Creating a baseline model of Manufacturing Execution Systems using Petri nets : Literatture overview

Adil ARAMJA
LTI
National School of Applied Sciences
Tangier, Morocco
adil.aramja@gmail.com

Oualid KAMAch
LTI
National School of Applied Sciences
Tangier, Morocco
Okamach@yahoo.fr

Samir CHAFIK
ENSEM
Casablanca, Morocco
s_chafik@yahoo.fr

Abstract—**the current economical context is pushing companies to do more with less, with better quality, to do it faster and most of all in a cost effective manner. Apart from creating economies of scales, ensuring operational efficiencies is also of a paramount importance. To do so, many companies strive to implement lean processes and best practices and amongst other alternatives, implementing IT software solutions such as Manufacturing Execution Systems (MES). Such tools can help manufacturing companies shorten the manufacturing cycle, improve the process performances and increase therefore the company competitiveness in a very challenging market landscape. Acquiring such tools would be most of the times very expensive especially for small and medium businesses that are very cautious about their CAPEX/OPEX spending. This is mainly because MES solutions are offered as a package of several modules and their integration with the existing systems and infrastructure imply additional cost and burden for this type of companies.**

In this paper, we are presenting the literature view on modeling MES solution systems which will be as a guideline for our approach to assist small and medium industries with a baseline model of MES solutions. The intended model will be established by first of all setting a benchmark of the MES solutions in European market, second a survey will be distributed to different Industrial companies in Moroccan market in order to grasp their needs and finally making a reference model using modeling tools such as Petri nets.

Keywords—MES, benchmark, baseline model, survey, modeling, Petri

I. GENERAL OVERVIEW OF M.E.S

The manufacturing Execution Systems (MES) are software systems intended to manage, control and coordinate the different tasks defined at the production and manufacturing level in order to improve the company's operational performances.

The development of MES solutions has gone through different stages. According to Rondeau (2011), there were five stages that witnessed the evolution and development of manufacturing planning and control systems:

- Reorder Point Systems (ROP), which consisted in a continuous monitoring of available warehouse stock of a given product. While using materials from the warehouse, the system checks if this use will lead the stock level to reach the reorder level usually indicated as ROP.

- Materials Requirement Planning (MRP) approach is based on determining the number of parts, components and materials to produce each end item. MRP systems also provide the schedule specifying when each item should be ordered or produced [2].

- MRP II systems which stands for Manufacturing Resource Planning is just a direct evolution of MRP Systems. This evolution was mainly driven by the evolution the development of the information

processing technology. MRP II systems control the entire system from order entry through scheduling, inventory control, finance, and accounting [2].
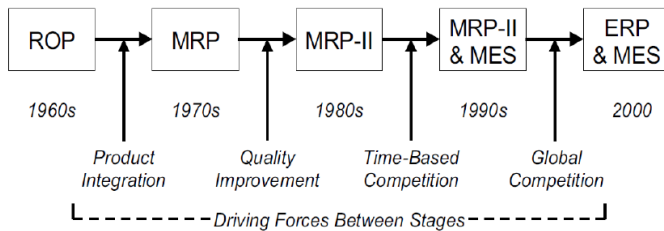

Fig. 1. Evolution of manufacturing planning and control systems [1]

The MES solutions encompass nowadays several components of the CIM model such as CAP (Computer Aided Planning), CAM (Computer Aided Manufacturing), CAQ (Computer Aided Quality Assurance), PDA (Production Data Acquisition), MDA (Machine Data Acquisition), and PTR / T&A (Personnel Time Recording, Time & Attendance) [3]. As a result of this integration, MES plays a key role being the single data repository for the different production departments and also by giving a consolidated and customized reports that can be used by the business and management systems such as ERPs.

A. MES norms and Guidelines

Norms and guidelines represent the outcome of efforts established by different industrial groups and eventually normalization bodies. These efforts are meant to offer the different industry players a standardized model of MES solutions which will help not only vendors to create solutions quickly increasing therefore the adoption rate of these solutions, but also reducing risks for customers related mainly to the financials, technical integration and interoperability with existing systems [6]. In this section, we are going to focus mainly on the models defined by MESA and ISA.

