KPI Selection for Tooling and Die Industry

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In the last few decades, the fast technological development has caused high competitiveness among companies, encouraging a pursuit for strategies that allow them to gain competitive advantage, such as the monitoring of performance by using key performance indicators (KPIs).

Keywords: continuous improvement ; analytic network process ; business intelligence ; key performance indicators

1. Introduction

The automotive industry has always been a significant contributor to the global economy since it represents one of the largest manufacturing industries [1]. In Europe, this industry represents 6.1% of the total workforce and large percentage [2] of total production and capital investment in the manufacturing sector–a turnover over 7% of EU gross domestic product (GDP) [3]. Due to the high number of companies operating in the manufacturing sector, competitiveness between them has been increasing, motivating the awareness that to remain active in the market and to differentiate from different competitors, they would have to invest in innovation techniques among their operational areas [4]. The insufficiency of control over the processes/activities carried out in a company affects its operating results and process performance, driving the company to identify which are the most affected areas that need to be improved. One of the strategies that has been adopted by companies over the past decades is the measurement of process performance, as well as the use of tools that allows the visualization and monitoring of their status [5].

Measurement is a fundamental tool for all companies and institutions, since the result directly impacts the way of executing the processes and the behavior of those who make part of it, setting them at an evaluation stage in relation to the objectives set by the organization [6]. Hence, performance measurement systems (PMS) were introduced [7], which allows the visualization and analysis of the performance of the different processes [8]. In order to achieve a proper performance of such types of systems, it is necessary to define key performance indicators (KPIs) [9][10]. KPIs are, undoubtedly, the essential measurement and control tools within all the processes of an organization. These indicators allow identifying if the activities are being carried out efficiently, and help optimizing all the resources involved [11]. KPIs must reflect the corporate strategy and competitive factors of the organization, and they must focus on the method to achieve results [12][13]. KPIs have also to be meaningful, coherent, objective driven, and a standard for objectively comparing different organizations [14].

However, the process of selecting KPIs can be difficult since there is a wide range of alternatives from which, in order to obtain the greatest benefit, an adequate number must be chosen. Therefore, it is important to define the main concepts of the decision-making process and select the most suitable KPIs. This can be achieved by resorting to analytic network process (ANP) [15]. Therefore, many professionals are relying on decision-making methodologies [16][17][18], such as ANP, to review which are the aspects or criteria that must be considered in management, in order to obtain a greater benefit for the company.

In previous studies, the ANP model has been used to assist the decision-maker in the process of selecting KPIs, being identified as a valuable and powerful tool for management, since it uses the decision-makers input to prioritize KPIs logically and consistently [19]. However, just a small number of studies concerning the application of the ANP to prioritize KPIs for manufacturing industry were identified [19][20][21][22]. Specifically in the automotive tool, die and molding industry, where only one study was identified [23]. However, this study focused on the development of generic KPIs for smart factories and tested their method in several industries and only one of those industries comprised injection molding.

The automotive tool, die, and molding industry is a specific industry with unique characteristics. Although most KPIs are general in nature and can be easily modeled to different processes, industry specific KPIs would allow maintaining a good alignment with the strategy and processes of tool, die, and molding manufacturing processes.

2. Literature Review

2.1. Performance Evaluation and Performance Measures

Due to the high competitiveness environment in which the industry finds itself in, the interest in techniques and tools that enable better control and supervision of the companies' performance has been steadily growing [24]. The research for techniques and tools for controlling and visualizing performance allows companies to identify gaps in their processes, allowing an improved management of their resources, enhancing possible improvements in them [11]. The use of KPIs emerges as a tool to evaluate and quantify the performance of the processes, regarding a set of previously established objectives [25]. The use of these metrics has been embraced in several areas such as education, agriculture [26], financial service [27], transport [28], industry [29], healthcare [30], supply chain [31], risk management [32], quality control [33], maintenance [34], and construction [35], among others.

Currently, many different metrics are employed for measuring the performance in almost all types of processes. However, sometimes these happen to be erroneous and used incorrectly, leading companies to work with wrong measures and be incorrectly monitored. Inadequate metrics can lead to problems such as poor information concerning the root causes of many problems [36] or poor alignment between the strategic and operational levels of companies [37][38]. Hence, the use of inaccurate or inadequate indicators causes companies to fail in meeting the initially established objectives.

