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A STUDY IN THE FIELD OF PROBABILITY: A BIBLIOMETRIC APPLICATION

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ABSTRACT

Although the search information is the foundation of knowledge, a large amount of information without treatment and classification can make it harder to find instead of easier. Several tools are used to prevent this problem. This paper uses a bibliometric approach to the analysis of books published in the last few decades related to the subject of probability, applied probability and probability problems. First, we present historical aspects and rules of a bibliometrics, then a practical application. Results indicated a decreasing interest in the topic in the last few years and a very poor contribution of Brazil to the subject, and, at the same time, the relevance of bibliometrics as an auxiliary tool for the research in the area of Mathematics and probability.

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INTRODUCTION

The search for information is an important aspect of the evolution of knowledge. According to Marques [1] bibliometric studies are becoming increasingly relevant as a source of information for numerous areas of research, enabling the diversity of knowledge and contributing to the evolution of technology and science. There is no knowledge without the spread of information. The current context of research and development generates a large volume of new texts and publications every day. While on the one hand it can be argued that the more information, the more knowledge, on the other hand, this large volume of information without the proper treatment and classification makes it difficult to navigate in the search for the results of academic research [2]. In this context, it is important to have tools that facilitate the aggregation of this information, providing an overview of the subjects studied. Bibliometrics presents itself as a set of methods and techniques for the development and use of several of these tools. The word bibliometrics comes from the Greek *biblion*, which means book, and from the Greek *metrikos*, which means measurement. The term was proposed by Alan Pritchard in the 1960s, as a substitute for "statistical bibliography", previously used, and can be understood as the application of mathematical and statistical methods for the analysis of books and other works of written communication [3]. Bibliometric research is based on quantitative and statistical methods. It was perfected in the 21st century by numerous authors such as Bradford, Lotka, Zipf, Price,

among others. Regarding the definition of bibliometrics, the following can also be added: "[...] an extensive area of the Science of Information covering all studies, seeking to quantify the processes of written communication and applying specific numerical methods" [4]. The evolution of bibliometrics has directly followed the evolution of the Internet, enabling the creation of computer programs aimed at bibliometric techniques. Bibliometrics has been gaining more popularity over time and higher quality and quantity of published studies, which significantly helps understanding the intellectual performance of researchers [3]. Thus, bibliometrics can be used as an important step in mapping the literature to verify the relevance of a particular topic. This article presents the results of a bibliometric analysis of the literature on probability, applied probability and probability exercises. The analysis was performed using the R project [5] software, and the information regarding the selected publications was taken from the Scopus database, using the terms "probability", "applied probability" and "probability problems", achieving at first an overview of the theme and reaching a higher level of expertise at each stage. The structure of this article presents in Section 2 the theoretical framework that supports the most relevant concepts related to bibliometric analysis. Section 3 contains the results and analyses of the search associated with probability. Similarly, Section 4 provides the results of the bibliometric analysis associated with applied probability. Section 5 provides the results regarding probability problems, and finally, in Section 6, the conclusion of the work.

THEORETICAL REFERENCE

In this topic the theoretical base of this work will be presented to situate readers on the approached subject.

Bibliometric studies: Bibliometric studies started a long time ago. According to Faria [6] such studies have existed since 1929. Schmidiaerapud Faria *et al* [6] points out that the first bibliometric research was published in 1917. However, it was in the beginning of 1960 that Pritchard proposed the term bibliometrics, defining it as the application of statistical and mathematical methods in the analysis of literary works [3]. In order to complement what had been exposed, it is worth mentioning that Ziman, cited by Barreira[7], states that the value of a scientific research lies not only in exposing a certain theme, but also in how this work will influence future researchers. In the field of science, bibliometric studies focus on searching and examining the production of articles on a given theme. The analysis consists in mapping the academic communities, identifying the networks of researchers and their respective motivations for their areas of interest [9]. According to Vanti *apud* Pimenta [2] bibliometrics is the use of quantitative methods to analyze the evolution and processes in scientific production, i.e., it is a tool that makes it possible to monitor the growth and development of different fields of science. This type of research aims to create indicators, seeking to summarize the most prolific institutions and authors of each theme, as well as the most cited academics and networks of co-authorships [9]. According to Araújo [4] the first use of the reference counting method, which is currently one of the main techniques to develop a bibliometric study, was carried out in 1927 by Gross and Gross, followed by Allan in 1929. As a result, the methodological techniques were improved and, in 1960, with the great technological advance of computing data, it was possible to create the Science Citation Index (SCI) by Eugene Garfield [10], which is the first index of scientific citations. Since then, information science and its technologies support and enable the development of new methodologies for bibliometric research, stressing that the researcher Eugene Garfield [10] also formulated the concept of Impact Factor, calculated through the number of citations received from each author and the degree of relevance of its publications [2].

