



Modelling the boundaries of project fast-tracking



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ABSTRACT

Fast-tracking a project involves carrying out sequential activities in parallel, partially overriding their original order of precedence, to reduce the overall project duration. The current predominant mathematical models of fast-tracking are based on the concepts of activity sensitivity, evolution, dependency and, sometimes, information exchange uncertainty, and aim to determine optimum activity overlaps. However, these models require some subjective inputs from the scheduler and most of them neglect the merge event bias.

In this paper, a stochastic model for schedule fast-tracking is proposed. Relevant findings highlight the existence of a pseudo-physical barrier that suggests that the possibility of shortening a schedule by more than a quarter of its original duration is highly unlikely. The explicit non-linear relationship between cost and overlap has also been quantified for the first time. Finally, manual calculations using the new model are compared with results from a Genetic Algorithm through a case study.

1. Introduction

Fast-tracking involves performing activities, initially viewed as sequential, in parallel by overlapping their execution. It is considered to be one of the three most common schedule compression or acceleration techniques, along with activity “crashing” and activity “substitution” [1]. However, unlike activity crashing and substitution, which generally increase project costs directly, activity overlapping is thought to increase project risk due to an increase in the potential for change and/or rework [2,3] which can lead to increased costs.

The first papers describing the implementation of fast-tracking practices in construction projects were written by Ruby [4] and Baker and Boyd [5]. Ruby described how “phased construction”, as it was previously called, could significantly shorten plant construction projects by allowing an early start for certain long lead time project phases. Baker and Boyd noted all the challenges for successful fast-tracking of a Nuclear Power Plant construction project in the Gulf States. In this project, construction costs amounted to one million US dollars per extra day of execution.

Numerous publications analysing the practical considerations for implementation of fast-tracking practices in a number of settings have been published since then. Some examples include: construction of oil pools [6], automobile instrument panel development [7], subsea tie-back pipeline projects [8], surface water conversion systems to reduce groundwater usage [9], fluid catalytic cracking plant revamps [10], installation of spectrographs in astronomy observatories [11], etc. These papers discuss the varied challenges and repercussions of a

shortened schedule in a real context.

Hence, it is clear from all of these studies that fast-tracking is not risk-free, and overlapping dependent activities can negatively impact project performance and has the potential to raise project costs [12]. Indeed, recent reviews of large scale pipeline projects have shown that fast-tracking during the construction stage doubles the probability of project failure, and concurrent design (fast tracking during the engineering phase) multiplies risk by a factor of four [13].

This is also probably why fast-tracking has attracted interest from an organisational point of view too. In this regard, several studies have examined how team coordination, the flow of information (including feedback loops) and some organisational structures can hamper or facilitate the implementation of fast-tracking practices [7,14–17].

From the mathematical point of view, a number of models have been developed to analyse activity overlapping and concurrent engineering. As these models are highly relevant to this study, they will be discussed separately in the literature review.

With regards scheduling algorithms and computational methods, Genetic Algorithms (GA) have been used most frequently in fast-tracking computer applications by researchers as they provide quicker and more accurate solutions in comparison with other non-linear optimisation methods [18–21]. Mixed Integer Linear and Non-Linear programming models [1], mixed algorithmic approaches (e.g. [22,23]), and other heuristic methods [2] have also been used. However, these latter methods have more commonly been applied to the simultaneous implementation of two or three time–cost trade-off techniques (crashing, overlapping and substitution), and have normally required

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simplifying assumptions such as a linear relationship between cost and overlapping, the independence of overlapping and crashing, single path scenarios, etc. Finally, branch and bound algorithms have also been developed and have proven to be particularly effective when fast-tracking resource-constrained schedules [24,25].

The current research attempts to make a contribution to the area of fast-track modelling by proposing a novel stochastic activity overlapping model. The model captures the type of information used by most previous models and algorithms, but employs an alternative parametrisation that allows for the use of simpler explicit expressions without any loss of generality. New project-level insights will be provided concerning the relationship between predecessor(s)–successor overlap times, costs and the probability (risk) of an unsuccessful overlap. A case study will be used to compare manually calculated results from this model with those from a Genetic Algorithm. The difficulties of fast-tracking a project from a mathematical point of view will be considered in the *Discussion*, and a summary of the findings and model limitations will be presented in the *Conclusions*.

2. Materials and methods

2.1. Literature review

The literature discussing the implications of overlapping and rework in product development and construction projects is plentiful [26]. Recently, Dehghan and Ruwnapura [27] and Dehghan et al. [20] presented a thorough review of the current and previous fast-tracking models for both product development and project design and execution. This review makes no attempt to be as comprehensive, but instead focuses on identifying the most well-known models and highlighting their major contributions and limitations. The models will be reviewed in chronological order; their most significant contributions are highlighted in Fig. 1.

