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Fuzzy-logical self-organisation system modelling—Illustrating case of self-organisation Czech restaurants during the Covid-19 pandemic

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Abstract

The aim of this paper is to show how Niklas Luhmann's concept of self-organization can be formalized using fuzzy logic. This approach is based on the shared assumptions of systems theory and fuzzy logic and focuses on natural language expression and the complexity of social processes. It involves modelling the operations of the system in relation to the fuzziness of the environment, that is, the transformation of environmental stimuli in gradual uncertainty to binary codes of communication. Based on these operations, it is possible to formalize their unified pattern, which shows the observation of past operations and the simultaneous observation of the environment. An example is given of the formalization of restaurant self-organization in the Czech Republic during the Covid-19 pandemic. The model illustrates and explains how the restaurant system reduces lockdown as an environment, in other words, how the system stabilizes its behaviour in a complex pandemic period.

KEYWORDS

fuzzy logic, Luhmann's theory, modelling, self-organisation, uncertainty

1 | INTRODUCTION

In this paper, we deal with the concept of self-organisation and its modelling in social sciences. Self-organisation-provides a procedural view of social world, which has its benefits due to the mostly static perspective of the mainstream, yet it is not a common explicitly used concept. We have the ambition to support the development of self-organisation using fuzzy modelling. We are based on the system theory of Niklas Luhmann, who formulated self-organisation for a self-referential system. Fuzzy logic has been used in Luhmann system theory by Thomas Kron and Lars Winter, who showed how to model the vague character of social processes in the perspective of gradual differentiation. The paper builds on these authors because they show how it is possible to examine the social world not dichotomically, but comprehensively in various degrees of differentiation, in other words not in black and white, but in various degrees of grey. At the same time, we want to contribute to the spread of formalisation in social sciences by showing how fuzzy modelling can help explain the behaviour of systems in complex conditions. The main contribution of this article is therefore to present the potential in fuzzy modelling of self-organisation as the transformation of irritations, that is, stimuli from a complex environment into system operations and simultaneously as the production and reproduction of the structural unity that determines these processes.

The aim is to specifically show how to model the operations of a system that will stabilise behaviour in a complex environment. This aim is reached by the solutions of two following research questions. Research question 1: *How can we model in fuzzy logic the self-organisation of a system in a complex environment? That is, how can we model the processes of reference to the environment and self-reference to the operations of the system as balancing in the indeterminacy of the two sides of a particular code?* Research question 2: *How can we model in fuzzy logic the unity of self-organisation by which a system reduces the complexity of the environment?*

An illustrative case shows how Luhmann's concept of self-organisation of Czech restaurants during the Covid-19 pandemic can be modelled using fuzzy logic. Based on verbal statements, categorised into so-called argument forms and operationalised into variables, and using fuzzy similarity and centrality points, we will identify the key processes of self-organisation and their unified logic.

Thus, the model represents self-organisation processes in the context of a complex environment. That is, operations take place in reference to both the environment and the internal operations of the communication system. Empirically, the model illustrates and can explain how many restaurants reduce lockdown as an environment, in other words, how these organised systems stabilise its behaviour in a complex pandemic period.

We first introduce the concept of self-organisation and its potential for formalisation, then describe self-organisation in Luhmann's theory. This will be followed by a section on the use of fuzzy logic in system theory by Kron and Winter, and then we will present the shared assumptions for the use of fuzzy logic in system theory to modelling. This is followed by a section that explains the fuzzy logic procedures we will work with and present their use in our case in the follow-up section. Finally, we point out the benefits and possibilities for further development of our model.

2 | SELF-ORGANISATION IN SOCIAL SCIENCES

The concept of self-organisation represents a way of creating order under conditions of entropy without this order being established by any agent (Gershenson & Heylighen, 2003). Self-organising systems operate through contextual local interactions of individuals, which then give rise to complex collective behaviour. Such a system modifies its structure to adapt to changes to requirements and to the environment based on previous experience (Di Marzo Serugendo et al., 2004). As with most social science concepts, self-organisation cannot be characterised by a single definition. However, according to Anzola et al., it is possible to identify four factors that are common to all definitions, namely, pattern formation, autonomy, robustness and resilience and dynamics (Anzola et al., 2017, p. 224). It is also important to consider that self-organisation is the modelling of reality by the observer. Thus, the system does not represent a real ontologically given world but is given by the observer. So a phenomenon can be constructed as a self-organising system (Gershenson & Heylighen, 2003).

