Identifying the Critical Success Factors for the Introduction of an Asset Management System: A Delphi Study in the Healthcare Sector

DOI: 10.12776/qip.v29i1.2113

Damjan Maletič, Justyna Trojanowska, Matjaž Maletič

Received: 9-12-2024 Accepted: 3-3-2025 Published: 31-3-2025

ABSTRACT

Purpose: For decades, attention has been paid to standardized management systems, both in academia and in practice. This study focuses on an asset management system (AMS), specifically the key critical success factors (CSFs) for implementing an AMS in healthcare organizations.

Methodology/Approach: The study is based on a Delphi method with 15 participants from various Slovenian healthcare organisations who validated and defined the most important CSFs.

Findings: The study shows a strong consensus among the experts with regard to specific CSFs in the areas of management and leadership, employee competencies and methods and tools for process improvement.

Research Limitation/Implication: The Delphi study method is based on a selected sample of experts, which could have an impact on the generalizability and replicability of the research.

Originality/Value of paper: This study provides a better understanding of CSFs for the implementation of AMS based on the opinion and consensus of experts holding different positions and professions in healthcare. As this topic has received little attention in healthcare research and practice, this study serves as a preliminary study to stimulate future work in this under-researched area.

Category: Research paper

Keywords: asset management system; standardization; critical success factors; healthcare; Delphi

Research Areas: Quality Management; Strategic Quality Management

1 INTRODUCTION

Organisations are increasingly seeking to implement management system standards, for example, to meet customer expectations and reduce performance variability (Su et al. 2015). There are clear parallels here between the quality management system (QMS) and the asset management system (AMS), as both systems aim to reduce risk, improve performance and add value to an organisation (Heerden and Jooste 2018; Alsyouf et al. 2021). In recent years, asset management has become a more commonplace ambition for asset-intensive organizations (Lima et al. 2021; Almeida et al. 2022; Maletič et al. 2023). It can help organizations to achieve the desired balance between costs, risks and performance by managing risks and opportunities (ISO 55000). The management of assets in healthcare facilities is of great importance (Rousek et al. 2014). When it comes to management systems, ISO 55001 and ISO 41001 can help organizations in this matter. Implementing ISO 55001 and ISO 41001 can enable organizations to better utilize and manage facilities and assets, focus and optimize activities, and derive the required function and value to achieve their goals. While ISO 41001 provides guidance for the management of physical buildings and related services, ISO 55001 extends to the management of all assets. This is particularly important as rising healthcare costs have become a critical issue worldwide (Prabhod 2024). The rising cost of medical equipment, including proper maintenance, is one of the reasons for the increase (Rousek et al. 2014). However, asset management is more than just maintenance; it is about strategically optimizing the performance and life cycle of assets. It does not focus on the asset itself, but on its value to the organization in accordance with its policies and objectives. Although the field of asset management evolved decades ago, the publication of the ISO 55001 standard has been an important catalyst for the asset management discipline, helping professionals to develop more structured approaches to AMS (Maletič et al. 2020; Alsyouf et al. 2021). ISO 55000 defines asset management as the coordinated activity of an organization to realize value from assets (ISO 55000). Therefore, it seems important for asset-intensive organizations to formally establish processes that support and clearly demonstrate the achievement of the objective of asset management, i.e. the realization of value from assets (Trindade et al. 2019). Setting up an AMS is an important strategic decision for an organization. ISO 55001 sets out the requirements for an AMS but does not specify how the system should be designed. Although guidelines can be found in ISO 55002, organizations still face many challenges in properly setting up and implementing the AMS (Maletič et al. 2023). An AMS impacts the entire organization, including its stakeholders and external service providers, and can link many of the organization's activities and functions. Building an AMS therefore requires a thorough understanding of the individual elements and the policies, plans and procedures that integrate them (ISO 55000).

Asset management has transformed various industries in terms of managing assets economically, improving reliability and, most importantly, ensuring safety (Lima et al. 2021). One could argue that these aspects are also crucial for the healthcare

industry, which is the topic of the present paper. Efficient and properly functioning assets that are available 24/7 are crucial for the healthcare industry. Therefore, their lifecycle - from selection through procurement and maintenance to final disposal - must be carefully managed to ensure that they are cost-effective, up to date and continue to support the healthcare organization's business objectives (McCarthy et al. 2020). Effective asset management is therefore essential to the delivery of safe, high-quality services that meet current and future needs. It can help to optimize resources, control costs and enhance patient care and safety, especially as patient safety is paramount (Runciman et al. 2006).

Asset management is becoming an increasingly important field of research (Maletič et al. 2020; Lima et al. 2021; Sandu et al. 2022; Maletič et al. 2023). There is a growing body of scientific evidence on the positive impact of asset management on business performance (Lima et al. 2021), operational performance (Maletič et al. 2020; Alsyouf et al. 2021) and sustainability performance (Maletič et al. 2018; Sandu et al. 2022). In recent years, the number of scientific publications in the field of asset management has increased (Figure 1). As the term asset management is associated with various industries and disciplines, the trend is expected to continue to grow.

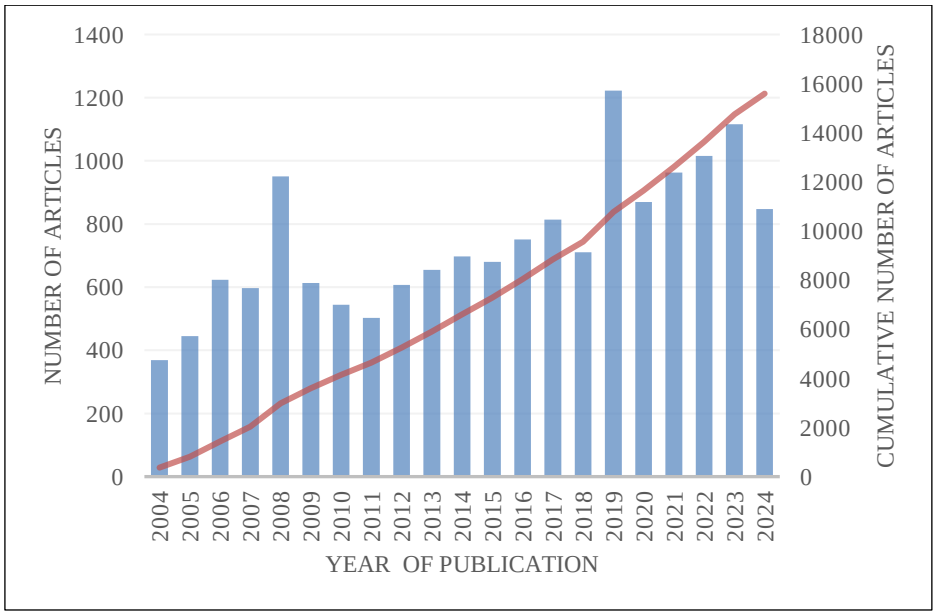

Figure 1 – Annual and cumulative number of articles in Scopus (search term: "asset management", operator "TITLE-ABS-KEY", data collection period 2004 to 2024)