Bibliometrics in Brazil: According to Medeiros [11], the first study on the subject was published in Brazil in 1972. Since then, bibliometric production in the country has followed the world trend, with a drop in the 1980s and a resumption in the 1990s with the widespread use of personal computers and technological innovation. Mueller, quoted by Medeiros [11], states that the main area of knowledge using bibliometric techniques was Science of Information. This was confirmed by Rostirolla*apud* Medeiros [11] when he published a study on the presence of bibliometrics in Brazilian theses, 29% of which were in the field of Information Science. In addition, other Brazilian bibliometric studies include the areas of Health, Psychology, Architecture, Urbanism and Landscaping, Archivology, Communication, Education, Geosciences, Computer Science, Engineering, Scientific and Technological Policy and Nuclear Technology. It is interesting to note that Probability or even applied Mathematics are not among the areas mentioned. This is one of the motivating factors for this essay, since Bibliometrics has a connection with Probability and Mathematics.

Bibliometric Rules: As a quantitative and statistical methodology, whose objective is the measurement of the production of scientific knowledge, the study of bibliometrics is in constant evolution, due to the growing need to evaluate the dissemination and production measurement of scientific studies. According to Guedes and Borschiver [12] this methodology is based on the elaboration and application of three Empirical Laws known as: Authors' Productivity Law (LOTKA, 1926); Journal Dispersion Law (Bradford, 1934); and the Law of Words Frequency (ZIPF, 1949). Bradford's Law, also known as the Dispersion Law, relates the dispersion of production, allowing the establishment of a nucleus assisting in the development of policies for the acquisition and disposal of journals on specific

topics [12] [13]. Lotka's Law, also called Reverse Square Law, is responsible for studying the productivity of each author, by identifying the frequency of their publications. This law was created in 1926 after a study on the productivity of scientists [13] [14]. Zipf's Law or Minimum Effort is one that relates the number of entries of a word in a text, that is, measures and generates a list of high and low frequency terms in journals [12]. This law was created in 1949, aiming to describe the relation and order of words in a text [15]. That said, the rigor of these studies is characterized by the fulfillment of such premises, which govern each of the methods. According to Pimenta (2017) [10], for the bibliometric case, it is expected that the authors comply with the Laws that govern these studies, then following five steps of the integrative literature review:

- Step 1 - Elaborate a research protocol.
- Step 2 - Identify the most relevant studies in the field.
- Step 3 - Assess the quality standards of surveyed studies.
- Step 4 - Synthesize gathered data.
- Step 5 - Integrate final results.

In the Brazilian research field, there is the need and challenge of implementing the above-mentioned methods, using tools that may assist in the task of systematizing literature. The following sections will present bibliographic studies on probability, applied probability and on probability exercises, using the English terms.

Probability: This bibliometric analysis was started using probability as a keyword, and the search focused on books. In the table "Main Information - Probability" (Table 1) the gathered information may be observed. The selected time frame was the period from 1984 to 2020. We identified 174 published books containing the above word in the title, and 272 authors. The research presents 108 single-authored documents, an average of 0.64 books per author, 1.56 authors per book and 1.68 co-authors per book.

Table 1. Main information – Probability

Description	Results
Time frame	1984-2019
Documents	174
Average number of quotes per document	39.18
Average quotes per year per document	4.665
Associated keywords (ID)	413
Keywords (DE)	98
Authors	272
Author entries	293
Authors of books with single authorship	101
Authors of books with several authors	171
Books with single authorship	108
Books with several authors	66
Books per author	0.064
Authors per book	1.56
Co-authors per book	1.68
Collaboration index	2.59

Source: Own elaboration based on analyzed data

The publishing of books focused on the topic of probability was initiated in 1984 with 2 titles, followed by 5 titles in 1985. After this period, a new book appeared only in 1993, that is, 8 years later. The year 2012 presented the maximum of publications per year, reaching a number of 19 books. From 2016 there is a sharp drop and quickly comes to only 3 publications in 2019 (Figure 1).

