Adolfo Crespo Márquez · Marco Macchi ·
Ajith Kumar Parlikad *Editors*

Value Based and Intelligent Asset Management

Mastering the Asset Management Transformation in Industrial Plants and Infrastructures

Springer

Value Based and Intelligent Asset Management

Adolfo Crespo Márquez · Marco Macchi ·
Ajith Kumar Parlikad
Editors

Value Based and Intelligent Asset Management

Mastering the Asset Management Transformation in Industrial Plants and Infrastructures

Springer

Editors
Adolfo Crespo Márquez
Department of Industrial Management
School of Engineering of the
University of Seville
Camino de los Descubrimientos
Seville, Spain

Marco Macchi
Department of Management,
Economics and Industrial Engineering
Politecnico di Milano
Milan, Italy

Ajith Kumar Parlikad
Department of Engineering
University of Cambridge
Cambridge, UK

ISBN 978-3-030-20703-8 ISBN 978-3-030-20704-5 (eBook)
https://doi.org/10.1007/978-3-030-20704-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

I dedicate this book to my friend and
companion Pedro Moreu de León
as sincere gratitude to his many life lessons
Adolfo Crespo Márquez

To my parents, to whom I owe the possibility
of doing an amazing job; and to my mentor
Marco Garetti, with whom I have been
growing professionally, learning dedication
and passion to research
Marco Macchi

To Priya and Sid, for enduring my extended
absences during my secondments
which made this book possible
Ajith Kumar Parlikad

Foreword

Asset management has been happening throughout human history. Early humans knew how to make, utilize, and discard tools that provided the means for their hunter-gatherer livelihood. Over 250 years ago or so, modern humans created and utilized assets that provided the means to harness water and steam to power the mechanized production of the First Industrial Revolution. The scope, range, and variety of engineered assets continued to increase as man harnessed electricity to power the Second Industrial Revolution, and then information and communications technologies as the driver of the Third Industrial Revolution. By the time, this book is published, the Fourth Industrial Revolution (4IR) will be underway, and the management of engineered assets toward our seemingly insatiable desire for instant gratification will continue to be a challenge.

The human desire for instant gratification is a daunting value proposition given the scope, range, and variety of engineered assets that will be required. The 4IR technologies will not only enable us to develop smarter and intelligent assets but also the concomitant fusing of the biological, digital, and physical worlds implies that we must seek new ways to manage such assets. Thus, the concept of value takes on new significance for the management of increasingly complex and more sophisticated engineered assets like rail and road infrastructure, industrial facilities, and cyber-physical systems.

This book includes seventeen chapters contributed by several scholars carrying out research on the management of smart and intelligent assets. The scope covered in the book ranges from technical issues like failure prediction, reliability, condition monitoring, diagnostics and prognostics, and digital twins, to models for decision making based on the value ethos. Many case studies are presented in the book, and such case studies constitute an invaluable resource for academia, as well as practitioners and policy makers.

Seville, Spain
February 2019

Joe Amadi-Echendu, D.Phil. CEng. PrEng. FISEAM
Professor, Engineering and Technology Management
University of Pretoria

Formerly Editor-in-Chief
Engineering Asset Management Review Series, Springer

Director and Chair of Board
International Society of Engineering Asset Management (ISEAM)

Director and Board Treasurer
International Association for the Management
of Technology (IAMOT)

Preface

The fundamental motivation of this book is to contribute to the future advancement of asset management in the context of industrial plants and infrastructures. The book aims to foster a future perspective that takes advantage of value-based and intelligent asset management in order to make a step forward with respect to the evolution observed nowadays. Indeed, the current understanding of asset management is primarily supported by well-known standards. Nonetheless, asset management is still a young discipline and the knowledge developed by industry and academia is not set in stone yet. Furthermore, current trends—in new organizational concepts and technologies—lead to an evolutionary path in the field. Therefore, this book aims to discuss this evolutionary path, starting first of all from the consolidated theory, then moving forward to discuss:

- The strategic understanding of value-based asset management in a company;
- An operational definition of value, as a concept on the background of value-based asset management;
- The identification of intelligent asset management, with the aim to frame a set of "tools" recommended to support the asset-related decision-making process over the asset lifecycle.

