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AN ATTEMPT AT SUPPLEMENTING SOME SYSTEMS OF CAUSAL LOGIC*

The inadequacy of classical logic to the formalization of reasonings of everyday life, empirical sciences, philosophical disciplines, etc., has often been stressed in logical and philosophical studies of the last few decades. This holds true especially of expressions in which "if p, then q" in the sense of "that p is the case is the cause of q being the case". Classical logic formalized reasonings of mathematics. Its achievements in this field are indisputable. However, mathematics is a peculiar science because, among others, it refers to objects which do not change in time. The functors "is", "if, then", etc., used in mathematics are non-temporal. Meanwhile, causal propositions in physics refer to that which is changing in time. These differences between the propositions of mathematics and empirical sciences turned the logicians attention to inquiries into the formal elaboration of reasonings conducted in the languages of various empirical sciences.

Recently, some attempts have been made to construct logical systems to express the following meaning of the common conditional, "if p is the case, then it is the cause of q being the case"[1]. There is a need to conduct a comparative and substantive critique of these formulations, because the authors in most cases did not take into account one another's studies nor inquired into the adequacy of their systems. The present paper focuses on the substantial aspect of the problem. Because only physical

* Translated from: *Próba uzupełnienia niektórych systemów logiki przyczynowości.* „Roczniki Filozoficzne" 25 : 1977 fasc. 1 pp. 75 - 88.

[1] Cf. S. Jaśkowski. *On the Modal and Causal Functions in Symbolic Logic.* "Studia Philosophica" 1949/1950 No 4 pp. 71-92; A. W. Burks. *The Logic of Causal Propositions.* "Mind" 60 : 1951 pp. 363-382; P. Suppes. *A Probabilistic Theory of Causality.* Amsterdam 1970; L. Borkowski. *Logika formalna (Formal logic).* Warszawa 1970 pp. 72-74; G. H. von Wright *On the Logic and Epistemology of the Causal Relation.* In: *Logic, Methodology and Philosophy of Science* IV. Warszawa 1973 pp. 293-312; G. Berger, *Elementary Causal Structures in Newtonian and Minkowskian Space-time.* "Theoria" 40 : 1974 No. 3 pp. 191-201; A. W. Burks. *Chance, Cause, Reason.* Chicago and London 1977 pp. 421-478.

causality has been discussed some terminological decisions must be made. The second, more extensive, part of the paper will point to the theses which must be included in the system of causal logic. The achievement of various scholars will be taken into account.

1. In the causal relation in physics any concrete individual event localized in time and space can be regarded as cause[2]. Strictly speaking, it cannot be asserted that the causal relation occurrs between classes of events of the same kind. Here, we can speak of causal laws which declare that every of a certain class X produces an event of class Y in certain conditions. Causal relations are individual cases of any causal law.

Thus, we are dealing with causal relations and causal laws. One can refer to a variety of causes and effects. This difference e ncompasses the kinds of transmitted energy and its quantity, as well as various changes accompanying bodies emitting or receiving energy. The quantitative approach involves various functional relationships between the same cause and the same effect, taking into account various parametres of bodies which are, respectively, carriers of cause and effect. Undoubtedly, the representatives of contemporary physics are searching for quantitative regularities.

Philosophers of science and logicians are interested in the general form of the causal law. It declares that in definite conditions W an event of the king X always produces an event of the kind Y[3]. It can be transcribed as follows:

(1) W→if an event of class X is the case, then it is the cause of an event of class Y.

It is also possible to interpret the following proposition so as to produce a more precise formula of the causal law:

(2) $\prod_{x \in X} \sum_{y \in Y} \sum_{W} (W \rightarrow xPy)$, when x and y are variables representing the names of events P is the symbol of the causal relation[4].

The latter formula is not perfect. Formulation (1) is inferrentially equivalent to following formula:

(3) $\prod_{x \in X} (W \rightarrow \sum_{y \in Y} xPy)$

It seems that it would be better to replace variables x and y with appropriate sentential variables which represent the descriptions of certain causally related events. In this case, the equivalent of symbol P must be the causal implication different from the material one. On the other hand every sentential variable may be represented

[2] The understanding of the concept "event" has been discussed elsewhere See S. Kiczuk. *Związek przyczynowy w fizyce a logika przyczynowości* (*Causal relation in physics and causal logic*). „Roczniki Filozoficzne" 25 : 1977 fasc. 3 pp. 119-134.

