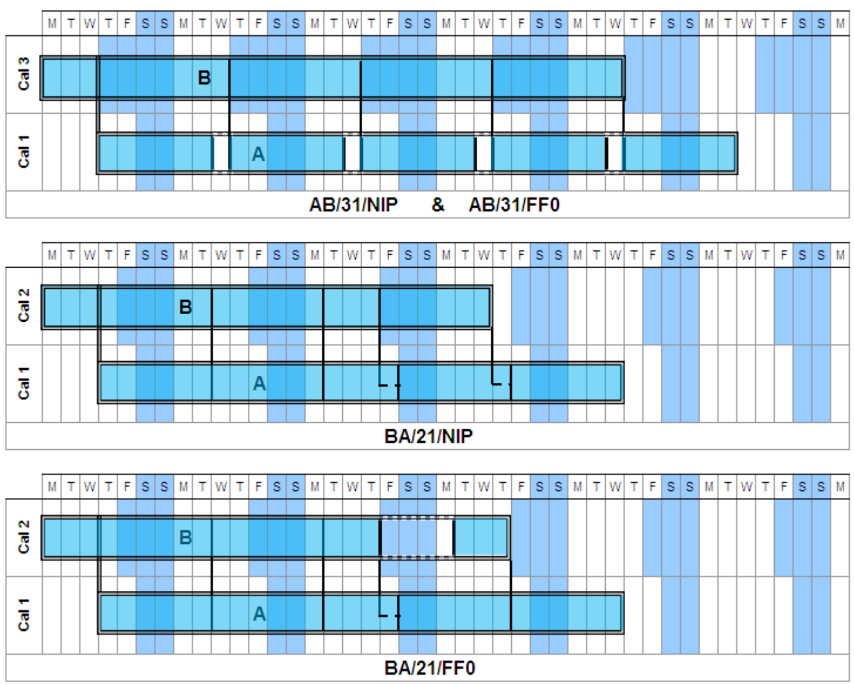

Figure 7. Predecessor uses calendar with more non-working days

The challenge with this approach is that it requires detailed preparation work, which is suitable for major activities such as building superstructure work. However, this method is less appropriate when several activities are interlinked together throughout their execution. Significant preparation work then imposes and compromises the visual aspects of the schedule by multiplying internal dependencies. One solution is the use of multiple layers, as CAD does. Data and constraints can be arranged on different layers in order to help the manager to improve the graphical visualizations of the schedule (Francis and Miresco, 2006c).

In order to address a practical solution, the internal interdependencies between any two activities can be represented by a mathematical function (Francis and Miresco, 2010), associated with the first Temporal Function. This relation contains the rules that manage the interdependencies between the two in progress activities.

5 Conclusion

The utilization of time as the only constraint to show relationship between activities, the inability to address the internal flow of work progression of dependant activities and the incorrect use of lags, are considered the three reasons for generated errors when using multi-calendar scheduling.
To address these shortcoming, the chronographic modeling operating process uses production-based linking time-scaled activities. The result is an error-free scheduling model with the capability to model any encountered situation without restriction.

The problem with this solution is the complication of the model visualization. In order to address a practical solution, the internal interdependencies between any two activities can be represented by a mathematical function, associated with the first Temporal Function. We can conclude that the answers proposed by the Chronographic Model will solve the problems related to scheduling using multi-calendars.

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