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Applying propositional calculus of formal logic to formulate research hypotheses in management sciences

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Abstract. The article is devoted to the topic of formulating research hypotheses in management sciences. On the basis of the author's research results, it may be concluded that although the related literature indicates the features of a properly formulated hypothesis, errors still tend to occur in the process of its construction and as a consequence, the answers to the question or questions determining the research problem are not correctly formulated. Examples of such errors include attempts to check statements which are unverifiable in practice, which could be observed even in Master's theses. The propositional calculus, whose source is in formal logic, may prove a useful tool in creating proper hypotheses. The primary aim of the article is to prove the usefulness of the propositional calculus of formal logic in formulating the main hypothesis and partial hypotheses in research work relating to management sciences. Prior to adopting a hypothesis for further proceedings, it should be decomposed into prime factors, followed by an analysis of the propositions. Adopting such a calculus when formulating each hypothesis should result in their comprehensible and logical form, compliant with linguistic rules.

Keywords: research hypotheses, formal logic, management, propositional calculus
JEL: A23, C12, I21

Propozycja wykorzystania rachunku zdań logiki formalnej do tworzenia hipotez badawczych w naukach o zarządzaniu

Streszczenie. Tematem artykułu jest formułowanie hipotez badawczych w naukach o zarządzaniu. Na podstawie wyników badania przeprowadzonego przez autora można stwierdzić, że choć w literaturze przedmiotu wskazywane są cechy prawidłowo sformułowanej hipotezy, to podczas tworzenia hipotez badawczych często dochodzi do błędów, a w konsekwencji odpowiedzi na pytanie (pytania) wyrażające problem badawczy są skonstruowane niepoprawnie. Przykłady takich błędów, m.in. próby sprawdzenia w praktyce stwierdzeń nieweryfikowalnych, można znaleźć nawet w pracach magisterskich. W tworzeniu poprawnych hipotez pomocny

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może być rachunek zdań mający źródło w logice formalnej. Celem artykułu jest udowodnienie przydatności rachunku zdań logiki formalnej w formułowaniu hipotezy głównej i hipotez cząstkowych w pracach badawczych z zakresu nauk o zarządzaniu. Przed przyjęciem hipotezy należy rozłożyć ją na czynniki pierwsze i przeprowadzić analizę zdań. Zastosowanie takiej procedury powinno doprowadzić do nadania każdej z hipotez zrozumiałej i logicznej postaci oraz zapewnić ich zgodność z regułami językowymi.

Słowa kluczowe: hipotezy badawcze, logika formalna, zarządzanie, rachunek zadań

1. Introduction

Research is a process of seeking answers to questions which have not yet been answered. The word 'research' is a combination of two components: 're' and 'search'. The first element is a prefix meaning 'again' or 'over again', while 'search' is a verb which signifies 'to examine carefully', 'to try and test' or 'to probe'. Together they form a noun which describes a systematic, careful and patient investigation in some field, undertaken to establish certain principles or facts. In the world of science, research can be therefore defined in the categories of a 'systematic and refined technique of thinking, employing specialized tools, instruments and procedures in order to obtain a more adequate solution of a problem than will be possible under ordinary means. It starts with a problem, collects data or facts, analyses them critically and reaches decisions based on the actual evidence' (Singh et al., 2021, p. 2).

Conducting research is not a simple procedure – each research undertaken in the discipline of management should be a specific sequence of activities defined e.g. in the literature. It shows that the decision to engage in research must be justified by the identification and diagnosis of a specific research gap. A bibliographic query is a particularly recommended and effective method of revealing research gaps. As noted by Backer et al. (2016, p. 24), it allows the identification of obvious gaps and contradictions in human knowledge and the explanation of the purposefulness of the undertaken research. The approach involving an initial recognition of a problem based on secondary sources aiming to identify potential directions for new research is also in line with the recommendations of other scientists who say that acquiring knowledge from the classical literature on the studied subject is an appropriate starting point for further research (Silverman, 2010, p. 121). The activity of acquiring knowledge from secondary literary sources can be described as 'an investigation' or 'secondary measurement'. It is not, however, a measurement in the strict sense of the word. It rather refers to collecting information, i.e. the results of primary or secondary studies and research previously carried out by others.