However, despite the growing attention being paid to the area of asset management since the advent of ISO 55001 in 2014, the number of ISO 55001 certifications issued is still relatively low, especially compared to most other ISO certification schemes (*ISO - The ISO Survey* 2023). It should be noted that the organizational context is very different from that faced by organizations in the 1990s when ISO 9001 was introduced. Many organizations have adopted a standardized basic

structure for management system standards (i.e. the High Level Structure). Considering that ISO 55001 is designed to be compatible with other ISO management system standards such as ISO 9001, ISO 14001, etc., the potential organizational effort to implement an AMS may not be as high as in organizations without ISO management systems (Hodkiewicz 2015).

Moreover, asset management is not new. The term asset management was already used in the 1980s in the private and public sectors in relation to physical assets (anatomy). The main developments prior to ISO 55001 were the BSI PAS 55 publicly available specification, published in 2004 and updated in 2008, and the first edition of the asset management landscape, published by GFMAM in 2011 (GFMAM 2011). Therefore, it should be expected that research on AMS would be gaining more attention from researchers. However, there is still a dearth of general research that addresses the implementation of AMS. Although it shows a positive trend (Figure 2), it is still relatively low compared to QMS. It should be noted that asset management discipline is rapidly developing (see Figure 1), however there is still lack of research on AMS itself.

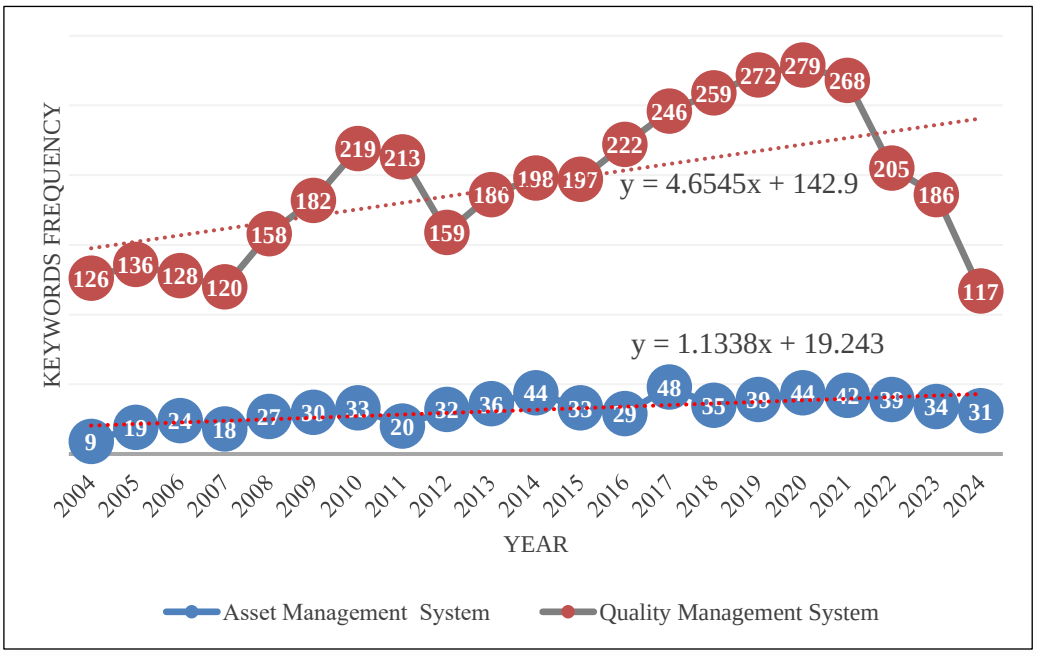

Figure 2 – Keywords frequency appearance in Scopus (search term: "asset management system" OR "ISO 55001" OR "ISO 55000" and "quality management system" OR "ISO 9001" OR "ISO 9000" - operator "KEY", data collection period 2004 to 2024)

Some scholars have engaged in the study of factors influencing the adoption of an AMS, as shown in the studies by Maletič et al. (2023), Beitelmal et al. (2017), Jooste and Vlok (2015) and Maletič et al. (2024). While the first two studies were more concerned with the barriers and challenges in the introduction of an AMS, the latter two studies focused on the critical success factors (CSFs). In this context,

Jooste and Vlok (2015) examined the factors affecting the synergy between asset management and services. The authors identified 13 CSFs. Maletič et al. (2024) identified 17 potential CSFs that could be essential for the successful implementation of an AMS. Furthermore, Nowakowski et al. (2017) also highlight some of the obstacles that reduce the possibility of effective implementation of the AMS in accordance with the requirements of ISO 55001 requirements. Moreover, Roda and Macchi (2016) revealed main elements to be considered to properly implement asset management within organizations.

For the healthcare sector, CSFs were examined to explore their role in strategic change initiatives (Kash et al. 2014). The authors identified key factors to be considered, namely culture and values, business processes, and people and engagement. Previous studies have also looked at areas that could provide important background for this study, such as CSFs important to continuous improvement (Brandrud et al. 2011) and teamwork training (Salas et al. 2009). However, to gain a more comprehensive understanding, future research is needed to further investigate and discuss the factors that facilitate the adoption of AMS in different organizational settings. The aim of this study is to focus primarily on the identification of CSFs for the adoption of an AMS in the healthcare sector. As healthcare assets, such as facilities, are associated with quality outcomes, patient safety, clinical outcomes, and patient and staff stress, it is even more important to examine the CSFs for AMS in healthcare (Salem and Elwakil 2021). Since CSFs and AMS have received little attention in healthcare research and practice, this study serves as a preliminary study to stimulate future work in this under-researched area.

The paper is structured as follows. Section 2 sets out the methodological approach, while section 3 presents the main results of a Delphi study. Sections 4 and 5 contain a discussion and a conclusion.