The use of key performance indicators (KPIs) as a metric to control has been much more recurrent due to the fast growth and adaptation of companies to the concepts of Industry 4.0, which aims to access information through technological means, greatly facilitating the use of KPIs [39]. Therefore, the use of KPIs becomes a tool of great importance for management, since through its use it becomes possible to separate non-useful from useful information, offering company managers a transparent view, and possible paths on how they can improve these processes [11]. However, KPIs can also be used in the risk analysis area, as they demonstrate where problems are located in processes that cause delays and malfunctions in the company (bottleneck) [40]. Accordingly, KPIs are metrics that define the state of the process to be studied in comparison to a previously established objective [41].

2.2. Multicriteria Analysis to Support Decision in Choosing KPIs

Performance evaluation can be defined as a systematic activity, which consists of quantifying, effectively and efficiently, a concept or an action. Consequently, the activity of measuring the performance of the processes involves the use of performance measurement systems (PMS) in order to take advantage and benefit from the available information, hence changing companies by making them open organizations in terms of sharing information [42]. For companies to benefit from PMS, it is crucial that these systems present clear definitions of the performance of activities and that the metrics are highly accurate. Hence, it is essential that a rigorous selection of KPIs is used to control the activities that are being carried out [43]. However, selecting KPIs is a complex task for companies, in addition to being one of the most key aspects in the development and use of PMS, the choice should be very restrictive since only a small number of KPIs should be selected. The restrictive selection is done as it is intended to avoid overloading the PMS with irrelevant information, allowing companies to obtain a clear view of the performance of their activities. However, it is a common practice to choose a higher number of KPIs for measuring the company's performance by its managers, since there are is high number of KPIs available for them to choose [43].

Since the number of KPIs to be selected represents a finite number and its selection decision process implies the analysis of different factors to be taken into account, it is possible to state that the process is characterized as a multiple criteria decision making (MCDM) [44][45]. Through model application, it is possible to identify which KPIs are most relevant for measuring the company's performance. In literature, the most common MCDM models include the elimination et choice translating reality (ELECTRE) model; the technique for order of preference by similarity to ideal solution (TOPSIS) model; the analytic hierarchy process (AHP) model [46]; and the fuzzy AHP model [47].

2.3. Analytic Network Process

The use of analytical network process (ANP) in decision problems, specifically in problems related to performance measurement, is still very poor in the scientific literature. However, in the study [48], it was possible to verify the application of ANP in the scope of decision problems, having presented some of the application areas of the ANP, as well as some examples of its use. With the realization of this study, it was possible to conclude that the areas where the application of ANP is more common are business and financial management.

The identified studies where the ANP was used to assist the selection of KPIs appears to be quite comprehensive as to their areas of application. However, a limitation in the research is found regarding the application area, and no studies of the application of the ANP model were identified in the automotive press molding industry.

The ANP is an MCDM considered a generalization of AHP. The ANP was developed by Saaty in 1980 to assist in the decision-making process in problems where a need exists to relate the elements in the clusters, but also relate the different clusters [49]. The largest difference between the AHP and the ANP is the fact that the ANP does not require a linear hierarchical structure, but rather a structure where it is possible to relate the different elements of the several hierarchical levels, modeling the decision problem in a network structure. In addition to this differentiating aspect, the ANP also presents a feedback relationship between the different hierarchical levels of the structure. Therefore, when using the network structure, where all factors and criteria that influence the decision are included, it is possible to identify the feedback relationships that exist not only within the clusters themselves (internal dependency) but also among others (external dependency) [50][51].

The ANP's most known advantage is that the method allows comparisons to be made not only between elements within the same cluster but also between elements of different clusters, considering the impact of these dependencies through feedback, leading this method to show more reliable results. However, since this method considers different existing dependencies, as well as the impact they have on each other, carrying out a large number of comparisons is required and, consequently, generates problems of inconsistency [52][53]. Hence, ANP captures the inherent complexity of decision problems instead of forcing them into a hierarchy simplification, such as in the case of AHP or TOPSIS [54]. Since the automotive tool, die, and molding industry is a specific industry with distinctive characteristics and many KPIs, an ANP decision model with many comparisons could be a solid contribution to the literature.