When conducting a bibliographic query, in addition to reliable literature-based sources (e.g. conceptual articles or those presenting the results of empirical and

laboratory research), one can also encounter sources that are not fully reliable[1] or such that are suspicious or subjective and therefore not credible. They contain data that should be used with considerable caution. Bearing this in mind, a bibliographic query should be conducted in accordance with the methodology of a systematic literature review, which focuses on a clearly formulated goal and uses certain defined scientific methods of the identification, evaluation and synthesis of all sources adequate to meet the cognitive needs of the researcher. In contrast to traditional reviews, a systematic review involves following specific standards (Tranfield et al., 2003) and a sequence of actions whose purpose is to reveal a research gap. These activities form a series of logical, consecutive stages, whose completing measurably increases the chance of success in the review (this topic will be elaborated on by the author in a separate work). Seeking research gaps should then be viewed as an inherent activity of every researcher.

In the next step, the findings and conclusions concerning the occurrence of specific knowledge gaps discovered by means of a library query should be verified by carrying out a preliminary research, which is usually done on a sample of business practitioners.

Consultations with company managers (e.g. through a questionnaire or personal interview) are conducted to ensure that the problems observed by the researcher are indeed significant from the point of view of managerial practice. Moreover, a discussion with them may help in conducting an in-depth analysis of the predicted regularities and contribute to the exploration of new phenomena or the empirical reinforcement of additional, previously unseen assumptions which, if necessary, may become the subject of further research. The act of ensuring that the potential gaps in knowledge revealed by the study of the literature are justified is referred to as managerial perception. A number of scientists, including Lyon, Lumpkin and Dess, write about it, deeming it extremely useful (Lyon et al., 2000). Through this method, information is obtained from people who are most familiar with issues related to management practice. It is crucial to establish relations directly with the companies' leaders. There are several tools that can be used to 'take the community's pulse', such as focus groups, surveys, individual interviews and participation in company meetings. The inquirer can obtain many additional variables from the managers regarding the observed research gaps. 'Investigating what is "squeaking in the grass" – what variables are involved and how they are related to each other – is very

[1] Unsure sources contain data that require checking, supplementing or modification. An example may be all kinds of encyclopaedic websites, the resources of which are created and then verified in accordance with the principle of free participation of internet community members. Compare: Kaczmarczyk (2011, p. 189).

important' (De Wit & Meyer, 2007, p. 82), especially since management problems are generally not clear and simple, but rather complex and non-transparent.

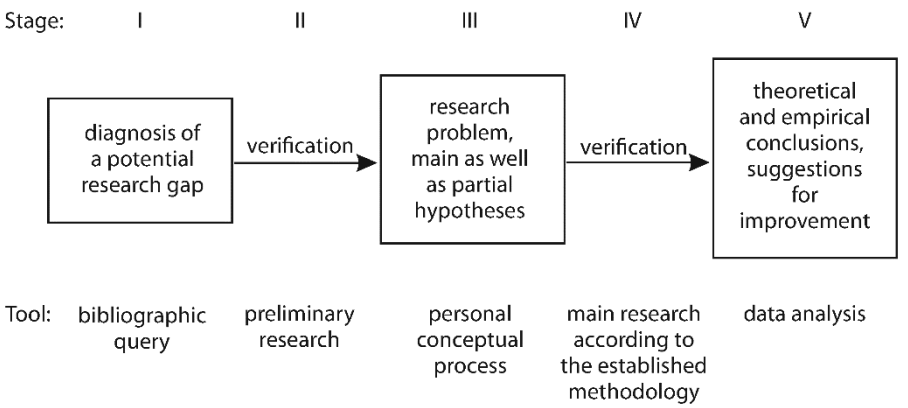
The analysis of domestic and foreign literature on management, as well as conducting a preliminary survey among practitioners performing managerial functions should lead to the evolution of the research problem as well as the hypotheses. Further parts of this paper are devoted to this subject. At the same time, however, based on the author's own studies, it turns out that the hypothetical answers to the question or questions defined in the research problem are not always correctly formulated. The propositional calculus of formal logic is a useful tool in overcoming the faulty formulation of research hypotheses. Prior to adopting a hypothesis for further proceedings, it is worth decomposing it into prime factors and conducting its propositional calculus in order to make sure that it is logically formulated.

