LIFE CYCLE PREDICTION ON HEAVY EQUIPMENT: A SYSTEMATIC LITERATURE REVIEW

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Abstract

The heavy equipment industry is one of the supporting commodities in the fields of infrastructure development, agricultural development, mineral mining and coal mining. the heavy equipment industry in Indonesia continues to grow by recording sales in 2020 of 5,393 units and an increase in 2021 of 14,706 units or an increase of 172% [1]. From the pre-survey that we conducted, 24% of owners did not know when the unit would decline and when to buy a new unit.

Purpose Main purpose this paper to make a literature review study to identify concepts and methods to predict the life cycle of heavy equipment in supporting the owner's decision.

Method To identify concepts and methods to predict the life cycle of heavy equipment Articles were reviewed using a systematic literature review with data from ScienceDirect.

Result Result in this study presents data analysis from 7811 articles on life cycle prediction that have been analyzed using vosviewer software as well as descriptive analysis from 427 relevant articles on heavy equipment life cycle.

Conclusion Conclusion of this study provides a perspective on research conducted on heavy equipment life cycle predictions which results in an important note that no one has discussed heavy equipment investment decision making by considering heavy equipment life cycle predictions comprehensively.

Keywords: Systematic Literature Review, Life Cycle Prediction, Heavy Equipment, Decision making, Investment.

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1. Introduction

Annual report 2021 PT United Tractors recorded sales of heavy equipment of 3,088 units with a target of 1,700 units in 2021. In terms of sectoral distribution, they are in the mining sector 53%, construction 25%, forestry 12% and agriculture 10%. Meanwhile, the target set for 2022 is 3,700 units [2]. The heavy equipment in mining and construction sector has been widely used in various parts of the world. the results of a survey on the use of heavy equipment in Indonesia stated that 24% of owners or users of heavy equipment did not know when the unit should decline and buy a new unit. This is what motivates researchers to make a prediction model for the life cycle of heavy equipment in the future.

Many models have been developed to measure various needs, such as heavy equipment cycle management decision making[3]. Research that is being developed such as life cycle assessment [4], Life Cycle Cost Assessment [5], Double Decline Method [6], Hybrid Life Cycle Assessment [7], Life Cycle Comparison [8], Life Cycle Modeling [9], Environmental Life Cycle [10], Social Life Cycle [11], Live Cycle Inventory [12] dan Life Phases Analysis [13]. However, research on new types of heavy equipment models is minimal so that stakeholders have doubts in selecting/buying new units. For this reason, this paper will explore existing literature to obtain an overview of the development of predictions for the life cycle of heavy equipment in the future based on various perspectives, both technological and economic.

This study uses systematic literature review to review heavy equipment life cycle articles. Descriptive analysis will help to see the uses and gaps of this literature review research. There are 2 research questions in this literature study as follows:

RQ.1 What are the literature reviews on life cycle prediction heavy equipment?
RQ.2 What are the research questions on life cycle prediction heavy equipment?
RQ.3 what are the main results of life cycle prediction heavy equipment?

To answer the first question, this article presents data obtained from Science Direct for descriptive analysis using the Vos Viewer software. To answer the second question, this article presents a review of articles that are relevant to the life cycle of heavy equipment so that gains and gaps can be obtained from the topic of predicting the life cycle of heavy equipment.

2. Methods

Systematic literature review is a research method for identifying, evaluating and interpreting all relevant research results related to certain research questions, certain topics or phenomena of concern. [14]. In principle, a systematic review is a research method that summarizes the results of primary research to present more comprehensive and balanced facts. Meanwhile, a non-systematic review (traditional review) is a review method (review) in which the method of collecting facts and synthesis techniques does not follow the standard methods as a systematic review. The difference between systematic review and traditional review is shown in Table 1. [14]. Literature was obtained from publications on sciencedirect.com where in previous research the number of publications with the keyword "multiphoton microscopy" was more than Scopus. While the level of paper precision is better than Google Scholar. and 9 of the top 10 journals are from ScienceDirect publications. [15]

Table 1. Comparation Literature review

No	Systematic Literature Review	Traditional Review
1	Using a scientific methodological approach to summarize research results	Does not use a scientific methodological approach (depending on the wishes of the author)
2	Engage research team	Done by a researcher (writer), usually by an expert
3	Using a research protocol	Did not use the research protocol
4	The search for research results and articles is carried out systematically	The search for evidence and articles was not carried out systematically
5	There are clear criteria for which articles will be included	There are no clear criteria regarding which articles will be included
6	Minimize bias	Contains biases
7	Can be replicated	Cannot be replicated
8	Synthesis of results: can be by meta-analysis or narrative (metasynthesis)	Synthesis: narratively