3. Methodology for KPI Selection

3.1. Proposed ANP Model to Select KPIs for Mold Manufacturing

To aid in the KPI selection process an ANP decision model is used, since it can evaluate the influences that KPIs have on each other, either directly or indirectly (feedback relations) [50][51]. The proposed ANP model, as depicted in **Figure 1**, consists of three sets of clusters: objective, criteria, and alternatives.

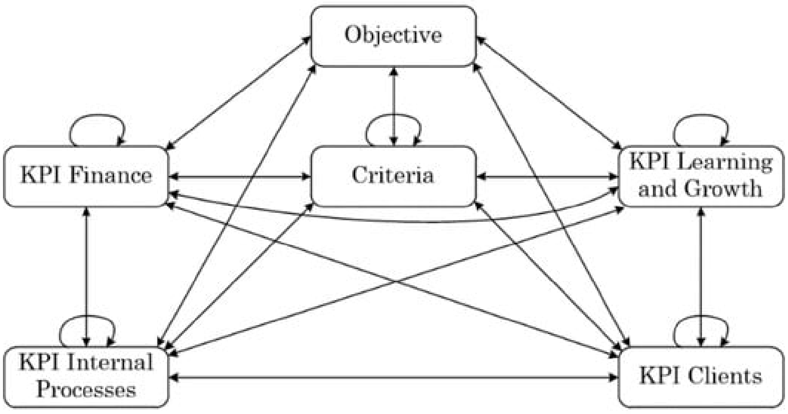

Figure 1. ANP structure in the KPI selection process.

The "objective" cluster consists of a single element, which is the objective of the problem: "the identification of KPIs that allow monitoring performance of the mold manufacturing process".

The objective is fulfilled through the selection of alternatives (i.e., KPIs) evaluated through a set of criteria. The "criteria" cluster consists of a set of factors that influence the decision-making process, from the set of alternatives presented to the decision-maker. The existence of criteria ensures that the decision-maker considers different aspects when choosing between different alternatives. The set of criteria selected was based on a research process in the scientific literature, with the following criteria and respectively associated identified objectives [49]:

- Costs: reduce;
- Productivity: increase;
- Quality: increase;

- Employee satisfaction: increase;
- Safety: increase;
- Learning and growth: increase;
- Customer satisfaction: increase.

The “alternatives” cluster is made of the several alternatives available for the decision-maker to make a choice. Thus, KPIs represent the alternatives that the decision-maker has. The arrangement between those clusters in the structure of network instead of a hierarchy due to the high number of existing KPIs that are adequate to mold manufacturing performance measurement. Since cluster size should not exceed nine elements [55], developing the ANP model led to arranging KPIs in Balanced Scorecard (BSC) categories [56][57]:

- Financial: It includes financial KPIs, such as profit and return on investment, allowing shareholders to verify the company’s financial success;
- Internal processes: In this perspective there are KPIs that reflect the effectiveness and efficiency of the operations carried out in the company, ensuring that they meet the expectations and requirements imposed by both the company itself and the customer. An example of KPIs used in this perspective can be productivity and efficiency;
- Learning and growth: It refers to the infrastructure and available resources that the company holds, whether physical, human, or organizational procedures. Therefore, KPIs related to the performance of employees and their development within the company are used, such as employee satisfaction, hours of training, and retention rate;
- Customers: This category is based on the necessary measures to satisfy the requirements imposed by the customer and to remain competitive in the market. As such, customer oriented KPIs are used, such as customer satisfaction and customer retention.

Apart from splitting the “alternatives” cluster into four BSC clusters, another reason for selecting ANP instead of AHP was the dependencies among cluster elements. Before model implementation, direct and reciprocal dependencies must be identified [58].