The primary aim of the article is to prove the usefulness of propositional calculus of formal logic in formulating the main and partial hypotheses in research work relating to management sciences. The aim was achieved through the implementation of partial goals. The first theoretical partial goal emphasised the meaning of a hypothesis as an alleged, anticipated answer to the question contained in the research problem. The second was to present and define the features of a correctly formulated hypothesis. The empirical partial goal referred to the research results that justified the need to attribute more importance to the process of formulating hypotheses, whereas the applicative partial goal recalled a model for the proper use of propositional calculus in formulating hypotheses.

2. Hypothesis as a predicted answer to an identified scientific problem

As shown in Figure 1, after discovering a potential research gap and verifying its legitimacy among practitioners, it is time to formulate the research problem, which concerns, generally speaking, relationships between variables. According to Brzeziński (2004, p. 216), in this case we are talking about dependent variable Y (or a set of variables) and independent variables X_h..., X..., treated by the researcher as being in a cause-and-effect relationship with variable Y. Formulating the research problem is a crucial phase for further research. Many authors believe that being able to 'choose good problems is essential to being a good scientist' (Alon, 2009, p. 10). Some researchers even compare defining a research problem to identifying a destination prior to the journey. 'A research problem is like the foundation of a building. The type and architecture of the building depends on the foundations' (Kumar, 2011, p. 47). Therefore, if the research problem is well-formulated, one may expect credible and valuable results.

Figure 1. Stages in the research of management sciences



Source: author's work based on Babbie (2013, p. 50).

The general concept of a scientific problem derives from Greek (from the word 'problema', which meant a difficulty or obstacle). A problem can be considered in three different contexts: colloquial, didactic and scientific. In the colloquial sense, a problem is a contentious matter, an issue or a task subject to, and often requiring immediate resolution, an explanation or a solution, because it causes discomfort and complications in the life situation of an individual: 'a problem always has to do with dissatisfaction about a certain situation' (van Boeijen et al., 2020, p. 101). Whether a problem is resolved depends on our knowledge: if we have it, we will remove the problem, if not, the problem remains unresolved (Apanowicz, 2000, p. 67). When the knowledge objectively exists, but we do not have it and there is a need to gain it, the meaning of a problem becomes a didactic one. Scientists conducting research in the field of management and quality, on the other hand, are interested in the significance of a problem in the scientific sense. In this context, it should be interpreted as the subject of research or the object towards which our cognitive endeavours orientate (Sztumski, 1995, p. 38). The problem becomes then a radical specification and direction of the researcher's interests (Plich, 1977, p. 66).

In the literature on the methodology of research, a research problem is usually interpreted as a description of the research topic, its purpose and questions which the researcher wants to answer by carrying out his or her studies. In a narrower sense, it is simply a question or a set of questions that the research is expected to provide answers to (Błachut, 2007, p. 67). Obtaining answers (by conducting research) serves to eliminate ignorance on a given issue. However, while research problems are always questions, it should be emphasised that not every question is

a research problem (Jeszka, 2013, p. 32). For example, questions about facts to which answers are obvious or those whose aim is to obtain a ready piece of information from another person are not research problems. Pieter (1997, p. 67) defined research problems as questions to which we seek answers by means of scientific research. By putting them forward, we formulate a question as to the nature or environment, not to the other person. We attempt to find answers to questions posed through our own effort.

In practice, a problem statement usually takes the form of one or two questions whose aim is to explain the problem that the research process will address. As soon as the research question is formulated, it makes the hypothesis formulation imperative, since it is a tentative solution or an intelligent guess about a research question under study. A predictive statement which is made in the light of the available facts relating to the problem under study is a hypothesis. This word consists of two components: 'hypo' (tentative or subject to verification) and 'thesis' (statement about the solution to a problem). The meaning of the components of the word 'hypothesis' can also be translated as (operational meaning):

- hypo – composition of two (or more) variables to be verified;
- thesis – position of variables in the frame of reference.