The book compiles information gathered from interesting research and innovation efforts in projects that were relevant to this scope, especially considering the evidences from state of the art and current research trends of Physical Asset Management (PAM) and Operations and Maintenance (O&M) of industrial plants and infrastructures. Among the new trends, digitalization is enabling new capabilities for asset management, by means of the appearance of cyber-physical systems (CPSs), and the subsequent issues resulting from building the digital twins of the physical assets. This may lead to a new era of intelligent asset management systems. At the same time, basic principles of asset management will continue to be relevant in the new era, helping to guide the development of digitalization programs in assets intensive companies, and being transformed along the evolutionary path toward the achievement of a more digitized and intelligent management.

Relevant Topics

One of the main challenges in the field of physical asset management is to enhance the identification and quantification of cost and value to evaluate the total cost and value of industrial assets throughout their lifecycle. These concepts have been widely discussed in the literature, by offering different perspectives and also using plenty of terms partially overlapping or providing slightly different interpretations. Terms, such as total cost of ownership (TCO), lifecycle cost (LCC), whole-life cost (WLC), cost of ownership (COO) and, if extending to values, total value of ownership (TVO) and whole-life value (WLV), are widely cited. If one surfs the Internet, a myriad of definitions and references can be found. This does not mean that the terms are well understood and widely adopted in practice.

Considering the industrial applications of TCO and TVO, it is worth remarking that their benefits are clearly envisioned (e.g., the benefits of TCO can be considered cost control support, management strategy selection, quality optimization, and best cost-effectiveness management). However, in practice, some missing links can be pointed out with regard to their use: Even though the need and desire to implement lifecycle costing is very much talked about, there are a number of difficulties that limit a widespread adoption by industry. This is even more challenging when extending to value and, thus, to the whole-life value, which is a more recent concept.

Another relevant challenge addressed by physical asset management is the assurance of the cost and value along the asset life cycle. Henceforth, appropriate "tools" are required in order to assure that the value delivery from industrial assets (at reasonable cost) is effectively achieved and, when not, that proper decisions are activated with the aim to guarantee value delivery. In particular, proper "tools" should be used when planning in advance, and when monitoring and controlling the effective outcomes, to eventually activate re-planning in case of extant discrepancies with respect to expectations, thus leading to a continuous improvement of what is decided over the asset life cycle. Identification and quantification of value delivered by the assets are essential in all the cases.

Structure of the Book

The book is divided into four parts. In Part I, the first chapter introduces fundamental concepts used in this book and presents a generalized framework providing relevant dimensions of value-based and intelligent asset management. The rest of the chapters in this part offer a long-term perspective of asset management, dealing with topics like societal impact of investments in infrastructure assets, performance and economic impacts of investments in manufacturing plants, and long-term deterioration and renewal of assets.

In Part II, the value-based decision-making approach is stressed as an overall perspective for management of the assets over their life cycle and also exemplified in real-world specific cases. The concept of value, understood as presented in the first Chapter of this book, is *operationalized* to drive day-to-day management decisions and activities.

Part III is dedicated to different advanced developments at the operational level. Different tools are presented to predict and/or to determine properly assets conditions leading to the release and execution of the maintenance activities. Predictive analytics are used to make predictions about assets' future behavior. Many techniques from data mining, statistics, modeling, machine learning and artificial intelligence can be applied to analyze current data to make predictions about future. The scalability of these emerging models, in this new scenario of individualized asset prognostics, is another topic discussed in this part of the book, trying to find a compromise between accuracy and computational power of these tools.

Part IV is devoted to new emerging processes and new ideas that can be implemented by exploiting the power of new technologies such as cyber-physical systems that can certainly embed more intelligence and orientation to value in existing asset management systems.

European Project and Worldwide Collaboration

This book results from a collaboration of the authors, strengthened within the context of Sustain Owner, "Sustainable Design and Management of Industrial Assets through Total Value and Cost of Ownership," a project sponsored by the EU Framework Program Horizon 2020 and based on a knowledge sharing scheme involving many universities worldwide, from the Americas, Asia, and Africa.