This paper conducts a literature review on the topic of life cycle prediction on heavy equipment considering that only the article is effectively a systematic literature review and it addresses topics relevant to life cycle prediction on heavy equipment, as will be detailed in the following sections.[16]

2.1 Research Protocol

The aims of this study were: i) to map the existing literature review on life cycle prediction, ii) to identify the research questions and objectives of this study, and iii) to discuss the contribution of this study to the literature. To achieve this goal, a research protocol was developed, summarized in Table 2. This protocol includes the steps of article collection, selection, and analysis.[16]

Table 2. Research Protocol

1. Research question	1.1 What are the literature reviews on life cycle prediction heavy equipment? 1.2 What are the research questions on life cycle prediction heavy equipment? 1.3 what are the main results of life cycle prediction heavy equipment?
2. Databases	Science Direct
3. Search criteria	3.1 Search terms : Life cycle prediction on heavy equipment 3.2 Years of Publication : 2018 to 2023 3.3 Language : English 3.4 Subject area : Engineering on vehicle and heavy equipment 3.5 Document Type(s) : Review 3.6 Date of Search : 1 December 2022
4. Screening	Keyword AND Year of Publication : 7.811 AND Language : 7.811 AND Subject area(s) : 1.426 AND Document type(s) : 427 Total After elimination of duplicate records : 427
5. Inclusion criteria	5.1 Article is a systematic literature review (method) 5.2 Article does address life cycle issues in heavy equipment (scope)
6. Selection	6.1 after reading the title, abstract and keyword 6.2 after first reading
7. Analysis	7.1 Descriptive analysis 7.2 Content Analysis (second reading)

2.2 Survey of Paper

Once the research question is defined (step 1 of 7), the next step is to survey the articles. Articles were submitted using Science Direct (step 2 of 7) on December 1, 2022. This selection, verified in many of the articles reviewed in this study, provides a wide coverage of the literature reviewed. The search was carried out using the keywords "Life cycle prediction", "Life cycle prediction on vehicle" and "Life cycle prediction on heavy equipment." Additionally, they are limited to publications from 2018 to 2022, English, and review type documents. The Engineering field is selected (step 3 of 7). That initial search on the Science Direct database turned up 7,811 articles. Until our total after limitation reached a sample of 427 articles (stage 4 of 7).

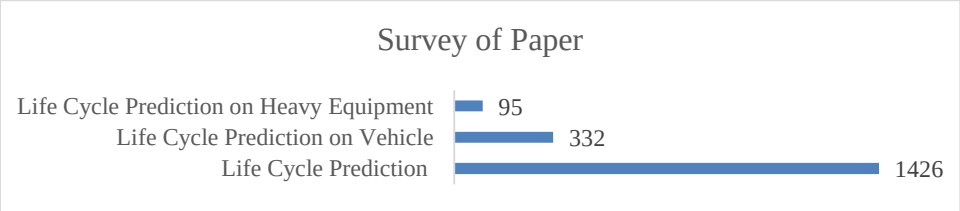

Figure 1. Survey of Paper

2.3 Selection of Paper

After determining the sample, the articles are sorted in descending order of the average number of citations per year and are included or excluded based on the criteria specified in Table 1 (step 5 of 7). This selection takes place in two stages of reading: i) title, abstract, and keywords and ii) first reading of the article. Two researchers conducted the analysis, which was scored (on a scale from 1 to 5) for each article, based on two criteria: method and scope. These scores were discussed and used to determine the final sample. An article is considered very suitable if it is effective in a Systematic Literature Review (SLR) and the topics discussed are related to the life cycle. From reading the abstract, we classify articles within the scope into three classes, as follows: (i) Life cycle assessment: articles that cover concepts and methods of assessing the lifetime value of a product, (ii) Life cycle cost: articles that discuss specifically cost of a product, (iii) life cycle prediction: an article that discusses innovation in predicting the life cycle of a product.

2.4 Second reading and annotations

Once the 95 articles were selected, we did a second read and created a spreadsheet with the metadata and notes of each article's main points. The records include: (1) author, (2) institution, (3) country, (4) title, (5) year, (6) journal, (7) field of journal, (8) author keywords, (9) number of citations, (10) citations per year, (11) abstract, (12) scope, (13) objective, (14) research question, and (15) main contribution. Finally, descriptive and content analyzes were performed, the results of which are presented in Sections 3 and 4.