A hypothesis is composed of a group of hypothetical answers to the research problem. It also functions as a guide to data collection and interpretation. A hypothesis may also refer to the relationships occurring in a given domain of reality, to the regularities and mechanisms that determine the functioning of the studied phenomena or their important properties (Skorny, 1984, p. 72). In the dictionary of the Polish language, the definition of a hypothesis has been formulated slightly differently, i.e. as a sentence not fully verified, which explains certain facts or assumptions (Szymczak, 1989, p. 307). However, as mentioned before, in practice it should be considered in terms of the expected answer to the question presented by the research problem, formulated with a significant degree of the researcher's belief in its truthfulness. It is a kind of a guess about the reality and it can be verified by comparing the real state of things with the hypothetical one.

Some of the other key roles of hypotheses include helping with theory testing, serving as a platform for investigative activities, suggesting and developing theories, helping understand data needs, acting as a bridge between theory and research, and providing guidelines for research work or study (Bang et al., 2012, pp. 4–5). What is more, they prove useful in learning the most appropriate analysis techniques as well as in identifying the most relevant type of tests.

3. Features of a correctly formulated hypothesis

As was mentioned before, a hypothesis is a preliminary statement about a relationship between two or more variables. In other words, it is a concrete, verifiable prediction of what the researcher expects in his or her research. A statement of expectation or prediction that will be tested through research is usually considered as the principal instrument in research. Its main function is to suggest new experiments and observations. Other functions of hypotheses include (Singh & Bajpai, 2008, pp. 97–98):

- delimitation of the field of investigation and determination of the specifics of what to study and what might provide possible solutions to the problem;
- serving as a base to the formulation of other hypotheses;
- providing the researcher with a definite statement which may be tested (accepted or rejected), and suggestions of how to interpret the results and draw conclusions;
- sensitising the investigator to work selectively and assume a realistic approach to the problem;
- offering a simple means for collecting evidence for verification.

As the list of functions above suggests, a 'hypothesis is the focal point around which the future research efforts will be directed. The kind of data to be collected, the tools of analysis are influenced by the hypothesis' (Gupta & Gupta, 2021, p. 13). However, in order for the hypotheses to fulfil their function, they must be properly formulated. To be complete, a hypothesis must refer to three elements:

- the variables;
- the population;
- the relations between variables.

Below there is a list of other important and basic characteristics of a correctly formulated hypothesis. A hypothesis should:

- be formulated using the simplest possible terms so that it is easy understandable to all recipients. If a hypothesis is not clear and precise, the inferences drawn on its basis cannot be reliable;
- be written in correct, intelligible language including correct terminology;
- derive from experience in research. Even though the formulation of a hypothesis should precede data collection, some degree of data collection, literature review or a pilot study will help in the development and gradual refinement of a hypothesis;
- never take the form of a question. A hypothesis can be formulated in a descriptive or relational form;
- in most cases start with the phrase: 'it is assumed that';
- be testable and empirically verifiable. It should ensure that the available tools and techniques can be effectively used for the verification purposes. Testability is

considered one of the primary features of a scientific hypothesis, which founds its reflection in an 'if... then' statement summarising the idea and in the ability to be supported or refuted through observation and experimentation. Hypotheses are considered testable if other deductions can be made on their basis. These, in turn, can be confirmed or rejected by observation (Devi, 2017, p. 63). Some prior study might have to be done by the researcher in order to make a hypothesis testable;