Chapters Including Previously Published Research Results

This book compiles a set of chapters that were previously published as journal papers by the research groups involved in the Sustain Owner project. The editors would like to identify the correspondence between each chapter and the original research paper. According to Springer policy, the publishers were asked to provide their permissions for this work to be presented in its current form. The editors thank the publishers for their cooperation making this book possible. The referred chapters are:

– Chapter 2: Heaton, J., Parlikad, A.K., "A conceptual framework for the alignment of infrastructure assets to citizen requirements within a smart cities framework," *Cities*, Volume 90, pp 32–41, 2019.

- Chapter 3: Roda I., Garetti M., "Application of a Performance-driven Total Cost of Ownership (TCO) Evaluation Model for Physical Asset Management". In: Amadi-Echendu J., Hoohlo C., Mathew J. (eds) 9th WCEAM Research Papers. *Lecture Notes in Mechanical Engineering*. Springer, Cham, 2015, © Springer International Publishing Switzerland 2015, https://doi.org/10.1007/978-3-319-15536-4.
- Chapter 5: Roda, I., and M Macchi. "A framework to embed Asset Management in production companies." *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability* 232, no. 4: 368–378, 2018, © IMechE 2018, https://doi.org/10.1177/1748006x17753501.
- Chapter 6: Srinivasan, R., Parlikad, A.K., "An approach to value-based infrastructure asset management," *Infrastructure Asset Management*, Volume 4, Issue 3, pp 87–95, 2017.
- Chapter 9: Olivencia Polo F.A, Ferrero Bermejo J. Gómez Fernández JF., Crespo Márquez A., "Failure mode prediction and energy forecasting of PV plants to assist dynamic maintenance tasks by ANN based models". *Renewable Energy,* Volume 81, pp 227–238. 2015.
- Chapter 10: Liu, B., Liang, Z., Parlikad, A.K., Xie, M., Kuo, W., "Condition-based maintenance for systems with aging and cumulative damage based on proportional hazards model," *Reliability Engineering & System Safety*, Volume 168, pp 200–209, 2017.
- Chapter 11: C. Colace, L. Fumagalli, S. Pala, M. Macchi, N. R. Matarazzo, M. Rondi., "Implementation of a condition monitoring system on an electric arc furnace through a risk-based methodology." *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, Volume 229, Issue 4, August 2015, 327–342, 2015, © IMechE 2015, https://doi.org/10.1177/1748006x15576441.
- Chapter 12: Erguido A., Crespo Márquez A.. Castellano E., Gómez Fernández JF., "A dynamic opportunistic maintenance model to maximize energy- based availability while reducing the life cycle cost of wind farms". *Renewable Energy,* Volume 114, pp 843–856. 2017.
- Chapter 13: Negri E., L. Fumagalli, M. Macchi, "A Review of the Roles of Digital Twin in CPS-based Production Systems", in *Proceedings 27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017*, Volume 11, 939–948, 27–30 June 2017, Modena, Italy, (Eds.) Marcello Pellicciari, Margherita Peruzzini, 2017, 2351-9789, © 2017 The Authors. Published by Elsevier B.V., https://doi.org/10.1016/j.promfg.2017.07.198.
- Chapter 14: Li, H., Salvador-Palau, A., Parlikad, A.K., "A Social Network of Collaborating Industrial Assets," *Proceedings of the IMechE Part O: Journal of Risk & Reliability*, Volume 232, Issue 4, pp. 389–400, 2018, © IMechE 2018, https://doi.org/10.1177/1748006x18754975.
- Chapter 15: Salvador-Palau, A., Liang, Z., Lutgehetmann, D., Parlikad, A.K., "Collaborative Prognostics in Social Asset Networks," *Future Generation Computer Systems*, Volume 92, pp 987-995, 2019.

– Chapter 16: Chekurov S, Metsä-Kortelainen S, Salmi M, Roda I, Jussila A., "The perceived value of additively manufactured digital spare parts in industry: an empirical investigation". *International Journal of Production Economics,* 2015, 87–97, 2018, 0925-5273 © 2018 The Authors. Published by Elsevier B.V. T., https://doi.org/10.1016/j.ijpe.2018.09.008.