3. Descriptive Analysis

To answer the first research question, two descriptive analyzes were used to be performed. The first considers the 95 selected review articles, and the second includes all references cited in the selected articles, totaling 427 articles.

3.1 Descriptive analysis of the review articles

427 selected review articles were written by 1129 researchers from 120 journals. Articles were collected by authors from 25 countries, dominated by the United Kingdom, a country where 48% of reviewers work. These review articles were published in 120 journals. Five journals account for 33% of all publications, namely: i) Energy with 24 papers (7%), ii) Applied Energy with 24 (7%), iii) Journal of Energy Storage with 23 papers (7%), iv) International Journal of Fatigue with 23 papers (7%), v) Journal of Power Sources with 16 papers (5%). Fig.4 shows the areas of journals that published articles analyzed, according to Scimago Journal and Country Rank. As expected, there is a greater concentration in engineering journals (58%). Another point that is analyzed is the keywords used by the author. We found a total of 921 keywords with two or more occurrences, of which the 5 most frequently used keywords were: lithium-ion battery 55 times (4%), remaining useful life 31 times (2%), machine learning 29 times (2%), fatigue life 16 times (1%), and life prediction 14 times (1%). The 427 analyzed review articles were published in the last 6 years (2018–2023), with the majority published in 2022 with 110 papers (33%). These articles are classified into three classes, as shown in Fig.1. First, there is an article that discusses the concept of Life cycle prediction in general (77%). Then came an article that specifically discussed the Life cycle prediction on vehicle (18%). Finally, several articles discuss Life cycle prediction on heavy equipment (5 %). Content analysis of the review articles in each category will be carried out in detail in Section 4. Furthermore, in Section 3.2, we present a bibliometric analysis of the references cited in the selected articles for a broader view of the research. Life cycle prediction on heavy equipment.

3.2 Descriptive analysis of the references cited

This section provides an analysis of the references cited in the 427 selected review articles, initially adding up to 1426 references. From this total, the following are excluded: duplicate references, references to websites, books, conference articles, and references that relate to other topics, such as articles on research methodology. After this filtering, the final sample has 427 original articles, which are analyzed below.

3.2.1 Publication per years

Figure. 3 presents the distribution of articles over time, showing an increasing trend in the number of articles published through 2022. The decrease from 2023 is because we used the references cited in the selected review articles, as mentioned in Section 3.1, published between 2018 and 2023.

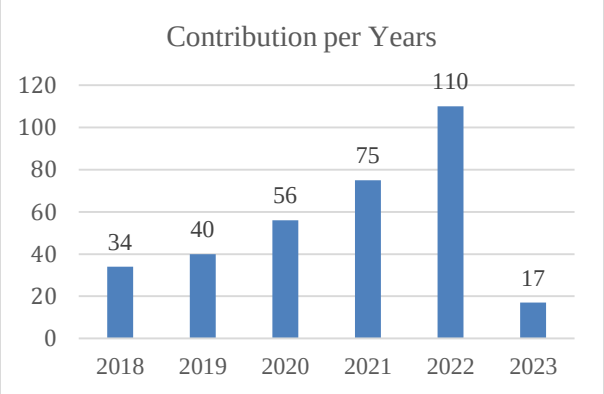

Figure 2. Contribution per Years

3.2.2 Contribution by Country

The original article gathered authors from 25 countries, with dominance for the United Kingdom, Netherlands, United State, Brazil, and China. Figure 4 shows that 95 % of the authors come from only 8 countries.

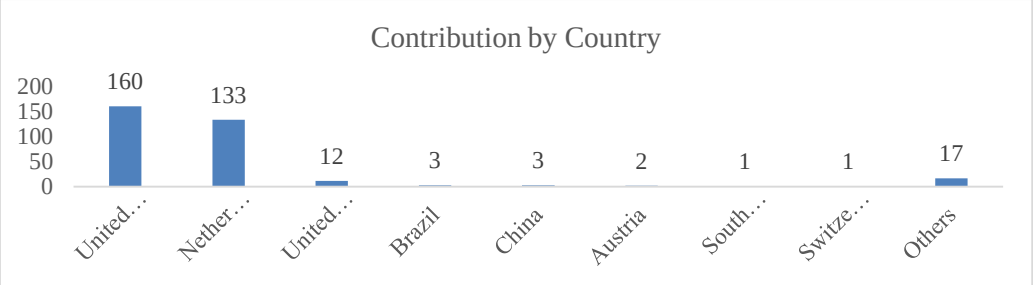

Figure 3. Contribution by Country

3.2.4 Contribution by journal

427 articles published in 120 different academic journals. Figure 5 shows the academic journals with the highest share of published articles in the sample.

