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Comparative Study On Human Reliability Methods Based On Bibliometrics

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Abstract

Human reliability Analysis (HRA) is a method for evaluating the reliability of human and the Human Error Probability (HEP). Currently, numerous human reliability analysis methods have been developed and applied. Numerous scholars and engineers have also effectively applied them to improve the efficiency, reliability, and safety of human operations in complex systems. However, facing many HRA methods, which one is should be firstly selected is an issue that needs to be analyzed. Therefore, this paper selects five commonly used human reliability analysis methods, namely CREAM, HEART, SLIM, SPAR-H, and THERP, by consulting China National Knowledge Infrastructure (CNKI) resources. Based on bibliometrics, a comparative analysis is conducted to quantitatively present the application fields and trends of each human reliability method. The result shows that, the selection order of the five HRA method. CREAM > HEART > THERP > SLIM > SPAR-H. It is clear that CREAM is a relatively high practical evaluation method. The ranking of human reliability methods obtained in this study can provide effective reference and guidance for the selection and application of future human reliability methods in various fields.

Keywords: HRA, bibliometrics, comparison study

1. Introduction

The research on human reliability began with military aviation electronic devices. At the end of World War II, half of the electronic devices used by the United States in its operations against Japan were transported to the battlefield and could not be used normally, seriously affecting operations. After the war, the United States was the first to conduct systematic research on reliability as a discipline. In 1952, Herman Williams and Purdy Meigs first evaluated the impact of human error on mechanical reliability in risk analysis of complex equipment systems. The study found that humans had a higher error rate on the ground than in the air(Ma et al., 2023),with a probability of up to 0.02. According to statistics, 50%-90% is related to human reliability, and the proportion of accidents directly or indirectly caused by human reliability is as high as 70%-90% (Li et al., 2011). Therefore, how to consider the impact of human error on accident risk to prevent accidents in advance has become an urgent issue that needs to be addressed. In this context, human reliability analysis has gradually developed into a research field. The human reliability analysis method as an important reliability assessment method, can support a complete assessment of system safety and reliability. So far, dozens of human reliability analysis methods have been developed. Different methods have different advantages and characteristics. However, there is currently no unified view on the selection of human reliability methods for practical engineering problems. Inconsistent viewpoints can lead to low consistency in evaluation conclusions and errors in method selection by users.

Given the above analysis, the paper will conduct a comparative analysis of human reliability methods in order to provide support for users in selecting reasonable and effective methods. According to bibliometric research, there is a positive correlation between papers in a certain field and the development of the discipline. The changes in the number and structure of literature reflect the current research status and development trends in this field (Yang et al., 2017).And it can be used for bibliometric analysis and prediction of the current research status and development trends in a certain field. At present, some scholars at home and abroad have reviewed

and analyzed the research progress in the field of human reliability. For example, Read(Read et al.,2021), Sun Linhui (Sun et al., 2022), and others have used literature analysis to summarize the main viewpoints on human error. However, traditional literature review methods are used to analyze papers, which makes it difficult to present the analysis process and conclusions through quantitative and visual means(Naveen et al., 2021). Therefore, based on the theory of scientific econometric methods, this paper will select five commonly used human reliability methods (THERP, HEART, SPAR-H, CREAM, SLIM) for analysis. This paper uses the most commonly used CNKI as a data source for fuzzy retrieval, and exports relevant articles for visual analysis and processing. The paper will use the professional bibliometric analysis software Citespace to analyze and visualize literature data. By Citespace software,_the literature indicators, research levels, publication trends, academic value, disciplinary bias, and author distribution data of the five methods were analyzed and visualized. The ranking of each method in various aspects was processed and ranked, and the comprehensive ranking of each method was ultimately obtained. This paper is arranged as follows: Section 2 introduces the specific steps for conducting bibliometric analysis; Section 3 constructs core data forms for five human reliability methods and assigns ranking values. Section 4 summarizes the analysis results and forms conclusions to support the effective selection of human reliability analysis methods.

2. Research methodology

In this study, there are five main steps: determining the research purpose and scope, collecting data, conducting bibliometric analysis, and reporting the results. In this section, the review process of bibliometrics for this study is elaborated in detail. Figure1 summarizes the paper in five steps.

