Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 67 (2018) 58 – 62

www.elsevier.com/locate/procedia

11th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '17

Timed coloured petri nets for modelling and managing processes and projects

Maurizio Bevilacqua[a], Filippo Emanuele Ciarapica[a], Mazzuto Giovanni[a,*]

[a]*Department of Industrial Engineering and Mathematical Science, Polytechnic University of Marche, via brecce bianche, 60100 Ancona (Italy)*

* Corresponding author. Tel.: +39 071 2204361; fax: +30 0712204770. *E-mail address:* g.mazzuto@univpm.it

Abstract

The Resource Constrained Scheduling Project (RCSP) is one of the most complex tasks in the sector of project management. Many researchers devoted effort during the last years to solve this criticality. Moreover, interesting studies analyse the problem regarding mathematical formulation. In so doing, the exact and/or heuristic solutions tools allow extending the analysis to a broad range of Operation Management problems.

The proposed article describes a new approach for project/process modelling based on Timed Coloured Petri Nets (TCPNs), to simplify the resource allocation in a resource-constrained problem. In particular, its utilisation provides a robust formalism to represent and analyse parallel systems. The TCPNs utilisation allows analysing interdependencies, criticality, substitution, conflicting resource priorities and variations in the availability of resources. This paper proposes a new model and highlights the usefulness of the model for real-time activity scheduling in a resource-constrained project environment. A case study for an industrial project is described to provide a systematic analysis of the proposed tool.

Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Intelligent Computation in Manufacturing Engineering

Keywords: Timed coloured petri nets; Project management; Project modelling; CCPM

1. Introduction

The execution of a project requires competencies from different areas of the business for being coordinated and synchronised. Various parameters exist for the success of any project, such as the completion time, a specific budget and technical requirements [1]. The selection of the right project, at the outset and screening out potentially unsuccessful projects, it is the most important step for ensuring total project success. In particular, as suggested by [2], factors influencing the success of project management are several, including the inadequate basis for the project, inadequately defined tasks and administration techniques misuse. The last factor is the most relevant, and it highlights the choice of a particular project management technique for implementing projects successfully. Moreover, project execution needs many activities involved in different sectors. Also, according to [3], the variation in the economic, financial and environmental causes makes each project distinct because of unforeseen events are common during project implementation. Therefore, to manage a complex project, it is indispensable to apply a rigorous methodology based on principles and systematic rules. The proposed study aims at developing a new approach for project modelling and managing using powerful graphical and analytical tools named Timed Coloured Petri Nets (TCPNs) in the System Dynamics (SD) research field. In particular, as described by [4], demonstrates as system dynamics can help managers to understand the project dynamics for modelling the inter-relationships between factors and quantifying their combined effect, illustrating the effect occurred on a design-and-manufacture project. In this context, TCPNs offer many advantages to project managers because of they are capable of modelling a system where many activities take place concurrently and asynchronously also considering concurrences and conflicts. System deadlocks can be determined. The structure of the paper is the following. Section 2 briefly describes some TCPN applications and the TCPN methodology. Section 3

Peer-review under responsibility of the scientific committee of the 11th CIRP Conference on Intelligent Computation in Manufacturing Engineering
doi:10.1016/j.procir.2017.12.176

summarises the adopted research approach, the modelling projects phase, and the used methodology with the case study description. Section 4 presents and discusses the empirical results about the case study. Finally, Section 5 concludes the findings of the study.