2 RESEARCH METHODOLOGY

2.1 Delphi method

Delphi method was developed in the late 1950s by the Rand Corporation (Helmer and Rescher 1959). The purpose of using the Delphi method is to ensure a reliable consensus of a group of experts through an interactive process carried out by means of a questionnaire and the provision of feedback (Nasa et al. 2021). It is a tool that we can use to understand the problem from the perspective of expertise. Sometimes it is important to look at the problem from the perspective of the professionals and the end users, especially when making strategic decisions. It is often used to gather practical information, repeating the process with the panellists using a questionnaire until consensus is reached among them. The Delphi method has three main aspects, such as anonymity, consensus and iteration (Diamond et al. 2014). Anonymity between panellists ensures limited bias. It also ensures that their views are treated equally, while avoiding expert dominance over the opinions

of others (Jairath and Weinstein 1994). The consensus means that the agreement between the experts in the field of the study allows conclusions to be drawn about the outcome of the study. The iterative nature of the method is one of its main strengths, as panel members can adjust their opinions based on the panel's overall responses (Chalmers and Armour 2019). The modified Delphi technique is also often used to develop a consensus on group opinion. In this regard, experts are often consulted to give their input and opinion on a predefined set of items/variables from the literature, rather than being asked traditional open-ended questions (Chalmers and Armour 2019). Or even the first questionnaire by post (or email) could be replaced by face-to-face meetings (Boulkedid et al. 2011).

2.2 Panel characteristics

Based on the criteria that participants should be involved in the healthcare sector (C1), have knowledge of management systems with a focus on asset management (C2), and following the recommendation that the minimum Delphi sample size should be at least 7 participants (Chalmers and Armour 2019), we identified a potential group of participants to attend the training course on asset management at University of Maribor, conducted in December 2023/January 2024. The panel consists of 17 participants from different positions within the healthcare sector. Of the 17 participants, 15 took part in a Delphi study, resulting in a response rate of 88.23%. Broken down by gender, 70% of the participants were female and 30% male. Homogeneity and heterogeneity of the panel were also considered. The diversity of the panel is ensured by the fact that the participants come from different hierarchical levels and professions in the healthcare sector (healthcare professionals - team leader 20%, healthcare professionals - unit manager 13%, healthcare professionals - team member 53%, medical professionals - 13%).

2.3 Facilitator information

It is suggested that the facilitator is responsible for ensuring that a reliable outcome of the Delphi study is achieved by a stable panel and that the time between rounds is kept as short as possible, as well as ensuring that the survey questions are clear and feedback is given to panel members (Green 2014). It is also essential that facilitator is someone with expert knowledge of the topic being discussed. The facilitator in this study has in-depth knowledge of management systems, with a focus on asset management. He is a member of the technical committee for maintenance and asset management at the Slovenian Institute for Standardization (SIST), which is recognized as the national standardization organization in the Republic of Slovenia. He is also a member of European and international committees in the field of asset management.

2.4 Procedure

The modified Delphi method was used in this study. A face-to-face meeting was held before the first open round. The aim was to discuss the current state of the

literature on the topic under investigation. In addition, some challenges in relation to management systems were highlighted. The subsequent rounds were conducted online to ensure anonymity. As explained above, anonymity of individual members in a Delphi study is essential to rule out inherent biases such as dominance and group conformity (e.g. the process by which people change their behaviour to conform to a group) (Chalmers and Armour 2019). In addition, the first face-to-face meeting also served to explain the Delphi method and encourage participants to take part in all rounds in order to achieve a high retention rate between rounds. Some dropout between survey rounds is to be expected (Bardecki 1984). However, motivating the experts and ensuring a quick turnaround between survey rounds can help to reduce the dropout rate (Hsu and Sandford 2007).

The importance of the individual CSFs was rated on a five-point Likert scale from 1 (unimportant) to 5 (extremely important). The mid-point 3 was coded as "moderately important", which is commonly used in Delphi studies (Castro-Calvo et al. 2021). In accordance with the current guidelines for Delphi research methods (Castro-Calvo et al. 2021), consensus was considered achieved if the experts rated the CSF as ≥ 80% "very important" or "extremely important". If the CSF was rated as "very important" or "extremely important" by ≤ 20% of the experts, it was assumed that the experts had reached a consensus to reject it, and the CSFs were not re-rated in the subsequent Delphi rounds. The remaining CSFs is to be re-rated in the subsequent rounds. The flow of the study is presented in Figure 3.

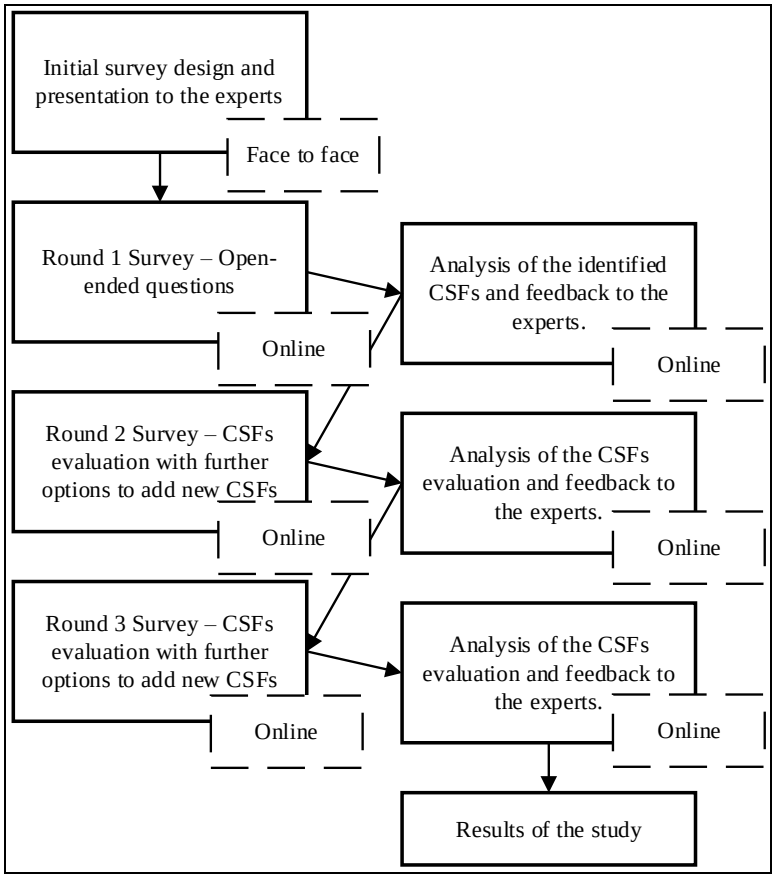

Figure 3 – Flow of the study

3 ANALYSIS AND RESULTS

As highlighted in the methodology section of this paper, the aim of this study is to apply the Delphi technique to clarify the CSFs for the implementation of AMS and to reach an agreement among experts. In brief, a Delphi study was led by a facilitator (see section 2.3.) who was responsible for the methodology, planning, recruiting experts, conducting a Delphi, providing feedback after each Delphi round, and presenting the final results to the panel experts. Responses from the expert panel were collected using a pre-designed questionnaire (online survey), with the experts adding new CSFs where appropriate. The Delphi process involved several iterations to reach agreement between the experts. The first list of CSFs was drawn up on the basis of a literature review, followed by open-ended questions in round 1. In addition, an open question was asked in the second and third rounds of the study to give the experts the opportunity to suggest additional CSFs. The process of the Delphi study is shown in Figure 4, while Table 1 contains the percentages of agreement achieved in the respective rounds of the study.

