FUNCTIONS OF SCIENTOMETRICS IN SCIENCE MANAGEMENT

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Abstract

The development of science largely depends on the efficiency of management of science and scientific activities. In terms of making the right decisions in science management, scientometrics is important. This article addresses questions about the functions of scientometrics in science management.

The purpose of the research is to justify the role of scientometrics in the management of science and scientific activities at different levels of the social hierarchy. The most important task of the research is to identify the functions of scientometrics as a symbiosis of sociology of science and infometrics. The relevance of this article is determined by the need to reveal the potential of scientometrics in science management, especially at the level of scientific organizations and research (and other) universities. The article highlights the functions of scientometrics, presents the possible directions of scientometrics application. It also addresses the relationship between measurements in social systems and measures to increase the effectiveness of scientific activities. It is justified that the expansion of the functions of scientometrics is primarily associated with the expansion of the range of measured indicators.

The article also discusses modern methods of science management. It is shown that they can be divided into two main groups: administrative and economic. These methods need to be used differently in the management of fundamental and applied sciences / research. For the selection of those forms, again, one should turn to scientometrics, modern methods of gathering information about scientific activity. It is also presented the «network model» of science management, which is modern and effective and can be applied in Armenia.

Research methods. analysis of scientific literature, best practices in the management of scientific activities at research universities and scientific organizations (benchmarking), set theory methods, quality measurement and expert assessment methods, mathematical statistics methods. Methodological foundations of the research are systemic, sociological, informational-cognitive, qualitative and statistical approaches.

Key words and phrases: scientometrics, functions, science management, technology, science efficiency, monitoring, scientific activity, management models.

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Համառոտագիր

Գիտության զարգացումը մեծապես կախված է գիտության և գիտական գործունեության կառավարման արդյունավետությունից: Գիտության կառավարման մեջ ճիշտ որոշումներ կայացնելու տեսանկյունից կարևոր նշանակություն ունի գիտաչափությունը: Սույն հոդվածն անդրադառնում է այն հարցերին, թե ինչպիսի գործառույթներ ունի գիտաչափությունը գիտության կառավարման մեջ:

Հետազոտության նպատակն է հիմնավորել գիտաչափության դերը սոցիալական հիերարխիայի տարբեր մակարդակներում գիտության և գիտական գործունեության կառավարման գործում: Հետազոտության կարևորագույն խնդիրն է բացահայտել գիտաչափության գործառույթները՝ որպես գիտության սոցիոլոգիայի և ինֆոմետրիկայի սիմբիոզ: Սույն հոդվածի արդիականությունը պայմանավորված է գիտության կառավարման մեջ գիտաչափության ներուժի բացահայտման անհրաժեշտությամբ, հատկապես գիտական կազմակերպությունների և հետազոտական (և այլ) համալսարանների մակարդակում: Հոդվածում կարևորվում են գիտաչափության գործառույթները, ներկայացվում են գիտաչափության կիրառման հնարավոր ուղղությունները: Այն անդրադառնում է նաև սոցիալական համակարգերում չափումների և գիտական գործունեության արդյունավետության բարձրացմանն ուղղված միջոցառումների կապին: Հիմնավորվում է, որ գիտաչափության գործառույթների ընդլայնումն առաջին հերթին կապված է չափված ցուցանիշների տիրույթի ընդլայնման հետ:

Հոդվածն անդրադառնում է նաև գիտության կառավարման ժամանակակից մեթոդներին: Ցույց է տրվում, որ դրանք կարելի է բաժանել երկու հիմնական խմբի՝ վարչարարական և տնտեսական: Այս մեթոդները հարկավոր է տարբեր կերպ օգտագործել հիմնարար և կիրառական գիտությունների կառավարման ժամանակ: Այդ ձևերի ընտրության համար, կրկին, պետք է դիմել գիտաչափությանը, գիտական գործունեության մասին տեղեկատվության հավաքման ժամանակակից մեթոդներին: Ներկայացվում է նաև գիտության կառավարման ցանցային մոդելը, որն արդիական է և արդյունավետ, կարող է ներդրվել Հայաստանում:

Հետազոտության մեթոդներ. գիտական գրականության, գիտական կազմակերպությունների և հետազոտական համալսարանների գիտական գործունեության կառավարման լավագույն փորձի վերլուծություն (բենչմարկինգ), բազմությունների տեսության մեթոդներ, որակի չափման և գնահատման ու փորձագիտական գնահատման մեթոդներ, մաթեմատիկական վիճակագրության մեթոդներ: Հետազոտության մեթոդական հիմքերը՝ համակարգային, սոցիոլոգիական, տեղեկատվական–ճանաչողական, որակական և վիճակագրական մոտեցումներ:

Բանալի բառեր և բառակապակցություններ. գիտաչափություն, գործառույթներ, գիտության կառավարում, տեխնոլոգիա, գիտության արդյունավետություն, մշտադիտարկում, գիտական գործունեություն, կառավարման մոդելներ:

ФУНКЦИИ НАУКОМЕТРИКИ В УПРАВЛЕНИИ НАУКОЙ

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Аннотация

Развитие науки во многом зависит от эффективности управления наукой и научной деятельностью. С точки зрения принятия правильных решений в управлении наукой наукометрия имеет важное значение. В статье рассматриваются вопросы о функциях наукометрии в управлении наукой.

Цель исследования является обоснование роли наукометрии в управлении наукой и научной деятельностью на разных уровнях социальной иерархии. Важнейшей задачей исследования является выявление функций наукометрии как симбиоза социологии науки и инфометрии. Актуальность данной статьи определяется необходимостью раскрытия потенциала наукометрии в управлении наукой, особенно на уровне научных организаций и исследовательских (и других) университетов. В статье выделены функции наукометрии, представлены возможные направления ее применения. Также рассматривается взаимосвязь между измерениями в социальных системах и мерами по повышению эффективности научной деятельности. Обосновано, что расширение функций наукометрии связано, прежде всего, с расширением диапазона измеряемых показателей.

В статье рассматриваются также современные методы управления наукой. Показано, что их можно разделить на две основные группы: административные и экономические. Эти методы необходимо по-разному использовать в управлении фундаментальными и прикладными науками/исследованиями. Для выбора этих форм опять-таки следует обратиться к наукометрии, современным методам сбора информации о научной деятельности. Также представлена «сетевая модель» управления наукой, которая является современной и эффективной и может быть применена в Армении.

Методы исследования: анализ научной литературы, передовой опыт управления научной деятельностью в исследовательских университетах и научных организациях (бенчмаркинг), методы теории множеств, методы измерения качества и экспертной оценки, методы математической статистики. Методологической основой исследования являются системный, социологический, информационно-когнитивный, качественный и статистический подходы.

Ключевые слова и фразы: наукометрия, функции, управление наукой, технологии, эффективность науки, мониторинг, научная деятельность, модели управления.

Introduction

Science management is a necessary but not always sufficient condition for its development and successful research activities. Science management can do nothing without scientometrics: any social management is unthinkable without obtaining reliable information **[1].**

It is known that scientometrics, as a symbiosis of infometrics and sociology of science, has long and firmly gained positions throughout the world **[2, 3].** Currently, most scientometric indicators are based on citations. According to generally accepted views, scientometrics studies the development of science in general, and scientific activity in particular, as an information process, which is fully consistent with the information-cognitive approach **[4].** It is obvious that the criterion-diagnostic apparatus of scientometrics cannot include indicators based on citations alone, although they certainly play a leading role. For example, if a university holds a conference, then to assess the effectiveness of a scientific event it is not necessary to use indicators based on citations; especially since conference proceedings are less likely to be cited than monographs and articles in journals. This could

be, for example, indicators such as the total number of presentations, the total number of participants from outside (i.e., those who not working at the organizing university), the number of scientific organizations whose employees took part in the conference, etc. These indicators reflect how popular the conference is in the scientific community. Let us empasize that a publication is a materialized "unit" of research results, and a citation is a "unit" of communication within the scientific community.