3.2. The Proposed Method for Selecting and Implementing KPIs

In order to assist the selection process of KPIs using the suggested ANP model, the method depicted in **Figure 2** is proposed. The KPIs selection process starts with the identification of KPIs in literature. Subsequent steps are organized in two phases: model development and model application. In the first phase, criteria to evaluate alternatives is researched in literature and selected. Then, dependencies among objects (objective, criteria, and KPIs) are mapped. The subsequent phase consists in obtaining pairwise comparisons correspondent to objects’ relationships. After the ANP model is developed and applied, one must verify the matrices’ inconsistencies. When matrices are consistent, results must be analyzed and discussed with decision-makers. Last, after selecting the necessary KPIs, then they are implemented.

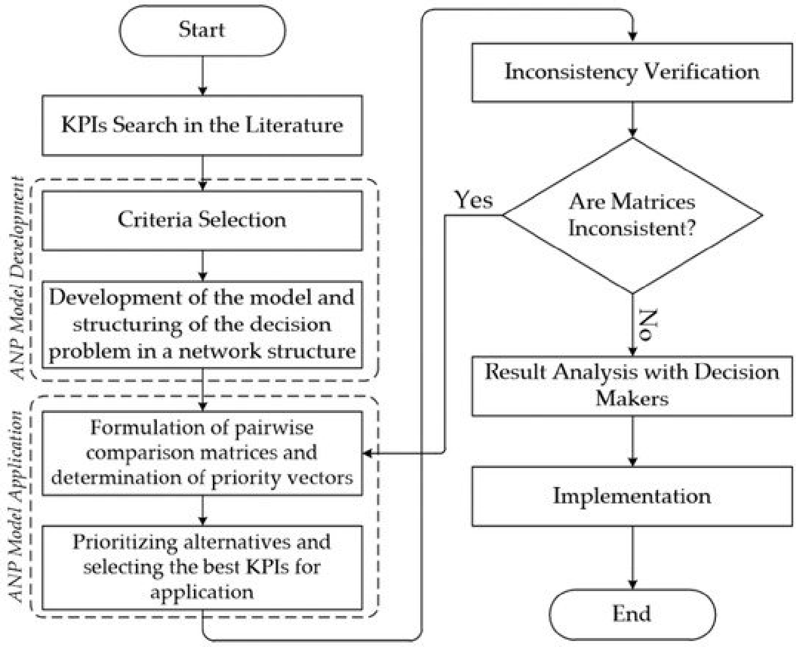

Figure 2. Proposed methodology to select and implement KPIs.

3.3. KPIs Applied in the Manufacturing and Mold Industry

In order to identify the existing KPIs in the manufacturing and mold industries a literature review was conducted. The research carried out was based on publisher search engines such as Science Direct, Emerald Insight, and Springer, where terms such as "mold casting KPIs"; "KPI manufacturing industry"; "KPI industry"; and "Performance indicators manufacturing industry" were mostly searched.

As many as 58 KPIs were identified through this search that can be observed in **Table 1**, these being related to industry, which comprise areas such as planning, project management, financial, logistics, environmental, quality, production, and security. Although the objective was to determine KPIs for manufacturing and mold industry, the identified KPIs are general in nature and transversal to other industry sectors. Through this literature review it was not possible to identify industry specific KPIs for mold manufacturing. However, the correct application of KPIs requires their correct adaptation to the manufacturing and business processes.

Table 1. KPIs that can be used to access performance in the automotive press molding industry.

KPI	References
Deviation from the project budget	[59]
Budget for operational activities	[59]
Transport and warehouse costs	[59]
Maintenance costs for production carried out in a given period of time	[14]
Labor costs	[60]
Profit	[21]
Return on investment	[21]
Rework costs	[61]
Inventory cost	[61]
Percentage of total cost spent on manufacturing	[62]
Percentage of machine usage	[63]
Rate of good quality products	[64]
Product loss rate	[64]
Rate of products manufactured with quality at first time	[64]

KPI	References
Rate of products requiring rework	[64]
Mean time to failure (MTTF)	[64]
Corrective maintenance rate	[64]
Queue times	[63]
Quantity of waste	[63]
Planned busy time	[63]
Planned operational time vs. planned	[63]
Order execution time vs. planned	[63]
Machine downtime	[63]
Unit busy time	[63]
Actual unit setup time vs. planned	[63]
Percentage compliance with planned operations time	[14]