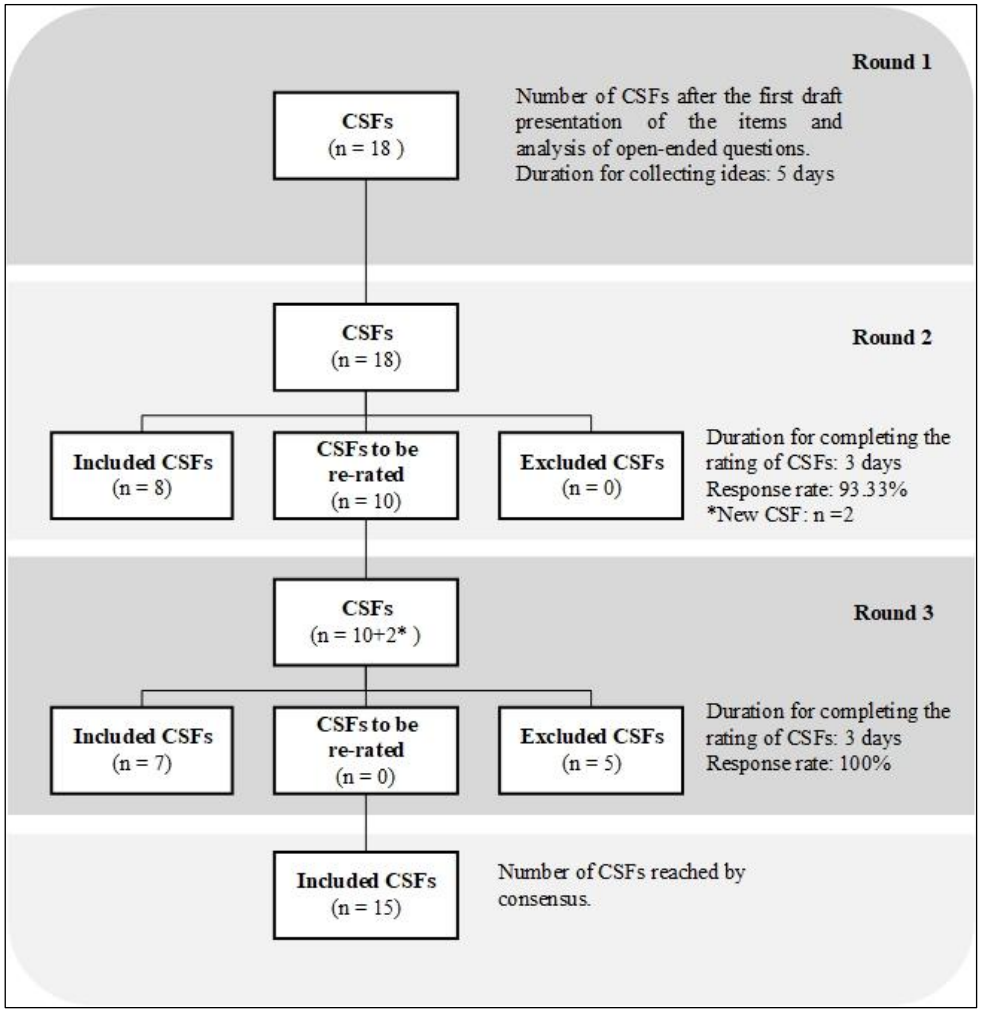

Figure 4 – Flowchart of inclusion, exclusion or re-rating CSFs during the study rounds

After each round, the panellists' responses were reviewed to determine which CSFs met with agreement criterion. As can be seen from the results, 8 CSFs reached agreement for inclusion (i.e. ≥ 80% of the experts rated the CSF as "very important" or "extremely important") in round 2. In the second round of the Delphi study, 2 new CSFs were added by the panellists. In round 3, seven CSFs achieved expert agreement (> 80 % agreement among the experts), while the five CSFs did not achieve the criterion. However, it should be noted that the CSFs marked in blue did not reach agreement for either inclusion or exclusion (i.e. > 20% of experts but < 80% rated the criterion as "very important" or "extremely important"). The McNemar $\chi 2$ test was employed to assess stability of the responses (Castro-Calvo et al. 2021) between the second and third round. If the statistical significance level (i.e. the p-value) is below 0.05 (i.e. $p < 0.05$), it can be assumed that there is a statistically significant difference in the result and in the proportion of responses (important or non-important CSFs) between round 2 and round 3. According to the results of the McNemar $\chi 2$ test, the p-value for CSF8 was 0.5959, for CSF9 0.07435, for CSF17 0.1048, for CSF18 0.05020 and for CSF19 0.4990). From this we can conclude that there is no significant difference between round 2 and 3 as far as the decision of the expert group is concerned. However, it should be noted that the percentage of agreement for CSFs that were not included in the final list of CSFs is still remarkable; therefore, their importance should not be neglected.

Table 1 – CSF proposed by panel of experts

No.	CSF	Consensus reached
1	Leadership and commitment	85.71% in round 2
2	Clear AM strategy and objectives	85.71% in round 2
3	Organisational culture	85.71% in round 2
4	Understanding business needs	85.71% in round 2
5	Stakeholder orientation	80.00% in round 3
6	Change and risk management	85.71% in round 2
7	Interdepartmental communication	86.67% in round 3
8	Legal compliance	33.33% in round 3
9	Result-oriented approach	46.67% in round 3
10	Strategic planning	85.71% in round 2
11	Use of consultant support	80.00% in round 3
12	Resource availability	80.00% in round 3
13	Employee training and education	85.71% in round 2
14	Employee engagement	80.00% in round 3
15	Employee awareness	80.00% in round 3
16	Business process management	85.71% in round 2
17	Continuous improvement	53.33% in round 3
18	Benchmarking information	73.33% in round 3

No.	CSF	Consensus reached
19	Digital integration	73.33% in round 3
20	Data analytics	80.00% in round 3
Green cells indicate that there was consensus on the CSF (i.e. ≥ 80% of experts rated the CSF as “very important” or "extremely important"); blue cells indicate that there was no consensus for inclusion or exclusion (i.e. > 20% of experts but < 80% rated the CSF as “very important” or “extremely important”).		

