Risk Sources Affecting the Asset Management Decision-Making Process in Manufacturing: A Systematic Review of the Literature

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Abstract. Asset Management (AM) is promising for value creation from assets in the long term. A major concern to this end relates with the capabilities to achieve effective AM decision-making at every organisational level, i.e. operational, tactical, and strategical. Therefore, the goal of this research, grounded on a systematic literature review, is to identify which are the main sources of uncertainty that may influence the achievement of AM system related objectives and, as such, should be taken into consideration in a risk-informed decision-making process. Taking the manufacturing sector as a reference, the risk sources addressed by the extant literature are identified and mapped against a reference classification scheme. As a result, the research offers a comprehensive framework where risk sources, affecting the AM decision-making process, are systematically mapped. Information management is found to be the main risk source when making asset-related decisions.

Keywords: Risk management · Asset risk management · Risk sources · Asset Management · Manufacturing

1 Introduction

Asset Management (AM) as discipline and business process is recently at the centre of the scientific and industrial debate. In fact, AM has been climbing top management's priority list, having a special concern in physical assets [1], i.e. those assets that exist independently from any contract, as opposed to financial assets [2].

During its development, the AM system view promoted a holistic approach, leading to more attention to strategic, risk, safety and environment, as well as human factors [2–4]. Four founding principles are also remarked – i.e., lifecycle, system, risk, and asset-centric orientation – as levers to set an AM system within an industrial organisation [5]. While remarking the holistic approach, value creation has recently emerged as another essential concept to the purpose of AM. Indeed, AM embraces different kinds of actors that together aim at realising value by managing assets through coordination and in alignment with the organisational strategy [6]; accordingly, "effective

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control and governance of assets … is essential to realize value … to achieve the desired balance of cost, risk and performance" [6]. In order to achieve such a balanced cost, risk and performance, the focus on value in asset-related decisions is remarked by the most recent discussion on value-based AM [7–9].

Different application fields/sectors advocated the adoption of AM and, specifically, of an AM system. The establishment of AM as a business process was initially evident in the mid-90s in the oil and gas sector; later on, infrastructure and distributed network systems have progressively aimed to introduce AM in their core processes; manufacturing is, nowadays, still lagging behind the achievements in the other sectors, especially discrete manufacturing.

Notwithstanding the application sector, and the relative AM maturity within it, a common understanding is that a proper and efficient AM requires to set up an effective decision-making process, capable of supporting asset-related decisions through all the lifecycle phases of an asset [10]. In this perspective, risk management plays an important role in improving the decision-making process within AM [6]. Risk management has, in fact, a huge impact on the correct setup of a well-performing decision-making process [11]. However, within the AM field, asset-related decisions and decision-making are not particularly supported by practical guidelines [3, 4] in accordance with risk management. For this reason, the present work focuses on the relationships between the decision-making process within AM and the related risks. More specifically, the aim is the identification of possible risk sources affecting the decision-making process within AM, while particular attention is put on manufacturing companies, considering how the general concepts and principles of AM are currently implemented in this business context.

From a research perspective, this work fosters the importance of risk management, with the aim of enhancing its role in AM decision-making; from a practical perspective, the paper gives hints to asset managers about what risk sources should be considered for implementing a risk-informed decision-making process.

The paper is so structured: Sect. 2 describes the reference framework for AM risk sources, proposed as a background, and built by integrating the risk-orientation principle to the lifecycle-orientation; Sect. 3 deals with the systematic literature review methodology, and it describes how the framework is fulfilled based on the literature findings; Sect. 4 proposes the results of the literature review, then Sect. 5 states some conclusions and work limitations for future improvements.

2 Framework for Asset Management Risk Sources

This work assumes a reference framework for the analysis of the most impactful risk sources for the AM decision-making process. The framework is composed of two dimensions: asset-related decisions and operational risk sources (see Fig. 1).

The first dimension includes the asset-related decisions mapped against each lifecycle phase, see the bottom part of the scheme in Fig. 1. This dimension adopts an asset user perspective, so it does no include decisions as pricing, or maintenance service provision offering. The currently included decisions are related to evaluation of alternatives and suppliers, maintenance strategy definition, and budgeting for the BoL