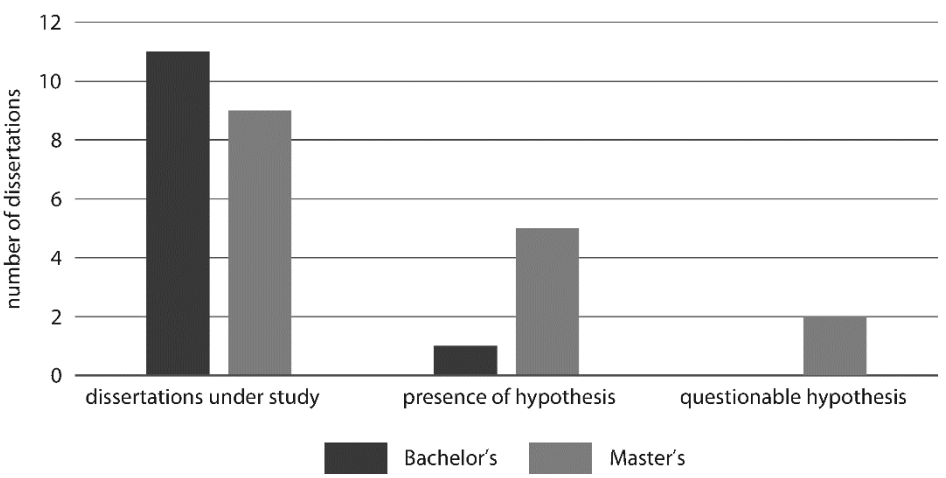
- not contradict any law of nature known to be true. Hypotheses should be consistent with most known facts, i.e. with a substantial body of established facts;
- not take the form of a normative, but an empirical statement. It should not be based on subjective, personal judgements, statements about duties or about what is right or wrong, etc., or on moral judgements. The concepts in a hypothesis must refer to empirical experience;
- identify the variables between which a researcher can establish a relation-ship;
- maintain a clear distinction between theory, law, facts, assumptions and postulates;
- describe only one issue (which might, however, limit the possibility of using more statistics);
- explain the facts that need clarification. This means that by using a hypothesis with other known and accepted generalisations, one should be able to deduce the original problem. Thus, a hypothesis must actually explain what it claims to explain. In other words, it should refer to empirical experience and be stated in a way allowing the logical deduction of certain inferences close to the level of a concrete observation, so that they can be tested through observation in the field;
- be testable within a reasonable amount of time. One should not consider using a hypothesis, even an excellent one, if it were to take a lifetime collecting data to test it;
- not contradict the main hypothesis when a detailed one is created;
- guarantee that the available tools and techniques will be effectively used for the purpose of verification;
- ensure that the methods of verification are under control of the researcher and that the subject of examination is readily approachable.

As mentioned before, the development of a hypothesis is one of the most fundamental tools for research in any kind of investigation and 'serves as a powerful beacon that lights the way for the research worker' (van Dalen, 1973, p. 17). According to the sequence of research phrases presented earlier, it is the third step to follow in any kind of research process. Taking into account its significance as well as the fact that the literature on the methods of conducting research provides many specific tips on how to properly formulate hypotheses, it would seem no major

problems should occur in the correct formulation of a tentative generalisation, the validity of which is to be tested through research effort.

In practice, however, the situation is different, especially in the case of less experienced researchers (e.g. students learning to prepare written work). In 2021, 20 sample diploma theses were reviewed in terms of the hypotheses formulated in them. They were defended at the faculty of management in the previous year. The dissertations were made accessible to the author following his request to this end to the library's authorities, in the library's reading room. Only those works whose authors had agreed to share them were subject to the study. The theses for review were selected randomly: the first 20 of them whose titles contained the 'management' keyword were selected for further study. The final group consisted of 11 Bachelor's theses and nine Master's theses. Figure 2 presents a list of the studied papers.

Figure 2. Hypotheses in the studied dissertations



Source: author's work.

As Figure 2 shows, the majority of the first-cycle theses contained no hypotheses, which, however, is consistent with the requirements for this type of dissertations (prepared on the basis of the applicable legislation, including study regulations as well as traditions and good practices cultivated at universities). Universities recommend that the introduction to a diploma thesis contains information explaining the purpose and scope of the work, justification for undertaking a given topic, the layout of the work with a brief description of chapters, as well as the definition of the cognitive and practical values of the study. A hypothesis or hypotheses can be quoted in the introduction only on request of the thesis

supervisor. The hypotheses presented in two dissertations were questionable in terms of the correctness of their formulation.

One of them was expressed in a way that suggested the author's uncertainty or limited trust in their hypothesis. The other had all the appearances of being unverifiable (no detailed theoretical evidence seemed to be available to support the idea), whereas, as mentioned before, a hypothesis that cannot be empirically tested cannot claim to be a scientific one (Brzeziński, 2004, p. 225).

The examination of a small number of studies indicate the need to pay closer attention to the meaning of a hypothesis, its significance and proper formulation. The propositional calculus of formal logic may prove a helpful tool in the correct formulation of hypotheses, which will be explained and demonstrated in the following chapter.

