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A Framework for simulator development for Fixed Horizon, Rolling Horizon and Real Time Management Modelling and Evaluation

Abstract

This paper presents a framework for simulator development for fixed horizon, rolling horizon and real time management models for their modelling and evaluation in ubiquitous production networks under conditions of dynamic environments for economic and environmental sustainability.

Keywords

Real time management, Fixed horizon, Rolling Horizon, Simulator.

1. Introduction

Globalization and market's internationalization causes variations on product demand creating problems on production planning. Therefore, enterprises' agility, quick reaction and response to market changes and proactivity are needed, as well as the availability and capacity to "answer" to the market and globalization requirements.

Ubiquitous and cloud manufacturing are seen as an instrument that enables these requirements. Emergent ICT (Information and Communication Technologies), promotes the emergence of ubiquitous and cloud production networks, arising the ideal conditions for the creation of new paradigms of scheduling, such as Real Time Management (RTM). Considering manufacturing systems, this new paradigm focuses on the capacity to quickly respond to the needs and the real time decision making, aiming to eliminate planning as a controlling instrument in reference to predefined horizons, such as "Fixed Horizon" and "Rolling Horizon".

The main objective of RTM is to enable quick adaptation to the dynamic external (market) and internal (organizational) changes and initiatives, in other words to both reactive and proactive dynamic scenarios.

However, a simulator to validate this new scheduling paradigm (RTM) has not been found in literature yet.

The purpose of this simulator development is to find which is the "solution space" where the above mentioned management paradigms are more suitable in different contexts.

There are also different thesis that should be also proved, by the simulator to be developed, such as: (1) RTM paradigm is more suitable for production scheduling in a factory workshop under conditions of dynamic environments than the "Fixed Horizon" and "Rolling Horizon" paradigm; (2) RTM paradigm is more suitable for production scheduling in ubiquitous production networks under conditions of dynamic environments than the

"Fixed Horizon" and "Rolling Horizon" paradigm; and (3) RTM paradigm contributes to economic and environmental sustainability.

This paper presents a framework for a simulator development for fixed horizon, rolling horizon and real time management models for their modelling and evaluation in ubiquitous production networks under conditions of dynamic environments for economic and environmental sustainability.

Besides the introduction presented in Section 1, the paper is organized as follows. In Section 2 a brief literature review is described, and in Section 3 the approach to the three production scheduling paradigms is presented. Section 4 present the framework for the simulator development comprising the simulator's development architecture and simulator's development functionalities. Finally, the major conclusions are presented in Section 5.

2. Literature Review

The "Fixed Horizon" (FH) and "Rolling Horizon" (RH) are implemented in production scheduling (Clark & Clark, 2000; Fleischmann, Meyr, & Wagner, 2005; Li & Ierapetritou, 2010; Mohammadi, Ghomi, Karimi, & Torabi, 2010; Prasad & Chetty, 2001). Simpson (1999) uses simulation for validate nine multiple level planning heuristics in a deterministic demand environment, relating rolling horizon results with fixed horizon results.

"Real Time Management" (RTM) paradigm has emerged recently following the emergent Information and Communication Technologies (ICT), especially applied on the development of so-called "Smart Objects" and RFID technology (Zhang, Huang, Qu, Ho, & Sun, 2011), M2M Devices and advanced architectures such as MIMOSA (Machinery Information Management Open System Alliance) (Cha, Song, & Choi, 2005). These technologies enable the creation of the "Internet of Things"(Atzori, Iera, Morabito, & Nitti, 2012) and, in effect, real time monitoring of all production data, their processing, decision making and issuing of execution orders, creating the base for the RTM.

However, a simulator to validate this new scheduling paradigm (RTM), considering the ubiquitous production networks under conditions of dynamic environments for economic and environmental sustainability, has not been found in literature yet.