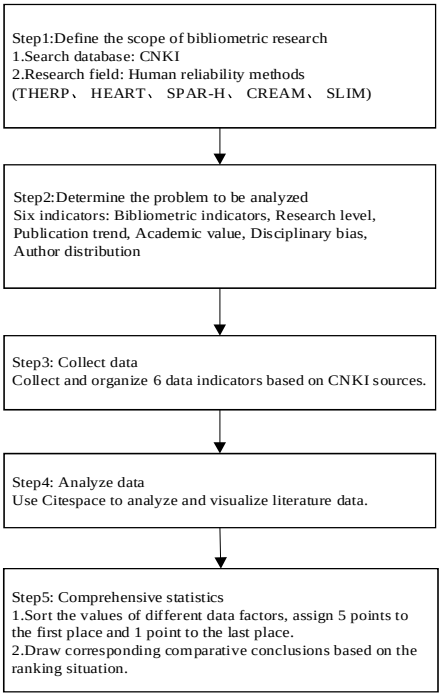

Fig.1. The study analyzes the process.

2.1. Defining the scope of bibliometric research

CNKI is currently the largest knowledge platform and academic literature online publisher in China, which collects most of China's academic literature resources (Jing et al., 2023). It can conduct comprehensive searches for various papers, conferences, foreign literature, etc. Therefore, this paper selects CNKI as the human reliability analysis platform and selects human reliability methods such as THERP, HEART, SPAR-H, CREAM, SLIM.

2.2. Identify research questions

Using principal component analysis to determine the categories of quantitative data to be collected, multiple indicators are transformed into several comprehensive indicators (i.e. principal components), including six comprehensive indicators such as publication time, discipline, journal, distribution of research institutions, funding status, and research level. Based on these indicators, bibliometric analysis is conducted on five commonly used human factor reliability methods.

2.3. Collecting data

After determining the human factor development focus of CNKI sources, five commonly used human factor reliability analysis were identified as keywords. A literature review of the research field was found. Collect and organize relevant data for six indicators within the CNKI source based on the level of literature research, Publication year interval of literature in the entire field, Distribution of main and secondary themes, Statistical sources, Distribution of all disciplines, Overlap of research fields, and Correlation of keywords.

2.4. Analyze data

Using Citespace (Kun et al., 2023) to analyze keywords in domestic human reliability methods and the author collaboration network function in visual analysis tools, draw author distribution and collaboration network diagram, complete data visualization analysis, and reveal research hotspots and development trends in the field of human reliability.

2.5. Draw a conclusion

According to the ranking of the six different data factors, the first place is assigned a score of 5, and the last place is assigned a score of 1. Corresponding comparative analysis conclusions are drawn based on the ranking situation.

3. Bibliometric analysis

In this section, a comparative analysis is conducted on five human reliability methods based on the level of literature research, publication year interval of literature in the entire field, distribution of main and secondary themes, statistical sources, resources, institutions, funds, distribution of all disciplines, overlap of research fields, and correlation of keywords. Translate the above data results into six comprehensive indicators, construct core data forms for human reliability analysis. Meanwhile, six indicators were ranked and assigned values. The final analysis results were summarized to form conclusions to support the effective selection of human reliability analysis.

3.1. CREAM

The statistical results of various elements that can be retrieved by CREAM within the CNKI source are as follows:

First, using CREAM as the main keyword and selecting human factors and human reliability as screening items, the number of literatures on technology research, engineering research, engineering and project management at domestic and foreign research levels in CNKI sources was counted. The statistical results showed that technology research is currently the mainstream research level.

Second, according to the statistics of literature in the entire field, it is known that the earliest publication of CNKI sources was in 1994, with 2016 being the year with the most research publications.

Third, combining the main and secondary themes can display the main themes and research directions of the literature. According to statistical results, the literature with CPC as the theme has the highest number of articles.

Fourth, by collect undergraduate graduation designs and doctoral theses from prestigious universities for statistical purposes. Only the portion of funds at or above the city or provincial level will be collected for statistical purposes (Francesco et al., 2021). The results indicate that the publishing institutions and funding sources of the CREAM method are mostly from doctoral theses funded by the National Natural Science Foundation of China.

