

Chapter 12

A Model–Driven Methodology to Evaluate Performability of Metro Systems

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ABSTRACT

Metro systems are required to continuously achieve acceptable levels of reliability, availability, maintainability, and performance (performability) in order to comply with the target values reported in operation and maintenance contracts. These requirements are regulated by several international standards that control the lifecycle defining both processes, documentation flows, and enabling techniques, aiming at controlling disturbances on service performed by the system. This chapter focuses on a complete model-driven methodology with the aim to support the performability evaluation of a metro system during design and in-service phases, as well as requirements assessment. In detail, the methodology allows the automatic generation of those formal models required for performability analysis, specialized according to the specific track layout and the defined operational strategies. The proposed methodology is perfectly coherent with the European Standard CENELEC EN 50126 and it allows the generation of all the technical reports needed in the related documentation.

INTRODUCTION

Metro systems are rapid transit train systems, operating in an urban area with a high capacity and frequency, totally independent from other traffic. These systems are demand-oriented systems, since the reasons why they are built are strongly related to people transportation. The achievement of good Quality of Service levels, offered to passengers,

is, for the most part, linked to the attainment of acceptable levels of Reliability, Availability, Maintainability and Performance (Performability). More and more often target values are defined in contracts for the designer companies, and their attainment is strictly connected with economic bonus (when exceeded) and penalties (when not reached). Lastly the achievement of good Quality of Service levels increases the system competitive-

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ness in the people transportation domain, which is really important for system operators.

A Metro system can be classified as a complex system, due to its large-sized distributed architecture and to the components heterogeneity, both hardware and software, as well as their continuous and discrete temporal evolution. This complexity makes the design, construction and maintenance very difficult, in particular with the aim of controlling both the Quality of Service and the Performability: it is necessary a continuous assessment during all the lifecycle, including also operation phase.

Quality of Service (QoS) offered to customers hence represents the main requirement a Metro System shall satisfy, and it needs to be considered by operators (Kotler, 1991). The QoS is a measure of the “customers’ satisfaction”, it estimates different issues such as cost of tickets, waiting time at stations, total on-board travel time, cleanness, safety level, travel time variability and so on. According to classical literature in the field of transportation engineering (Cascetta, 2009), customer satisfaction is maximized when the so called “users’ generalized cost” is minimized, where the independent variables are bounded among a certain set of discrete alternatives. Specifically for a single passenger, the generalized cost (C_i), choosing an alternative i , can be expressed as a linear combination of the K attributes ($X_{K,i}$) concerning that alternative, weighted by their respective homogenization coefficients $\beta_{K,i}$, which mostly represent specific costs of the attribute: $C_i = \text{SUM} (\beta_{K,i} * X_{K,i})$. As previously mentioned, for a single customer attributes $X_{K,i}$ can represent both quantitative variables as well as qualitative variables correctly discretized.

The perceived QoS is strongly dependent on Performability levels delivered by the system. The Performability indexes estimate “the ability to maintain performance, also degraded, in presence of failures”, properly combining system performance with its dependability. For a Metro System, as well as other service-providing

systems, Performability indexes are expressed through mathematical formulas referred to the offered service, measuring both the correct and the degraded service carried out by the system; these indexes are defined in tender documents and may vary for the specific project. They are often described by the ratio between performed (actual) and target (designed) service; as an example, a common Performability index is given by “Punctuality (P)”, which can be defined as $P = (t_s - t_l) / t_s$, where t_s is the number of scheduled trips within a certain time period and t_l is the number of lost and delayed trips (i.e. the number of not-realized trips, or those which arrive over a certain delay threshold at the measurement station) calculated over the same time interval. Performability indexes are commonly known, wrongly, as “RAM indexes” due to the strict relationships with Reliability, Availability, Maintainability attributes.

The European Standard CENELEC EN 50126 (CENELEC, 1999) defines a complete process for the management of Reliability, Availability, Maintainability and Safety, denoted by the acronym RAMS, of Railway and Metro Systems. This norm suggests a common “V” lifecycle (the RAMS lifecycle), decomposed in fourteen phases; for each one of them objectives, inputs, requirements, deliverables and verification techniques are defined. The RAMS lifecycle is depicted in Figure 1, where, neglecting the minor, main phases are indicated. All these phases can be grouped together into the following macro-phases: definition, design, installation and operation. If, on one hand, this norm is well focused on the process, on the other hand it does not impose any approaches for the Performability evaluation, leaving a wide margin to adopt an appropriate methodology depending on the adopted formulas that, as said previously, are specifically defined for each project.

To date, the Performability evaluation of a complex system during development stages can be carried out through analytical approaches or relying on the model usage. The adoption of the first, especially in the industry, has the enormous

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