An analysis of scientific literature and the practice of managing scientific activities at universities has shown that the use of scientometrics most often comes down to assessing a limited number of indicators on the basis of which the activities of scientific and pedagogical teams and workers are assessed. In the context of the implementation of the so-called "effective" contract (it is used in the vast majority of universities), scientometrics mainly performs a target - motivational function, i.e. directs employees to achieve "premium" indicators. Similarly, when one investigates the activities of chairs or department heads, they also evaluate certain approved targets that the managed team should "strive for" (for example, the average number of articles per scientific and pedagogical worker over five years). There is managerial primitivism: they use a limited set of indicators and implement practically the only function of scientometrics. Within the framework of a scientific and applied problem, one cannot fail to mention such a social disaster as the desire to artificially "improve" the Hirsch index (h-index) in order to "gain positions" (bonus payments, election to a vacant position at the university or research institute, etc.).

The paradoxical nature of the situation increases for two reasons. **Firstly**, modern information technologies make it possible to carry out comprehensive collection and complex processing of information about subjects of scientific activity and its results. It should be noted that it is possible to implement monitoring management technologies, especially in a digital scientific and educational environment. Let us mention that monitoring in any area is an information management mechanism that integrates the necessary information processes (obtaining both actual and model information). **Secondly**, scientometrics, as a symbiosis of the sociology of science and infometrics, has "stepped far forward" even compared to the beginning of this century (especially compared to the founding period); the set of scientometric parameters is constantly expanding. Thus, the capabilities of scientometrics are not fully used in science management.

The objectives of scientific activities, the research problem and the methodology

Naturally, most scientific research is concentrated in specialized scientific organizations. In particular, in Armenia the main share of fundamental research falls on the institutes of the National Academy of Sciences. Industry science is partly developed in research institutes belonging to ministries, partly in some specialized purely commercial organizations. Universities play an important role in scientific research. In many western countries they are the main generators of scientific production. In addition, part of applied science is developed in companies engaged in the creation of innovative products, in which the scientific part is an important, and often the main component.

In general, it was established the division of scientific research into two streams—fundamental and applied. Without speaking about the conventionality of such a division, we note that here lies one of the main internal contradictions in the science management. On the one hand, the big number of organizations that finance scientific research are interested in work aimed at solving the necessary (whatever that means) problems. On the other hand, science develops according to its own laws. This is a fact, ignoring which more or less quickly leads to the degradation of entire areas of science, often potentially important precisely in its applied aspect. No funding organization, as a bureaucratic body, is capable of setting scientific goals. They usually rely on the opinion of a certain group of scientific

experts **[13]**. This is an important factor that can be taken into account when we speak about the science management. As a principle of democracy, scientists determine the goals of scientific research, but the financing and evaluation of the results are done by the authorities – political power. The priority purpose of fundamental science in the development of innovative processes is determined by the fact that it acts as a generator of ideas and opens paths to new areas. But the probability of a positive outcome of fundamental research in world science is only 5%. Fundamental research, as a rule, is financed from the state budget on a competitive basis and, much less often, can partially use extra-budgetary funds.

The research problem and the task of the study is to highlight the main functions of scientometrics and expand its role in the management of science. The purpose of the study is to substantiate the role of scientometrics in the science management at various levels of the social hierarchy. The object of the study is the science management in universities / research institutes, and the subject of the study is the role of scientometrics in the management of science.