4 DISCUSSION

4.1 Theoretical implications

This paper contributes to the increasing interest in AMS as a key approach in realizing value through the entire lifecycle of assets (El-Akruti et al., 2013). Healthcare is no exception, as AMS provide a systematic approach to managing and optimizing the use of physical and technological assets. This includes the management of facility, medical equipment, pharmaceutical supplies, mobility aids and other assets to ensure the desired outcome of healthcare processes. It could be argued that in today’s dynamic healthcare environment, efficient asset management is critical to improve compliance and reduce risk, improve quality of patient care and patient satisfaction, manage costs and finances, and improve decision making (Ashari et al. 2024).

Through a Delphi study, this study provides important insights into the CSFs for AMS implementation from a healthcare perspective. Against this background, this paper is one of the first attempts to identify and analyse the most important CSFs for the introduction of AMS in the healthcare sector. These CSFs will enable further research into AMS, as they will form the basis for the development of AMS models in the context of healthcare. According to the findings of this study and in alignment with previous studies (Jooste and Vlok 2015; Maletič et al. 2024), categorization of CSFs for AMS implementation is provided as shown in Table 2.

Table 2 – Categorization of barriers to asset management system implementation

Category	Number of the CSF	Description	Supported literature
Management and leadership	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	It is important that the leadership team of a healthcare organisation understands the benefits of managing its assets. In this regard, the role of the leadership team is also to instil confidence in stakeholders about the direction and benefits of AMS. While the AMS provides a framework, the leadership team should demonstrate its commitment to the AMS through strategy and goals, decision making, employee engagement, training and development, communication, culture support, etc.	(Jooste and Vlok 2015; Trindade et al. 2019; Maletič et al. 2023)
Employee competencies	13, 14, 15	Organizations need to identify the current competency level in asset management and then fill	(Brunetto et al. 2014; Al

Category	Number of the CSF	Description	Supported literature
and engagement		the gaps with the competency level required for AMS. The organization should define the competency levels required for all asset management roles, responsibilities and accountabilities and the awareness, knowledge, understanding, skills and experience required to perform these tasks. While commitment is an essential part of the strategy and success of AMS implementation, employee engagement is also seen as key to success.	Marzooqi et al. 2019; Maletič et al. 2024)
Process improvement methods and tools	16, 17, 18, 19, 20	The AMS should not stand alone. The AMS should demonstrate the integration of asset management processes, activities and data with those of other functions or management systems in the organisation. A data-driven approach is an integral part of the AMS through the collection, collation, management and analysis of asset data. A strategic approach to the definition, collection, management and reporting of asset information is essential to the implementation of the organisation's asset management strategy and objectives.	(Crespo Márquez et al. 2020; Jasiulewicz-Kaczmarek et al. 2023; Krhač Andrašec et al. 2024)

Notes. The CSF numbers shown in red are those that did not reach consensus; however, they were not excluded (agreement between 20% and 80%).

In this research, we distinguish 20 CSFs related to AMS adoption using the literature survey and feedback received from the experts. The main purpose of this study is to identify the contextual relationships between the different CSFs identified in order to contribute to the AMS knowledge landscape. As shown in Table 2, three main categories of CSFs were identified, namely "Management and leadership", "Employee competencies and engagement" and "Process improvement methods and tools". Although a hierarchy between CSFs was not analysed in this study, the paramount importance of management-related CSFs could not be neglected. In the context of ensuring a successful implementation of AMS, it is necessary to develop appropriate strategy and roadmap for AMS (Maletič et al. 2024). Previous studies (e.g. El-Akruti et al. 2013) have indicated that asset-intensive organizations have insufficient awareness of the potential role of AMS in defining and implementing corporate strategy. From this perspective, it is even more important to understand the strategic perspective of AMS implementation and the underlying supporting factors, such as inclusive leadership that creates a culture in which all employees can contribute to the development and adoption of AMS. Furthermore, it is no longer sufficient to view asset management as merely the maintenance of an asset, but rather as a holistic approach to asset management that includes elements such as strategy, risk measurement, safety, environment and human factors (Frolov et al. 2010; Maré 2015). In addition, it is considered essential to integrate an organisation's AMS and QMS, especially to successfully address strategic and daily operational challenges (Heerden and Jooste 2018). In fact, many asset-owning organisations are required by their regulators to maintain both an AMS and a QMS (Yates 2016).

Recently, the importance of intangible assets for value creation in healthcare has been increasingly recognized (Gaspary et al. 2024). Intangible assets such as values, human capital, competencies and data remain critical in healthcare organizations (Rider et al. 2019). Our study has shown that intangible assets (e.g. employee-related CSFs) play an important role in the implementation of AMS. Similar to the implementation of quality programs in the healthcare sector (Gowen et al. 2006), employee commitment initiatives are also seen as a driver for the introduction of AMS. However, not all intangibles or related activities can be formalized through an AMS. For example, culture, motivation and behaviour, which can play a crucial role in achieving asset management objectives, can be managed by the organization through agreements outside the AMS (ISO 55001 2024). In healthcare context, leaders in top positions such as hospital director have the ability to bring diverse individuals together to foster collaboration and cohesion among staff (Yee et al. 2024).

According to the experts involved in the Delphi study, an understanding of processes and the application of systematic and evidence-based methods are seen as important prerequisites for the introduction of AMS. Approaches, methods and techniques for improving business processes have received much attention in the literature (Krhač Andrašec et al. 2024) as well as in standardisation, as demonstrated by the first international standard for quality management in healthcare (ISO 7101 2023), which emphasises continuous improvement of all processes and the importance of applying evidence-based decision making. Indeed, healthcare organizations are under increasing pressure to improve their operations and demonstrate the quality and efficiency of their organizations (Kujala et al. 2006). However, there are some characteristics in healthcare organizations that make them different from traditional industrial organizations (Hellström et al. 2010). The authors pointed out that the organization itself can in many ways become an obstacle to the realization of a process-oriented management style. Referring to this argument and based on our findings, we would further reinforce the notion that an organization needs to reach a certain level of maturity in process management before the adoption of AMS is possible. It should be substantianed that healthcare organizations need well-defined processes and well-planned activities to improve the quality and safety of outcomes (Häggström et al. 2023).