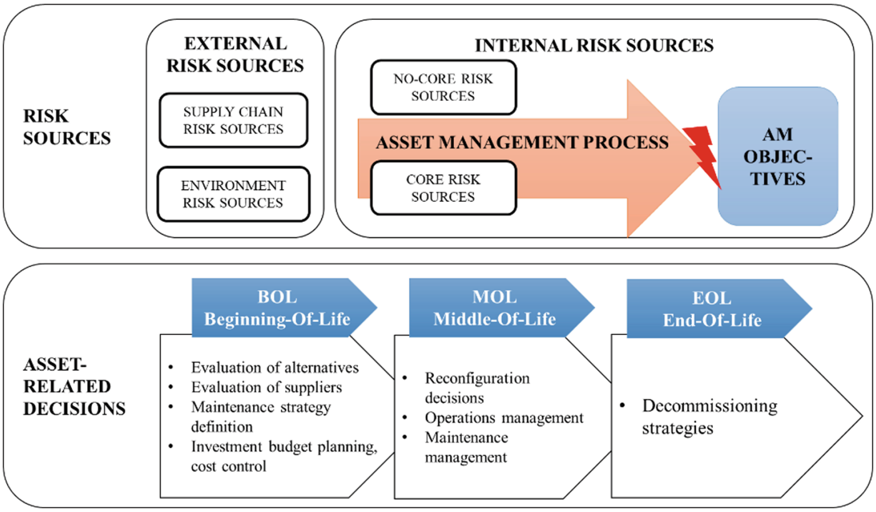

Fig. 1. Framework for Asset Management risk sources.

phase of the asset. The MoL phase is related to the operation of the asset, thus including operations and maintenance management decisions, and reconfiguration decisions to adapt the asset to everchanging production conditions. At the end of the asset lifecycle (EoL), the main decision is related to the selection of decommissioning strategies. For more insights into the asset-related decisions model, refer to [12].

The second dimension considers the operational risk model adopted to classify the risk sources and the respective risk categories, having as major concern the physical assets and their management process. The operational risk model adopted for the analysis is the one proposed by [13]: the risk model considers as a basic concept the definition of a risk source as "any entity or circumstance with the potential to generate uncertain conditions"; it is used as a reference to map risk sources found out from the systematic literature review.

Correspondingly, at the top of Fig. 1, the scheme of the operational risk model, as adopted in this research, is presented. Therein, the AM process is heading towards the AM objectives; however, the achievement of such objectives is affected by different risk sources that impact on the AM process. In particular, the impact of the different risk sources is identified as the variation in reaching the AM objectives.

Four different risk source categories are identified, which represent different types of risk sources, both internal and external to the company:

- *Core risk sources* belong to the internal risk category and are associated with the core processes of the company, which is a process that directly contributes to the value creation according to the company's objectives. In the context of the present study, the AM process is the core process of interest.
- *No-core risk sources* belong to the internal risk sources and are associated with the no-core processes of the company. A no-core process is a process that is considered ancillary with respect to the core process and supports it in value creation. For

example, spare parts management is an ancillary process, relevant to support the AM process towards the generation of value from physical assets.

- *Supply chain risk sources* belong to external risk sources with respect to the AM decision-making process and are associated with the organisation in a broader view with respect to the core and no-core risk sources, which are internal. These risks stem from the interaction with suppliers. This may occur with the Original Equipment Manufacturers (OEMs) providing new assets, the OEMs/service providers supporting maintenance services, and the MRO (Maintenance Repair Operations) material suppliers.
- *Environment risk sources* belong to external risk sources and are associated with the environment surrounding the company and influencing the core process as well. Environment does not mean only natural events, but all the set of geographical, political, social, and cultural factors that could influence, as contextual factors, the core process. For example, new legal requirements or the lack of skilled workforce may influence the AM process.

The focus of this research work is on the second dimension of the framework (i.e. operational risk sources, the top part of the scheme of Fig. 1). A systematic literature review is applied to analyse scientific literature dealing with risk and AM in manufacturing, as described in Sect. 3. Then, Sect. 4 presents the mapping of risk sources against risk source categories.

3 Literature Review Methodology

A systematic literature review is carried out to explore risk within AM in manufacturing industries; in particular, the literature search is performed to look for the risk sources affecting the decision-making process.

The literature review is pursued looking at works present in databases as Web of Science (WoS), Scopus and Google Scholar. In particular, it is done considering the following features:

- adopting a comprehensive search in title, abstract and keywords;
- keywords used are *Asset Management* AND *Risk* AND *Manufacturing*;
- English documents are the only ones considered.

The literature search finds out 985 documents (16 in WoS, 189 in Scopus, and 780 in Google Scholar). After applying the elimination of all non-English written documents and filtering according to title and abstract, the final list is composed of 27 works. The bottleneck criterion is the one related to the screening phase because, even though manufacturing is introduced in the keywords, most of the documents, especially in Google Scholar, deal with risk and/or assets in the financial sector. Then, the final list of 27 documents is further screened through full paper readings to understand if each paper analyses some risk sources in the manufacturing sector.

Considering the above findings, it has to be noticed that the main limiting criterion of the literature review adopted so far is the confinement within the manufacturing sector: most of the documents treat risk within AM in infrastructure and distributed networks. Thus, even though the systematic literature review methodology is adopted to look in depth at the scientific documentation, the results are not completely satisfactory, since the number of papers after the last screening phase is small. To overcome this problem, additional literature is introduced to better feed the proposed framework: it comes from the background of AM in the scientific community, and it also considers the ISO 5500x body of standards, which gives some hints about risk in AM.