[3] It is possible to express the quantitative relationships of causal bonds by means of certain equations. It is also possible to select different parameters for one causal law, and so to obtain different quantitative laws.

[4] Cf. W. Krajewski. *Związek przyczynowy* (*The Causal Relation*). Warszawa 1972 p. 229.

as a propositional function. This form seems to be most appropriate in the case of formalization of causal laws[5].

Taking into account the fact that the causal bond is a relationship between two individual events and that this relationship may be generalized by formulating a judgement about the kinds of events, we shall prefer the first possibility in our subsequent considerations[6].

The causal principle receives much attention in philosophy of science. This principle, which Bunge regards as the philosophical assumption of science, the hypothetical principle of scientific ontology, is tacitly assumed by the physicists before beginning scientific research[7]. It is an expression of any efficient causation. The physical principle of causality which is something different from the causal principle in metaphysics takes into account only that aspect of the world which is investigated by the physicist as a representative of a special science.

2. Bearing in mind the above assumptions and the results of the analyses of the causal relation in physics, belonging to philosophy of science, one can proceed to a detailed evaluation of systems of causal logic, or rather the particular laws of these systems with regard to their adequacy in representing causality in physics[8].

First, referring to Burks' system, we shall make some remarks concerning logical laws in which counterfactual implication appears[9]. Conditional sentences are classified in a variety of ways. First of all, they are divided into general and particular conditional sentences. Conditionals may have as their point of departure either the present situation or the situation existing in the past. In the first case, we may speak of something that will occur if a certain condition is fulfilled, or what happen if a given condition was fulfilled. Conditionals of the second type refer to what would have happened if it had happened differently from that which actually happened. In these two kinds of sentences verbs in conditional mood appear. Conditionals which take as their point of departure the situation existing in the past are called counterfactual propositions by the majority of scholars.

[5] Some critical remarks can be made about the so-called formulations of scientific laws introduced by W. Mejbaum in his article *Prawa i sformulowania* (*Laws and formulations*) published in *Prawo, konieczność, prawdopodobieństwo* (*Law, necessity, probility*). Warszawa 1964 pp. 225-262.

[6] The general character of the analyses is ensured by the fact that the physical conception of causal relations postulates their repetitiveness. When we say that a stone thrown into the water produces spreading concentric waves, we assume that such waves always follow the throwing of the stone into the water if the water has analogical properties in each case (e.g., its temperature is not below 0°C).

[7] Cf. M. Bunge. *Causality*. Cambridge Mass. 1959 p. 198.

[8] The analysis of the causal relation in physics, with an intention to make use of these considerations in causal logic, has been given ample attention elsewhere. See Kiczuk, op. cit.

[9] Logics of counterfactual statements shall not be discussed because they are beyond the scope of the present paper. Many such systema are constructed at present. See, for example, D. Nute. *Counter-factuals*. "Notre Dame Journal of Formal Logic" 16 : 1975 No. 4 pp. 476-482; B. F. Chellas. *Basic Conditional Logic*. "Journal of Philosophical Logic" 4 : 1975 No. 2 pp. 133-153.

The use of conditional sentences has two different, though somehow similar, aims. In this way it is often pointed out that the antecedent of the conditional sentence is false. In this way it is also possible to express the causal relation between the fact asserted in the antecedent of the conditional sentence and the fact asserted in the consequent[10]. The appropriate examples given by the logicians suggest that counterfactual sentences are used for this purpose. These sentences state that a certain relationship between certain classes of events is of such a type that if event A is the case, which according to those who utter this sentence canont happen, then event B must be the case too[11].

According to many scholars counterfactual sentences cannot be adequately expressed in extensional logic[12].