Fifth, collect the distribution of all disciplines within the discipline distribution map, but only assign values to the top five disciplines for comprehensive evaluation. According to the survey, the top five disciplines involved in the CREAM method are safety science and disaster prevention, aerospace science and engineering, power industry, oil and gas industry, and nuclear science and technology.

Sixth, the author distribution map and keyword index represent the degree of overlap in the research field and the degree of relevance of keywords, respectively. The connections between different fields and keywords can support the statistical viewpoints mentioned earlier, as shown in a real and effective relationship diagram (Patriarca et al.,2020). Figure 2 shows that the research field of CREAM is relatively broad as shown in the figure, and the distribution of authors is more scattered, indicating that the theoretical directions of researchers are more diverse.

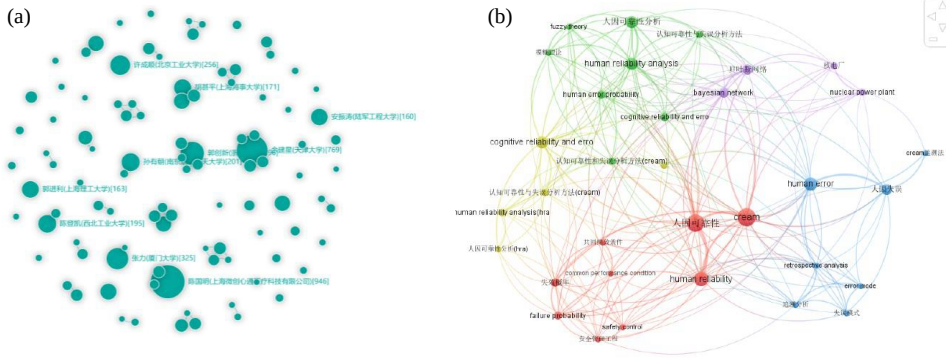

Fig.2. (a) Author distribution and collaboration network diagram; (b) Keyword mutual index graph.

3.2. HEART

The statistical results of each element that HEART can retrieve within the CNKI source are as follows:

First, using HEART as the main keyword, the statistical results show that technical research is currently the mainstream research level.

Second, according to the statistics of literature in the entire field, it is known that the earliest publication of CNKI sources was in 2004, with 2020 being the year with the most research publications.

Third, the merger of main and secondary themes can indicate that the research directions of the literature are human factor analysis, HRA, and nuclear power plants.

Fourth, the sources are mainly key research projects from various universities, with strong expertise in the field.

Fifth, the top five disciplines are safety science and disaster prevention, power industry, aerospace science and engineering, fuel chemical engineering, and nuclear science and technology.

Sixth, Figure 3 shows that the keyword mutual indexing range of HEART is relatively small, and the distribution of authors is concentrated, indicating a relatively small research scope.

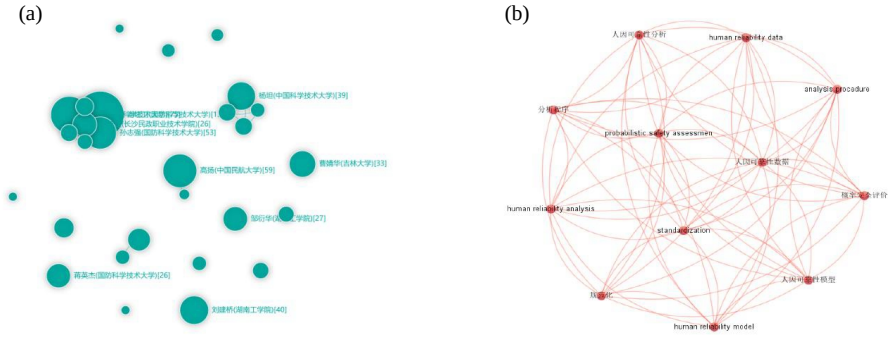

Fig.3. (a) Author distribution and collaboration network diagram; (b) Keyword mutual index graph.

3.3. SLIM

The statistical results of each element that SLIM can retrieve within the CNKI source are as follows:

First, using SLIM as the main keyword, the statistical results show that engineering research is currently the mainstream research level. Second, the earliest publication of CNKI sources was in 2009, with 2011 being the year with the most research publications. Third, the combination of main and secondary themes can display Human Error Probability as the main theme and research direction of the literature. Fourth, most of the publishing institutions come from world-class universities and have received significant funding from the National Natural Science Foundation of China. Most of the sources are national level journals with high academic value. Fifth, the top five disciplines are safety science and disaster prevention, aerospace science and engineering, road and waterway transportation and railway transportation, power industry, and automotive industry.Sixth, Figure 4 shows that the keyword mutual indexing range of HEART is relatively small, and the distribution of authors is concentrated, indicating a relatively small research scope.