Seville, Spain — Adolfo Crespo Márquez
Milan, Italy — Marco Macchi
Cambridge, UK — Ajith Kumar Parlikad

Acknowledgements

The authors wish to thank specific people and institutions for providing their help during the years 2016–2019, making the publication of this book possible.

This research work was performed within the context of Sustain Owner ("Sustainable Design and Management of Industrial Assets through Total Value and Cost of Ownership"), a project sponsored by the EU FP Horizon 2020, MSCA-RISE-2014: Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE) (grant agreement number 645733—Sustain-Owner—H2020-MSCA-RISE-2014).

We offer our sincere gratitude to the project partners of Sustain Owner—Prof. Joe Amadi-Echendu at the University of Pretoria, Prof. Makarand Kulkarni at the Indian Institute of Technology (Mumbai), Prof. Ashish Darpe at the Indian Institute of Technology (Delhi), Prof. Mohsen Jafari at Rutgers University, Prof. Jay Lee at the University of Cincinnati, and Prof. Julio Canales and Prof. Adolfo Arata Andreani at Pontificia Universidad Católica de Valparaíso. This book would not be possible without the secondments carried out by our researchers with them and their input during their secondments with us.

We would like to thank our colleagues in the Department of Industrial Management of the University of Seville, in the Department of Engineering at the University of Cambridge and in the Department of Management, Economics and Industrial Engineering (DIG) at the Politecnico di Milano. They did provide their help and support to this work; many of them also co-authored some of the papers serving as basis for different chapters of the book. We fully appreciate the amicable and friendly working atmosphere in our research groups over these years, where the area of asset management could importantly develop.

We would like to specially thank Dr. Irene Roda as she was a cornerstone, coordinating the Sustain Owner project during its scientific and technical activities, besides being part of the knowledge exchange and, thus, bringing valuable concepts as a follow-up of her doctoral work.

Likewise, during this time we had the opportunity of interaction with engineers and research fellows from universities around the world contributing to this book: Mondragon University, City University of Hong Kong, Aalto University, and VTT Technical Research Centre of Finland. We received precious benefits of their knowledge, which in turn have influenced the development of this book. At the same time, we would like to thank them for their friendship, enriching our personal life.

We also want to give special thanks and our warm recognition to companies and associations providing their exceptional and very valuable professional experience to the book. Within these companies, many colleagues gave their support offering a practical view helping us to understand different aspects of asset management. In order of appearance in the list of contributors, these institutions are: Tenaris Dalmine, IK4-Ikerlan, Magtel Systems, Viesgo Distribución Eléctrica and the Institut für Mathematik, AG Topologie.

Last but not least, we wish to express our gratitude to our families for their unconditional trust, encouragement, and unconditional support enabling this work to be accomplished.

To all of them, Thanks.

Contents

Editors and Contributors

About the Editors

Adolfo Crespo Márquez is currently Full Professor at the School of Engineering of the University of Seville and Head of the Department of Industrial Management. He holds a Ph.D. with Honors in Industrial Engineering from this same University. His research works have been published in journals such as *Reliability Engineering and System Safety*, *International Journal of Production Research*, *International Journal of Production Economics*, *European Journal of Operations Research*, *Omega*, *Decision Support Systems and Computers in Industry*, among others. He is the author of nine books, the last six with Springer Verlag (2007, 2010, 2012, 2014, and 2017) and Aenor (2016) about maintenance, warranty, supply chain, and asset management. He is Fellow of ISEAM (International Society of Engineering Asset Management) and leads the Spanish Research Network on Asset management and the Spanish Committee for Maintenance Standardization (1995–2003). He also leads the SIM (Sistemas Inteligentes de Mantenimiento) research group related to maintenance and dependability management and has extensively participated in many engineering and consulting projects for different companies, for the Spanish Departments of Defense, Science and Education as well as for the European Commission (IPTS). He is President of INGEMAN (a National Association for the Development of Maintenance Engineering in Spain) since 2002.