Research methods used: analysis of scientific literature and best practices in managing scientific activities in universities - benchmarking, methods of mathematical statistics and expert assessments. Methodological foundations of the study: a systematic approach (considers scientometrics in its close connection with the monitoring of research activities, and monitoring as an information management mechanism), sociological approach (considers the scientific community in general, and scientific teams in particular, as social systems, information- cognitive approach (considers the development of science in general, and research activities, in particular, as information processes) **[5, 6].**

The results: functions of scientometrics

We have identified the functions of scientometrics, the full implementation of which will enhance its role in science management, and due to this, increase the efficiency of science management in both universities and scientific organizations. Let's look at those functions below.

a) **The motivational function** stimulates the leadership of the scientific and educational environment to effectively organize scientific activities taking into account its interrelations with other types of activities, including educational and methodological. It is most evident when assessing the performance of the scientists, when calculating incentive payments (bonuses) to researchers and when electing them to a vacant position. Such an incentive system is in place at the ISEC **[7].**

b) **The economic function** of scientometrics allows us to assess the personnel security of scientific organisations (for example, what will be the consequences when the university or scientific organisation losses the best scientists), the quality of human capital (i.e. scientists, researchers), the intensity and quality of work of scientists - their adequate wages, competitiveness of the scientific and educational environment, etc. One should not think that the economic function is related to the assessment of the economic effect of scientific research (scientometrics just arose as an alternative to the direct assessment of the economic effect). But there are a great many economic aspects of universities themselves, as scientific and educational environments, and the process of their functioning, and it is at least strange to ignore the possibilities of scientometrics. Why not focus scientometrics on diagnosing economic aspects? It is especially important to note the competitiveness of universities and research organisations. For example, doesn't a university's H-index reflect its competitiveness on a national or international scale? There are a many universities in the world, in our region, and even in Armenia, therefore, it is very important to determine which is the leader in the given field. For example, it is defined the role of ISEC in management of doctoral studies at the National Academy of Sciences for the sphere of research and development in Armenia **[8].**

c) **The control function** is to obtain primary information about the subjects and results of research activities. Note that the assessed scientometric indicators, including the Hirsch index, most often are not primary information. Primary information is most often a database, the processing of which will make it possible to evaluate scientometric indicators. For example, to calculate the H-index of a researcher, you need to have an array of citations of her/his scientific publications; in order to have the specified collection, you need to have a database about the worker's publications and citations to them; accordingly, identifying citations and/or links from publications is also a very complex process of information processing.

d) **Diagnostic function** – assessment or measurement of scientometric parameters on a linear scale, as well as the state of the research activity of an employee or community. Diagnostics always algorithmic, especially if it is implemented via digital systems. Diagnosis can be multi-stage. For example, to estimate the i-index of a scientific team or institution, you must first evaluate individual Hirsch indices of all workers. If diagnostics are made using nonlinear scales, then we are not talking about assessment or measurement, but about state identification. For example, for scientific team are assessed by linear scales a number of indicators that transformed into values using nonlinear scales (for example, "unsatisfactory", "satisfactory", "good"). It is also possible to assess the general condition research activities of the team (for example, five possible states - crisis, pre-crisis, normal, positive, prosperous).

e) **Causal function** – identifying significant factors in the effectiveness of research activities, as well as increasing social and professional competence of scientists. For example, what factors affect the effectiveness of research activities at the university (or at the research institute)? But in order to identify causal relationships, it is necessary to clearly know what parameters we are talking about. In the above example, it is necessary to mean that it should be considered a criterion (or criteria) of the success of the university's research activity. European specialists give a clear answer to this question. Criterion of successful research activity of the European University - number of articles in top-25 journals **[1].** Do not forget also that it is about social systems (the science is a social institute!). For example, it is strange to expect from a scientific team that has very low scientometric indicators (for example, two articles within a year) that after a short period of time it will become "advanced." This also refers to the currently actively discussed unification of universities and transfer to the "academic city", which, in fact, will not solve any problem **[9].**

f) **The planning and forecasting function** consists of forecasting research activities, planning results, as well as selecting methods and means for achieving target parameter values. Of course, both planning and forecasting are types of modelling, designed to answer the questions "How should it be?" and "How will it be?", and not "How is it?". Without criteria, it is impossible to carry out either planning or forecasting (there is nothing to plan and/or forecast). For example, if a university's H-index is 9, then what is the probability that in a year it will be at least 10? Planning research work for five years and for a year has become a standard activity in universities, and planned indicators are most often scientometric.