3. Three Production Scheduling Paradigms

With the emergence of production networks, creating sharing of resources and increasing the level of trust between partners, and the development of ICT, arise the ideal conditions for the creation of new paradigms of scheduling, such as the "Real Time Management". Considering manufacturing systems, RTM focuses on the capacity to quickly respond to the needs and initiatives and the real time decision making, aiming to eliminate planning as a controlling instrument in reference to predefined horizons (Figure 3 and Figure 4), creating a more and more dynamic networks of enterprises, when evaluated with other production scheduling paradigms "Fixed Horizon" (Figure 1) and "Rolling Horizon" (Figure 2). (Figures 1-4 depict Time-To-Market (TTM) as one of the performance measures for the reconfiguration management, i.e. for the production scheduling under the conditions of turbulent environment.)

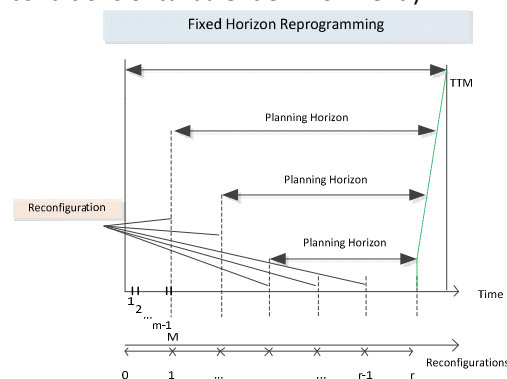


Figure 1. "Fixed Horizon" production scheduling paradigm approach

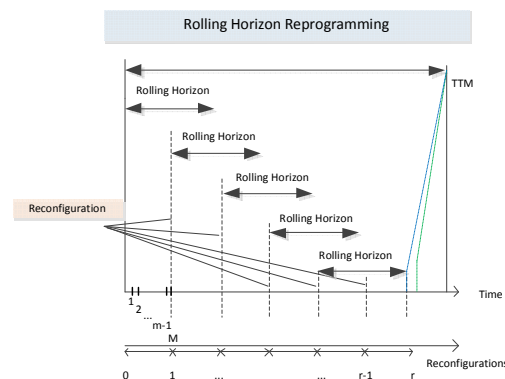


Figure 2. "Rolling Horizon" production scheduling paradigm approach

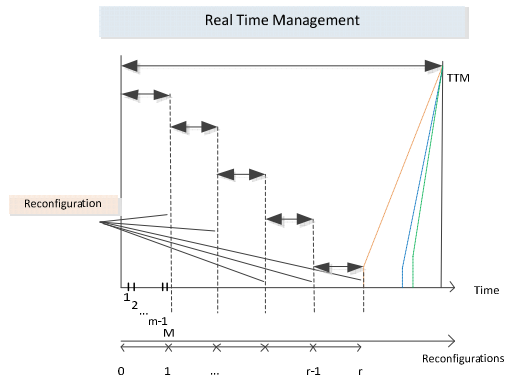


Figure 3. "Real Time Management" production scheduling paradigm approach

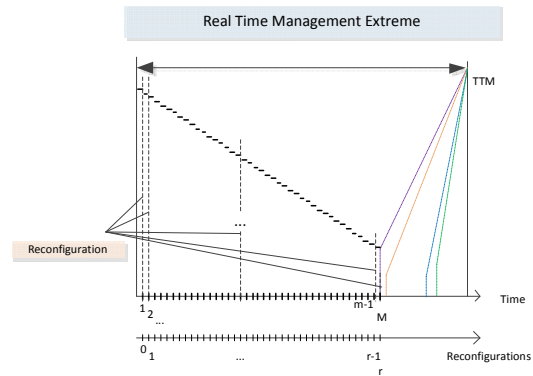


Figure 4. "Real Time Management Extreme" approach

The capacities for each paradigm, at the reconfiguration moment, are different than the predicted at the moment of scheduling plan formulation, due to dynamic environment, that requires scheduling plan replanning. This means that as longer scheduling plan period, bigger is the difference between the planned and the reality. This implies that the planning period should be the shortest possible, to ensure the minimum error in planning (each error means lost competitiveness or lost opportunity, assuming that where the size (the size of the "grey areas" on Figure 5) of loss is proportional of economic loss), comparing with the reality (Figure 5), in the limit, it planning period should tend to zero¹.