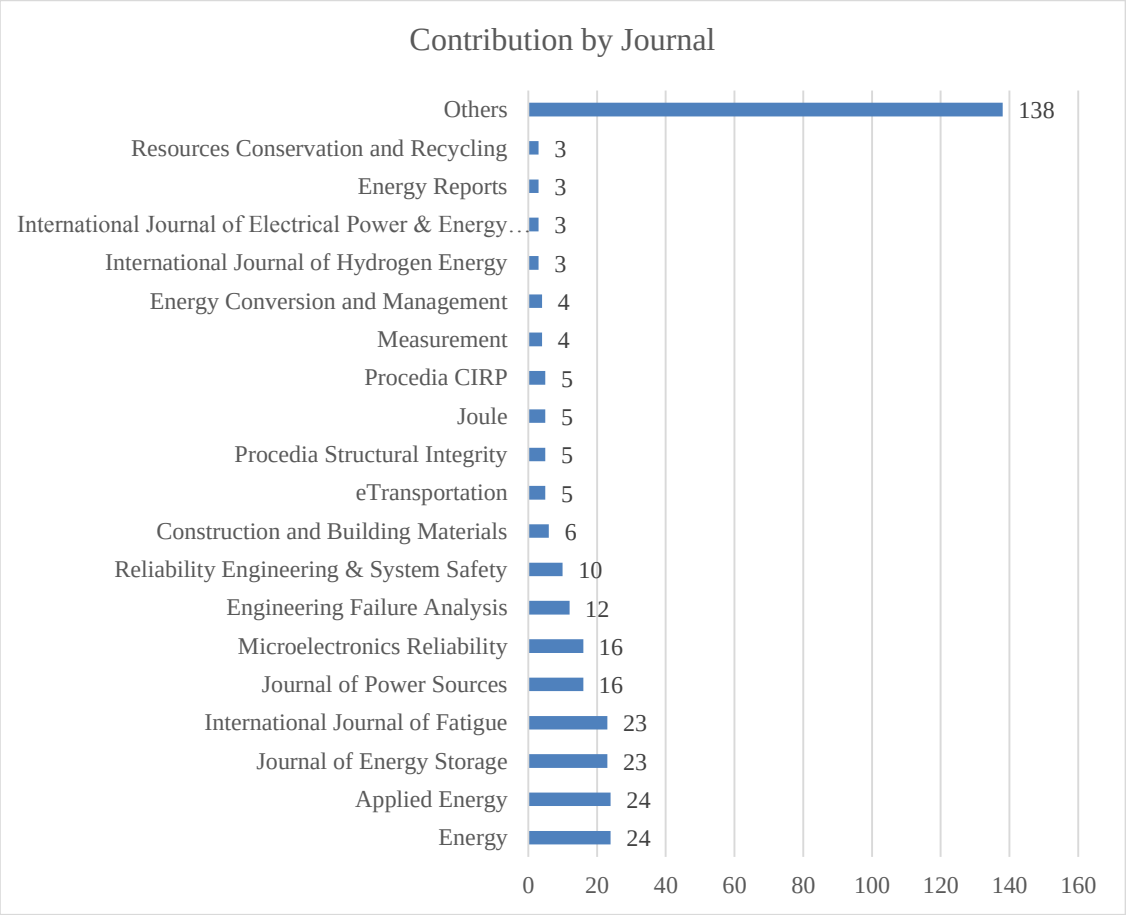

Figure 4. Contribution by Journal

3.2.5 High-contributing authors

Figure 6 shows the primary authors by number of publications and co-authorship networks. The circle size is related to the number of articles published, and the color is related to the interconnection between authors. The top 20 authors by number of publications are listed in Table 3.