2. Modelling with TCPNs

The analysed literature highlights the relevant interest of the scientist on the factor linked to project success. [5] analysed Public – Private Partnerships Critical Success Factor reviewing about 72 scientific papers published in 52 different international journals. [6] research outcome indicates the guidelines for project managers to clearly focus and prioritise the project goals and properly organise the project activities. Moreover, in the scientific literature, it is possible to find many types of research regarding traditional project modelling tools such as [7], [8] and [9]. Project management standards propose tools for helping project execution and control. However, it is worth to note that standards are largely industry specific, and often, they do not assist cross-industry and cross-organisational collaboration [10]. On these grounds, traditional management tools do not allow extending their application. In doing so, many complex industrial systems have recently been analysed using high-level Petri nets including “colour”, “time” and “hierarchy” attributes. In particular, a recent study by [11] highlights the way to extended attributes of Petri nets for helping managers to manage project activities parameters (as costs and to deeply control project execution). [12] developed a methodology, TCPN based, for designing and managing a supply chain (SC) and, at the same time, for evaluating the performance of every stakeholder involved in a production chain. [13] applied a CPN to model activity interfaces and composite activity versions, focusing on the internal states of all activity interfaces. Also, [14] demonstrated the usefulness of the CPN for modelling construction schedules, describing a new scheduling method using CPN to develop a Critical Chain Scheduling (CPN-CCS) model. [13] used TCPNs to define formalism for configuring supply chains. In fact, they provided a modelling tool to supply chain configuration, capable of assisting companies to configure appropriate supply chains from an added value point of view. [15] used TCPNs approach proposing a Concurrent Project Modeling Method to arrange the activities of a bank marketing division, presenting the philosophy of Concurrent Engineering into software project management. In particular, according to [16], PNs are powerful graphical and analytical tools in the project management field and, specifically, TCPNs models allow the analyst considering typical features of control engineering models such as parallelism and concurrency, synchronisation and resource sharing.

2.1. The Coloured Petri Nets structure

In the context of PN, different approaches for modelling exist, according to the complexity of the request. In the PNs, places represent the conditions and results of operations (identified by the transition), and the information is only the structure of the system. Timed and Stochastic PNs (TPN, SPN) can be considered time-based and include probabilistic information [17]. Finally, Coloured PNs (CPN) are an extension of TPCs; the information circulating within the model also affect the nature of resources and how they influence the evolution of the system. The presence of colours makes CPNs/TCPNs the ideal

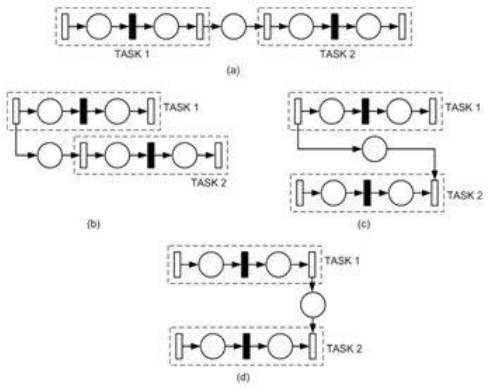

Fig. 1. Representations of project management relationships between activities (a, start to finish; b, start to start; c, finish to

tools to describe systems containing many interacting components [18]. CPNs/TCPNs are developed to provide the mechanisms for accommodating the system changes system.

Graphically, all of the mentioned nets consists of places, transitions, and arcs. Arcs connect a place to a transition or vice versa, never between two objects of equal nature. “Input places” is the name of the places from which an arc runs to a transition; “output places” is the name of the places to which arcs run from a transition to a place. White circles identify places; transitions with white (for untimed transition) or black rectangles (for timed transitions). For more specification about CPNs/TCPNs, it is possible to refer to [18].

2.2. TCPN for project modelling

The model based on TCPN are capable of modelling a system in which many activities take place concurrently and asynchronously. In particular, it is possible to consider modelling concurrence and conflicts as well as system deadlocks. Moreover, the use of TCPNs allows a project manager to check the project health state, finding probable delays of the activity. TCPNs can also model regenerating and rescheduling activities, taking into account breakdowns and resource constraints. Using places and transitions it is possible to represent the project/process dynamic graphically through subnets, making it is possible to simulate the entire system. The system model will so be able to represent resource interdependency, partial allocation, substitution and mutual exclusivity. Behavioural properties such as reachability and boundedness allow modelling, complex system with the presence of resources constraints. In doing so, the use of higher-level Petri Nets allows reducing the graphical size of the network, avoiding the cumbersome inclusion of dummy activities and making easier to model and represent precedence relationships as shown in Fig. 1.