The above considerations do not exclude the possibility of accepting the following formula in causal logic:

$$(p \; s \; q) \rightarrow \sim p,$$

where s is a symbol of the functor of counterfactual implication. Variables p and q represent propositions referring to events which are, respectively, cause and effect. Every proposition of causal logic refers to this relation as occurring in certain conditions. These conditions must exist when event A, described by p, occurs, and when event B described by q takes place. We shall not introduce the variable which represents propositions describing the conditions among the propositions of causal logic.

Burks pointed out that causal laws in physics may be expressed by means of affirmative conditional sentences. The implication involved in such a law was called by him causal implication. He used the symbol "c" to denote this implication. The causal relation expressed by this implication is not a causal relation in contemporary physics dominated by relativity theory. In the light of semantic considerations of the causal relation in contemporary physics, in our characterization of the equivalent of "if, then", used in some sense in physics, in the language of formal logic, we must take into account more moments of content than Burks did.

We shall call the new functor needed here the functor of relativist implication and denote it by "c_w".

The expression $(p \; c_w \; q) \rightarrow ((p \wedge r) \; c_w \; q)$, whose equivalent is a proposition in Burks' system may be adopted in the system of causal logic if r described the conditions in

[10] Cf. P. J. O'Connor. *The Analysis of Conditional Sentences.* "Mind" 60 : 1951 p. 351 ff; Wright, op. cit. p. 294.

[11] This does not mean that causal relations are expressed only in counter-factual conditional sentences.

[12] Cf. H. Kahane. *Logic and Philosophy.* Belmont-California 1969 p. 325 ff. Burks, op. cit. p. 366; O'Connor, op. cit. pp. 356-359; J. Giedymin. *Charakterystyka pytań i wnioskowań kontrfaktycznych (Characterization of counter-factual questions and inferences).* „Studia Metodologiczne" 1 : 1956 pp. 24-26. Giedymin clearly emphasizes that conditional counterfactial conjunction is not a truth-functor.

which the causal relation occurs or describes events which have no effect on the relationship between events described by p and q.

Because the causal relation is transitive the following proposition may be adopted:

$$((\text{T } 1)\ ((pc_w q) \wedge (qc_w r)) \rightarrow (pc_w r).$$

The task of formal logic is always to demonstrate the relation between different functors. Thus, we may discuss the usefulness of the following formulas:

$$((pc_w q) \wedge (\sim p)) \rightarrow (psq)$$ [13]

$$((psq) \wedge (qsr)) \rightarrow (psr)$$

$$((psq) \wedge (qc_w r)) \rightarrow (psr).$$

The functor of relativist implication is not a truth-functor. If two sentences describing certain events of interest to contemporary physicists are conjoined by the functor of relativist implication then it is possible to connect them with the functor of material implication. This can be expressed in the following way:

$$(\text{T } 2)\ (pc_w q) \rightarrow (p \rightarrow q)$$

The functors of material and relativist implication play different roles in the system of causal logic. The role of relativist implication cannot be compared to the tasks of the questionable implication in one of S. Jaśkowski's systems[14]. The questionable implication plays an analogous role to that of material implication, i.e., the primary rule of modus ponens can be based on it. On the other hand, in Burks' system there is no rule of modus ponens for causal implication, there is only a rule for material implication. Causal implication, or relativist implication here, conjoins two sentences not only on account of logical value but also on account of their content[15]. The complex sentence formed with the help of such an implication may be either true or false. It may be an antecedent or a consequent of material implication. The introduction of new kinds of implications characterized by methods of contemporary logic furnishes us with indispensible tools of logical analysis of the languages of physics and other sciences.

Burks adopted a series of laws of causal logic by establishing the relationships between causal implication and strict implication. According to him strict implication entails causal implication. However, the modal functor appears in systems of

[13] Burks assumes as a thesis the following expression: $(p\ s\ q) \equiv ((\sim p) \wedge (p\ c\ q))$. This equivalence gives rise to substantive objections because with the help of counterfactual implication it is possible to express not only causal relations, and especially not only causal relations in physics.

[14] *Rachunek zadań dla systemów dedukcyjnych sprzecznych* (*Sentential Calculus for contradictory deductive systems*). "Studia Societatis Scientiarum Torunensis" 1 : 1948 No. 5 p. 66.