4.2 Managerial implications

Our findings provide substantial guidance to practitioners seeking to design and implement strategies for AMS implementation. There are arguments suggesting that CSFs evolve over time in parallel with sectoral changes, organizational and/or technological changes and challenges. Therefore, it is crucial to identify the current state of CSFs in relation to a specific context such as healthcare. In this study, 20 CSFs were identified and 15 were confirmed by Delphi study. The CSFs presented serve as a guide for healthcare organizations considering an AMS initiative. Since many management initiatives fail in organizations, it is critical to understand what

mechanisms managers can use to increase the likelihood of success. Delving into the realm of CSFs reveals the pivotal role of leadership as it directs, motivates and guides the organization's efforts to improve asset management. One role of leadership is to redirect resources into more coordinated processes to build relationships, identify best practices, focus on value, and work collaboratively to shape regulations and regulatory regimes for efficient and effective asset management (IAM 2022). In addition, healthcare organizations looking to implement an AMS should develop a strategy that resonates with employees by focusing on their active participation and constant two-way communication. Organizations can overcome internal barriers by creating authentic and transparent leadership communication that leads to employee engagement, trust and collaboration. Although employees play an important role in all aspects of the AMS, data-driven decision making and the use of methods/tools to support the development, implementation, monitoring and evaluation of the AMS should not be neglected.

4.3 Limitations and future research directions

The present work has some limitations and future research directions as well. This research suggests CSFs for AMS implementation as per experts' feedback and achieved consensus. As such our findings ground on expert's judgements, which needs to be carried out very carefully. This work suggests 20 CSFs (15 of them reached consensus) in relation to implementation of AMS in the healthcare sector. The identification of the CSFs could be further explored. 15 experts from Slovenian healthcare institutions took part in our Delphi study. Future research can therefore extend our findings by including more experts, e.g. from the field of asset management and/or academia, to ensure a more even distribution of respondents. It is also possible to establish a hierarchy between CSFs or to compare them with different components of AMS as well as to consider different contextual frameworks. As far as the methods used are concerned, the CSFs determined can be further evaluated using DEMATEL and the analytic hierarchy method (AHP) and the results compared. The use of case studies would also make it possible to examine the link between practice and theory on CSFs in the healthcare sector. These options can provide a more detailed picture of the main CSFs for different healthcare settings, e.g. primary, secondary or tertiary care.

5 CONCLUSION

The aim of the study is to determine the CSFs for the introduction of AMS in the healthcare sector. The CSFs, which reflect the healthcare sector, have not yet been systematically studied. Although this study has made a major contribution to the body of knowledge, it is important to note that further research should be conducted to develop an AMS implementation framework based on the CSFs identified in this study. By reviewing the factors previously proposed in the literature and conducting a Delphi study, the CSFs considered appropriate for the

implementation of AMS in healthcare were identified and elaborated in this paper. The study composed CSFs into main categories required for the implementation of AMS. However, it is not the purpose of this paper to analyse these CSFs in detail, but rather to establish a consensus among healthcare experts to create a common understanding of CSFs. Therefore, these CSFs will enable further research on AMS as they will provide the base for AMS model development in the context of a healthcare. In addition, future studies could focus on integration attributes, especially in relation to QMS and AMS. To this end, barriers, motives and performance benefits related to the integration of management systems (e.g. quality-focused AMS) could be investigated.

ACKNOWLEDGEMENTS

This research was supported by the Slovenian Research Agency; (Program No. P5-0018—Decision Support Systems in Digital Business).

REFERENCES

Al Marzooqi, F.A., Hussain, M. and Ahmad, S.Z., 2019. Performance of physical asset management using the analytic hierarchy process. *Property Management* 37(3), pp. 327–345. doi: 10.1108/PM-07-2018-0039.

Almeida, N., Trindade, M., Komljenovic, D. and Finger, M., 2022. A conceptual construct on value for infrastructure asset management. *Utilities Policy* 75, p. 101354. doi: 10.1016/j.jup.2022.101354.

Alsyouf, I., Alsuwaidi, M., Hamdan, S. and Shamsuzzaman, M., 2021. Impact of ISO 55000 on organisational performance: evidence from certified UAE firms. *Total Quality Management & Business Excellence* 32(1–2), pp. 134–152. doi: 10.1080/14783363.2018.1537750.

Ashari, R., Suakanto, S., Hamami, F., Mat Raffei, A.F. and Nuryatno, E., 2024. Development of an Application for Visualizing Medical Asset Distribution to Enhance Hospital Asset Management Efficiency. In: *2024 7th International Conference of Computer and Informatics Engineering (IC2IE)*. pp. 1–6. Available at: https://ieeexplore.ieee.org/abstract/document/10748015 [Accessed: 2 December 2024].

Bardecki, M.J., 1984. Participants' response to the Delphi method: An attitudinal perspective. *Technological Forecasting and Social Change* 25(3), pp. 281–292. doi: 10.1016/0040-1625(84)90006-4.

Beitelmal, W., Molenaar, K.R., Javernick-Will, A. and Pellicer, E., 2017. Challenges and barriers to establishing infrastructure asset management: A comparative study between Libya and the USA. *Engineering, Construction and Architectural Management* 24(6), pp. 1184–1202. doi: 10.1108/ECAM-12-2015-0200.

Boulkedid, R., Abdoul, H., Loustau, M., Sibony, O. and Alberti, C., 2011. Using and Reporting the Delphi Method for Selecting Healthcare Quality Indicators: A Systematic Review. *PLOS ONE* 6(6), p. e20476. doi: 10.1371/journal.pone.0020476.

Brandrud, A.S., Schreiner, A., Hjortdahl, P., Helljesen, G.S., Nyen, B. and Nelson, E.C., 2011. Three success factors for continual improvement in healthcare: an analysis of the reports of improvement team members. *BMJ Quality & Safety* 20(3), pp. 251–259. doi: 10.1136/bmjqs.2009.038604.

Brunetto, Y., Xerri, M. and Nelson, S., 2014. Building a Proactive, Engagement Culture in Asset Management Organizations. *Journal of Management in Engineering* 30(4), p. 04014014. doi: 10.1061/(ASCE)ME.1943-5479.0000251.

BSI PAS 55-1, 2008. *Asset Management. Part 1: Specification for the optimised management of physical assets*. London, UK: British Standards Institution.

Castro-Calvo, J. et al., 2021. Expert appraisal of criteria for assessing gaming disorder: an international Delphi study. *Addiction* 116(9), pp. 2463–2475. doi: 10.1111/add.15411.

Chalmers, J. and Armour, M., 2019. The Delphi Technique. In: Liamputtong, P. ed. *Handbook of Research Methods in Health Social Sciences*. Springer Singapore, pp. 715–735.

Crespo Márquez, A., Macchi, M. and Parlikad, A.K., 2020. Fundamental Concepts and Framework. In: Crespo Márquez, A., Macchi, M., and Parlikad, A. K. eds. *Value Based and Intelligent Asset Management*. Cham: Springer International Publishing, pp. 3–38.