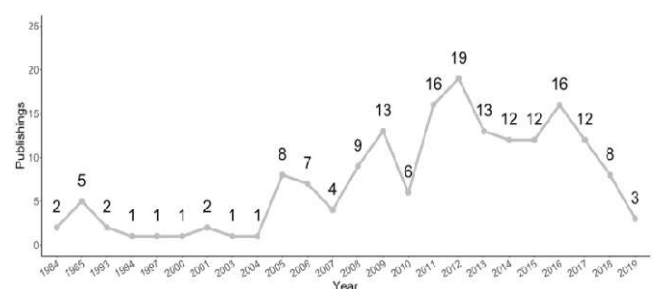


Fig. 1. Lineplot - Books focused on probability published per year

The bibliographic study highlights the most productive authors: Fabozzi FJ., Kelbert M., Olofsson P., Rachev ST., Suhov Y. are the ones who have produced the higher number of individual authorship books (3 each). Olofsson P. is the one who has produced the higher number of books with multiple authors (2.5). He also appears in the list of those who have published more books of individual authorship (Table 2).

Table 2. Main authors – Probability

Authors	Books	Authors	Shared authorship
FABOZZI FJ	3	OLOFSSON P	2.5
KELBERT M	3	GRIMMETT G	2.0
OLOFSSON P	3	PAOLELLA MS	2.0
RACHEV ST	3	PONS O	2.0
SUHOV Y	3	RAZDOLSKY L	2.0
GRIMMETT G	2	ROSS SM	2.0
HARTMANN S	2	WILKS DS	2.0
KOMATSU S	2	KELBERT M	1.5
NAKAYAMA T	2	SUHOV Y	1.5
PAOLELLA MS	2	APPELBAUM D	1.0

Source: Own elaboration based on analyzed data

Searching by countries, the United States comes first with 20 published books, which is approximately 7 times more than the United Kingdom, which comes second in the list with 3 publications, followed by Italy and Sweden with 2 books each. The other countries have only one publication. Brazil does not appear on the list of the 10 most producing countries (Figure 2).

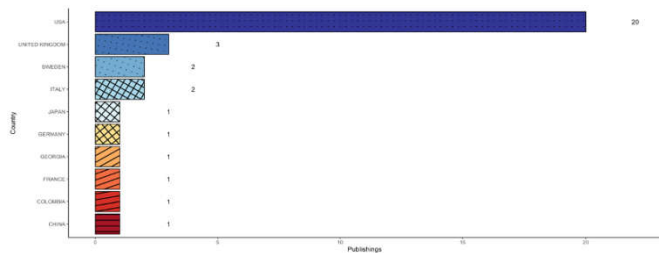


Fig. 2. Barplot- Books production per country (books focused on probability)

Figure 3 shows the collaboration between countries on the publications. It can be observed that the United States is connected to all the other countries mentioned.

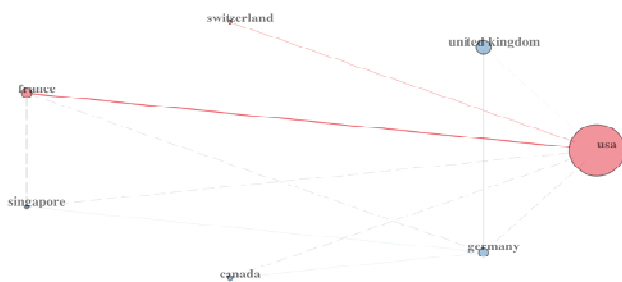


Fig. 3. Collaboration between countries (books focused on probability)

The most quoted book is "Uncertain Judgements: Eliciting Experts Probability" by O'Hagan, A (2006) with 962 quotes. In second place is the book "Probability and Statistics with Reliability, Queuing, and Computer Science Applications" by Trivedi, KS (2016) with 725 quotes. The list of the 10 most quoted books can be seen below (Table 3).