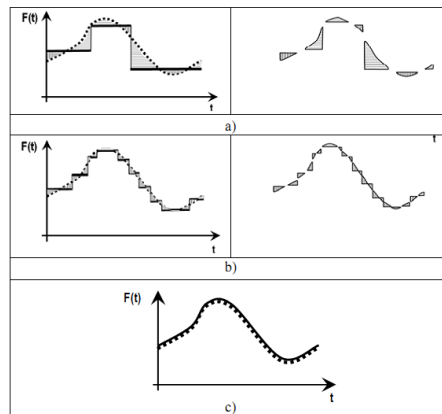


Figure 5. Alignment of enterprise capacity with market (Putnik, Cunha, Cortes, & Ávila, 2007)

With RTM paradigm it is possible to create a systems reconfiguration dynamics, i.e. the higher system adaptation dynamics to the dynamic environment, implies choosing always the best resource in each moment. For Fixed Horizon and Rolling Horizon paradigms, the best resources choice focuses on the plan for the planning horizon that induces the planning error comparing with the reality dynamics.

4. A Framework for simulator development

The framework's objective is to present:

- (1) an architecture for the abovementioned production scheduling paradigms, for future simulator's development, and
- (2) a simulator development functionalities for the simulator's processes.

¹ Similarly to the problem in mathematical analysis of calculating the area below a function. In order to eliminate error of calculation it is applied the Riemann Sum concept, i.e. an integral of the function in case.

This framework for both architecture and functionalities is based on the “tightly coupled and interactive” computer simulation’s subfields (Figure 6) (Fishwick, 1998).

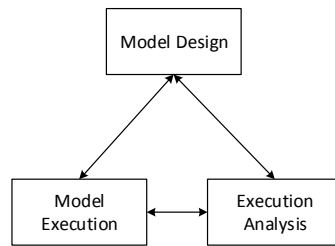


Figure 6. The three computer simulation’s subfields (Fishwick, 1998)

4.1 Simulator development architecture

The architecture for simulator development for the abovementioned production scheduling paradigms modelling and evaluation is presented in Figure 7.