[15] He attempts, for example, to take into account the moment of temporal succesion of effect after cause, which shall be discussed at greater length in the further parts of the work.

strict implication. The meaning of the expression "it is possible", "it is necessary" appearing in the propositions of these systems is not quite clear. The analysis of the causal relation in physics reveals that necessity is a feature of this relation in physics, but necessity understood in a way peculiar to these relations. Burks did not give any semantic justification of his introduction of functors taken from C. J. Lewis' system to the system of causal logic.

Apart from modal functors connected with systems of strict implication Burks introduced into his system yet another kind of modal functors. He speaks of causal necessity and causal possibility. However, it is difficult to accept as a proposition the expression declaring that if a logical necessity occurs, then causal necessity occurs too, as was assumed by Burks. In a later paper he slightly modified this approach but he continued to try to define the functor of causal implication by means of the functor of causal necessity and material implication[16].

The functors of possibility and necessity are formal constructs, as a matter of fact redundant in the formalization of reasonings conducted in the language of physics. The logic of the causal relation in physics cannot be a formal theory of relations between physical and logical necessities. It must be a logic searching for laws governing the use of the functor of relativist implication whose equivalent in the language of physics can be found in the conjunction "if, then" meaning "that p is the case, is the cause of q being the case". Furthermore, the causal relation is a two-member relation occurring between elements which ought to be interpreted as events. Thus, it is difficult to refer to consequents or antecedents of relativist implication as true or false on the basis of causal laws. On the basis of causal laws the propositions which are particular instances of these laws are either true or false. These propositions are conditional sentences. Burks' own examples bring this out. In some of these propositions variables p and q represent simple sentences describing events, and in the propositions in which symbols of causal possibility and necessity have been introduced, these variables represent certain conditional sentences. Thus, it seems redundant to introduce the functors of causal possibility and necessity to the system of causal logic, and it is inadmissible to rely on the functors "it is possible" and "it is necessary" without pointing to their meaning in physics. Methods of formal logic alone do not insure against mistakes in solving the problems connected with non-classical logics which are non-extensional. Various intuitively paradoxical propositions appear. For example, the expression $p\ c_w\ p$ cannot be a proposition of causal logic. But the following formula is such a proposition:

$$(\mathrm{T}\ 3) \sim (p c_w p).$$

In the system of causal logic it is not possible to adopt as a proposition the formula appearing as number 6 of the expressions of Burks' system. The negation of the

[16] *Dispositional Statements*. "Philosophy of Science" 22 : 1955 p. 175.

sentence describing an event refers to the non-existence of this event. It is difficult to accept the non-existence of the carrier of effect as the cause of the non-existence of changes in the carrier of cause.

In connection with the asymmetry of the causal relation in physics the following expression is a proposition:

(T 4) $(pc_w q) \rightarrow \sim(qc_w p)$.

If the event a_1 produces the event b_2, then the event b_2 does not produce a_1. For example, the transmission of speed and energy by the ball A will be the cause of the change of speed of ball B, but not the other way round[17].

The existing laws do not make the meaning of relativist implication clear enough. They do not take into account all features accorded to the causal relation in physics, especially the features of necessity and temporal succession. Laws which would give a desired meaning to the ambiguous conjunction "if, then" must be found. Von Wright's ideas may be of use here. However, his formulations are not beyond dispute because he investigates causal relations in the atomistic model of the world constructed artificially. Thus it is necessary to take into intuitions from physics when formulating a logic to represent causal relations in physics. From the point of view of physics it is objectionable to treat the total state of the world as a set of logically independent atomic states which can be grasped cognitively and expressed as propositions connected only with truth-functors.

On the other hand it is possible to accept von Wright's assumption of the discreteness of time. We may add that these units of time in which no further parts are distinguished may be called moments of time.

Every theory of contemporary physics excludes the time which is characterized by the topology of a closed construct. Even in relativity theory it is asserted that events are ordered in space by means of the relation "earlier" or "later" although time does not have to be metrical here. The relation "later" allows of discrete, dense and even continuous time.

We cannot agree with von Wright when he speaks only about the ramified structure of time in the relativist world and the temporal incomparability of every two events apearing after another event, when these events are considered in terms of relativity theory.