Thus, the risk sources found out in the scientific documents are classified according to the risk source categories therein discussed (Sect. 4). More specifically, the risk sources are derived by the analysis of the literature: the eligible papers clearly state the authors are addressing specific risks, even though usually they do not refer to specific decisions. As a consequence, with this information it is possible to complete one dimension of the framework, the one dealing with risk sources (top part of Fig. 1), mapping them against risk source categories, defined while going through the literature analysis.

4 Risk Sources Against Risk Source Categories

The framework of risk sources versus risk sources categories is fed as a result of the step of full paper reading using the 27 works selected from the systematic literature review. The analysis of the articles allows either to understand which kinds of risk sources are highlighted in the scientific literature, either to associate them with the relative risk source categories. The analysis is firstly done considering the eligible papers; then, this set is enlarged thanks to additional literature (highlight by an * in Table 1) that has grounded the basics of AM, such as the ISO 5500x body of standards. For the sake of transparency, if the risk source is not derived from the eligible documents, a * is put next to the risk source; instead, if the risk source is identified in both eligible and not eligible documents, a (*) is used. Thus, Table 1 proposes the results of this analysis.

The analysis of the risk identified in literature allows to classify them according to the framework proposed in Fig. 1 (column of Table 1), and to group them into risk sources (rows of Table 1), which could be:

- Equipment: risk source related to machines, components or systems that could fail or, somehow, affect the possibility to achieve the desired AM objectives;
- Information management: risk source associated with the way information is gathered and managed;
- Human factor: risk source connected with leadership, culture, motivation, behaviour and competence within the organisation;
- Organisational architecture: risk source related to the organisational structure;
- Supplier: risk source associated with the suppliers of the organisation that could, in some way, affect reaching AM objectives.

The main finding of this analysis is the importance of considering information management as the most impactful risk source on the AM process. However, the second place is taken by the human factor, underlining the need for knowing and understanding AM principles to correctly manage systems of assets in the long-term perspective.

Table 1. Classification of risk sources against risk source categories

	Core risk sources	No-core risk sources	Supply chain risk sources	Environment risk sources
Equipment	[14]	[14, 15]		
	Security	Security Failure		
Information management	[6, 16, 25–27]*	[7, 16, 17, 19, 26, 27]*	[19, 20]	[21, 22]
	Information tracking (*) Information availability* Data collection* Data management*	Information tracking (*) Data tracking (*) Data security Data collection* Data management*	Data security Information security	Information security Data security External hacking
Human factor	[6, 15, 23, 28]*	[18, 23, 28]*		
	AM knowledge lacking (*) Leadership* Motivation* Culture*	AM knowledge lacking Maintenance knowledge lacking		
Organisational architecture	[7, 24]*			
	Framework guideline stating AM objectives misalignment* Responsibility allocation*			
Supplier	[6]*		[27]*	
	Responsibility allocation*		Maintenance activities outsourcing*	

5 Conclusions

The present study focused on the analysis of risk sources to be taken into account within the decision-making processes supporting the implementation of AM in the manufacturing sector. The aim is to promote a risk-informed decision-making process tackling the lifecycle perspective of an asset, thus being aligned to the AM principles of risk- and lifecycle-orientation [5]. The main findings of the work are expected to bring a contribution both to researchers and to practitioners.

From a scientific perspective, the work fosters the importance of risk management in asset-related decisions. The main finding of the analysis is that information management covers a primary role as the most critical risk source in asset-related decisions. Furthermore, the culture of AM, identified by the knowledge ecosystem, seems to play an important role as a risk source, since the knowledge and capabilities not merely related to the technical aspects of AM, but also to the managerial ones, could promote and make effective and successful the decisions.

From a practical standpoint, the proposed framework (Table 1) will enhance the possibility of asset managers to correctly reflect on the decision drivers and the associated risks. This will allow them to take preventive actions in this regard.

Clearly, the present work is a starting point to bring forward new research work. In particular, the proposed classification should be completed, with the aim to map the risk sources against asset-related decisions in the lifecycle, as defined in the reference framework (Fig. 1). This additional analysis could make the proposed framework more valuable for both academia and industry since it creates a direct relationship between each risk source and each asset-related decision. In so doing, a more risk-informed AM decision-making process could be established, and the asset user will be aware of possible misbehaviour of this process.

Moreover, the research developed in this work and its results are limited to the needs and peculiarities of the AM in manufacturing. Another limitation of the review regards the explicit exclusion of maintenance as the scope of the literature review, even if it could be used as an exploratory field to enlarge the collection of research works that address the risk orientation as a precursor of AM [29]. These limitations may stimulate a wider scope of the systematic literature review in future works.

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