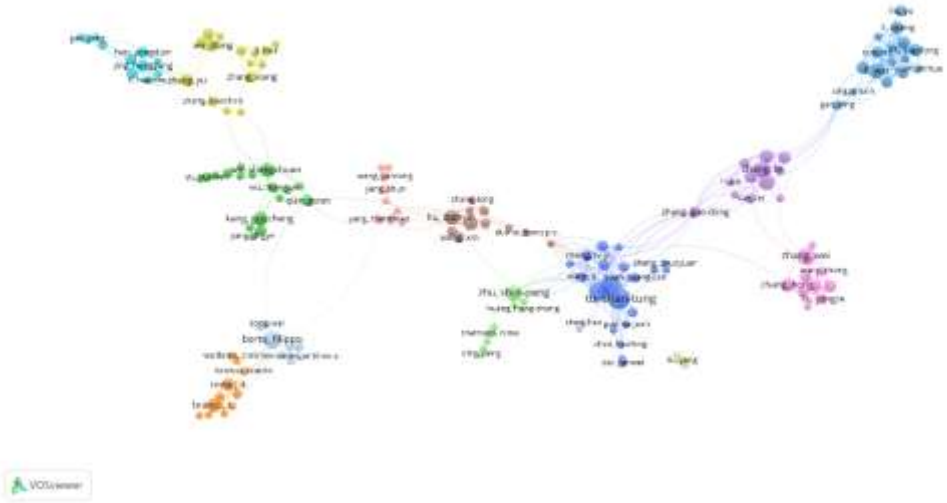

Figure 5. Contributing Author by VosViewer Software

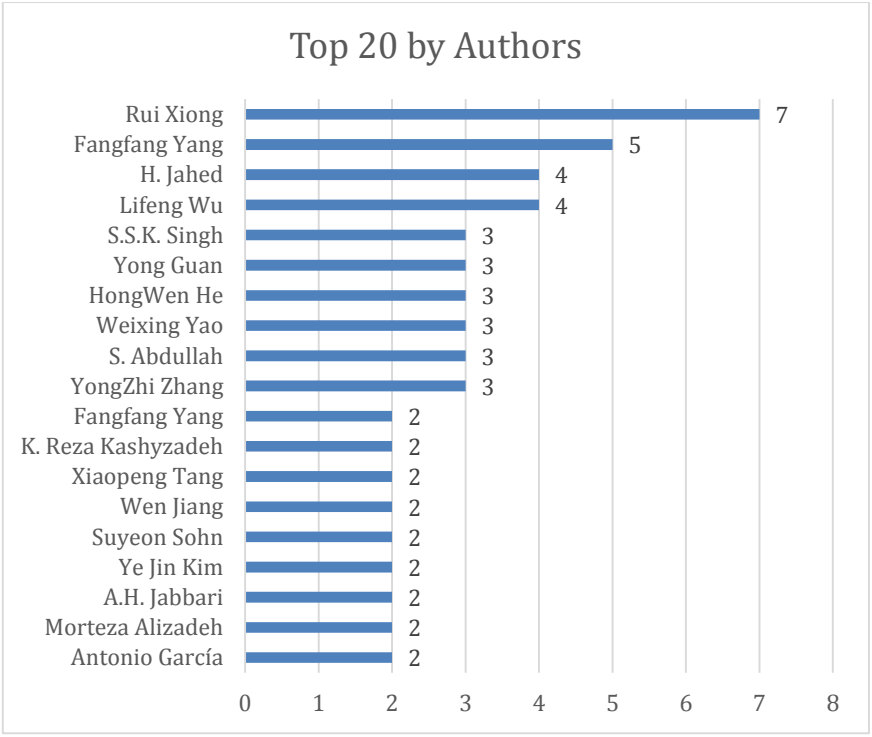

Figure 6. High-Contributing Authors

3.2.6 Keyword statistic

Figure 7 shows the 100 most frequently used words and their relationships. The size of the circle is related to the number of times these words are quoted, and the color is related to the interconnections between these words. The top ten keywords are: i) lithium-ion battery, ii) remaining useful life, iii) machine learning, iv) fatigue life, v) life prediction, vi) life cycle assessment, vii) state of health, viii) remaining useful life prediction, ix) fatigue, x) deep learning.