In order to grasp the meaning of relativist implication it is necessary to accept the following proposition:

(T 5) $(pc_w q) \rightarrow (p \rightarrow tTq)$,

where T is a symbol of von Wright's tense-logic .Von Wright constructed two logical systems, each containing one of the two different functors symbolically denoted

[17] The mutual interaction occurs only between bodies A and B. Their mutual interactions are simultaneous. However, none of them is the cause in relation to the other.

by T[18]. In the first of these systems T should be read as "and next", and in the second, as "and then". The two systems differ only in a single axiom. The lexicon and primary rules of both systems are identical. Von Wright considers various possible structures of time, e.g., ramified time, linear time, circular time, etc. Every such possibility entails the change of an axiom of tense-logic. The above observations concerning time in physics enable us to eliminate some possibilities. It is ultimately possible to accept in the calculus "and then" all axioms of the "and next" system except the second one, i.e.,

$(pTq) \wedge (pTr) \equiv (pTq \wedge r)$ which must be replaced with the

following von Wright's axiom:

$$(pTq) \wedge (pTr) \equiv (pTq \wedge r \vee (qTr) \vee (rTq))$$

This axiom eliminates ramified time[19].

The feature of the necessity of the causal relation is prominent among its features. Thus, causal logic should include the following proposition:

(T 6) $(pc_w q) \rightarrow N(p \rightarrow q)$,

where N should be read "it is necessary". The definition of the features of necessity of the causal relation in physics comprises temporal expressions. Von Wright analyses modal functors with the help of certain temporal expressions. Although his analyses refer to the artificial world constructed by him it is also possible to speak about causally related events rather than about the total states of the world. For example, that "Mp" is now true, may mean that the event denoted by p will appear 1° either the next moment or 2° at a later moment. "Np" and "MMp" can be interpreted analogically[20]. Both conceptions of modal functors enable us to accept the propositions of von Wright's system that if p is true of an event at the next moment, then the state of affairs denoted by p is now a possibility.

Taking into account semantic analysis of the causal relation in physics we should adopt the second interpretation of modal functors which appear in propositions of causal logic, because an impulse of energy spreading with finite speed, e.g., as electromagnetic radiation may reach the carrier of effect after one, two, etc., units of time (moments). We cannot distinguish any number of the moments because the constructed logic would lose its generality.

[18] Cf. G. H. von Wright. *Always*. "Theoria" 34 : 1968 pp. 208-221. The letter "t" a is symbol of any tautology of propositional logic.

[19] In tense-logic on which the system of causal logic in physics is based, the axiom of circular time cannot appear, because theory of relativity assumes open time.

[20] The functor of necessity can be defined by means of negation and the functor of possibility. However, it must be stressed that model functors in logic of causality are understood in a different way than, for example, N and M, in J. Łukasiewicz's fundamental modal logic.

The second interpretation comprises as its propositions the expression $Czp \to Mp$ which can be transformed into $Np \to Zaw\ p$[21], meaning that if p necessary, then p always.

As a result of these considerations the following proposition should be adopted:

(T 7) $(pc_w q) \to Zaw(p \to q)$.

The temporal functor used here appears implicitly in von Wright's calculus "and then" because Zaw can be replaced with $p \wedge \sim(tT \sim p)$. The latter formula means that now it is that p and some time later there shall be no p.

It seems that the modal functor used to characterize the causal relation in physics is adequate to the findings which can be made in the intuitive basis of the logical system under discussion.

Von Wright offered an outline of tense-logic which, appropriately modified, can be used in causal logic. However, his entire determination of the causal relation from the point of view of contemporary physics is unacceptable. It permits the coincidence of causes and effects. The examples used by him suggest that he does not distinguish clearly enough the different conceptions of the causal relation in physics and in everyday life. Moreover, he gives too few logical propositions to make this relation sufficiently precise.

In order to take into account all features of the causal relation one can add new specific propositions, among others, by an appropriate transformation of the formulations in the language of theory of relations proposed by G. Berger[22], e.g.,:

$qLp \to \sim(pc_w q)$,

where L should be read as "later than". Propositions which include truth-functors, beside the functor of relativist implication, can also be accepted in the system of causal logic:

(T 8) $(pc_w q) \wedge (pc_w r) \equiv pc_w(q \wedge r)$.

