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Decision Support

# The use of a GERT based method to model concurrent product development processes

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A B S T R A C T

This paper proposes a time-computing model using the Graphical Evaluation and Review Technique (GERT) to analyse concurrent New Product Development (NPD) processes. The research presented here differs from previous work carried out on concurrent engineering. First, we conceptualise a concurrent NPD process using the GERT scheduling technique and derive a method of modelling the information and communication complexities within the process. Second, we extend previous research carried out on concurrent engineering and incorporate it within our model. Finally, we present an alternative method of analysing concurrent NPD process for both researchers and project managers alike. The GERT model developed in this paper was successfully employed at two NPD firms located in Ireland and Iran.



## 1. Introduction

New Product Development (NPD) is concerned with the process of getting any new product or service to market. In NPD, speed-to-market is viewed as a vital weapon which can yield competitive advantage, realise higher profits and market share, and exploit opportunities within the market place (Cooper, 2001). In recent years, companies have adopted acceleration techniques to scheduling NPD projects, focusing more on concurrent engineering.

The conventional approach to scheduling projects focuses on the traditional sequential approach, where subsequent stages of a project commence only when the preceding stages have terminated and have supplied complete and final information. This sequential approach to project management requires a great deal of time and as such, has become a barrier to entry for projects in fast-moving markets. Over the past three decades, concurrent engineering has become a guiding stratagem for reducing the time-to-market for new products. In contrast to the sequential approach, activities in concurrent engineering are jointly managed to work in parallel; allowing following stages in a project to begin prior to the completion of earlier stages. In effect, the concurrent engineering strategy significantly reduces the project development time, facilitating an increased speed-to-market.

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Furthermore, by enabling different operations to be undertaken concurrently, the needs of the project as a whole are better satisfied (Jones, 1997). This allows engineers and designers to coordinate their work and make mutual adjustments in their designs which might be necessary to avoid compromises at later stages. While there is substantial research showing that concurrent engineering practices can dramatically reduce project lead times, the successful application and modelling of concurrent NPD processes has proven difficult due to the increased level of network complexity.

In concurrent NPD processes, the interdependencies within the project are bi-directional and constrained by physical, resource and knowledge based relationships. These constraints are recognised by Ford and Sternman (2003) as precedence relationships, activity durations, information dependencies, the availability of work, coordination mechanism, and the number, skill and experience of project staff. Depending on the degree of network overlapping, concurrent engineering relies on a complex myriad of information flows and bi-directional interdependencies. The overlapping of dependent phases means that many events are initiated on designs or specifications that are incomplete or may change over time. Therefore, concurrent engineering practices generally incorporate a high probability and need for activity iterations and rework loops on errors or omissions that may arise during the process. Oftentimes, this leads to increased development costs (Krishnan, 1996; Roemer, Ahmadi, & Wang, 2000; Terwiesch & Loch, 1999). Furthermore, NPD processes create additional planning complexities as the data required for modelling are

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only partially known initially (Smith & Morrow, 1999) and much of the input data are generated on speculation.

The majority of difficulties surrounding the representation of concurrent NPD networks concern: communication complexities in the transfer and flow of information, activity rework, overlapping strategies, resource usage, and the implementation of a new strategy. Since concurrent NPD project networks are based on complex physical and information dependencies, current methods of modelling concurrent NPD processes rely heavily on the capacity of the modeller to represent the NPD process using conventional scheduling techniques.

The Project Evaluation and Review Technique (PERT) has long been established in industry as a tool for planning and managing projects. While recent advances use Markov PERT networks to model queuing, resource allocation, and multi-objective analysis (Azaron, Katagiri, & Sakawa, 2007; Azaron, Katagiri, Sakawa, Kato, & Memariani, 2006), the shortfalls are in its rigid analysis of the project structure and inability to represent complex interactions (Wang & Lin, 2009). Despite this, PERT-path developed by Pontrandolfo (2000) is particularly interesting as it draws strong parallels with other scheduling techniques while addressing the optimistic bias of PERT.

The majority of current modelling carried out on concurrent engineering (Browning & Eppinger, 2002; Carrascosa, Eppinger, & Whitney, 1998; Yan, Wang, Xu, & Wang, 2010) focuses on the use of the Design Structure Matrix (DSM). While the DSM is a widely used scheduling tool, it has several drawbacks: activity iteration implies the repetition of the same previously completed activity (Lévárdy & Browning, 2009); and it does not provide a graphical output or flow-diagram of the information dependencies and communication flows necessary for implementation.