Marco Macchi is currently Full Professor at Department of Management, Economics and Industrial Engineering of Politecnico di Milano. His teaching activity is in the area of production systems, industrial technologies, asset lifecycle management, operations and maintenance management, both to undergraduate and postgraduate students; he also regularly teaches for the doctorate program in Management Engineering, in the area of modeling and simulation of complex systems. His research interests are focused on several topics concerning asset and operations management within engineered systems. He is author or co-author of 4 books and more than 100 papers at national and international levels. Serving to the scientific community, he is currently Vice-chair of the IFAC (International Federation for Automatic Control) TC (technical committee) 5.1 Manufacturing Plant Control, and Chair of the IFAC Working Group A-MEST (Advanced Maintenance Engineering, Services and Technology), WG affiliated to the IFAC TC 5.1 Manufacturing Plant Control; he is Member of the IFIP (International Federation for Information Processing) WG 5.7 Advances in Production Management Systems and the IFAC TC 5.3 Enterprise Integration and Networking; besides, he is Book Reviews Editor and Editorial Board Member of the *International Journal Production Planning & Control: The Management of Operations*, Taylor & Francis.

Ajith Kumar Parlikad is Senior Lecturer in Industrial Systems at Cambridge University Engineering Department (CUED). He is Head of the Asset Management Group at the Institute for Manufacturing and a Co-investigator for the Centre for Smart Infrastructure and Construction and the Centre for Digital Built Britain. His research focusses on examining how asset information can effectively be managed and used to improve asset investment and maintenance decision making. He is Author or Co-author of 2 books and has published more than 100 papers in peer-reviewed international journals and conference proceedings. His research has been funded by the UK Government, EU H2020, and Industry. He sits on the steering committee of the IFAC Working Group on Advanced Maintenance Engineering, Services and Technology and is a member of the Management Advisory Board for the Centre for Digital Built Britain. His current research focusses on the development of infrastructure digital twins and how data from disparate sources such as BIM models and condition-monitoring and sensing technologies can be integrated and brought to bear to improve asset management.

Contributors

Eduardo Castellano MIK Research Centre, Mondragon University, Gipuzkoa, Spain

Sergei Chekurov Department of Mechanical Engineering, School of Engineering, Production Technology, Aalto University, Espoo, Finland

Cristian Colace Tenaris Dalmine S.p.A., Dalmine, BG, Italy

Adolfo Crespo Márquez Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain;
Intelligent Maintenance System Research Group (SIM), Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

Antonio de la Fuente Carmona Intelligent Maintenance System Research Group (SIM), Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

Antonio González Diego Viesgo Electrical Distribution. PCTCAN, Santander, Spain

Asier Erguido Ruiz Ikerlan Technology Research Centre, Operations and Maintenance Technologies Area, Gipuzkoa, Spain;
Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

Eduardo Candón Fernández Intelligent Maintenance System Research Group (SIM), Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

Jesús Ferrero Bermejo Magtel Operaciones, Seville, Spain

Luca Fumagalli Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milan, Italy

Marco Garetti Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milan, Italy

Juan F. Gómez Fernández Intelligent Maintenance System Research Group (SIM), Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain;
Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

Vicente González-Prida Díaz Intelligent Maintenance System Research Group (SIM), Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

Antonio J. Guillén López Intelligent Maintenance System Research Group (SIM), Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

James Heaton Institute for Manufacturing, University of Cambridge, Cambridge, UK

Juan Izquierdo Ik4-Ikerlan Technology Centre, Operations and Maintenance Technologies Area, Gipuzkoa, Spain

Ari Jussila VTT Technical Research Centre of Finland Ltd., Espoo, Finland

Way Kuo Department of Systems Engineering and Engineering Management, City University of Hong Kong, Kowloon, Hong Kong

Hao Li Institute for Manufacturing, Cambridge, UK

Zhenglin Liang Department of Engineering, Institute for Manufacturing, University of Cambridge, Cambridge, UK

Bin Liu Department of Systems Engineering and Engineering Management, City University of Hong Kong, Kowloon, Hong Kong

Daniel Lütgehetmann Institut für Mathematik, AG Topologie, Berlin, Germany

Marco Macchi Department of Management, Economics and Industrial Engineering (DIG), Politecnico di Milano, Milan, Italy

Pablo Martínez-Galán Fernández Intelligent Maintenance System Research Group (SIM), Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