One of the first mathematical models of fast-tracking was published by Krishnan et al. in 1997 [28]. Their model focused on the activity-to-activity attributes of sensitivity (how quickly a predecessor activity releases information) and evolution (how quickly a successor activity progresses). Based on these concepts, they developed a model that, despite its simplicity, constituted the first good representation of the fast-tracking mechanism. The model proposed in this paper also includes the potential for incorporating different activity sensitivities and evolutions, but uses an alternative parametrisation.

In 1998, Nicoletti and Nicolò [29] developed a first decision support tool that modelled the information flows between activities in order to identify which activities should be overlapped and to what extent. The biggest limitation (simplification) of their model was that it assumed

project completion time was not critical, which is not generally true. They did, however, include similar concepts to activity sensitivity and evolution, and managed to incorporate them into a complete project schedule for the first time.

Three years later, in 2001, Peña-Mora and Li [30] developed a dynamic planning and control methodology by integrating axiomatic design, concurrent engineering, the graphical evaluation and review technique (GERT) and system dynamics modelling. The major contribution of this work was the inclusion of a probabilistic view of activity overlaps. The main limitation of their model is that it can only be applied to pairs of activities. The model proposed here makes use of a similar probabilistic approach, but can be applied to complete schedules.

Between 2005 and 2009, Bogus et al. and Blacud et al. [31–33], contributed to the study of activity evolution and sensitivity through a series of expert interviews. They identified the aspects which make an activity more or less sensitive or make it evolve to a greater or lesser extent. Their studies took the first steps to translating the information gathered from real project contexts into inputs for mathematical models. However, their eminently qualitative approach still require further research efforts before those contributions can be translated into fully quantitative models like the one proposed here.

Ramadan et al. in 2011 [34] developed a methodology for capturing and quantifying the exchange of dependency information between pairs of activities once it is known how sensitive they are and how they evolve. These attributes are indirectly accommodated in the model here as part of *Risk* which is related to the probability of achieving a successful overlap.

Following on from their previous studies on activity-to-activity sensitivity and evolution, Bogus et al. [35] implemented, still in 2011, one of the first comprehensive computer algorithms for optimising overlaps in complete schedules. This algorithm used Monte Carlo simulations to predict different discrete outcomes for each activity to obtain a more accurate understanding of the probability of rework. Monte Carlo simulations are also used in the model proposed here to estimate project duration.

In 2013, Cho and Hastak [21] developed one of the first Genetic Algorithms for fast-tracking dependent activities in construction projects. The main limitation of their model was that it considered projects with a single chain of critical activities. However, they were among the first researchers to consider compressing a schedule with multi-predecessor activities.

In the same year, Srour et al. [36] used the Dependency Structure Matrix (DSM) to improve the way dependent and interdependent relationships between activities are represented. Their approach had several advantages; for example, the DSM was able to represent

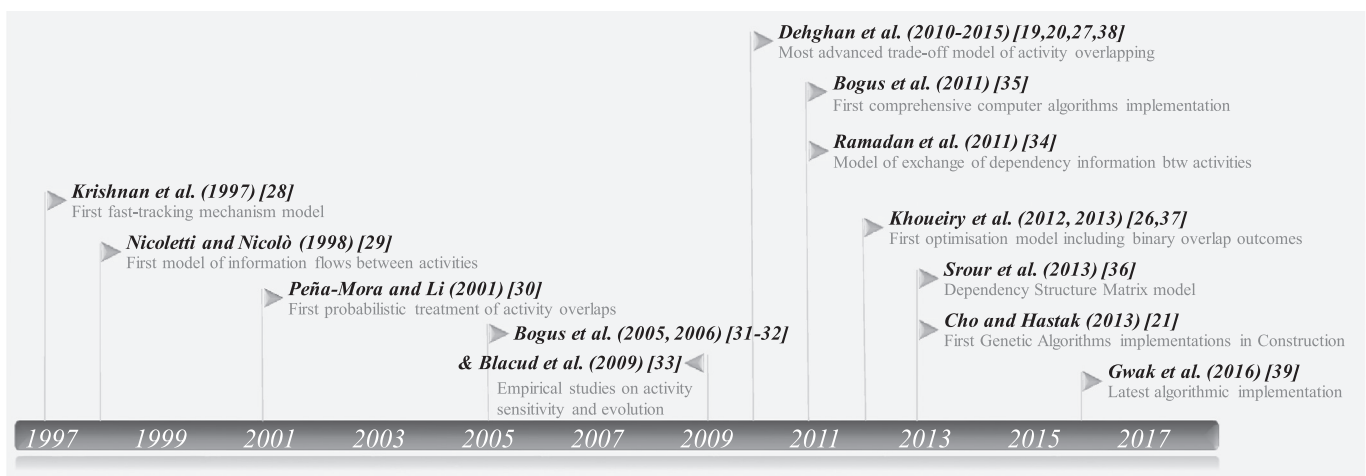


Fig. 1. Timeline of major contributions to project fast-tracking research since 1997.

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