POST-PRINT Version

Cite this paper as:
Polenghi A., Roda I., Macchi M., Pozzetti A. (2019) Conceptual Framework for a Data Model to Support Asset Management Decision-Making Process. In: Ameri F., Stecke K., von Cieminski G., Kiritsis D. (eds) Advances in Production Management Systems. Production Management for the Factory of the Future. APMS 2019. IFIP Advances in Information and Communication Technology, vol 566. Springer, Cham
https://link.springer.com/chapter/10.1007%2F978-3-030-30000-5_36#citeas

Conceptual framework for a data model to support Asset Management decision-making process

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Abstract. Information and data management is nowadays a central issue to support the Asset Management (AM) decision-making process. Manufacturing companies have to take different decisions along the asset lifecycle and at different organisational levels, and, to this end, they require proper information and data management. In the literature, besides the crucial role played by information and data, there is evidence of existing gaps, especially related to information management and integration, and transformation of data into useful information. Thus, a conceptual framework is proposed to guide the definition of a data model to fulfil the previously identified gap. Generally, the framework aims at contributing to the improvement of the integration of information along the AM decision-making process. Specifically, it is intended to be aligned with the AM theory and, in particular, its fundamentals defined in the scientific literature and the ISO 5500x body of standards. Overall, thanks to the improvement of the information management and integration along with the AM decision-making, the expectation is to be capable of achieving more value-oriented decisions for the asset lifecycle.

Keywords: data management, information management, asset management, decision framework, manufacturing.

1 Introduction

The deployment of the disruptive technologies developed and used during the Industry 4.0 era is changing the way organisations are looking to their assets. The black box has been opened through the extensive installation of sensors to gather raw data. Therefore, databases are created for the collection of data from different sources to realise centralised data storages, even unstructured (also called data lakes). Moreover, software tools for data analytics aimed at catching information behind the Big Data are growing in number and capabilities [1].

To acquire a leading role in this context, a successful digital transformation of the company is required and, to this end, capabilities are becoming central to manage information and data flows, recognise important data from waste (i.e. concept of Smart Data [2]), and analyse data to extract information properly (from "simple" mathematical artefacts to machine learning techniques [3]).

During this digital transformation, the way the assets are managed receives new stimuli to improve their management policy, relying on increased knowledge and information through data collection. However, this technological jump has not been painless, and sometimes, results are not guaranteed.

In section 2, following an analysis of the most relevant works in this field performed, the main gaps encountered in the scientific literature are listed, with a special focus on physical assets within manufacturing systems. Then, in section 3, a summary of the AM fundamentals is provided, before introducing the proposed conceptual framework, aimed at guiding data modelling to support AM decision-making. Finally, some concluding remarks and future researches are stated in section 4.

2 Literature review on information and data management

The AM development, featuring an integrated approach along the asset lifecycle, is inherently geared towards sharing information and data between different databases, systems, and organisational functions, finally asking for an asset-centred orientation that relies on an effective asset data management [4]. A lot of work has been done so far in this direction, not only in AM [5] but also in maintenance [6], considered its natural precursor. However, two main extant gaps are recognised in the scientific literature when dealing with information and data for AM in manufacturing [7]:

- **Information management and integration**: consisting of the correct management and suitable integration of information in different asset control levels and between systems to support asset-related decisions [4], [8], [9];
- **Data to information transformation**: consisting of the suitable exploitation of the data to derive information (and then knowledge) from the system [10]–[12].

Overall, the information and data management results to be critical for a suitable AM system in manufacturing, especially when dealing with information integration. Different approaches are proposed to improve its body of knowledge while complying with AM fundamentals.

Among them, it is worth to notice the connection between AM and BIM (Building Information Modeling), which brought to the publication of the ISO 19650 (substituting the PAS 1192). Aligned with BIM, the asset information exchange is analysed in the ISO 19526, which took advantage from researches in the field of product data [13]; despite the focus on process plants, it is adaptable to manufacturing [5]. Also, maintenance has taken the endeavour to face information and data within the wider scope of AM [14]: meaningful examples may derive from what developed in data management [15], or E-maintenance [16], [17]. In this very field, an interesting framework to guide information and data management has been developed in [18] but enclosed within the scope of maintenance without looking at the AM theory, which is the aim of this work.

As demonstrated by the literature, most of the data models adherent in terms of scope to AM derive from the maintenance field. Those data models help in structuring the maintenance decision-making process, dealing with alert generation for abnormal conditions of the assets, maintenance strategy definition for the assets, including CBM (condition-based maintenance) programs. Nevertheless, a first attempt to move towards AM decision-making process is recognised in [19], which means enlarging the scope of decision-making along the asset lifecycle

Moreover, data models based on object-oriented modelling and, as the next step, ontology, have been proven to be suitable to support problems related to information and data management, especially their integration along the lifecycle [20], [21].