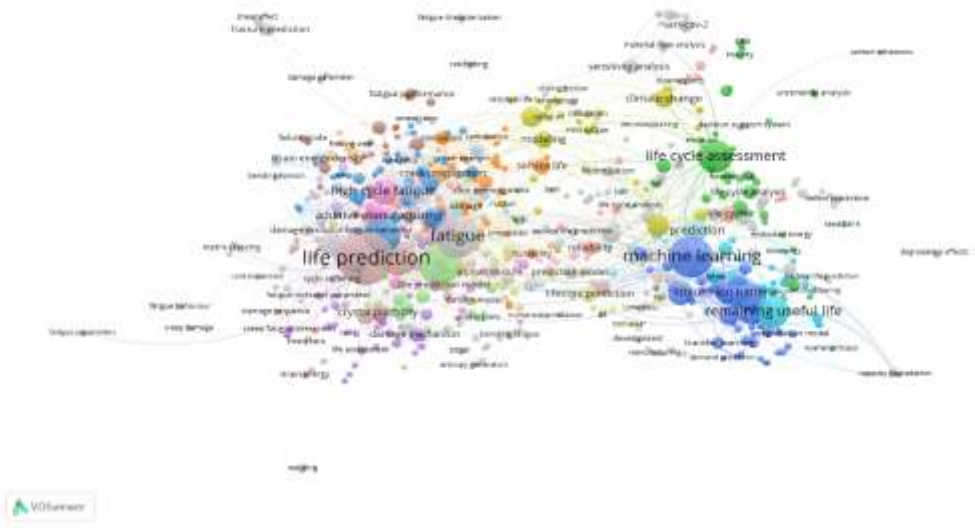

Figure 7. Keyword Analysis by VosViewer Software

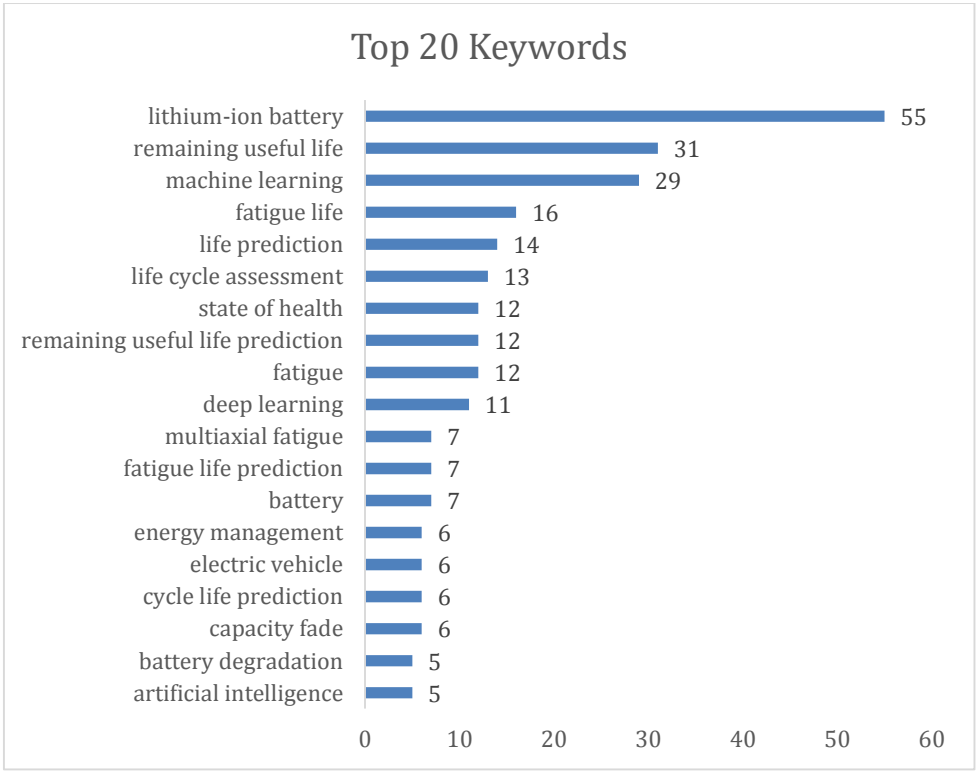

Figure 8. Top 20 Keywords

4. Content analysis

In the previous section, we presented a descriptive analysis of selected review articles (427 articles) and their references (1426 articles) to provide an overview of research on life cycle prediction. This section presents an analysis of the content of the article in three parts: i) Ownership cost, ii) Lifetime Value, and iii) Predictive life cycle on heavy equipment.

4.1 Ownership cost

In a sample of 95 review articles, 21 were classified in the first class, formed by articles that relate to the topic in a conceptual and general way. From reading the articles, with special attention to the research questions and objectives, we define the research questions as shown in Table 3.

Table 3. Research Question Section Ownership Cost

Topic	Research Question	Authors
Life Cycle Cost	What impact life cycle cost to multi-objective optimisations?	[17]
Life Cycle Cost	What impact life cycle cost to building renovation scenarios?	[18]
Life Cycle Cost	What impact Holistic analysis to prediction of life cycle cost?	[19]
Life Cycle Cost	What impact Incremental cost-benefit assessment to green building?	[20]
Life Cycle Cost	What impact Life Cycle Cost analysis to solar cell?	[21]
Life Cycle Cost	What impact Life Cycle Cost analysis to energy performance?	[22]
Life Cycle Cost	What impact prediction of exergy to life cycle cost performance?	[23]
Life Cycle Assessment	What impact Statistical proxy modelling for life cycle assessment?	[24]
Life Cycle Assessment	What impact comparative assessment to offshore wind installation?	[25]
Life Cycle Assessment	What impact life cycle assessment to predict energy and environmental?	[4], [26], [27], [28]
Life Cycle Assessment	What impact Life cycle assessment to infrastructure sustainability?	[29], [30]
Life Cycle Assessment	What impact LCA to Fatigue characteristics and environmental sustainability?	[31]
Life Cycle Assessment	What impact Life cycle assessment to emissions aircraft?	[32]
Life Cycle Assessment	What impact Data-driven approach to life cycle inventory?	[33], [34],[35]
Life Cycle Assessment	What impact Comparative life cycle assessment to life cycle vehicle?	[36], [37]