4. Using the propositional calculus of formal logic in creating hypotheses

Logic as a science, i.e. the theoretical and methodical research into the ways of reasoning and expressing thoughts, originated in ancient Greece. It is therefore one of the oldest sciences. Aristotle (384–322 B.C.) already gave logic such a perfect shape that even in the 18th century Immanuel Kant believed that nearly nothing else can be added to it. According to Trzęsicki (1996), the laws governing logic are universal and thus may apply to all reasoning, regardless of the area. The laws of logic are also necessary, which means that any reasoning contradicting them is incorrect. Currently, there are two central areas on which the science of logic focuses. The first is clear, precise, consistent and orderly speech and thinking. The other is correct inference (Kiczuk, 1995, p. 41). Within the second area, logic does not deal with specific conclusions, but presents the issue in general. It attempts to indicate the examples of correct inference by comparing them with those of erroneous inference. The branch of logic dealing with such issues is called formal logic.

According to formal logic, each science is characterised by a set of its own specific concepts and a set of dedicated words (names of objects and properties studied by a given science, etc.). For instance, there are terms and concepts specific to physics (e.g. 'electric charge', 'speed'), biology ('cell', 'tissue'), mathematics ('number', 'integral'), management sciences ('manager', 'enterprise'), etc. Concepts and words that are specially dedicated to a given science can be described as linguistic (non-logical) constants. In all sciences, however, in addition to their specific terminology, there are also terms common to all sciences (they are, or can be, used in the

formulation of theorems of various sciences). They are known as logical constants and are divided into three groups:

- terms, e.g., 'to be';
- quantifying words, e.g., 'none', 'everyone', 'certain';
- inter-sentence conjunctions and a pre-sentence conjunction, e.g., 'no'.

Each science builds its sentences using both the words specific to it and the common scientific terms. Formal logic examines expressions which are created this way. One of its basic branches is the calculus of sentences, which studies the relationships between sentences or sentence functions that are formed by means of sentence-forming functors (sentence conjunctions) from sentences or simpler sentence functions. In other words, propositional calculus determines the ways of using sentence functors in correct inference (Jarmużek & Tkaczyk, 2015). It also describes the laws and logical diagrams that are exclusively built of logical constants and variables (symbols which can be replaced with constants of an appropriate category, i.e. names, numbers, functions, sentences). As sentence variables, it uses the letters: p, r, s, q, p_1, r_1, s_1, q_1, p_2, r_2, s_2, q_2... The constants of propositional calculus are sentence-making functors with sentence arguments. Appropriate symbols are introduced for these constants which enable a concise and clear formation of sentences.

Since formulating hypotheses involves *de facto* creating sentences, and the formal objective of logic is always correctness[2], the postulate to combine both areas and formulate hypotheses in accordance with the rules of the propositional calculus of formal logic seems justified. According to it, the basic categories of expressions that make up a language are: sentences (in the logical sense), names and logical functors. The definition of a sentence in the logical sense does not differ from the commonly accepted understanding of a hypothesis: it is a grammatically declarative statement, true or false, which cannot be both true and false at the same time. Its being true or false is defined as a logical value by introducing the following symbols: 1 – true sentence, 0 – false sentence. However, determining the truthfulness of specific sentences does not belong directly to logic, but constitutes the cognitive side of individual sciences (of specific disciplines). For example, the sentence: 'Poznań lies on the Warta river' is true from the point of view of geography, but false from the point of view of propositional calculus. In more scientific categories: this sentence's logical scheme p is not a tautology. This is consistent with the essence of the hypothesis, the truth of which must be tested through research.

[2] Ajdukiewicz (1960, p. 3), analysing the benefits of studying logic, refers to the analogy between logic and grammar. Just as grammar sets the rules for correct speech, formal logic provides the rules for correct reasoning and justifying statements.

Therefore, logic does not deal with the evaluation of the correctness of a sentence, it is rather helpful in creating correct patterns of statements which have to be verified anyway. Given that logic takes into account not the content, but the structure of sentences, when creating a hypothesis according to its rules, one should focus on building the language of schemas, i.e. formulas (sentence functions). Language (and therefore a set of sentence patterns) is divided into a dictionary and syntax (it defines the way of building correct expressions). The dictionary of sentence calculus consists of:

- sentence variables – symbols of the letters of the second part of the Latin alphabet, for which any sentences can be substituted (they are the carriers of sentences): p, r, s, q, ..., p_1, ..., p_n, r_1, ..., r_n, s_1, ..., s_n, q_1, ..., q_n, ...;
- logical conjunctions (functors) – see Table 1;
- auxiliary symbols (punctuation marks – commas, brackets).