This paper aims at contributing to this promising direction. To this end, as a first methodological step (see [22] for ontology development methodology), a conceptual framework to support data model development for AM decision-making is proposed in section 3, after a brief overview on AM fundamentals defined in the literature.

3 Proposed conceptual framework

The proposed conceptual framework starts from the work done in [18], and it paves the way to widen the scope towards AM. This goal is reached by firstly analysing which AM fundamentals must be considered to build decision-making coherent with AM theory. These fundamentals are summarised in a recent work published in 2018 [23]:

1. Asset lifecycle stages (BoL Beginning of Life, MoL Middle of Life, and EoL End of Life);
2. Asset control levels (strategic, tactical, operational);
3. AM principles (Lifecycle, System, Risk, Value orientation).

The underpinning goal of the conceptual framework is to enlarge the scope of the decision-making process (including decisions related to different areas such as capital investment, operations & maintenance, shutdown and outage, and others [24]): the decomposition into blocks of the proposed framework helps to reach this purpose.

The framework (in Fig. 1) has the aim of being a conceptual reference for the development of data models for the description of the AM decision-making processes.

On one side, the AM fundamentals are mapped considering the block in which they first appear (other blocks "receive" fundamentals due to cascade effect as well as information and data). In so doing, the conceptual framework aims at integrating these fundamental in the overall decision-making process, which starts from the asset (Physical description block) and ends up with the final decision (AM decision-making block).

On the other side, it promotes information integration, which happens at the block named Value-driven system analysis. This block is responsible for carrying out the analysis that supports the decision-making: information and data coming from different sources must be considered and integrated. Thus, the proposed conceptual framework wants to foster the need for a structured way to integrate information to better support the AM decision-making process.

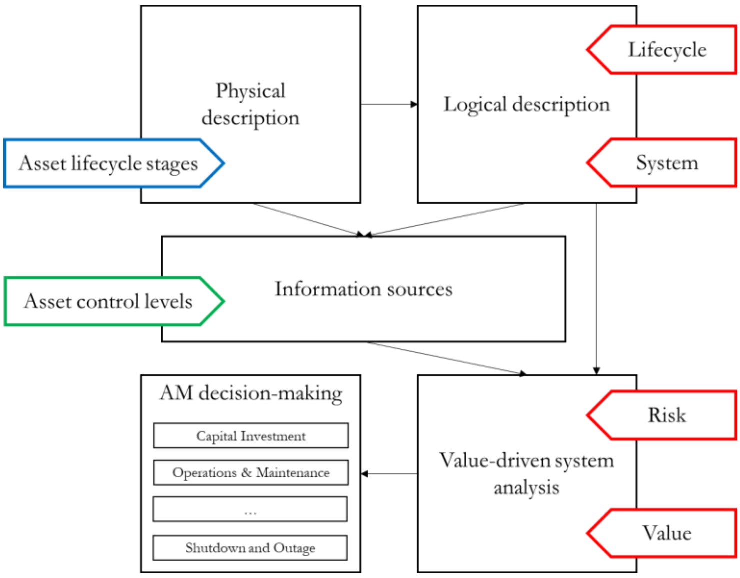

Fig. 1. Conceptual framework with a mapping of AM fundamentals.

3.1 Physical description

The Physical description block is devoted to the physical representation of the asset. The asset model may derive from the conceptualisation/idealisation activity in BoL (whose information and data are gathered in CAx systems), or from an installed asset in MoL / EoL (whose information and data are gathered in systems like CMMS, Computerised Maintenance Management Systems, besides CAx systems). Thus, in this block, the asset lifecycle stages are introduced since the asset is currently in BoL/MoL/EoL stage; this differs from the Lifecycle orientation, as explained after.

3.2 Logical description

The Logical description block aims at describing the function the asset must undertake; for example, in the maintenance context, this block describes how the asset works and how it fails. For this reason, this block enables modelling interdependencies and relationships between assets in the system (e.g. to logically represent the series or parallel configuration of two machines); so, it introduces the System orientation as AM principle. Moreover, the Lifecycle orientation is inserted here since *"AM process should incorporate long-term objectives and performances to drive decision-making"*[23], so the logical description enables the understanding of consequences of a decision. There is a difference between the asset lifecycle stages and the Lifecycle orientation: the former one only represents the stage in which the asset is (BoL, MoL, EoL), while the Lifecycle orientation represents how the decision is taken (driven by long-term objectives and asset, asset system, performance).

3.3 Information sources

The Information sources block represents the layer between the physical and logical description of the system, and the value-driven system analysis and AM decision-making. It is intended to represent the IT ecosystem or landscape (also called industrial software stack [25]), collecting the software tools adopted to support company decision-making processes, and AM among them.