Diamond, I.R., Grant, R.C., Feldman, B.M., Pencharz, P.B., Ling, S.C., Moore, A.M. and Wales, P.W., 2014. Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi studies. *Journal of Clinical Epidemiology* 67(4), pp. 401–409. doi: 10.1016/j.jclinepi.2013.12.002.

El-Akruti, K., Dwight, R. and Zhang, T., 2013. The strategic role of Engineering Asset Management. *International Journal of Production Economics* 146(1), pp. 227–239. doi: 10.1016/j.ijpe.2013.07.002.

Frolov, V., Ma, L., Sun, Y. and Bandara, W., 2010. Identifying Core Functions of Asset Management. In: Amadi-Echendu, J. E., Brown, K., Willett, R., and Mathew, J. eds. *Definitions, Concepts and Scope of Engineering Asset Management*. Engineering Asset Management Review. London: Springer, pp. 19–30.

Gaspary, J.F.P., Gerhardt, V.J., de Freitas Michelin, C., Lopes, L.F.D., Rosa, C.B. and Siluk, J.C.M., 2024. Healthcare can’t stop evolving: innovation as the catalyst for unleashing the managerial potential of value-based healthcare by stimulating intangible assets and enhancing organizational resilience. *Frontiers in Psychology* 15.

GFMAM, 2011. *The Asset Management Landscape, First edition*.

Gowen, C.R., Mcfadden, K.L., Hoobler, J.M. and Tallon, W.J., 2006. Exploring the efficacy of healthcare quality practices, employee commitment, and employee control. *Journal of Operations Management* 24(6), pp. 765–778. doi: 10.1016/j.jom.2005.09.005.

Green, R.A., 2014. The Delphi Technique in Educational Research -. *Sage Open* 4(2).

Häggström, M., Ingelsson, P., Sten, L.-M. and Bäckström, I., 2023. Success Factors for Quality and Safety of Intensive Care Unit Transitional Care – Listening to the Sharp End. *Quality Innovation Prosperity* 27(1), pp. 1–20. doi: 10.12776/qip.v27i1.1789.

Heerden, M.A.V. and Jooste, J., 2018. A guide for integrating total quality management and physical asset management in the food industry. *The South African Journal of Industrial Engineering* 29(4), pp. 155–170. doi: 10.7166/29-4-1944.

Hellström, A., Lifvergren, S. and Quist, J., 2010. Process management in healthcare: investigating why it's easier said than done. Leseure, M. and Hudson-Smith, M. eds. *Journal of Manufacturing Technology Management* 21(4), pp. 499–511. doi: 10.1108/17410381011046607.

Helmer, O. and Rescher, N., 1959. On the Epistemology of the Inexact Sciences. *Management Science* 6(1), pp. 25–52. doi: 10.1287/mnsc.6.1.25.

Hodkiewicz, M., 2015. Asset management - quo vadis (where are you going)? *International Journal of Strategic Engineering Asset Management* 2(4), pp. 313–327. doi: 10.1504/IJSEAM.2015.075411.

Hsu, C.-C. and Sandford, B.A., 2007. The Delphi Technique: Making Sense of Consensus. *Practical Assessment, Research, and Evaluation* 12(1). Available at: https://openpublishing.library.umass.edu/pare/article/id/1418/ [Accessed: 11 October 2024].

IAM, 2022. Asset Management Leadership [White paper]. *The Institute of Asset Management and Asset Leadership Network*. Available at: https://theiam.org/ [Accessed: 23 November 2024].

ISO - The ISO Survey, 2023. Available at: https://www.iso.org/the-iso-survey.html [Accessed: 19 November 2023].

ISO 7101, 2023. *Healthcare organization management — Management systems for quality in healthcare organizations — Requirements*. Geneva, Switzerland: International Organization for Standardization (ISO).

ISO 9001, 2015. *Quality management systems - Requirements (ISO 9001:2015)*. Geneva, Switzerland: International Organization for Standardization (ISO).

ISO 14001, 2015. *Environmental management systems - Requirements with guidance for use (ISO 14001:2015)*. Geneva, Switzerland: International Organization for Standardization (ISO).

ISO 41001, 2018. *Facility management — Management systems — Requirements with guidance for use*. Geneva, Switzerland: International Organization for Standardization (ISO).

ISO 55000, 2024. *Asset management — Vocabulary, overview and principles*. Geneva, Switzerland: International Organization for Standardization (ISO).

ISO 55001, 2024. *Asset management — Management systems — Requirements*. Geneva, Switzerland: International Organization for Standardization (ISO).

Jairath, N. and Weinstein, J., 1994. The Delphi methodology (Part one): A useful administrative approach. *Canadian journal of nursing administration* 7(3).

Jasiulewicz-Kaczmarek, M., Antosz, K., Zhang, C. and Ivanov, V., 2023. Industry 4.0 Technologies for Sustainable Asset Life Cycle Management. *Sustainability* 15(7), p. 5833. doi: 10.3390/su15075833.

Jooste, J.L. and Vlok, P.J., 2015. Identifying the Critical Success Factors for Engineering Asset Management Services—An Empirical Study. In: Amadi-Echendu, J., Hoohlo, C., and Mathew, J. eds. *9th WCEAM Research Papers*. Lecture Notes in Mechanical Engineering. Cham: Springer International Publishing, pp. 397–413. doi: 10.1007/978-3-319-15536-4_32.

Kash, B.A., Spaulding, A., Johnson, C.E. and Gamm, L., 2014. Success Factors for Strategic Change Initiatives: A Qualitative Study of Healthcare Administrators' Perspectives. *Journal of Healthcare Management* 59(1), p. 65.

Krhač Andrašec, E., Urh, B., Roblek, M. and Kern, T., 2024. An Analysis of Methods and Techniques Used for Business Process Improvement. *Organizacija* 57(2), pp. 165–184. doi: 10.2478/orga-2024-0012.

Kujala, J., Lillrank, P., Kronström, V. and Peltokorpi, A., 2006. Time-based management of patient processes. *Journal of Health Organization and Management* 20(6), pp. 512–524. doi: 10.1108/14777260610702262.

Lima, E.S., McMahon, P. and Costa, A.P.C.S., 2021. Establishing the relationship between asset management and business performance. *International Journal of Production Economics* 232, p. 107937. doi: 10.1016/j.ijpe.2020.107937.

Maletič, D., Maletič, M., Al-Najjar, B. and Gomišček, B., 2018. Development of a Model Linking Physical Asset Management to Sustainability Performance: An Empirical Research. *Sustainability* 10(12), p. 4759. doi: 10.3390/su10124759.