Applied Probability: Throughout the research several techniques related to bibliometrics were applied, giving thematic emphasis to Mathematics and Probability. For this purpose, the procedures, methods, and techniques were applied on the search for "Applied Probability". The main information obtained is in the table "Main

Information - Applied Probability" (Table 4). The time frame was the period from 2001 to 2020, and the scope was restricted to books. A total of 992 published books and 1677 authors were identified. 47% of the books (466 books) were written by a single author and 53 had multiple authors (526 books). Overall, we have an average of 0.592 books by author, 1.69 authors by book and 1.92 co-authors by book. The collaboration index is the index of co-authors per book, applied only the set of multi-author books (total number of authors of books with several authors divided by the total of multi-author books).

Table 3. Most quoted books – Probability

Author	Year	Book	Quotes	Quotes (year)
O'hagan a	2006	Uncertain Judgements: Eliciting Expert' Probab	962	64.1
Trivedi ks	2016	Probab And Stat WithReliab, Queuing And Comput Sci Appl	725	145.0
Stewart wj	2009	Probab, Markov Chains, Queues, And Simul: The Math Basis Of Perform Model	339	28.2
Ross sm	2009	Intro To Probab Models: Tenth Edit	298	24.8
De finetti b	2016	Theory Of Probab: A Crit Intro Treat	277	55.4
Lyons r	2017	Probability On Trees And Networks	275	68.8
Simon mk	2006	Probability Distributions Involv Gaussian Random Variables: A HandbFor Engineers And Scientists	259	17.3
Horwich p	2016	Probability And Evid	246	49.2
Gray rm	2009	Probability, Random Processes, And Ergodic Properties	210	17.5
Jeffrey r	2004	Subjective Probability: The Real Thing	170	10.0

Source: Own elaboration based on analyzed data

Table 4. Main information – Applied Probability

Description	Results
Time frame	2001 – 2020
Documents	992
Average quotes per document	138.9
Average quotes per year per document	13.01
Associated keywords (ID)	2297
Keywords (DE)	276
Authors	1677
Author's entries	1903
Authors of books with single authorship	414
Authors of books with several authors	1263
Books with single authorship	466
Books with several authors	526
Books per author	0.592
Authors per book	1.69
Co-authors per book	1.92
Collaboration index	2.4

Source: Own elaboration based on analyzed data

Book publications have shown an upward trend since 2001 (6 books published) until 2013, when it reached its maximum (94 published books). From 2016 there is a sharp drop and we quickly reach only 2 annual publications in 2020 (Figure 4). Comparing the general average (50 books/year) with the average of the last 3 years (22 books/year) we see a reduction of 56%.

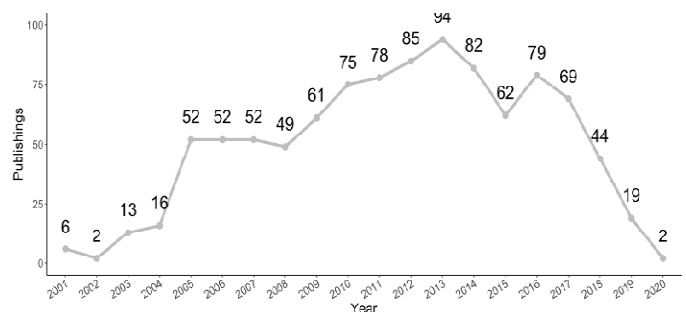


Fig. 4. Lineplot- Books production per country (books focused on applied probability)

Regarding the most relevant keywords attributed by the authors (DE) we observe a great variation, since the most frequent ones were used only twice. When we consider the keywords associated by SCOPUS, the terms "stochastic systems" and "students" were the most frequent, with 70 entries each, followed by "statistics", with 31 entries, and "graduate students", with 29 entries. Closing the list of the 10 most relevant terms, the numerical calculation software MATLAB appears with 16 entries (Table 5).