References

1. Grodzicki, M.J.; Skrzypek, J. Cost-Competitiveness and Structural Change in Value Chains—Vertically-Integrated Analysis of the European Automotive Sector. Struct. Chang. Econ. Dyn. 2020, 55, 276–287.
2. Pichler, M.; Krenmayr, N.; Schneider, E.; Brand, U. EU Industrial Policy: Between Modernization and Transformation of the Automotive Industry. Environ. Innov. Soc. Transit. 2021, 38, 140–152.
3. Marco, A.D.; Mangano, G.; Magistris, P.D. Evaluation of Project Management Practices in the Automotive Original Equipment Manufacturers. Procedia Comput. Sci. 2021, 181, 310–324.
4. Burggräf, P.; Dannapfel, M.; Adlon, T.; Kahmann, H.; Schukat, E.; Keens, J. Capability-Based Assembly Design: An Approach for Planning an Agile Assembly System in Automotive Industry. Procedia CIRP 2020, 93, 1206–1211.
5. Petrillo, A.; Felice, F.D.; Zomparelli, F. Performance Measurement for World-Class Manufacturing: A Model for the Italian Automotive Industry. Total Qual. Manag. Bus. Excell. 2019, 30, 908–935.
6. Parmenter, D. Key Performance Indicators: Developing, Implementing, and Using Winning KPIs/David Parmenter, 4th ed.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2020; ISBN 978-1-119-62077-8.
7. Lucianetti, L.; Battista, V.; Koufteros, X. Comprehensive Performance Measurement Systems Design and Organizational Effectiveness. Int. J. Oper. Prod. Manag. 2019, 39, 326–356.
8. Micheli, P.; Mura, M. Executing Strategy through Comprehensive Performance Measurement Systems. Int. J. Oper. Prod. Manag. 2017, 37, 423–443.
9. Verhaelen, B.; Mayer, F.; Peukert, S.; Lanza, G. A Comprehensive KPI Network for the Performance Measurement and Management in Global Production Networks. Prod. Eng. 2021, 15, 635–650.
10. da Silva Ramos, A.; Oliveira, F.L.C.; de Castro, C.M.B. Quantitative Approaches for Identification of Indicators and Their Relationships in Performance Measurement Systems: A Literature Review. In Industrial Engineering and Operations Management; Thomé, A.M.T., Barbastefano, R.G., Scavarda, L.F., dos Reis, J.C.G., Amorim, M.P.C., Eds.; Springer International Publishing: Cham, Switzerland, 2020; pp. 357–365.
11. Meier, H.; Lagemann, H.; Morlock, F.; Rathmann, C. Key Performance Indicators for Assessing the Planning and Delivery of Industrial Services. In Proceedings of the Procedia CIRP, Curran, Cranfield, UK, 5 November 2013; Volume 11, pp. 99–104.
12. Hristov, I.; Chirico, A.; Ranalli, F. Corporate Strategies Oriented towards Sustainable Governance: Advantages, Managerial Practices and Main Challenges. J. Manag. Gov. 2021, 1–23.
13. Helmold, M.; Terry, B. Operations and Supply as Integral Part of the Corporate Strategy. In Operations and Supply Management 4.0: Industry Insights, Case Studies and Best Practices; Helmold, M., Terry, B., Eds.; Future of Business and Finance; Springer International Publishing: Cham, Switzerland, 2021; pp. 85–95. ISBN 978-3-030-68696-3.

14. Lindberg, C.-F.; Tan, S.; Yan, J.; Starfelt, F. Key Performance Indicators Improve Industrial Performance. In Proceedings of the Energy Procedia, Abu Dhabi, UAE, 28 March 2015; Volume 75, pp. 1785–1790.

15. Pérez, J.L.R.; Rodríguez-Rodríguez, R.; Saiz, J.-J.A.; Verdecho, M.-J. An ANP-Based Network to Measure the Impact of Lean Production on Organisational Performance. J. Ind. Eng. Manag. 2018, 11, 222–228.

16. Becker, J.; Becker, A.; Sałabun, W. Construction and Use of the ANP Decision Model Taking into Account the Experts' Competence. Procedia Comput. Sci. 2017, 112, 2269–2279.

17. De Felice, F. Research and Applications of AHP/ANP and MCDA for Decision Making in Manufacturing. Int. J. Prod. Res. 2012, 50, 4735–4737.