g) **Organizing function** – organization of research activities of scientific and educational environments, scientific workers and teams. This is, first of all, setting targets for research activities, creating conditions for achieving them, and creating an organizational culture.

h) **Regulatory - ethical function** - comparison of actual and expected results of research activities, decision-making, timely correction of activities, prevention of negative trends in the functioning of the subject of research activities. In addition, it orients subjects

of research activities towards corporate responsibility, as well as compliance with ethical standards of research activities. For example, a researcher must realize that by publishing research results in the Web of Science or Scopus, he/she strengthens the authority of the university. Let's give an example: if a researcher's H-index is 12, and the organization's i-index is 10, then it plays a role in increasing the university's ranking. Another example: a university employee must ensure that his publications are not retracted, because this reduces not only his reputation, but also the reputation of the university.

i) **The information - analytical function** provides a variable interpretation of research activity (in a broader sense - the functioning of its subjects, i.e. workers, teams, organizations), its connection with other types of activities (especially educational and methodological, if we are talking about a university). In addition, this function is aimed at identifying trends in the functioning of the researcher. For example, it is possible to identify the researcher's regular co-authors, i.e. scientists with whom he/she collaborates.

j) **The reflexive function** allows the researcher, team or organization to perform self-analysis of research activities, but this also requires scientometric parameters. This function is also aimed at improving research activities, increasing its quality and intensity.

k) **The integrating function** allows you to combine monitoring information. These are pieces of information reflecting the research activity. This function ensures the technological unity of all types of monitoring as a mechanism for managing scientific and educational environments. For example, by assessing the effectiveness of the research and methodological activities of the scientific and educational environment, one can diagnose its scientific potential, competitiveness, the influence of research activities on methodological ones (for example, how research results are reflected in the content of training), etc.

l) **The consolidating function** is the unification of the efforts of society and the subject of science management to solve problems related to this management. It is a highly developed society that provides opportunities for building a system for monitoring research activities. Scientometrics stimulates the development of modern technologies and scientific knowledge, and society is responsible for this.

m) **The assimilation function** supports the desire of the subject of research activity (employee, team, organization) to accept the values, goals and norms of the scientific community as their own, the desire to be an integral part of the scientific community. For example, an indicator such as the Hirsch index orients an employee or team towards integration into the elite scientific community. Let's give another example: the number of scientific publications cited by a subject can also be considered a scientometric indicator. If the bibliography does not contain sources in foreign languages, most likely, the authors of the publication do not understand that science is an international phenomenon.

n) **The comparative function** allows to compare (based on the same indicators) the effectiveness of research activities of different scientists and teams, as well as assess the dynamics of research activities for the same subject (employee or team). But, firstly, it is possible to compare only subjects of the same level of social hierarchy. For example, it is absurd to compare the scientific and educational microenvironment of the department with the scientific and educational macroenvironment of the university. Second, it is much more appropriate to compare (for the same subject) its current and previous states, i.e. evaluate the dynamics ("compare yourself with yourself yesterday"). For example, the H-index of the scientific team was equal to 2, but became equal to 5, and this clearly reflects the progress of research activities.