The concept of self-organisation allows us to study social phenomena in the perspective of the dynamics of their processes and certain pattern formations and at the same time in an all-embracing scope in space and time. By knowing the attractors of self-organisation and pattern of mechanisms, it is thus possible to explain the dynamics and functioning of various complex systems such as markets or organisations and to predict their evolution. Self-organisation offers the perspective of observing that behaviour at a certain ‘level’ is more than the sum of individual behaviour. Through formalisation into models, these processes can then be represented and explained in the context of the social macro–micro level (Anzola et al., 2017, p. 244; Skår, 2003, p. 1054). In empirical work, the use of the concept of self-organisation varies according to the goal and methodology (e.g., Chaves-Maza & Martel, 2020; Focardi et al., 2002; Foss, 2018; McDowell et al., 2023).

Although the use of the concept of ‘self-organisation’ in the social sciences is increasing, it is not fast enough to reach the wider public or the social science mainstream (Anzola et al., 2017, p. 227). Indeed, self-organisation implies a revision of the epistemological perspective, of the social science mainstream and their reductionist perspective (Skår, 2003, p. 1054). In fact, the problem is the dynamic aspect of self-organisation, which is the opposite perspective to the predominantly static view of social reality in the social sciences, the lack of longitudinal data and the meanings of the term ‘pattern’. The background framework is therefore still small, and it is difficult to make the concept more developed. However, the concept is present in social sciences, and in an implicit form. Traditionally, however, these concepts have tended towards a static perspective to explain social events, which is the opposite of self-organisation, which emphasises a process perspective. In most cases, authors also do not opt for an all-encompassing approach and avoid explanations using models. Luhmann's concept of self-organisation is then one of the few that is explicit (Anzola et al., 2017, pp. 234–242).

Formalisation through models can contribute to the explicit extension of the concept of self-organisation in the social sciences (Anzola et al., 2017, p. 242). However, formalisation is also not a frequently used research tool in the mainstream of social science, mainly due to the rigid methodological paradigm Nevertheless, by using models, we can understand how the behaviour of participants or systems is shaped in the context of certain conditions or rules, and to verify how these micro-rules explain macroscopic regularities. Of course, the limitations of the models, such as the reduction of the content of the event depicted, must be acknowledged, but they will nonetheless allow attention to be focused on the main components of the social event and the relationships between them in space and time. The constant innovation of software then also allows for increasing potential in what these models can represent (Skår, 2003, p. 1055; cf. Silverman & Bryden, 2018, p. vii, chap. 1).

3 | SELF-ORGANISATION IN LUHMANN'S SYSTEM THEORY

Luhmann uses self-organisation to explain how social order is formed in communications, by which the system differentiates itself from the environment. In communications, the system reduces the complexity of the environment by forming expectations about the expectations of others, and the confirmed expectations become the premise for further communications (Luhmann, 2009). Communications are created in the medium of meaning and in forms of language. Meaning is reproduced in variable situations and condensed into generalised forms (Luhmann, 2006), which are then a reservoir for delivering meanings in variable situations (Andersen, 2007, 2011). Based on the media, every action contains a symbolic meaning, but in doing so, actions do not follow from the assumption of causality, but from the assignment of binary codes according to programmes that can change. For example, the economic system differentiates itself in the medium of money according to the programme of prices in the codes of money/non-money (pay/non-pay, own/non-own, etc.) (Luhmann, 1994, p. 231; 1997, p. 310ff.) The economic system observes the stimuli in the political system and transforms them into communication with economic meaning in one or the other side of the code.

Luhmann criticises the ontological dichotomous perspective of research in the social sciences. This means observation on the basis of the theses of classical logic, that is, either one value or the other is true and a third different value is not possible. Luhmann adopts Brown's concept of the form of distinction to deal with de-ontologisation. He formulates a thesis about the observation paradox between two opposite values of a code in a first-order observation, and thus both values can be valid. The solution of the paradox is possible by introducing time into the form, thus detemporalising reality (Luhmann, 1991, pp. 49–50). This time is a third value, which is determined by oscillation from one side to the other, and both sides are therefore implied. The paradox also extends the limit of observation (Luhmann, 1997, p. 46). Using the re-entry operation, which is based on past modes of observation, the difference between the two values is named (Luhmann, 1991, p. 230; 1993, 198ff.). This leads to the observation of another distinction, because 'understanding the topic is at the same time a building block for further communication' (Luhmann, 2000, pp. 59–60). By resolving the paradox in this way, meaning is assigned to each event, and thus the embedding of indeterminacy as the something being understood in the already understood occurs.