The allocation of each software tool to a specific asset control level is a prerequisite to implementing an optimal AM system.

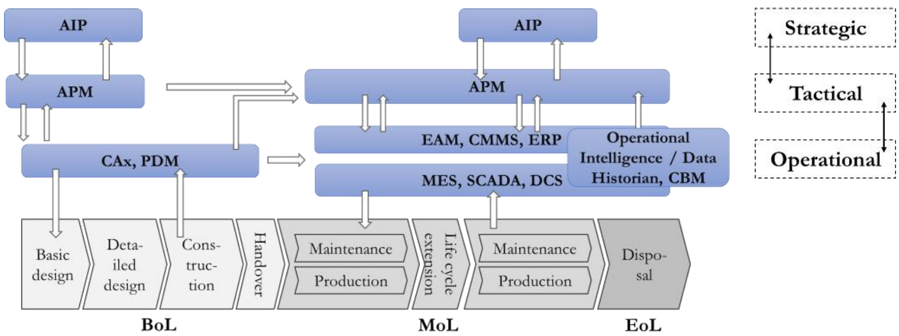

Fig. 2. IT ecosystem for AM decision-making (adapted by [26]).

Each software tool is so able to: i) provide/gather information and data to/from software tools belonging to other asset control levels or within the same one; ii) provide suitable information for the asset control level in which it is used to support the related decisions (e.g. asset health index for the development of strategies of asset replacement and maintenance, or Return On Investment for capital investment). This IT ecosystem has already been proven to be fundamental to implement a suitable strategy to manage the assets at best [27], especially to guide the analysis, as described in subsection 3.4.

3.4 Value-driven system analysis

The Value-driven system analysis block aims at supporting the AM decision-making process by developing suitable PIs (Performance Indicators), which must be adequate and aligned for the use in the final decision to be taken. The development of such PIs happens through an analysis that must comply with AM fundamentals previously cited, and it must also consider the three main drivers guiding the decision-making process: cost, performance and risk (aligned with [28]). The definition of appropriate value elements is a core activity at this step of the decision-making process because it allows performing analyses aligned with corporate objectives [29].

The Value-driven system analysis block is the one that collects inputs from all the other blocks and in which the information integration happens. As an example, refer to [18], where this block corresponds to the symptom analysis. Here, the health status of the machine is used to finally understand and analyse the symptom of a failure mode that is in evolution. The symptom analysis performed required the integration of information coming from information sources (monitoring variables), but also from the logical description (information about the failure mode, which could have a symptom). The integration of this information supports the symptom analysis that allows making a final maintenance decision.

Summarising, this block is the one responsible for information integration since all the analyses performed to sustain a final decision must rely not on one single information source, but different ones. Better structuring the connection between information sources and different analysis is valuable for an effective AM decision-making process.

3.5 AM decision-making

The enlargement of the scope towards the AM decision-making is represented by the last block that includes different asset-related decisions. The set of possible decisions to be considered within the scope of AM is large, but generally some classes of decisions could be recognised, from an asset user perspective [24], [30]–[32]: capital investment (evaluation of alternatives / suppliers, maintenance service contract selection, budget planning and cost control) in BoL; operations and maintenance (maintenance planning, operations planning, asset utilisation strategies), reconfiguration decision, and shutdown/turnaround/outage in MoL; reuse or rehabilitation strategy in EoL.

A suitable decision-making process enables these decisions, and they must rely on PIs developed in the previous block, i.e. Value-driven system analysis.

The correct integration of information in the previous analysis has a huge impact on the final asset-related decision.

4 Conclusions

The proposed conceptual framework claims to be a conceptual reference to develop data models, whose goals should be the integration of information to enable analysis on which decisions are taken. The framework serves as a guideline to enable a structured data modelling that could improve the AM decision-making process, including all the fundamentals. The framework is built looking at possible approaches to AM, in which maintenance plays a central role. Thus, starting from a framework developed for CBM programs, the proposed conceptual framework is built, whose decomposition into blocks helps in fulfilling and integrating AM fundamentals (asset control levels, asset lifecycle stages and AM principles), involving different decisions. Better structuring the relationship between different information sources and different analysis sustaining the decision is valuable to build a robust AM decision-making process. In so doing, thanks to the improvement of the information management and integration along with the AM decision-making, the expectation is to be capable of achieving more value-oriented decisions for the asset lifecycle.

Future research will be focused on the development of data models for the different decisions in AM to support all the decisions set, rather than only maintenance, with the final aim of creating a comprehensive data model that may support an ontology study.

As a side effect, it will also enable to formalise AM decision-making process, currently not yet fully described by extant reference or standard models.

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