Nelson R. Matarazzo Tenaris Dalmine S.p.A., Dalmine, BG, Italy

Sini Metsä-Kortelainen VTT Technical Research Centre of Finland Ltd., Espoo, Finland

Pedro Moreu de León Intelligent Maintenance System Research Group (SIM), Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

Elisa Negri Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milan, Italy

Fernando Olivencia Polo Magtel Operaciones, Seville, Spain

Simone Pala Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milan, Italy

Adrià Salvador Palau Institute for Manufacturing, Cambridge, UK

Ajith Kumar Parlikad Department of Engineering, Institute for Manufacturing, University of Cambridge, Cambridge, UK

Irene Roda Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Milan, Italy

Maurizio Rondi Tenaris Dalmine S.p.A., Dalmine, BG, Italy

Antonio Sola Rosique INGEMAN. Association for the Development of Maintenance Engineering, School of Engineering, Seville, Spain

Mika Salmi Department of Mechanical Engineering, School of Engineering, Production Technology, Aalto University, Espoo, Finland

Javier Serra Parajes Intelligent Maintenance System Research Group (SIM), Department of Industrial Management, School of Engineering, University of Seville, Seville, Spain

Rengarajan Srinivasan Department of Engineering, University of Cambridge, Cambridge, UK

Min Xie Department of Systems Engineering and Engineering Management, City University of Hong Kong, Kowloon, Hong Kong

Part I
Long-Term Vision for Proper Asset Management

Chapter 1
Fundamental Concepts and Framework

Adolfo Crespo Márquez, Marco Macchi and Ajith Kumar Parlikad

Abstract This chapter introduces those terms and concepts that we consider fundamental for the reader to understand the rest of the book. It provides a background and introduces a generalized framework providing relevant dimensions of value-based and intelligent asset management. Firstly, understanding the value that an asset can provide and how value-based asset management can be implemented is fundamental. Secondly, it is essential to understand that the realization of the value that an asset provides to an organization can be also done at a different indenture level to the one where asset operation and maintenance is managed. Indeed, understanding the systemic dimension of the problem is therefore a fundamental aspect too. Equally important is the emphasis that asset management places on an asset life cycle approach, to deal properly with many strategic decisions regarding investment and reinvestment in new capacity, extension of the useful life, assets health analysis, identification of possible major maintenance needs, etc. Thirdly, in a world subject to a sweeping digital transformation, we must also make use of better methods, skills and abilities that help us improve our levels of intelligence in management and allow us to take advantage of the data and information at our disposal to reach levels of unprecedented asset management. The last part of this Chapter is dedicated to present the generalized framework, to ease the understanding of these asset management dimensions, and to deal with each one of them in a proper manner for the long-term vision.

A. Crespo Márquez (✉)
Department of Industrial Management, School of Engineering, University of Seville, Camino de los Descubrimientos s/n, 41092 Seville, Spain
e-mail: adolfo@us.es

M. Macchi
Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Piazza Leonardo da Vinci, 32, 20133 Milan, Italy
e-mail: marco.macchi@polimi.it

A. K. Parlikad
Department of Engineering, Institute for Manufacturing, University of Cambridge, Cambridge CB3 0FS, UK
e-mail: aknp2@cam.ac.uk

A. Crespo Márquez et al. (eds.), *Value Based and Intelligent Asset Management*,
https://doi.org/10.1007/978-3-030-20704-5_1

Keywords Asset management · Value-based management · Whole-life assessment · Asset system and network level · Decision-making

1 The Definition of Asset Management

The current understanding of Asset Management (AM) is primarily supported by well-known standards provides a good reference to define what is an 'Asset' and what is 'Asset Management'.

The BSI PAS 55-1 standard specifications [1] defines an asset as "*plant, machinery, property, buildings, vehicles and other items and related systems that have a distinct and quantifiable business function or service*". The ISO 55000 standard on Asset Management [2] generalizes the definition, stating that an asset is "*an item, thing or entity that has potential or actual value to an organization*".

Correspondingly, some literature distinguishes the assets a company has, and classifies them as:

- Intangible assets, including designs, knowledge, software, intellectual property, and processes;
- Tangible assets, including liquid assets (cash or inventories) and fixed assets (consisting of physical assets such as the land, buildings and infrastructures, IT equipment, machineries, hardware, and product and service equipment).