18. Chemweno, P.; Pintelon, L.; Van Horenbeek, A.; Muchiri, P. Development of a Risk Assessment Selection Methodology for Asset Maintenance Decision Making: An Analytic Network Process (ANP) Approach. Int. J. Prod. Econ. 2015, 170, 663–676.

19. Carlucci, D. Evaluating and Selecting Key Performance Indicators: An ANP-based Model. Meas. Bus. Excell. 2010, 14, 66–76.

20. Lee, J.; Jun, S.; Chang, T.-W.; Park, J. A Smartness Assessment Framework for Smart Factories Using Analytic Network Process. Sustainability 2017, 9, 794.

21. Kucukaltan, B.; Irani, Z.; Aktas, E. A Decision Support Model for Identification and Prioritization of Key Performance Indicators in the Logistics Industry. Comput. Hum. Behav. 2016, 65, 346–358.

22. Joshi, D.; Nepal, B.; Rathore, A.P.S.; Sharma, D. On Supply Chain Competitiveness of Indian Automotive Component Manufacturing Industry. Int. J. Prod. Econ. 2013, 143, 151–161.

23. Mourtzis, D.; Papatheodorou, A.-M.; Fotia, S. Development of a Key Performance Indicator Assessment Methodology and Software Tool for Product-Service System Evaluation and Decision-Making Support. J. Comput. Inf. Sci. Eng. 2018, 18, 1–13.

24. Ramis Ferrer, B.; Muhammad, U.; Mohammed, W.; Martínez Lastra, J. Implementing and Visualizing ISO 22400 Key Performance Indicators for Monitoring Discrete Manufacturing Systems. Machines 2018, 6, 39.

25. Kourkoumpas, D.-S.; Benekos, G.; Nikolopoulos, N.; Karellas, S.; Grammelis, P.; Kakaras, E. A Review of Key Environmental and Energy Performance Indicators for the Case of Renewable Energy Systems When Integrated with Storage Solutions. Appl. Energy 2018, 231, 380–398.

26. Gonzalez, E.; Nanos, E.M.; Seyr, H.; Valldecabres, L.; Yürüşen, N.Y.; Smolka, U.; Muskulus, M.; Melero, J.J. Key Performance Indicators for Wind Farm Operation and Maintenance. In Proceedings of the Energy Procedia, Trondheim, Norway, 18 January 2017; Elsevier Procedia: Amsterdam, The Netherlands, 2017; Volume 137, pp. 559–570.

27. del Mar Roldán-García, M.; García-Nieto, J.; Maté, A.; Trujillo, J.; Aldana-Montes, J.F. Ontology-Driven Approach for KPI Meta-Modelling, Selection and Reasoning. Int. J. Inf. Manag. 2019, 10, 2018.

28. Scheepmaker, G.M.; Willeboordse, H.Y.; Hoogenraad, J.H.; Luijt, R.S.; Goverde, R.M.P. Comparing Train Driving Strategies on Multiple Key Performance Indicators. J. Rail Transp. Plan. Manag. 2020, 13, 100163.

29. Assad, F.; Alkan, B.; Chinnathai, M.K.; Ahmad, M.H.; Rushforth, E.J.; Harrison, R. A Framework to Predict Energy Related Key Performance Indicators of Manufacturing Systems at Early Design Phase. In Proceedings of the Procedia CIRP, Ljubljana, Slovenia, 12 June 2019; Elsevier: Amsterdam, The Netherlands, 2019; Volume 81, pp. 145–150.

30. Shawahna, R. Development of Key Performance Indicators to Capture in Measuring the Impact of Pharmacists in Caring for Patients with Epilepsy in Primary Healthcare: A Delphi Consensual Study. Epilepsy Behav. 2019, 98, 129–138.

31. Brint, A.; Genovese, A.; Piccolo, C.; Taboada-Perez, G.J. Reducing Data Requirements When Selecting Key Performance Indicators for Supply Chain Management: The Case of a Multinational Automotive Component Manufacturer. Int. J. Prod. Econ. 2021, 233, 107967.