In 1997, MESA has developed a very compact model which encompasses eleven function of a MES system. These functions are linked to each other and connected to other software solutions at the upper level [6].

MESA has later on defined what is called C-MES (Collaborative MES) which focus on how core operations interact with business operations considering factors such as increased competition, outsourcing, supply chain optimization, and asset optimization [6].

The other model that we are going to address was defined by ISA, the International Society of Automation (ISA). ISA is using more the term manufacturing operation system. Besides the terminology and definitions, the ISA-95 standard aims at defining which information has to be exchanged between systems for sales, finance and logistics and systems for

production, maintenance and quality. This information is structured using UML models which are the basis for the development of standard interfaces between ERP and MES systems.

Fig. 2. Eleven functionnalities of M.E.S as defined by MESA

B. Advantages and benefits of using MES systems

The adoption of Manufacturing Execution Systems was initially noticed within several discrete, batch and continuous process manufacturing industries, especially aerospace, automotive, semiconductor, pharmaceuticals and petrochemicals.

Market reports show that they are increasingly being applied in sectors such as metals, plastics and medical equipment.

We can summarize the main advantages of using MES in the following [11]:

- Better integration of information that is all the information need to be collected from machinery are stored in a single database.

- More reliable data about the production environment.

- Collecting the information in a real-time basis, allowing better decision making.

- Reducing paper work and improving documentation management

- Reducing manufacturing cycle times

- Reduction of errors and defects by permanent computer-based monitoring of all important production parameters.

- Reduction of production costs and better utilization of plant capacity as a result of computer-based production planning and scheduling.

- Reduction of set-up times by optimization of plant allocation.

- Inventory reduction (raw materials, finished products) by improved planning, and more flexible and demand-oriented production.

- Effective organization, monitoring, and documentation of processes which are subject to regulatory compliance

C. Investment decision in M.E.S

In order to argument the investment in M.E.S solutions for upper level management, a business case should be established. Traditional analysis gives more emphasize to financial criteria and indicators such as the NPV (Net Present Value), IRR (Internal Rate of Return), Payback period or even the TCO (Total cost of ownership). However, another non-financial criteria should also be considered such as the enterprise culture, i.e. the resistance factor that might arise from the employees.

Reference [4] suggested a methodology that may assist companies in making the right decision for MES solution based on a general decision model called BOCR (Benefits – Opportunities – Costs – Risks) and ANP (Analytical Network Process). ANP is very practical for decision making based on multi-criteria and it has been used in several cases related to IT projects.

The way how decision is taken can also vary depending on the size of companies. Large companies often consider investment in IT systems as strategic decision therefore carrying out an assessment is viewed as unnecessary. On the other hand for smaller companies which lacks time and personnel, making a comprehensive assessment is a complex task.

II. MES SYSTEMS MODELLING

Manufacturing systems are complex: they are comprised of people, processes, products, information systems and data, and material processing and handling systems. In order to design effective and efficient systems and integrate the various Components, manufacturing systems modeling is required. Because of system complexity however, systems must be modeled using various views, e.g., functional, informational, physical, control, etc. [12]

There quite many different modelling techniques and methods and each modelling method has its specific characteristics and may have different focuses on application systems. Nevertheless, these methods didn't succeed in reporting the full description of manufacturing process information and the complex internal relations [13].

In this section we are going to shed some lights on some work and efforts associated with the modelling of MES systems.

The modelling of Manufacturing Execution Systems is an interdisciplinary challenge. Actually, the information required for setting up the MES model requirements are spread among different stakeholders within the company. That is, people at the production process level have different view on the technical and the business process then operators and Management personnel might have [7]. Moreover they have different interests and requirements regarding the MES functionalities.

This fragmentation of the information would have consequences both on MES vendors and customers: The formers would experience difficulties to locate the different data points and report accurately the different performance indicators as specified by the customer since data are needed in different details from different stakeholders and for the latters, this will lead to a suboptimal cooperation and islands of knowledge among co-workers and thus to a non-efficient use of information potentially available [7].