Amongst them, we are primarily concerned with Physical Assets such as buildings, industrial plants or infrastructure. However, it is evident that nowadays intangible assets are also growing in their presence and importance; especially, Intelligent Asset Management will be increasingly relying on them, through the close connection of Cyber and Physical spaces.

BSI PAS 55-1 defines asset management as the "*systematic and coordinated activities and practices through which an organisation optimally and sustainably manages its assets, and their associated performance, risks and expenditures over their lifecycle for the purpose of achieving its organisational strategic plan*". A rather simplified, yet powerful definition as put forward by the ISO 55000 standard, states that Asset Management is the "*coordinated activity of an organisation to realise value from assets*" [2].

The critical and new term in the definition of Asset Management is value. Value is considered to be one of the fundamental pillars of Asset Management. It can be "tangible or intangible, financial or non-financial, and includes consideration of risks and liabilities" [2], and is the contribution of AM as a value-adding process to the core business of an organisation [2–5]. Therefore, it is worth clarifying what means value as a core element of AM.

2 Defining Value

Value is obtained by acquiring assets that allow an organization to fulfil its strategic objectives [5], and ensuring that the assets keep fulfilling those objectives throughout their life.

Notwithstanding this general understanding, no single detailed definition of value delivered by the assets can be found in the literature. In fact, its specific definition is very much dependent on the company's purpose, the nature of its assets (i.e., tangible and intangible assets), its strategic objectives and the expectations of its stakeholders.

What is generally agreed is that the realization of value involves balancing costs, risks, opportunities and benefits arising from the way assets are specified, procured, deployed, used, maintained and disposed. Hence, the assertion that the whole-life needs to be considered in making any asset management decision, is inherently important to value delivery.

Three remarks can be outlined as primary assumptions when dealing with value realization from assets:

1. Each organisation has to define its own conception of value, given the specific business context in which it operates;
2. When the management and utilisation of an asset encompass more than one organisation (it is normally the case especially for infrastructure assets), managing value requires to deal with conflicting objectives, asymmetric sharing of costs and risks, opportunities and benefits, etc.;
3. A whole-life assessment of value should be considered in order to deal with the fulfilment of company's objectives and the stakeholders' expectations throughout the whole-life of the assets.

Given these assumptions, we rely on some criteria derived from the literature and the experience shared during the SustainOwner project, to introduce a more operational definition of value. To this end, we consider a first requirement for proper value-based asset management implementation: asset management objectives should be clearly identified and should be SMART (Specific, Measurable, Achievable, Realistic and Timely), so to effectively drive operations and, thus, the actions performed towards the operations excellence. Our definition of stakeholders' requirements and value metrics aims at complying with this implementation requirement; the steps to this end are summarized in Table 1.

The definition of value metrics is aligned with the usual practices of performance measurement. Indeed, the organization (or its asset management function) needs to identify the desired performance targets and measures for each asset as well as for the asset management system [6]. Doing so, the asset management system performance measures will need to encompass technical (at system/network level and individual asset level), economic and organizational dimensions, reflecting the holistic characteristic of asset management; an even larger perspective, inclusive of the theories of sustainability, may also recommend the use of economic, environmental, social dimensions to frame the performance measures. All in all, the defined performances

Table 1 Definition of stakeholders' requirements and value metrics

#	Step	Description
1	Identification of the key stakeholders	The stakeholders as interested party that "can affect, be affected by, or perceive themselves to be affected by a decision or activity", are the starting point to define value [2]. Thus, the key stakeholders are firstly identified. Their identification is influenced by the business context, and should take into account the need to consider the *whole-life* assessment of value
2	Definition of the stakeholders' requirements	The stakeholders' requirements—expression of their objectives, needs and expectations—should be understood. We consider this understanding after the operational context is properly identified. Henceforth, the specific assets, assets systems or networks are firstly set within the boundaries of the operational context considered for the *whole-life* assessment; afterwards, the stakeholders' requirements are defined
3	Conversion of the stakeholders' requirements into value drivers and metrics	Requirements are converted into the main attributes assigned by the stakeholders to the assets, asset systems or networks under assessment. The attributes will be generally named as value elements, that is the elements worth of deserving proper control because they are influent on the value realization (i.e., on the balance of costs, risks, opportunities and benefits). In particular, the value elements are defined in two terms, as value drivers and value metrics: (i) the value drivers are the characteristics of assets, asset systems or networks, relevant to their business function or service as perceived by the stakeholder; (ii) the value metrics are the performance measures used in order to assess the value drivers

should be used to explicitly measure, through proper metrics, the achievement of satisfaction (or not) of the different value drivers set by the stakeholders.