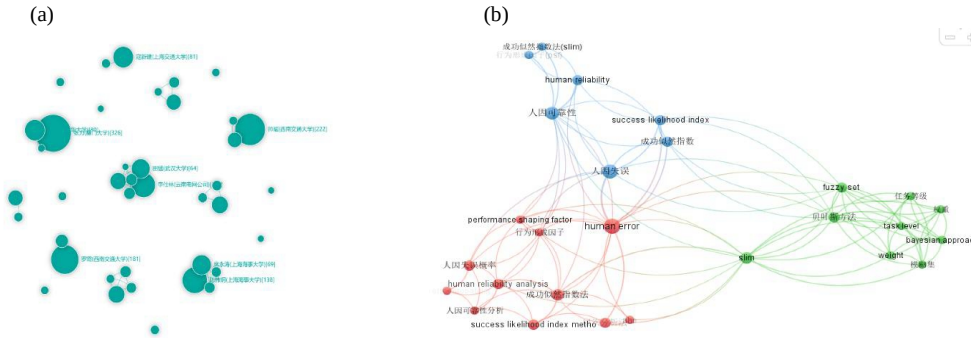

Fig.4. (a) Author distribution and collaboration network diagram; (b) Keyword mutual index graph.

3.4. SPAR-H

The statistical results of each element that SPAR-H can retrieve within the CNKI source are as follows:

First, using SPAR-H as the main keyword, the statistical results show that technical research is currently the mainstream research level. Second, the earliest time CNKI published articles was in 2014, with 2023 being the year with the most research articles. Third, the merger of main and secondary themes can display that the main themes and research directions of the literature are standardized nuclear power plant risk analysis, human error probability, operators, PSF, and task complexity. Fourth, SPAR-H is used in small-scale professional fields, and at the academic level, it is mainly limited to professional projects and personnel research, with academic content supporting each other. Fifth, there are only four types of disciplines involved, including nuclear science and technology, power industry, safety science and disaster prevention, and organic chemical engineering.Sixth, Figure 5 shows that the mutual indexing range of keywords is sparse and obvious, and the distribution of authors is also concentrated due to their professionalism.

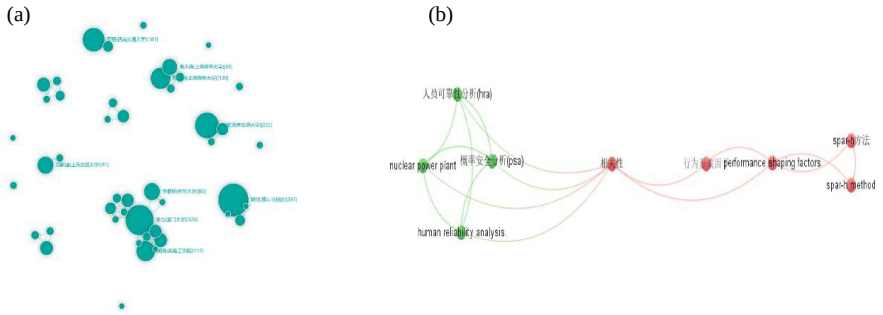

Fig.5. (a) Author distribution and collaboration network diagram; (b) Keyword mutual index graph.

3.5. THERP

The statistical results of each element that THERP can retrieve within the CNKI source are as follows:

First, using THERP as the main keyword, the statistical results show that technical research is currently the mainstream research level. Second, the earliest time CNKI published articles was in 2000, with 2007 being the year with the most research publications. Third, the merger of main and secondary themes can display that the main theme and research direction of the literature are human reliability analysis. Fourth, this method is often used in combination with other methods in journals and master's theses. There are many technical research projects funded by the Natural Science Foundation of China that use this method. Overall, it has high compatibility and academic value due to its relatively high compatibility. Fifth, the top five disciplines in the rankings are nuclear science and technology, safety science and disaster prevention, power industry, railway transportation, and mathematics. Sixth, Figure 6 shows that the keywords have a relatively large range of mutual indexes and a sparse relationship. The distribution of authors presents a situation of staggered concentration. The research scope is relatively large with more overlapping academic viewpoints and the research situation is more comprehensive.