Table 5. Keywords – Applied Probability

Author Keywords (DE)	Books	Associated Keywords (DI)	Books
Amplifiers	2	Stochastic systems	70
Applied probability and stochastic networks	2	Students	70
Evolution	2	Statistics	31
Forecasting	2	Graduate students	29
Models	2	Markov processes	29
Multilevel network	2	Random processes	26
Phase measurement	2	Stochastic models	26
3d printing	1	Bayesian networks	20
Agreements	1	Computer theory	19
Along with simultaneous biochemical and chemical reaction	1	Matlab	16

Source: Own elaboration based on analyzed data

Regarding the most productive authors, Janssen, J. and Manca, R. are the ones who have produced the highest number of books of individual authorship (7 books each). Beran J. is the author who has produced the highest number of books with multiple authors. It is interesting to note that there are no authors in common to both lists (Table 6).

Table 6. Main Authors – Applied Probability

Authors	Books	Authors	Shared authorship
Janssen J	7	Beran J	3.25
Manca R	7	Congdon P	3.00
Fabozzi F J	6	Glisic SG	3.00
Balarishnan N	5	Grabe M	3.00
Rachev St	5	Grous A	3.00
Beran J	4	Ibe Oc	3.00
Kleinert H	4	Pinedo ML	3.00
National Research Council Nrc	4	Vasegh SV	3.00
Ahsanullah M	3	Duffie D	2.50
Congdon P	3	Henry-Labordre P	2.50

Source: Own elaboration based on analyzed data

By country, the United States appears in first place, with almost three times more books than Germany, coming second (62 and 21 respectively). Brazil does not even appear in the list of the 10 most publishing countries (Figure 5).

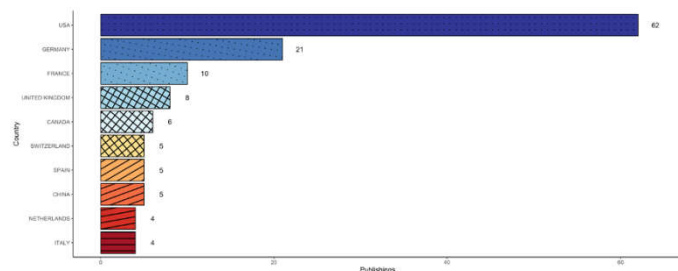


Fig. 5. Bar plot - Books production per country (books focused on applied probability)

In Figure 6 it is possible to observe different countries collaboration for publications on the subject. There is a strong relationship between the United States and the other countries. There is also a direct collaboration between the United Kingdom and France.

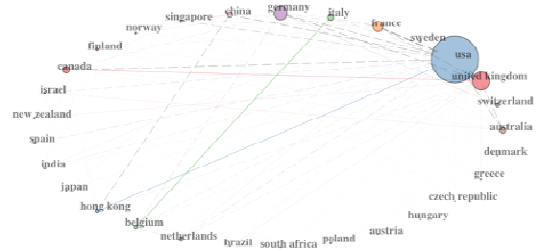


Fig. 6. Collaboration between countries (books focused on applied probability)

"Optimal State Estimation: Kalman, H Infinity, and Nonlinear Approaches" by Simon, D. (2006) is the most quoted book, with 4101 quotations. "Scheduling Theory, Algorithms, and Systems" by Pinedo, M. (2008) closes the list of the 10 most cited books with 1806 quotations (Table 7). Pinedo is the only one that also appears on the list of authors who have published most books in co-authorship.

Table 7. Most quoted books – Applied Probability

Author	Year	Book	Quotes	Quotes (year)
Simon D	2006	Optim state estm; alman, h. And nonlinear approaches	4101	273
Ripley Bd	2014	Pattern recognit and neural netwwors	3803	543
Koenker R	2005	Quantile regres	3012	188
Campbell JY	2012	The ergonometrics of financ mark	2554	284
Coelli TJ	2005	An introduction to efficiency and productivity analysis	2236	140
Mardia KV	2008	Dir stat	2217	171
Gelman A	2013	Bayesiandata analysis third edition	1921	240
Talbi EG	2009	Metaheuristics from des to implement	1862	155
Ltkepohl H	2005	New introduction to mult time ser analysis	1846	115
Pinedo ML	2008	Scheduling: theory, algorithms, and syst	1806	139

Probability problems: Finally, a bibliometric analysis of the term "Probability Problems" was made. The time frame was the period from 1985 to 2015, but only 8 books were identified, so it is little information for a more in-depth bibliometric analysis. From a total of 12 authors, we have an average of 0.667 books per author, 1.5 authors per book and 1.5 co-authors per book. The main information obtained are in the table "Main Information - Probability Problems" (Table 8).