4.2 Lifetime value

In a sample of 95 review articles, 22 were classified in this first class, formed by articles that relate to the topic in a conceptual and general way. From reading the articles, with special attention to the research questions and objectives, we define the research questions as shown in Table 4 and the Research Objectives in Table 5.

Table 4. Research Question Section Lifetime Value

Topic	Research Question	Authors
Fatigue	What impact calculated rain flow damage to fatigue life prediction?	[38]
Fatigue	What impact self-compacting concreate to fatigue strength prediction?	[39]
Fatigue	What impact temperature dependence to Lifetime prediction fatigue crack?	[40]
Fatigue	What impact new strain-life model to predict the fatigue life?	[41], [42]
Fatigue	What impact Damage mechanism to predict the fatigue life?	[43]
Fatigue	What impact tempering temperature to low-cycle fatigue?	[44]
Fatigue	What impact load types identification to predict the fatigue life?	[45], [46]
Fatigue	What impact crystal plasticity model to predict fatigue life?	[47]
Fatigue	What impact machine learning to predict the fatigue life?	[48], [49],
Fatigue	What impact fully-reversed creep-fatigue to life prediction?	[50]
Maintenance	What impact hybrid predictive maintenance to life cycle?	[51]
Maintenance	What impact Machine learning to Predictive maintenance?	[52], [53]
Maintenance	What impact Optimizing a condition-based maintenance to decision making?	[54], [55]
Maintenance	What impact Machine learning models for predicting to heavy equipment?	[56]
Maintenance	What impact Deep digital to predictive maintenance?	[57]
Maintenance	What impact condition-based maintenance to residual life bearing?	[58], [52]

Table 5. Object research section lifetime value

Object Research	Author
Battery	[59], [60], [61], [62], [63], [64]
Material	[47], [48], [43], [46], [43], [44], [44], [65], [66], [38], [40], [67], [68], [69], [70], [46], [28]
Machine CNC	[51]
Solar Energy	[21], [71]
Optimizing process	[72]
Bioenergy	[73]
Software	[74]
Carbon Emissions	[75]
Vehicle	[36]
Fuel & Emissions	[33]
simulation mechanism	[57]
Bearing	[58]
Aircraft	[32]
Rubber	[31]
Biology	[76]
Economics	[77]
Concrete	[39]
Environment	[19]
ANFIS Model	[78]
Maintenance	[54], [52], [79]
Modelling	[80]
Building & Infrastructure	[26], [5], [81], [82], [29], [20], [17], [83], [84], [85]
bioenergy	[86]
Plastic	[37]
Mechanism	[55], [25], [87], [49], [53], [42]
Geology	[88]
motorcycle	[34]

4.3 Predictive life cycle on heavy equipment

In a sample of 95 review articles, 18 are classified in the first class, formed by articles that relate to the topic in a conceptual and general way. From reading the article, with special attention to the questions and research objectives, we define the research questions as in Table 6 and the methods used as in Table 7.

Table 6. Research question section life cycle prediction on heavy equipment

Topic	Research Question	Authors
Forecasting	What impact forecasting life cycle to performance battery?	[61]
Sustainability	What impact Carbon footprint prediction for sustainability?	[75]
Sustainability	What impact supply and value chain for sustainability?	[62]
Sustainability	What impact sustainability model for bioenergy system?	[73]
Environment	What impact environmental effects on the structural behaviour?	[66]
Life Cycle	What impact Life Cycle Optimization to Renewable Energy Systems?	[63]
Life Cycle	What impact analysis identifies changes to Meroplanktonic life cycle?	[76]
Life Cycle	What impact Firm life cycle and the disclosure of estimates to economics?	[77]
Neural network	What impact neural network to life prediction?	[67], [89], [85]

Neural network	What impact RUL prediction for lithium-ion batteries?	[90], [59]
Prediction	What impact statistical method to Predication of construction risk?	[80], [81], [70]
Prediction	What impact Predicting the lifetime of Lithium–Ion batteries?	[91]
Prediction	How make early-prediction models for cycle life?	[74]