Table 1. Conjunctions used to form hypotheses according to the propositional calculus of formal logic

Conjuction	Name	Symbol	Lukasiewicz's symbol	Category (sentence-making functor from one or two sentence arguments)
It is not true that...	negation	$\sim$	N	$\frac{S}{S}$
or	alternative	$\vee$	A	$\frac{S}{SS}$
If..., it will...	implication	$\rightarrow$	C	$\frac{S}{SS}$
and	conjunction	$\wedge$	K	$\frac{S}{SS}$
Then and only if...	equivalence	$\equiv$	E	$\frac{S}{SS}$

Source: author's work based on Olejnik (2004, p. 12).

In the table above, symbol $\frac{S}{S}$ represents the sentence-making functor from one sentence argument. It means that this functor creates a sentence which precedes the original one. The sentence-making functor for two arguments $\left(\frac{S}{SS}\right)$ connects two sentences and, as a result, a new compound sentence is formed. The table also shows that we distinguish five basic logical connectives (Buszkowski, 2022). For example, the expression: 'it is not true that' is a negation conjunction used in the context of 'it is not true that p', where p stands for any sentence, e.g.: 'Poznań lies on the Vistula

river'. Badge ~, in the context of ~*p* means: 'It is not true that Poznań lies on the Vistula river'. A ~*p* type sentence is called the negation of sentence *p*.

Therefore, the use of the aforementioned components (variables, conjunctions and punctuation marks) allows the construction of a logically correct hypothesis in the form of a formula (a sentence function or otherwise a meaningful expression of a propositional calculus). Such formulas are the basic subject of research within the sentence calculus of formal logic. It is a calculus from the point of view of a sentence variable, i.e. we examine the relations between the component sentences and the compound sentences that form them by means of defined logical conjunctions. The main criterion for such research is the aspect of truthfulness. We examine the truth of a complex sentence compared to the truth (logical value) of the component sentences (arguments). The starting point here should be the construction of matrices, i.e. tables of truthfulness of individual logical conjunctions. The logical value of the entire formula is calculated using matrices and concentrating on the order of the individual functors of the studied formula.

For example, a pre-formulated hypothesis on the existence of social as well as ecological problems in a given area of research can be written in the form of an implication (if ... then; ... implies ...; from ... it follows that ...; or ... if ...), using the '$\rightarrow$' symbol – the sentence-making functor for two-sentence arguments: 'If there are ecological problems in the region, then there are social problems in the region'. It is a simple implication: $p \rightarrow q$, whose arguments are: the predecessor (the sentence after the word 'if') and the consequent. It should be read as 'if *p*, then *q*' or '*q* if *p*'.

A researcher who knows the truth of *p* and *q* can then check whether the formula (hypothesis) he or she has already created is true from the point of view of propositional calculus. The principle of the truthfulness of implication says that it is false only in one case: when the predecessor is true and the successor is false (true – false; this is a special case of submission – the principle that truth always leads to truth, never to falsehood); in all other cases the implication is true (Table 2).

Table 2. Conditions for the truth of implication

p	*q*	$p \rightarrow q$
1	1	1
1	0	0
0	1	1
0	0	1

Source: author's work.

An analytical condition of the truthfulness of implication can be formulated on the basis of Table 2:

$$[w(p \rightarrow q) = 1] \equiv [w(p) \leq w\,(q)]. \tag{1}$$

All combinations of numbers (0, 1), where the implication is true, satisfy the condition defined by inequalities (1≤1, 0≤1, 0≤0). The condition of inequality is not only met by what is called the 'Ten' (1–0), but means extending the meaning of the conjunction of implication to 'and only then'. For example 'If there are ecological problems in the region, then there are social problems, but not only social problems occur in the region when there are ecological problems'. This fact can be analytically expressed as:

$$[w(p \rightarrow q) = 0] \equiv [w(p) = 1 \wedge w(q) = 0]. \tag{2}$$

Thanks to the application of the calculus of sentences to the process of creating hypotheses, one can also go in a different direction and write the initially outlined hypothesis, using for example the conjunction (... and ...) through the sentence-making functor from two-sentence arguments. As a result, the hypothesis is shortened by saying: 'There are social and there are environmental problems in the region'.