32. Nolan, D.P.; Anderson, E.T. 8—OE/SHE Key Performance Indicators (KPIs). In Applied Operational Excellence for the Oil, Gas, and Process Industries; Nolan, D.P., Anderson, E.T., Eds.; Gulf Professional Publishing: Houston, TX, USA, 2015; pp. 147–163. ISBN 978-0-12-802788-2.

33. Kornas, T.; Knak, E.; Daub, R.; Bührer, U.; Lienemann, C.; Heimes, H.; Kampker, A.; Thiede, S.; Herrmann, C. A Multivariate KPI-Based Method for Quality Assurance in Lithium-Ion-Battery Production. Procedia CIRP 2019, 81, 75–80.

34. Ferreira, S.; Silva, F.J.G.; Casais, R.B.; Pereira, M.T.; Ferreira, L.P. KPI Development and Obsolescence Management in Industrial Maintenance. Procedia Manuf. 2019, 38, 1427–1435.

35. Kerzner, H. Project Management Metrics, KPIs, and Dashboards: A Guide to Measuring and Monitoring Project Performance, 3rd ed.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2017; ISBN 978-1-119-42732-2.

36. Maltz, A.C.; Shenhar, A.J.; Reilly, R.R. Beyond the Balanced Scorecard. Long Range Plann 2003, 36, 187–204.

37. Yeniyurt, S. A Literature Review and Integrative Performance Measurement Framework for Multinational Companies. Mark. Intell. Plan. 2003, 21, 134–142.

38. Bhasin, S. Lean and Performance Measurement. J. Manuf. Technol. Manag. 2008, 19, 670–684.

39. Morella, P.; Lambán, M.P.; Royo, J.; Sánchez, J.C.; Latapia, J. Development of a New KPI for the Economic Quantification of Six Big Losses and Its Implementation in a Cyber Physical System. Appl. Sci. 2020, 10, 9154.

40. Bhadani, K.; Asbjörnsson, G.; Hulthén, E.; Evertsson, M. Development and Implementation of Key Performance Indicators for Aggregate Production Using Dynamic Simulation. Miner. Eng. 2020, 145, 106065.

41. Govindan, K.; Dhingra Darbari, J.A.; Kaul, A.; Jha, P. Structural Model for Analysis of Key Performance Indicators for Sustainable Manufacturer–Supplier Collaboration: A Grey-Decision-Making Trial and Evaluation Laboratory-Based Approach. Bus. Strategy Environ. 2021, 30, 1702–1722.

42. Valmohammadi, C.; Ahmadi, M. The Impact of Knowledge Management Practices on Organizational Performance: A Balanced Scorecard Approach. J. Enterp. Inf. Manag. 2015, 28, 131–159.

43. Carlucci, D.; Schiuma, G. Determining Key Performance Indicators: An Analytical Network Approach. In Handbook on Business Information Systems; World Scientific: Toh Tuck Link, Singapore, 2010; pp. 515–536. ISBN 978-981-283-605-2.

44. Yalcin, N.; Bayrakdaroglu, A.; Kahraman, C. Application of Fuzzy Multi-Criteria Decision Making Methods for Financial Performance Evaluation of Turkish Manufacturing Industries. Expert Syst. Appl. 2012, 39, 350–364.

45. Ortega, J.; Moslem, S.; Tóth, J.; Péter, T.; Palaguachi, J.; Paguay, M. Using Best Worst Method for Sustainable Park and Ride Facility Location. Sustainability 2020, 12, 10083.

46. Ortega, J.; Moslem, S.; Palaguachi, J.; Ortega, M.; Campisi, T.; Torrisi, V. An Integrated Multi Criteria Decision Making Model for Evaluating Park-and-Ride Facility Location Issue: A Case Study for Cuenca City in Ecuador. Sustainability 2021, 13, 7461.

47. Ortega, J.; Tóth, J.; Moslem, S.; Péter, T.; Duleba, S. An Integrated Approach of Analytic Hierarchy Process and Triangular Fuzzy Sets for Analyzing the Park-and-Ride Facility Location Problem. Symmetry 2020, 12, 1225.

48. Kheybari, S.; Rezaie, F.M.; Farazmand, H. Analytic Network Process: An Overview of Applications. Appl. Math. Comput. 2020, 367, 124780.