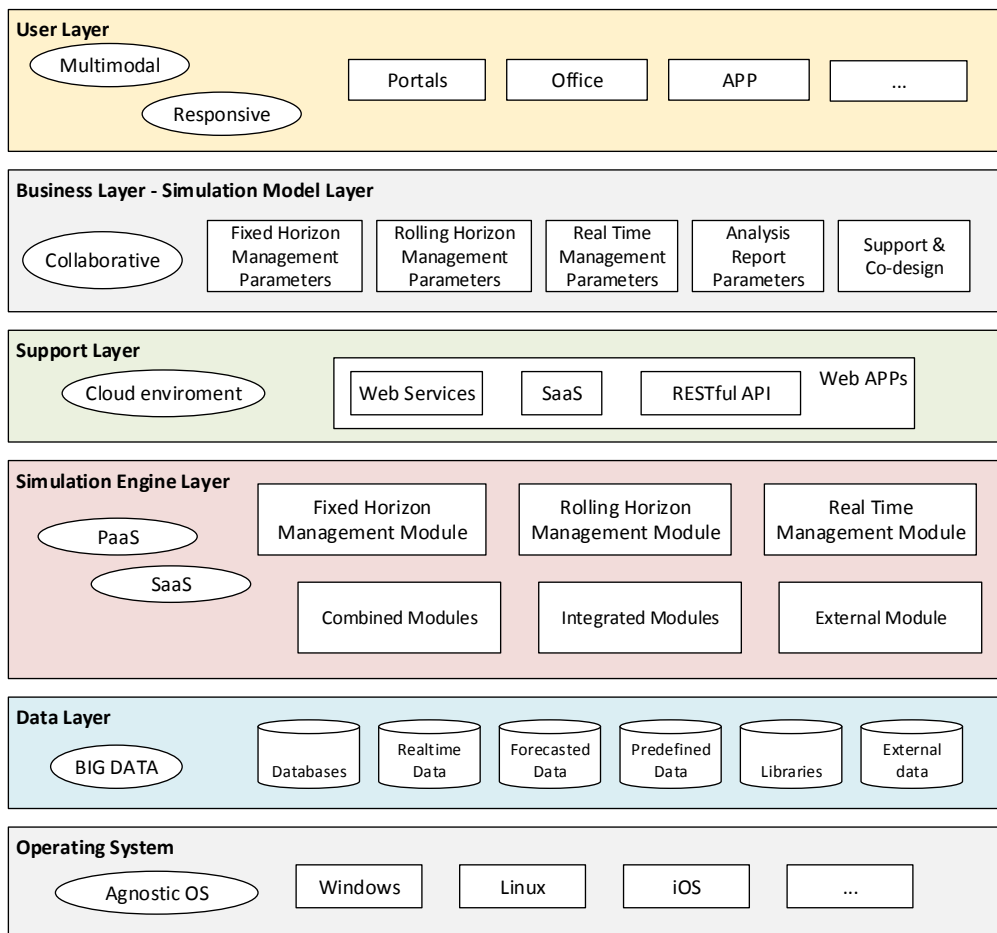


Figure 7. Architecture for simulator’s development

This is a 6-tier layer architecture consisting of (1) User Layer, (2) Business Layer (Simulation Model Layer), (3) Support Layer, (4) Simulation Engine Layer, (5) Data Layer, and (6) Operating System. Each “Layer” comprises two different representations (a) elliptical, and (b) rectangular, which corresponds to the layer’s characteristics or particularities and to the layer’s components, respectively:

1. *User Layer*: represents/defines applications and support for all interfaces, views, presentations and communications for users;

2. *Business Layer - Simulation Model Layer*: represents/defines applications and support for all “business” applications including Support and Co-design in a collaborative environment;
3. *Support Layer*: represents/defines applications and support for all Web App’s including Web Services, SaaS (Software as a Service), and RESTful API (which allows the integration of an external module);
4. *Simulation Engine Layer*: represents/defines applications and support for all simulation modules for each production scheduling, standalone, combined, “all-integrated” or external modules;
5. *Data Layer*: represents/defines applications and support for all applications for data repository and management, including real-time data and external data;
6. *Operating System*: represents/defines the “anyone” operating system that supports all the components.

4.2 Simulator development functionalities

Considering the three production scheduling paradigms a simulator development functionalities was developed. Figure 8 and Figure 9 present the simulator development functionalities divided into the “three subfields” presented by (Fishwick, 1998).

Model Design corresponds to the design of the case, through the case parametrization, and to the design of the simulator’s output, e.g. through the analysis report parametrization. Primarily the user should choose the management approach once this condition in the case parametrization (e.g. only for the Rolling Horizon approach, the “rolling period” is needed), and in the final results (performance measure) value. The input data comprises the lot size, the operations for each lot, the resources that can process each operations for each lot, the available capacity for each resource to process each operation for each lot and the resource transportation between resources.

The case parametrization and the analysis report parametrization are the parameters in which the user can parametrize their conditions, such as, type of product, type of transport between resources, type and size of market, resources selection method (e.g. heuristics, brokering services), type of negotiation, lots launching, performance measure (e.g. time-to-market, CO2 emissions, cost, quality), reconfiguration period, analysis parameters, graphical representation of the results, and similar.

After the data consistency checked, the simulator start the execution in function of the management approach selected previously. If the user chooses the resources selection value by the criteria of maximize the number of lots processed in the minimum time, the process for each management approach is the following:

- For Fixed Horizon: (step 1) the candidate resources selection for each operation to process the lots are calculated through the criteria referred above till the end of the lots processing. The performance measure (e.g. time-to-market) is calculated (step 2) for all lots processing and registered (step 3). If all lots are not finished (all operations concluded), return to (step 1), else the value is the last one calculated.
- For Rolling Horizon: (step 1) the candidate resources selection for each operation to process the lots are calculated through the criteria referred above till the end of the rolling period or lots processing. The performance measure (e.g. time-to-market) is calculated (step 2) for all lots processing and registered (step 3). If all lots are not finished (all operations concluded), return to (step 1), else the value is the last one calculated.
- For RTM: Candidate (step 1) the candidate resources selection for each operation to process the lots are calculated through the criteria referred above till the end of the reconfiguration period or lots processing. The performance measure (e.g. time-to-market) is calculated (step 2) for all lots processing and registered (step 3). If all lots are not finished (all operations concluded), return to (step 1), else the value is the last one calculated.

The execution analysis comprises the analysis report with the data and graphics in function of the analysis report parametrization.