Certain features of the causal relation have been expressed in the language of causal logic. However, all these propositions cannot constitute the contentual definition of this relation, so important in physics. We have already turned the attention to temporal asymmetry. The asymmetry of the causal relation is determined by the transmission of energy from the carrier of cause to the carrier of effect. Moreover, if a causal relation occurs between two events the change of the value of the cause entails the change of the extent of the effect. In other words, if a is the cause of b, and a undergoes a change, then b changes too. We must assume here the lack of influences of other bodies on the carrier of effect, apart from the workings of the carrier of cause.

[21] In von Wright's model analogous expression were also propositions. The symbol "Cz" appearing in these formulas should be read as "sometimes".

[22] Op. cit. p. 194.

Taking into account the fact that physics postulates the essential repeatability of all causal relations and (with an appropriately broad understanding of change) the asymmetry of the causal relation springing from the unilateral transmission of energy we may attempt to express in terms of the language of logical theory of change. Sometimes, we regard as a change of event *a*, appearing in time *t*, its non-appearance in the next moment, even though it could have appeared [23].

Outlines of the systems of logic of change can be found in works devoted to logic of actions and logic of norms [24]. The language of logic of deeds is formed through the enriching of the language of logic of change and the language of logic of categorical norms may be formed through a further enriching of logic of actions.

Logics of deeds describe different human attitudes toward changes, e.g., willful effecting of the change, causing the change partly under duress, willful renunciation of effecting the change, renunciation of causing the change under total duress [25]. In the logic of norms the simplest formulas have the following form: it is an obligation that a certain acting person adopts an attidude towards the change.

Formal characterizations of the functor of change appearing in logics of norms and deeds are not adequate to describe changes which could have a semantic interpretation in physics. A more detailed characterization of this functor is contained in logics of change dealing with changes alone. Logical systems constructed by A. A. Zinoviev [26] and S. Rudziński deserve attention in this respect. Rudziński's conception of the functor of change agrees with the characterization of the causal relation in physics although his system of logic of change should be subjected to major modifications [27].

In Rudziński's system the specific functor is treated as an inter-sentential one. The formula "*p*Zm*q*", where "Zm" is a symbol of a new functor may be read in the following way: "that that *p*, changes into that that *q*". A typical expression of various systems of logic of change is "*p* Zm$\sim$*p*". The interpretation of this expression given by Rudziński does not refer to physical events but to physical facts. It seems that

[23] Such conception of change is also encountered in many systems of logic of change or deontic logic. See, e.g., G. H. von Wright (*An Essay in Deontic Logic and the General Theory of Action*. Amsterdam 1968 p. 39).

[24] Logic of deeds is often called logic of actions.

[25] "To do" means to effect a certain change in the world or to obstruct its occurrence. See Wright. *An Essay* p. 38.

[26] *Logika nauki*. Moscow 1971 pp. 219-222.

[27] Cf. S. J. Rudziński. *Logika zmian w "Norm and Action" G. H. von Wrighta* (*Logic of changes in G. H. von Wright's "Norm and Action"*). "Acta Universitatis Wratislaviensis". Prace filozoficzne XII. Logika 3. Wrocław 1973 p. 43. T. Kubiński is the author of several articles devoted to logic of change. However, he always speaks of human actions connected with changes. In his systems of logic of change the peculiar functor may play the role of the sentence-forming functor in relation to nominal arguments. See T. Kubiński. *Kryterium matrycowe dla logiki zmiany von Wrighta* (*The matrix criterion for von Wright's logic of change*). „Ruch filozoficzny" 29 : 1971 No. 1 pp. 43-47; *Logiki czynów i ich semantyka* (*Logics of deeds and their semantics*). Ibid. 30 : 1972 No. 2 pp. 177-183; *Pewna hierarchia nieskończona modalnych logik zmiany* (*A certain infinite hierarchy of modal logics of change*). Ibid. 33 : 1975 No. 1 pp. 41-48.

this functor of the logic of change may be used in the formal characterization of the functor of relativist implication[28].