49. Liu, P.; Tsai, C. Using Analytic Network Process to Establish Performance Evaluation Indicators for the R&D Management Department in Taiwan’s High-tech Industry. Asian J. Qual. 2007, 8, 156–172.

50. Podgórski, D. Measuring Operational Performance of OSH Management System—A Demonstration of AHP-Based Selection of Leading Key Performance Indicators. Saf. Sci. 2015, 73, 146–166.

51. Triantaphyllou, E. Multi-Criteria Decision Making Methods: A Comparative Study; Applied Optimization; Springer: Boston, MA, USA, 2000; Volume 44, ISBN 978-1-4419-4838-0.

52. Van Horenbeek, A.; Pintelon, L. Development of a Maintenance Performance Measurement Framework—Using the Analytic Network Process (ANP) for Maintenance Performance Indicator Selection. Omega 2014, 42, 33–46.

53. Hennig, M.; Reisinger, G.; Trautner, T.; Hold, P.; Gerhard, D.; Mazak, A. TU Wien Pilot Factory Industry 4.0. In Proceedings of the Procedia Manufacturing, Braunschweig, Germany, 26 March 2019; Volume 31, pp. 200–205.

54. Saaty, T.L.; Vargas, L.G. The Analytic Network Process. In Decision Making with the Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks; Saaty, T.L., Vargas, L.G., Eds.; Springer: Boston, MA, USA, 2013; pp. 1–40. ISBN 978-1-4614-7279-7.

55. Cabral, I.; Grilo, A.; Cruz-Machado, V. A Decision-Making Model for Lean, Agile, Resilient and Green Supply Chain Management. Int. J. Prod. Res. 2012, 50, 4830–4845.

56. Kaplan, R.S. Conceptual Foundations of the Balanced Scorecard. In Handbooks of Management Accounting Research; Elsevier: Amsterdam, The Netherlands, 2009; Volume 3, pp. 1253–1269. ISBN 978-0-08-055450-1.

57. Modak, M.; Ghosh, K.K.; Pathak, K. A BSC-ANP Approach to Organizational Outsourcing Decision Support-A Case Study. J. Bus.Res. 2018, 103, 432–447.

58. Saaty, T.L. Decision Making with Dependence and Feedback: The Analytic Network Process, 2nd ed.; the Organization and Prioritization of Complexity; RWS Publ.: Pittsburgh, PA, USA, 2001; ISBN 978-0-9620317-9-3.

59. Pinna, C.; Demartini, M.; Tonelli, F.; Terzi, S. How Soft Drink Supply Chains Drive Sustainability: Key Performance Indicators (KPIs) Identification. In Proceedings of the Procedia CIRP, Stockholm, Sweden, 16 May 2018; Elsevier Procedia: Amsterdam, The Netherlands, 2018; Volume 72, pp. 862–867.

60. Behrens, B.-A.; Lau, P. Key Performance Indicators for Sheet Metal Forming Processes. Proc. Prod. Eng. 2008, 2, 73–78.

61. Mourtzis, D.; Fotia, S.; Vlachou, E.; Koutoupes, A. A Lean PSS Design and Evaluation Framework Supported by KPI Monitoring and Context Sensitivity Tools. Int. J. Adv. Manuf. Technol. 2018, 94, 1623–1637.

62. Ishaq Bhatti, M.; Awan, H.M.; Razaq, Z. The Key Performance Indicators (KPIs) and Their Impact on Overall Organizational Performance. Qual. Quant. 2014, 48, 3127–3143.

63. Varisco, M.; Deuse, J.; Johnsson, C.; Nöhring, F.; Schiraldi, M.; Woestmann, R. From Production Planning Flows to Manufacturing Operation Management KPIs: Linking ISO18828 & ISO22400 Standards. In Proceedings of the IFAC-PapersOnLine, Bergamo, Italy, 11 June 2018; Elsevier Science Direct: Amsterdam, The Netherlands, 2018; Volume 51, pp. 25–30.

64. Zhu, L.; Johnsson, C.; Varisco, M.; Schiraldi, M.M. Key Performance Indicators for Manufacturing Operations Management—Gap Analysis between Process Industrial Needs and ISO 22400 Standard. Procedia Manuf. 2018, 25, 82–88.