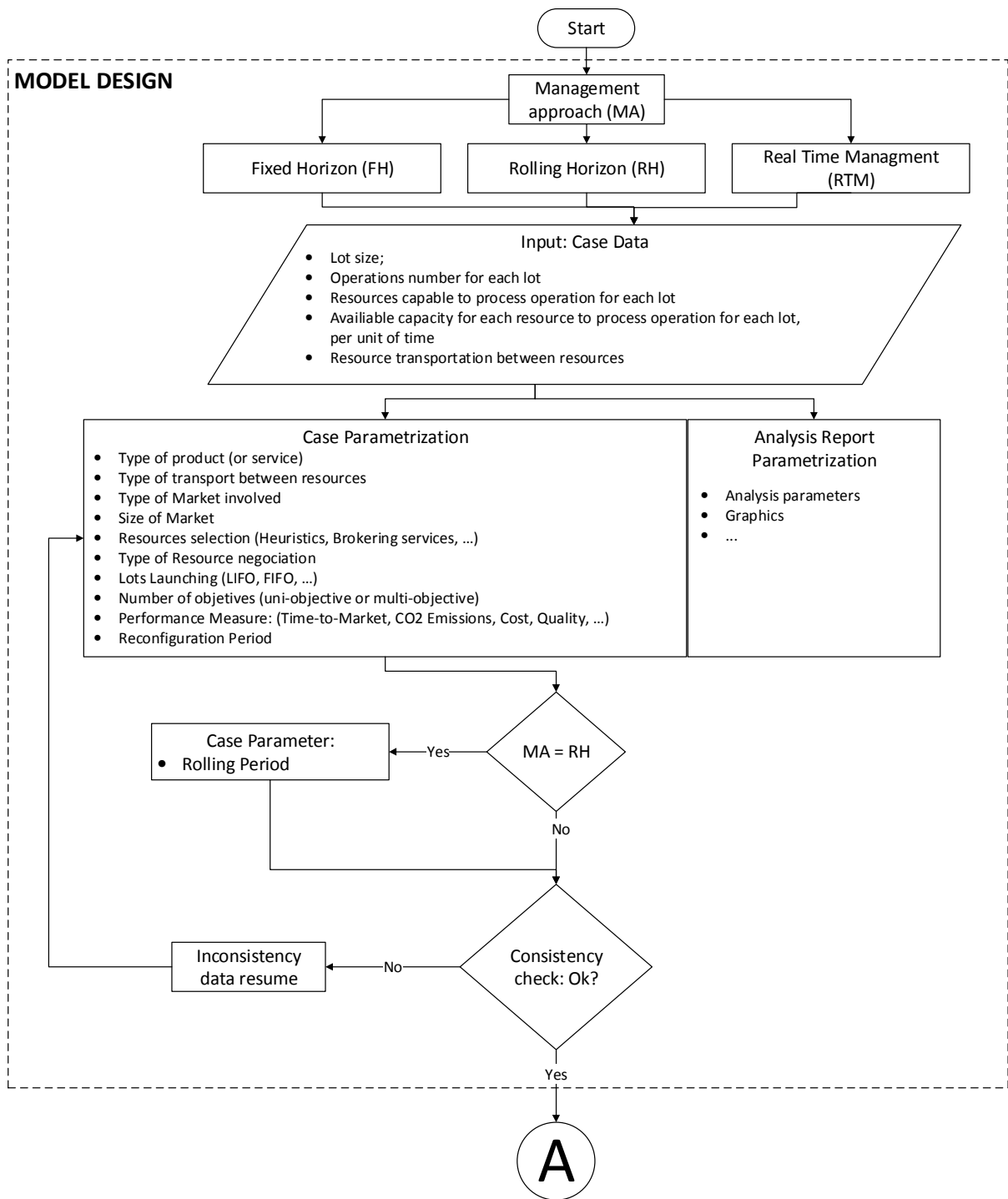


Figure 8. Simulator flowchart functionalities (1)