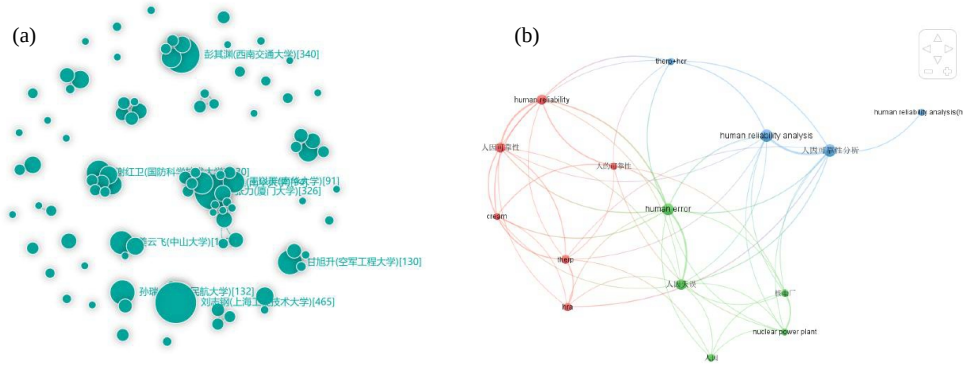

Fig.6. (a) Author distribution and collaboration network diagram; (b) Keyword mutual index graph.

4. Discussion

Sort 6 different types of data factors statistically and allocate them in descending order of ranking. For example, the evaluation method for the first place is 5 points, while the remaining scores decrease in order.

4.1. Literature indicator analysis

The main statistical factors in the literature review should be determined based on the characteristics of the research field and research question. Rankings and values should be assigned according to the analysis results. The assigned values are shown in Table 1.

Table 1. Analysis and assignment of literature indicators.

Method	CREAM	HEART	SLIM	SPAR-H	THERP
Number of references	5	3	2	1	4
Total number of references	5	3	2	1	4
Total number of arguments	5	3	2	1	4
Total downloads	5	3	2	1	4
Average number of references per article	1	5	3	2	4
Average number of citations per article	3	5	2	1	4
Average downloads per article	2	5	3	1	4
Download citation ratio	5	5	4	3	5
Total score	36	35	22	12	37
Ranking assignment	5	3	2	1	4

4.2. Research hierarchy analysis

The research level can be classified into technical research, engineering research, engineering and project management, development/management research, and application research. Different research levels and application fields also vary accordingly. Technical research, development/management research often focus on theoretical methods; Engineering research, engineering and project management, and application research focus on practical application effectiveness with solid models and large-scale experimental data as supporting evidence. The statistical results are shown in Table 2.

Table 2. Research analytic hierarchy process assignment.

Method	CREAM	HEART	SLIM	SPAR-H	THERP
technical study	34	9	3	2	11
engineering research	28	1	3	0	2
Engineering and Project Management	6	0	1	0	5
Development/Management Research	7	0	1	0	2
application research	12	2	1	1	2
Total score	92	15	14	4	26
Ranking assignment	5	3	2	1	4

4.3. Posting trend analysis

The trend of publication can be confirmed based on the upper limit and fluctuation trend of the visual chart as follows: CREAM>HEART>SLIM>SPAR-H>THERP.

4.4. Academic value analysis

Statistical analysis of factors related to academic value, including publishing institutions being world-class university, funding sources from provincial-level or above funding, articles coming from journals, and resources from journals or doctoral programs. The statistical results are shown in Table 3.

Table 3. Academic value analysis assignment

Method/%	CREAM	HEART	SLIM	SPAR-H	THERP
mechanism	1	5	4	2	3
capital	2	1	3	5	4
source	1	5	4	3	2
resource	1	5	4	3	2
Total score	6	21	19	16	13
Ranking assignment	1	5	4	3	2

4.5. Discipline bias analysis

The discipline is generally divided into 9 categories, numbered as ① Safety Science and Disaster Prevention and Control ② Electric Power Industry ③ Aerospace Science and Engineering ④ Oil and Natural Gas Chemical Industry Fuel Direction ⑤ Nuclear Science and Technology ⑥ Transportation Industry ⑦ Automotive Industry ⑧ Mathematics ⑨ Organic Chemical Industry. The analysis and assignment results are shown in Table 4.