This is a hypothesis written in the form of a conjunction, otherwise known as a logical ratio. The sentences forming its arguments are usually called conjunction factors. Knowing if p and q are true or false allows the determination of whether the conjunction is true (this can only happen in one case – when both factors are true):

$$[w(p \wedge q) = 1] \equiv [w(p) \cdot w(q) = 1]. \tag{3}$$

If the truth of the formula is determined according to the rules of the propositional calculus of formal logic, then one can proceed to the main research in order to verify the already created hypothesis. At the same time, as previously mentioned, when creating hypotheses according to the calculus of sentences, one should remember about the necessity of distinguishing the meaning of the word *correctness* from words seemingly synonymous with it, i.e. *meaningfulness* and *truthfulness*. It may then turn out that a sentence created in accordance with the rules of natural and formalised language, i.e. the classical propositional calculus, will be formally correctly formulated, but at the same time illogical (in other words, the reasoning being correct from the point of view of classical logic may not be correct from the perspective of everyday experience), e.g. 'If I'm not both a teacher and

a doctor, then I'm not a teacher or I'm not a doctor'. Moreover, there are examples of situations in which the reasoning which is incorrect from the point of view of logic is correct from the point of view of experience. It is conditioned by the fact that formal logic takes into account not the content of the records, but their structure. Therefore, before proceeding to the verification of hypotheses created with the use of propositional calculus, their logicality must be checked as well.

5. Conclusion

Many people nowadays want to live a peaceful life, hoping to be challenged by few problems and complications in their surroundings and the environment. Usually the emergence of difficult situations or matters requiring a solution is understood as something bad that should be avoided at all costs. Both in families and in the mass media it is often emphasised that an individual living in today's world should not create problems, but, in contrast, he or she should assume a problem-solving attitude, or even try to prevent difficult situations to arise in the future (Idziak, 2014, p. 3). One can even risk saying that avoiding problems has become one of the manifestations of a carefree and indulgent attitude of contemporary postmodern societies, which place pleasure rather than problem creation at their centre[3].

While avoiding problems is part of human nature, researchers, paradoxically as it might seem, create new problems (of a specific, scientific nature) in attempt to fill gaps in knowledge and on their basis create hypotheses that require verification through research. Such an approach – which does not emphasise the simplification of reality – should not be surprising, given that: 'the main function of science is the cognitive function of acquiring knowledge' (Strawiński, 2011, p. 323). Creating problems with the help of research hypotheses and their further verification is an essential and powerful tool that leads towards progress, which would otherwise – without systematic research – be barely achievable. Scientists' work is crucial for advancing knowledge and promoting progress. It enables people to relate more effectively to their environment in order to accomplish their duties and resolve conflicts. Best and Kahn (1998, pp. 18–19) rightly claimed that 'the secret of our cultural development has been research, pushing back the areas of ignorance by discovering new truths, which in turn lead to the better ways of doing things and better products'.

[3] Researchers believe that the societies of developed countries have now reached the third stage of development, referred to in the literature as 'postmodern era' or 'post-industrial era'. Postmodernism is a continuation of the modern (production) era and the one preceding it, i.e. pre-modern era. Each of them has its own specific characteristics and the distinctions between them are made on the basis of various factors. Compare: Dziewanowska and Kacprzak (2013, pp. 16–18).

In the process of formulating research hypotheses, it is worth using propositional calculus which takes into account the correctness of entries composing hypotheses rather than the truthfulness of their content. The examination of logical relationships between sentences, especially the implications, conditioned by the construction (structure) of sentences and based on the forms and rules of proper inference that is built on these relationships constitutes formal science. The term itself indicates that the form, not the content, is decisive (Urchs et al., 1997, p. 10). In the article, the author attempted to show that before adopting a hypothesis for further proceedings, it is worth decomposing it into prime factors and conducting an analysis of propositions to make sure that it is formulated in a logical manner. At the same time, the author is aware of the fact that the subject matter discussed in the article does not fully exhaust the issues arising from the frame of reference between formal logic and research hypotheses. However, it can be a starting point for further, in-depth studies and research.

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