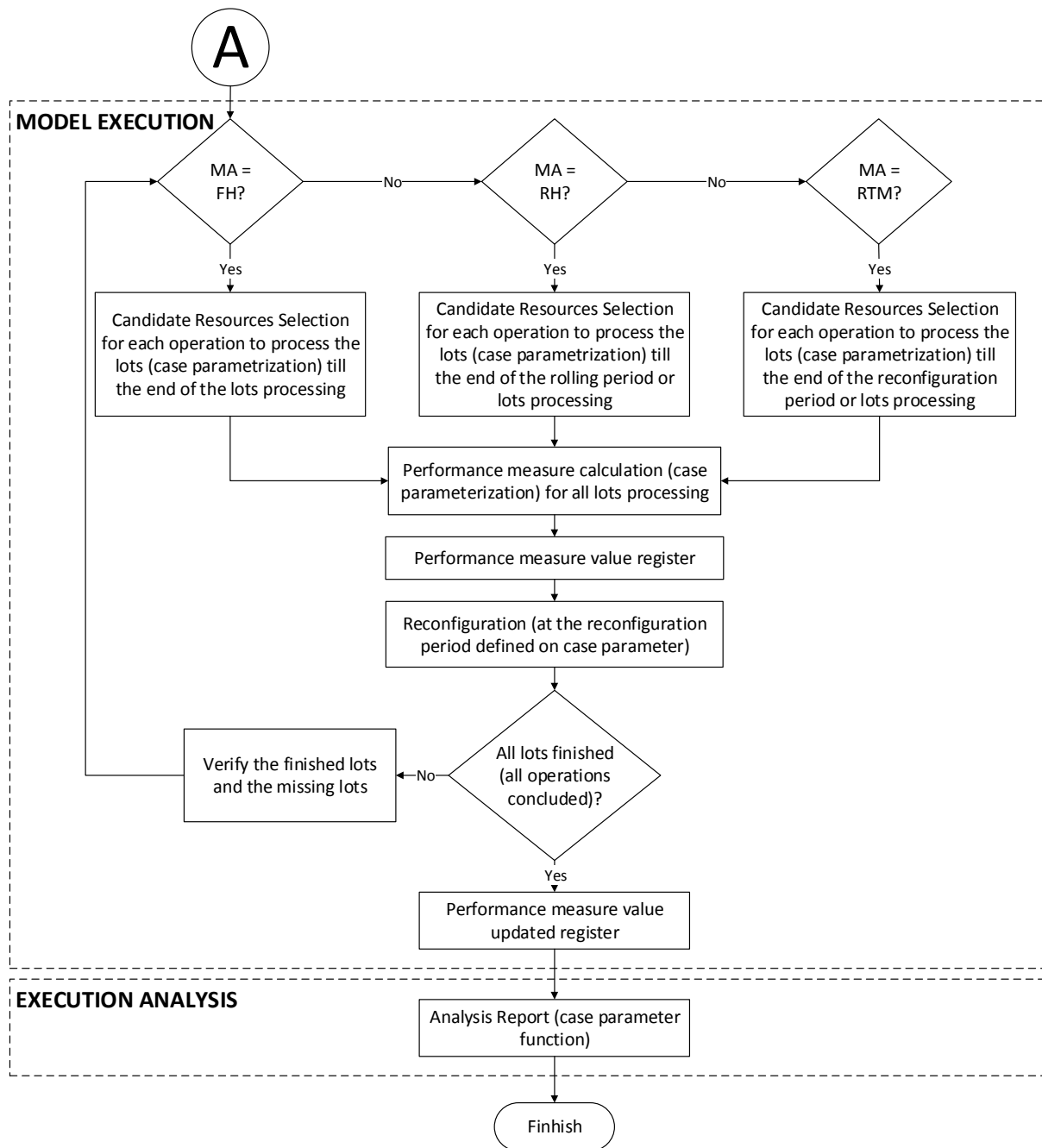


Figure 9. Simulator flowchart functionalities (2)

5. Conclusions

Besides the framework for simulator development presented, it is necessary to program and develop the simulator in order to prove the different thesis (presented in Section 1).

We don't want to focus on architecture's science, but present an architecture for our simulator development. With this simulator and future validation of the thesis presented, we will contribute to the research and to development of RTM paradigm, and contribute to the theory of production scheduling.

Future work includes the simulator development which could be further embedded into a cyber-physical system.

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