Table 4. Subject bias analysis assignment

Method/Ranking %	1	2	3	4	5
CREAM	① 20.4	③ 11.6	② 9.6	④ 7.2	⑤ 6.4
HEART	① 13.79	② 13.79	③ 10.34	④ 6.9	⑤ 6.9
SLIM	⑥ 21.42	① 17.86	③ 10.71	② 7.14	⑦ 7.14
SPAR-H	⑤ 40	② 40	① 10	⑨ 10	/ /
THERP	⑤ 22.55	① 17.65	② 14.71	⑥ 7.84	⑧ 4.9

The ranking of statistical results is as follows:

①：CREAM＞HEART＞SLIM＞THERP＞SPAR-H
②：SPAR-H＞HEART＞THERP＞CREAM＞SLIM
③：CREAM＞SLIM＞HEART
④：CREAM＞HEART
⑤：SPAR-H＞THERP＞HEART＞CREAM
⑥：SLIM＞THERP
⑦：SLIM
⑧：THERP
⑨：SPAR-H
The comprehensive ranking of subject involvement is CREAM＞HEART＞THERP＞SPAR-H＞SLIM.

4.6. Author distribution

There is a situation of joint discussion or teaching by teachers and students in the same college with theoretical research experts. The research scope ranking of human reliability methods is determined by visualizing the theoretical overlap of researchers and the distribution of colleges(Lin et al.,2021). Colleges with more involvement and higher relevance of viewpoints have a relatively high frequency of use, resulting in a relatively high ranking. The ranking is CREAM>THERP>SPAR-H>HEART>SLIM.

4.7. Comprehensive evaluation

The paper conducts comprehensive statistics and sorting on different types of element data, and evaluates them comprehensively based on the statistical results of the six indicators mentioned above. The corresponding statistical results are shown in Table 5.

Table 5. Comprehensive ranking

Method/%	CREAM	HEART	SLIM	SPAR-H	THERP
Literature indicators	5	3	2	1	4
Research level	5	3	2	1	4
Posting Trends	5	4	3	2	1
Academic value	1	5	4	3	2
Subject bias	5	4	1	2	3
Author distribution	5	2	1	3	4
Total score	26	21	13	12	18

The comprehensive evaluation shows that CREAM>HEART>THERP>SLIM>SPAR-H, indicating that CREAM is a relatively practical evaluation method. Statistics show that in terms of disciplines, the CREAM method is mostly suitable for safety science and disaster prevention, aerospace science and engineering, petroleum and natural gas and other chemical industry fuel directions, with high practicality in theoretical development and practical application. The HEART method is generally applicable in the same direction as CREAM, but it is not as widely used as CREAM and has a more practical theoretical development level. The THERP method is mostly suitable for safety science and disaster prevention, power industry, nuclear science and technology, and mathematics. It has a relatively low degree of standalone use and is basically complementary to other methods. SLIM and SPAR-H methods are also used in the fields of power industry, nuclear science and technology, automotive industry, and organic chemical engineering. However, SLIM has a significant impact on human factors, and SPAR-H is derived from risk analysis of nuclear power plants, so its usage ranks lower among the five methods.

5. Conclusion

With the development of science and technology, the reliability of equipment in human-machine-environment systems has been basically improved. Therefore, conducting research on human reliability will play an important role in the reliability of the entire system. In this paper, we used statistical and bibliometric analysis methods to fully evaluate and compare the practicality of five human reliability methods. The study found that CREAM

ranked first in literature review, research level, publication trend, disciplinary bias, and author distribution, making it a relatively practical evaluation method. Therefore, in this paper, the ranking of human reliability methods will provide important reference and guidance for the future application of human reliability methods in various fields. Meanwhile, with the gradual popularization of new technologies such as artificial intelligence and big data, the future application prospects of human reliability methods in more fields will also be broader. This paper conducts a detailed comparative study to help practitioners and scholars choose the most suitable method.

Acknowledgements

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