Table 7. Summary method section life cycle prediction on heavy equipment

Method	Author
Neural Network RUL Prediction	[59], [23], [67], [52]
Life Cycle Cost Analysis	[92]
Manufacturing Framework	[22]
Sustainability Model	[73]
prognostics method	[90]
Machine Learning	[93]
Programming Python	[74]
Supply chain modelling	[62]
Process Modelling	[81], [29], [17], [25], [75], [32], [94], [95], [96], [97], [31]
Comparation Modelling	[98]
Deep learning model	[57]
Experimental	[76],[99] , [39], [51], [48], [46], [43], [58], [44], [65], [66], [38], [100], [69], [70], [49], [46], [42], [31]
Statistical	[101], [54], [26], [79], [102], [103]
Economic, environmental & Society model	[20]
artificial intelligence methods	[104]
Mathematical Modelling	[63], [47], [51], [48], [43], [46], [43], [33], [58], [44], [65], [66], [38], [40], [105], [89], [106], [69], [70], [49], [29], [17], [25], [54], [26]
modified decision tree	[56]
Modified historical simulation statistical methods (MHSS)	[107]
Risk management	[108]
Descriptive analysis	[53]
material flow analysis	[28]

5. Discussion

This section examines the three research questions formulated in the introduction to this article, based on the descriptive and content analyzes presented in Sections 3 and 4.

RQ.1 what are some literature reviews on lifecycle prediction heavy equipment?

The literature on life cycle prediction is relatively new and there are considerable volumes of publications in high-impact journals. This massive production also resulted in a large number of published review articles. In this study, we selected 95 review articles based on the following criteria: i) Ownership cost, ii) Lifetime Value, and iii) Predictive life cycle on heavy equipment. Reviews point to this production concentration in engineering journals, which is to be expected since this field is responsible for developing life cycle predictions on heavy equipment. The heavy equipment lifecycle prediction literature is still dominated by conceptual publications, followed by articles on enabling technology, and finally, articles on innovation. Many researchers develop new technologies by experimenting in laboratories, using prototypes and computer simulations, but practical application studies in companies are still rare.

RQ.2 what is the research question of life cycle prediction on heavy equipment?

The main research questions of the reviewed articles, presented in section 4, focused first on mapping the research situation of Ownership Cost, Lifetime Value and life cycle prediction. Then, as it is the basis of the life cycle, most of the articles deal with enabling technologies, analyzing their maturity and applications. In addition, although it is still an unexplored theme, we found work related to Ownership Cost, Lifetime Value and life cycle

prediction, with a greater concentration on Investment planning.

RQ.3 what are the main results of lifecycle prediction on heavy equipment?

According to the analysis conducted in Section 4, the main results are related to the life cycle prediction on heavy equipment research agenda. As already highlighted, due to recent themes, most of the research is still conceptual. Therefore, there is a need for practical research that validates the many postulates in the literature. We identified that life cycle prediction is characterized by a high degree of digitization. Heavy equipment cycle prediction in terms of investment decision making is very little discussed in the literature or even does not exist. The more accurate the predictions in the life cycle of heavy equipment, the greater the opportunity to benefit from heavy equipment investment decisions.

6. Conclusion

This article presents a literature review that systematically analyzes the review articles on life cycle prediction on heavy equipment published by Science Direct. We analyzed 95 review articles, presenting bibliometrics on author, institution, country, journal, year of publication, keywords, and research focus. We then analyzed the content of the review articles, which were divided into three categories: (i) ownership cost, (ii) lifetime value, and (iii) life cycle prediction. The results confirm that life cycle prediction on heavy equipment is an extensive and multidisciplinary subject, with works addressing conceptual, methodological, technological, and business issues. Overall, the review articles highlight the need for more applied research in organizations of all sizes and sectors. This study has several limitations inherent in method research. First, for the selection of articles, the basis of only two articles is considered science direct, and the selection is based on the evaluation of two researchers, which always requires some subjectivity. Nonetheless, we consider that the selected articles are well representative of the life cycle prediction on heavy equipment literature. Despite its limitations, we believe that this review represents the state of the current research life cycle prediction on heavy equipment well and suggests suggestions for future research based on the gaps identified. The analysis of the reviewed articles allows us to conclude that the business transformation in other important machines is just getting started.

Conflict of interest statement

The authors' declaration of competing interests acknowledges that they have no knowledge of competing financial interests or personal relationships that could appear to influence the work reported in this paper.

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