Tables 2 and 3 show some cases of dependencies of value drivers and metrics from the stakeholders and their requirements. The cases are an extract taken from interviews to stakeholders in different contexts, that is a networked infrastructure and a production plant, while the asset studied is respectively the asset network (i.e. metro network) and the asset system (i.e., a complex production plant).

Generalizing the evidences shown in the table, the stakeholders' requirements result from the stakeholders identified amongst the interested parties internal or external to a company; value drivers and metrics are subsequently defined.

Some examples of stakeholders' requirements are herein summarized as derived from different contexts:

- For Customers: High% of Reliable delivery of products/services, High% of products Availability, 100% Quality of products, 100% Safety;

Table 2 Stakeholders' requirements and value metrics for a company in the food and beverage sector

Sector and asset	Stakeholders	Stakeholder type	Stakeholder requirements	Value drivers	Value metrics
Food and Beverage—production plants	Production department	Internal	Meeting production planning target	Production	Production volume Number of satisfied (production) orders
			Meeting quality standards	Quality	Scraps rate
	Maintenance department	Internal	Maximizing asset availability	Availability	Plant availability
	Energy department	Internal	Optimizing energy consumption	Energy	Energy efficiency
	Safety department	Internal	Granting 100% safety	Safety	Number of near missed/safety un-compliance
	Customers	External	Buying good product High service level	Customer satisfaction	Selling volume Fill rate

Table 3 Stakeholders' requirements and value metrics for a company in the transport sector

Sector and asset	Stakeholders	Stakeholder type	Stakeholder requirements	Value drivers	Value metrics
Transport—metro rail network	Customers	External	Reliable service	Service	Lost customer hours
					Reliability risk
			Cheap service	Cost	CAPEX
					OPEX
			Safe service	Safety	Frequency of accidents
					Number of passenger fatalities and casualties
			Good ambiance	Service	Complaints from users Column inches of bad press
				Reputation	
	Unions	Internal	Better pay	Cost	OPEX Number of workplace accidents
				Well-being at work	
			Safe environment	Safety	Number of workplace accidents
			Low impact on the environment	Sustainability	Carbon footprint
					Sustainability costs
					Penalties
	Metro	Internal	Safe workplace	Safety	
	Maintenance team			Well-being at work	Ambience at workplace

(continued)

Table 3 (continued)

Sector and asset	Stakeholders	Stakeholder type	Stakeholder requirements	Value drivers	Value metrics
			Efficient interventions	Cost	OPEX
			Ability to do things quickly	Cost	OPEX
				Service	
	Metro	Internal	Reliable, on-time service	Service	Lost customer hours
	Operations team		Cheaper to run	Cost	OPEX
			Minimizing disruptions to service	Service	Column inches of bad press
				Reputation	
	Metro	Internal	Safety	Safety	Frequency of accidents Number of passenger fatalities Number of workplace accidents
	Profession heads		Legal compliance	Compliance	Penalties Column inches of bad press
			Quality of works	Cost	OPEX

(continued)

Table 3 (continued)

Sector and asset	Stakeholders	Stakeholder type	Stakeholder requirements	Value drivers	Value metrics
				Service	
			Standards compliance	Compliance	Penalties Column inches of bad press
			Efficient interventions	Cost	OPEX
				Service	
			Efficient technologies	Cost	OPEX
			Low impact on the environment	Sustainability	Emissions
	Regulator	External	Effective technologies	Cost	OPEX
				Service	
			Wise investments (value for money) Low impact on the environment	Cost	OPEX, CAPEX Emissions
				Service	
				Sustainability	
	Mayor of City	External	Image of the city	Reputation	Ambience for users
					Column inches of bad press