The Graphical Evaluation and Review Technique (GERT) technique developed by Drezner and Pritsker (1965) and Pritsker and associates (Pritsker, 1966; Pritsker & Happ, 1966; Pritsker & Whitehouse, 1966) provides an alternative platform to resolve the modelling complexities associated with concurrent NPD processes. The precedence of probabilistic branching and network loops allows for the inclusion of both network feedback and activity rework to be considered within a stochastic network. The model has a predictive power within its domain and the knowledge acquired from its analysis can be used in making critical decisions involving the selection and evaluation of a network strategy. Furthermore, the output of GERT provides managers with a holistic graphical representation of the concurrent process necessary implementation.

Up until now, few studies have focused on the use of GERT to model NPD processes. Bellas and Samli (1973) were the first of its kind to investigate the use of GERT in sequential NPD processes and market research. Bellas and Samli used GERT to carry out a sensitivity analysis on project controls. Moore and Clayton (1976) applied GERT as a holistic scheduling method to a sequential NPD process. Taylor and Moore (1980) explored the use of Q-GERT, as an alternative to the PERT-CPM approach, on stages of research and development in sequential NPD projects. Aytulun and Guneri (2008) applied GERT to a sequential product development process in an attempt to evaluate the adaptability of the model to a business process. Wu, Kefan, Gang, and Ping (2010) analysed various risks in concurrent product development projects through a tree-dimensional early warning approach, incorporating GERT. Finally, Peña-Mora and Li (2001) developed a hybrid axiomatic design incorporating GERT and systems dynamics model to analyse fast-track construction projects.

Product development projects are perhaps the best examples of GERT applications however, its application to concurrent processes and in particular to NPD concurrent processes has yet to be fully examined. This paper employs GERT as a time-computing scheduling technique to model concurrent NPD processes. The proposed network resolves a lot of the drawbacks associated with conventional scheduling tools, providing an alternative method that explicitly represents and models the complexities arising from concurrent NPD processes. The results of this paper will provide managers and researchers with a method of modelling and analysing concurrent strategies with superior performance in NPD processes. Through this research, we propose a GERT based time-computing model concerning the project completion time by acquiring and modelling the dynamic characteristics of network activities and information flows in a concurrent NPD process.

The layout of this paper is as follows: Section 2 discusses the theoretical background motivating our approach, after which Section 3 introduces the proposed GERT model. Section 4 forms the basis of a research case study, and Section 5 outlines conclusions drawn and areas for future research.

## 2. Methodology

This section discusses the main methodological issues of the research including GERT network features, research limitations, and results verification and validation methods.

### 2.1. GERT network features

The GERT network represents the lowest possible level of defined activities within a project. This involves the decomposition of work packages into scheduled activities to provide a basis for estimating, executing and controlling the project. In GERT, a directed branch or arrow with transmission parameters of time and probability is used to represent a scheduled activity or communication path between two nodes.

The characteristics of GERT networks include:

- *Probabilistic branching*: GERT networks may contain probabilistic branching, deterministic branching, or a combination of the two. This allows for the representation of communication transfer links between both coupled and non-coupled activities.
- *Network looping*: GERT networks allow looping to be included. In NPD, it implies redoing or revising previously completed activities and that certain events may be realised more than once. Smith and Eppinger (1997) stated that understanding activity interaction and process iteration is fundamental to accelerating product development processes.
- *Node realisation logic*: The realisation of a node in GERT can be specified to occur with one or more completions of activities present in that node. This feature of GERT consists of two notations: the AND node and the OR node. As shown in Fig. 1, the AND node will be released only if all the branches leading to the node are realised. Similarly, the OR node consists of two notations: F denotes the number of predecessor activities that must first be completed for the first realisation of the node; and S denotes the number required for subsequent realisations. The OR node will be realised the first time once F of the total number of activities leading to the node are realised. If the node is contained in a loop, then the node can be realised subsequent times once S of the total number of activities leading to the node are realised.
- *Distribution of activity times*: GERT networks facilitate a selection of activity time distributions (normal, beta, gamma, etc.). In practice it is far more common to find multiple time distribution types for specific activities.
- *Terminal event (sink node)*: GERT networks allow for sink nodes to be incorporated into the network. In reality projects may often ceased or be withdrawn at a number of stages within a project depending on the scope and resources available.

### 2.2. Limitations of the method

One of the major limitations associated with concurrent engineering is the fact that the activity iterations cannot be precisely