We also consider it important to emphasize the following **indications** for the use of scientometrics for the effective management of science:

-analysis of the publication activity of research subjects (researcher, scientific team, department, university, etc.);

- assessment of the subject's recognition by the scientific community (many indicators based on citations, including the Hirsch index);

-analysis of the internationalization of scientific activities (organization and participation in international conferences, articles in foreign journals and journals of international importance, use of sources in a foreign language in bibliographic lists, etc.);

-diagnostics of the synergy of the scientific team;

- the process of training scientific personnel (PhD students) and their scientific - publishing activity [10];

-diagnostics of competencies and professional qualities of scientific workers;

-diagnostics of the competitiveness of the research team, its effectiveness, etc.

Science management methods

Obviously, management methods can be divided into administrative and economic **[11].** Administrative ones are applicable where there is direct subordination of the scientific team to a higher governing body. Economic - involve some procedure for direct payment for the work performed. In fact, such a division only superficially reflects real management processes. Let's start with one of the main issues - choosing a research topic. In most scientific organizations, a team of scientists works on a chosen topic, reflected in the approved plans. The role of management is limited to evaluating the results obtained. Almost the same situation arises in various kinds of academic programs. At the same time, cases of negative assessment of work performed are rare **[12]**. Therefore, the actual control levers when performing a specific job are very weak. The only real management is to simply "break up" a team that has not produced significant results for a long time. Applied research work carried out within the framework of the creation of specific products has a completely different nature. If the work is carried out by teams directly within the organization, then management has a normal administrative nature. The third type of management refers to work performed on orders from various foundations on a competitive basis. Although the management here is purely monetary, the main lever of management is the choice of topic and performer, since it is almost impossible to evaluate intermediate results in money, and the assessment of the final result. Thus, the main mechanisms for the science management are the choice of topic and implementing organization. This certainly applies to basic research. Scientific research carried out as part of R&D may have a more flexible management system.

Until now, we have considered the work of one scientific team on one scientific problem. However, in reality the situation is more complicated. Most scientists are involved in several grants, programs, and often commercial projects. In addition, teams often try to obtain several sources of funding for the same work. So, a whole "sales industry" is arising, including monitoring and writing applications, justifications, proposals, etc. In some teams, special divisions are forming that track information on new competitions, grants and prepare "related" scientific proposals. In others, the researchers themselves spend most of the time on this. Thus, scientific teams are faced with the task of optimizing their own resources and correctly presenting their capabilities and results. On the other hand, management structures must take into account the presence of different organizations engaged in similar topics. The possibilities of their competition, even confrontation, as well as the possibility of cooperation, constitute an important factor in management. In addition, scientists and entire scientific teams can migrate, which also requires controlling actions. Therefore, some

countries maintain centralized databases of all scientists receiving government funding for a more objective assessment of their achievements and proposals (Network method of management). Thus, a model of science management must provide for the interaction of a number of factors that do not fit into a linear chain.

Conclusion

Scientometrics, as a symbiosis of infometrics and sociology of science, can and should be a scientific and technological platform for science management. At present, it is not necessary to "refuse" scientometrics, but, the opposite, to expand its functions and range of areas. Scientometrics must be brought to a fundamentally new level required by life. For scientometrics to be a full-fledged tool for monitoring research activities and therefore – for the science management, it is necessary to expand its functionality. But for this we need to understand: traditional indicators based on citations alone, especially the Hirsch index, are clearly not enough. In the digital economy, it is necessary to fully use the capabilities of modern information technologies. What are we actually seeing? A narrow range of digital tools and methods of information processing used. Thus, scientometrics, which should be a full-fledged monitoring and management mechanism, is discredited by managerial primitivism, the narrowness of the indicators actually used, and the limited range of functions and technological capabilities. Currently, in science management, mainly the diagnostic and stimulating functions of scientometrics are implemented, and this is clearly not enough for effective management. It is also obvious that scientometrics, monitoring of research activities and science management should be synchronous with each other.

Prospects for further research – development of ontological models for monitoring research activities and effective management of science at universities and research centres (scientific organisations). We think that it can become a draft decision of the government, and after being approved, it can be applied in the scientific and educational area of Armenia.

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