Same problem was also reported by companies in industries working with low variety batches and relatively longer lead times MTO (Make-to-Order) Projects such as the aerospace industry. These type of organizations are working on islands of automation making it very difficult to carry out any analysis of the available data. Various functions are working independently and are unable to share information with each other [8].

In order to overcome this problem and to have a simple communication method and easily understandable by different stakeholders, it was argued that using understandable graphic modeling notations would be a very efficient solution. A new notation model was developed called "SpeziMES" which not only fulfills all essential requirements but also compliant with existing modeling standards [7]. MES specification requires at least three types of information and their relation to each other: information about the technical system, information about the production process and information about the required MES functions.
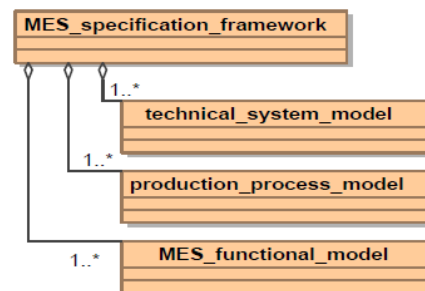

Fig. 3.   MES specification framework models

The MES model represents the core of this modeling framework. It displays the functions of MES embedded in interacting IT functionalities and systems. For a complete modeling of MES, all possible timing descriptions like discrete event-driven, time-discrete and time-continuous need to be expressed. In MES, synchronous, asynchronous and concurrent processes could take place, so that an appropriate modeling language allows the modeling of all of these three types of process synchronization [7].
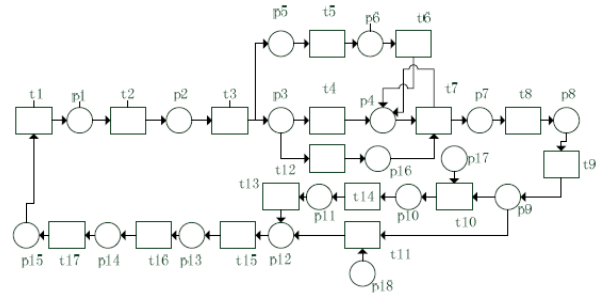
Other researches pointed Petri nets as an efficient modeling tool. The rationale behind this choice was that MES systems were a complex DEDS (Discrete Event Dynamic System) as such there were many random factors and unstructured problems in it and second Petri nets was a good tool for modeling and analyzing the dynamic system of discrete matters [9].

Petri nets development was motivated mainly by the need to model industrial systems. They have been used extensively to represent simple production lines with buffers, automotive production systems, flexible manufacturing systems, Just in Time and Kanban manufacturing systems [10].

Reference [9] showed how petri nets can be applied for modelling MES systems in a hybrid industry. The case study was taken from the manufacturing process of cotton yarn.

The first step was to understand the different steps of the production process of cotton yarn, this will give a clear overview on the flow of the different objects. Secondly, the establishment process of the production plan and how MES fits into it. Actually the production data is transferred using MES and if production has been modified, MES will respond accordingly. Therefore, the tasks that need to be modelled are the relationship between the different production activities.
The author used what is called colored Petri nets where color concept is applied to basic petri nets. The principle is as follow: same class individuals are endowed with same color, different class individuals are endowed with different color. In this way, one place can comprise several objects or one composite condition, and one transition can also denote different changes. At the same time, the token has been appended color, and can be used to depict the attribute information of object. Therefore it can simplify the complexity of the system model.

Fig. 4. The colored petri net model for the production process.

The colored petri nets model of production process can be built based on the production process characteristics of cotton spinning industry and the rules of colored petri nets.

III. CONCLUSION

In this paper, we tried to give a general overview on the previous works attempting to model MES systems. The functional model defined by ISA seems to be the main reference model used by different authors and industrial players. Petri nets and its variants are the most used techniques for modeling MES solutions as they are widely tested and experimented in industrial and manufacturing sectors.

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