Table 8. Main information – Probability problems

Description	Results
Time frame	1985-2015
Documents	8
Average quotation per document	4625
Average quotation per year per document	0.4727
Associated keywords (ID)	8
Keywords (DE)	0
Authors	12
Authors entries	12
Authors of books with single authorship	5
Authors of books with several authors	7
Books with a single author	5
Books with several authors	3
Books per author	0.667
Authors per book	1.5
Co-authors per book	1.5
Collaboration index	2.33

Source: Own elaboration based on analyzed data

From 1985 to 2008 only one book was published. Other 7 books were published between 2008 and 2015 and no book has been published

since then. So, we have an average of 0.27 books per year, considering the year of the first book published and the last one (Figure 7).

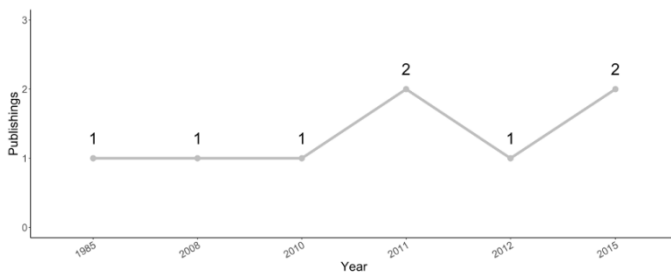


Fig. 7. Line plot - Books production per year (books focused on probability problems)

No information regarding keywords assigned by the authors were found. Regarding keywords associated by Scopus, a great variation was found with each term being used only once (Table 9).

Table 9. Keywords – Probability Problems

Associated keywords (ID)	Books
FAILURE ANALYSIS	1
FIRST PASSAGE FAILURE PROBABILITY	1
GAUSSIAN EXCITATIONS	1
PROBABILITY	1
RANDOM EXCITATION	1
RELIABILITY - ANALYSIS	1
STRENGTH DISTRIBUTION PROBABILITY	1
STRUCTURAL ANALYSIS	1

Source: Own elaboration based on analyzed data

"Classical Problems of Probability" by Gorroochurn P (2012) is the most quoted book, with 13 quotations, followed by "Polya Urn Models" by Mahmoud, HM (2008) with 11 quotations. Both books are of individual authorship (Table 10).

Table 10. Quotes – Probability Problems

Author	Year	Book	Quotes	Quotes (year)
Gorroochurn P	2012	Classic probl of probab	13	1.4444
Mahmoud HM	2008	Polya urn models	11	0.8462
Schwarzlander H	2011	Probab concepts and theory for eng	8	0.8000
Ghahramani S	2015	Fundamentals of probability: with stoch processes, third edition	3	0.5000
Batsaki Y	2011	Fict of knowl: fact, evid, doubt	1	0.1000
Petropoulou EN	2010	Some recent adv in partial differ equ	1	0.0909
Khare A	2015	Beautiful, simple, exact, crazy: mathematics in the real world	0	0.0000
Komatsu S	1985	Trans jpn soc civ eng	0	0.0000

Source: Own elaboration based on analyzed data

Final Considerations: The surveys presented provided an overview of what is bibliometrics, its historical context and how the technique is used. Regarding the probability area, the performed mapping provides an overview of how topics related to "probability", "applied probability" and "probability problems" were addressed in book publications between 1984 and 2020. In a more comprehensive way, it was observed a growing interest on the subject in the decade of 2000, and a decrease in the last 5 years. In a more specific way, a gap of more than 20 years was observed between the publication of the first book on Probability Exercises and the following one. In the last 5 years, no book has been published on the subject, which we understand as a relevant element to be examined in future research. It was also observed the low contribution of Brazil to the subject, with

no mention of the country on the list of the 10 main publishing countries, for the three analyzed topics. Thus, bibliometric analysis is understood as a timely tool in the stages of preparing a book on probability exercises, in addition to the need for more work integrating Bibliometrics, Probability and Mathematics. As we could see, the data collected indicate a scarcity of publications on the subject, and highlights its relevance in the current days, both in the theoretical field and with regard to the use of Bibliometrics as an auxiliary tool for the development of research in the Great area of Mathematics and the Probability Area.

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