The above considerations have demonstrated that the adopted propositions are true in the world of causally related events in physics. The propositions of the logical system outlined above were written with the help of functors from several logical systems constructed earlier by various authors. However, the selection was not accidental. In the course of the above considerations we have justified the choice of tense-logic, modal logic, and summary logic of change on the basis of semantic criteria. A partial modification of these systems has also been made[29]. The model of physical reality has served as the primary criterion for the sufficient harmonization in the formulation of particular theses. The specific theses of causal logic characterizing the primitive functors, including the functor of relativist implication, are not the only propositions of causal logic. Laws determining other functors which appear in propositions comprizing c_w also belong to the system. Thus, we can express all these theses in an axiomatic system[30]. The assumptions of causal logic would then be found in the axioms of sentential logic, axioms of the selected tense-logic (taking into account the attentions that have been made), modal axioms of von Wright's system which can be modified slighty, appropriate laws of logic of change and specific propositions of relativist implication. However, it is possible to introduce certain definitions which enable us to adopt a lesser number of these latter propositions as axioms[31].

The logical system comprizing the above propositions would be more adequate to represent causality in physics than earlier systems[32]. This logic takes into account intuitions from contemporary physics.

Concluding our considerations of causal logic it should be mentioned once again that the causal relation has been treated as a relationship between certain events. Cause and the causal relation may be treated in a different way, making reference to

[28] In causal logic it is possible to being a discussion on the following formula: $((p\ c_w\ q) \wedge (p\ Zm \sim p) \rightarrow (q\ Zm \sim q)$ with an intention to improve it. However, it is necessary to construct a new logic of change. In logic of change and causal logic there is a need to restrict the use of the functor of negation preceding the variables representing propositions concerning events.

[29] It has been demonstrated, for example, that the physical "model" entails the need to change in some way one of the axioms of von Wright's system „And Next", modifying, by the same act, the understanding of the functor T in order to make it coherent with the logic that is being looked for in order to represent causality in physics.

[30] Causal logic may be arranged in various deductive, formalized systems. However, systems with different axioms and primary rules may determine the same causal logic. However, it is not so that a formalized system determines two different logics. This differentiation of logic and formalized system in relation to non-classical logics is often encountered in the studies of the subject. See, for example, G. E. Hughes, M. J. Cresswell. *Omnitemporal Logic and Converging Time.* "Theoria" 41 : 1975 p. 11.

[31] We may try to define "Zaw" by means of "T". Definition of "N" by means of "Zaw" cannot be excluded.

[32] In connection with causal logic it is possible to conduct formal semantic investigations connected with tense-logics and modal logics.

everyday intuitions or considering cause as a realizer, or as a reciprocal interaction between elements, etc. However, the physicist views the cause primarily as an energetic cause, and it is this conception of cause that we have attempted to characterize formally. The axioms formulated in the language of logic determine certain essential properties and the nature of the causal relation in physics [33].

The projected causal logic is not disjunctive in relation to classical logic. Nor is it constructed with the same aims in mind as the many valued logic of Z. Zawirski [34] and P. Destouches-Février [35], which proclaimed the non-universal character of logical laws, maintaining that classical logic was true only in relation to the macrocosmos. It is simply assumed that intensional functions of everyday language or the language of science cannot always to expressed by means of extensional functions [36]. Causal logic seems to observe the specificity of certain intensional contexts. It also explicates an important notion in philosphy of science.

[33] It seems that it is difficult to speak here even of the scope definition of the causal relation. Such a definition may possibly be found in the conjunction of the consequents of the propositions of implication.

It is also possible to say that these axioms determine the meaning of the expression analyzed in this study.

[34] *Science et philosophie.* Varsovie 1937 p. 9; *Les Logiques nouvelles et le champ de leur application.* „Revue de metaphysique et de morale". 39 : 1932 pp. 503-519.

[35] *La structure des théories physiques.* Paris 1951 pp. 10-90.

[36] Cf. S. Kamiński. *Rola pewnych funktorów w logice i w języku potocznym* (*The role of certain functors in logic and everyday speech*). „Sprawozdania Towarzystwa Naukowego KUL" 7 : 1954 p. 221.