Maletič, D., Maletič, M., Al-Najjar, B. and Gomišček, B., 2020. An Analysis of Physical Asset Management Core Practices and Their Influence on Operational Performance. *Sustainability* 12(21), p. 9097. doi: 10.3390/su12219097.

Maletič, D., Marques de Almeida, N., Gomišček, B. and Maletič, M., 2023. Understanding motives for and barriers to implementing asset management system: an empirical study for engineered physical assets. *Production Planning & Control* 34(15), pp. 1497–1512. doi: 10.1080/09537287.2022.2026672.

Maletič, D., Todorović, V. and Maletič, M., 2024. A Study into the Critical Success Factors of an Asset Management System Implementation: A Review and Evaluation. In: Hamrol, A., Grabowska, M., and Hinz, M. eds. *Advances in Manufacturing IV*. Cham: Springer Nature Switzerland, pp. 92–106. doi: 10.1007/978-3-031-56474-1_8.

Maré, E., 2015. Market Risk Management in the Context of Engineering Asset Management. In: Amadi-Echendu, J., Hoohlo, C., and Mathew, J. eds. *9th WCEAM Research Papers*. Cham: Springer International Publishing, pp. 3–10. doi: 10.1007/978-3-319-15536-4_1.

McCarthy, J., Hegarty, F., Amoore, J., Blackett, P. and Scott, R., 2020. Chapter 2 - Health technology asset management. In: Taktak, A., Ganney, P. S., Long, D., and Axell, R. G. eds. *Clinical Engineering (Second Edition)*. Academic Press, pp. 17–30.

Nasa, P., Jain, R. and Juneja, D., 2021. Delphi methodology in healthcare research: How to decide its appropriateness. *World Journal of Methodology* 11(4), pp. 116–129. doi: 10.5662/wjm.v11.i4.116.

Nowakowski, T., Tubis, A. and Werbińska-Wojciechowska, S., 2017. ISO 55001 and difficulties of its implementation in polish enterprises. *Journal of KONBiN* 42(1), pp. 209–234. doi: http://dx.doi.org/10.1515/jok-2017-0026.

Prabhod, K.J. 2024. The Role of Artificial Intelligence in Reducing Healthcare Costs and Improving Operational Efficiency. *Quarterly Journal of Emerging Technologies and Innovations* 9(2), pp. 47–59.

Rider, E.A., Comeau, M., Truog, R.D., Boyer, K. and Meyer, E.C., 2019. Identifying intangible assets in interprofessional healthcare organizations: feasibility of an asset inventory. *Journal of Interprofessional Care*.

Roda, I. and Macchi, M., 2016. Studying the funding principles for integrating Asset Management in Operations: an empirical research in production companies. *IFAC-PapersOnLine* 49(28), pp. 1–6. doi: 10.1016/j.ifacol.2016.11.001.

Rousek, J.B., Pasupathy, K., Gannon, D. and Hallbeck, S., 2014. Asset management in healthcare: Evaluation of RFID. *IIE Transactions on Healthcare Systems Engineering*.

Runciman, W.B., Williamson, J. a. H., Deakin, A., Benveniste, K.A., Bannon, K. and Hibbert, P.D., 2006. An integrated framework for safety, quality and risk management: an information and incident management system based on a universal patient safety classification. *BMJ Quality & Safety* 15(suppl 1), pp. i82–i90. doi: 10.1136/qshc.2005.017467.

Salas, E. et al., 2009. What Are the Critical Success Factors for Team Training in Health Care? *The Joint Commission Journal on Quality and Patient Safety* 35(8), pp. 398–405. doi: 10.1016/S1553-7250(09)35056-4.

Salem, D. and Elwakil, E., 2021. Expert-based approach to rank critical asset assessment factors for healthcare facilities. *Facilities* 39(9/10), pp. 615–634. doi: 10.1108/F-05-2020-0060.

Sandu, G., Varganova, O. and Samii, B., 2022. Managing physical assets: a systematic review and a sustainable perspective. *International Journal of Production Research* 0(0), pp. 1–23. doi: 10.1080/00207543.2022.2126019.

Su, H.-C., Dhanorkar, S. and Linderman, K., 2015. A competitive advantage from the implementation timing of ISO management standards. *Journal of Operations Management* 37, pp. 31–44. doi: 10.1016/j.jom.2015.03.004.

Trindade, M., Almeida, N., Finger, M. and Ferreira, D., 2019. Design and Development of a Value-Based Decision Making Process for Asset Intensive Organizations. In: Mathew, J., Lim, C. W., Ma, L., Sands, D., Cholette, M. E., and Borghesani, P. eds. *Asset Intelligence through Integration and Interoperability and Contemporary Vibration Engineering Technologies*. Lecture Notes in Mechanical Engineering. Cham: Springer International Publishing, pp. 605–623. doi: 10.1007/978-3-319-95711-1_60.

Yates, S., 2016. *Asset management and quality: ISO 55000 & ISO 9000*. Available at: https://www.assetivity.com.au/articles/asset-management/linking-asset-management-quality-iso-55000-iso-9000-synergies/ [Accessed: 9 December 2024].

Yee, L.K., Putera, K.A.S. binti I., Krishnan, M., Libasin, Z. binti, Abdullah, N.N.R. binti and Saman, I.S. binti. 2024. Perceptions of healthcare providers on factors affecting lean sustainability in the hospitals under the Ministry of Health Malaysia. *International Journal of Healthcare Management*.

ABOUT THE AUTHOR / ABOUT AUTHORS

Damjan Maletič ORCID: 0000-0002-6871-2720 (D.M.) – University of Maribor, Faculty of Organizational Sciences, Slovenia, Assist. Prof., e-mail: damjan.maletic@um.si.

Justyna Trojanowska ORCID: 0000-0001-5598-3807 (J.T.) – Poznan University of Technology, Faculty of Mechanical Engineering, Poland, Assist. Prof., e-mail: justyna.trojanowska@put.poznan.pl.

Matjaž Maletič ORCID: 0000-0002-3845-744X (M.M.) – University of Maribor, Faculty of Organizational Sciences, Slovenia, Assist. Prof., e-mail: matjaz.maletic@um.si.

AUTHOR CONTRIBUTIONS

Conceptualisation, D.M. and M.M.; Methodology, D.M. and M.M.; Validation, D.M., M.M. and J.T.; Formal analysis, D.M. and M.M.; Investigation, D.M.; Resources, D.M.; Data curation, D.M. and M.M.; Original draft preparation, D.M. and M.M.; Review and editing, D.M., M.M. and J.T.; Supervision, M.M. and J.T.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.