Luhmann discusses self-organisation in relation to the concept of autopoiesis (Luhmann, 2000, 2009, p. 45). That is, self-organisation is based on operative closure and cognitive openness to the environment. So the system reproduces itself in communications through self-reference to internal operations and external reference to the environment (Luhmann, 1991, pp. 495ff; Bakken & Hernes, 2003). The operations of the system create the structure of communications, which in turn reproduces these operations into further operations. The structure then implies expectations in relation to the connectivity of operations (Luhmann, 2009, pp. 142–143; Baraldi et al., 2021, p. 40). The structure of the system is only relevant at one point in time, as it is continuously reproduced further through the elements.

Formalising the system theory could highlight and better promote its potential. As Silverman and Bryden (2018) also argue, formalising Luhmann's theory provides a different perspective than the social simulations used in the social sciences. In contrast to their narrow focus on a specific problem, system theory focuses on the interactions of agents that shape the order of society without being determined by pre-existing assumptions (Silverman & Bryden, 2018, pp. 96–97). Kron (2002) focuses on the very issue of what explanatory possibilities system theory modelling provides. The potential of formalising system theory shown by the work of Johnson and Leydesdorff (2013), Leydesdorff and Franse (2009), Achterbergh and Vriens (2002, 2006) and da Silva and Sibertin-Blanc (2018).

Fuzzy logic provides a suitable means for formalisation, as shown in the works of Kron and Winter. Their approach was also stimulating for this paper and will therefore be presented in more detail hereafter. They use Luhmann's theory as one of the concepts to set up their own theoretical framework. Language and complexity are then the assumptions that motivate the use of fuzzy logic to formalise system theory.

4 | SYSTEM THEORY AND FUZZY LOGIC ASSUMPTIONS

Kron and Winter used fuzzy logic to model complex social systems. For this purpose, the authors revise Luhmann's thesis on de-ontologising social events by means of form and extending the form with Latour's concept of hybridity and Beck's inclusive differentiation, as well as Kosko's fuzzy cube.

It assumes that the nature of social reality is hybrid and not dichotomous, and to know it is to distinguish gradual uncertainty, optimally as a gradual membership to both values of the code of communication. Sociology should therefore proceed from a many-value perspective rather than a two-value perspective according to the premises of classical logic. This means to distinguish according to the logic of how-so, that is both values apply to the characterisation of the social object. The concept of gradual differentiation leaves open gradation, which corresponds to the differentiation of social events (Kron, 2015, p. 89, Kron & Winter, 2021). Here, it is beneficial to use Luhmann's form of distinction by leading to the reproduction of one value into different affiliations to one or the other code value (Kron, 2015, pp. 108–181; Kron & Winter, 2018).

According to them, however, Luhmann's approach is not de-ontological and thus multi-valued, but is based on a quasi-ontological binary. It is not a distinction in the sense that the properties of a particular social event belong to both one side and the other, but merely a specification of an 'either-or' logic (either one value or the other applies) (Kron, 2015, pp. 183ff.; Kron & Winter, 2017).

It should therefore be emphasised that paradox in system theory and in fuzzy logic means something different. The paradox in Luhmann's case refers only to the observation of two values in time. Paradox is the indeterminacy in the observation of the system, but not the indeterminacy of the individual operations. Conversely, paradox in fuzzy logic means that the contradiction is the event itself, implying both opposite extremes of values simultaneously (Kron & Winter, 2005; pp. 208–209; Kron, 2015, p. 181ff.).

Fuzzy logic is built on a different basis from Aristotle logic and denies the validity of 2 binary principles of logic, which is the principle of negating the simultaneous validity of two opposing values $x = \text{not } (A \cap A')$ and the principle of excluding the third $x = A \cup A'$ (Kron & Winter, 2009). However, reality cannot be classified by just two true/not true values, but on a scale between them. Fuzzy logic allows this ambivalence of social processes to be operationalised and evaluated. Thus, in the fuzzy logic, social processes have a paradoxical nature and a paradox inherent in social processes. Social processes are social systems that are shaped by equalising the tension between opposing values, or organisation, in response to chaotic conditions of value uncertainty. The fuzzy logic makes it possible to describe, analyse and possibly manage the paradoxical and chaotic nature of social systems. Every element or value has its opposition and exists only in relation to it; the two opposing values are complementary and competitive in social situations (Dimitrov & Kopra, 1998, p. 117). Furthermore, Kosko wrote that the term paradox is mostly considered a state of emergency, but the fuzzy logic shows a different approach. Paradox is the rule, not the exception, except that something is only white, so others must be only black. But that could be different greys. The authors closely related to the fuzzy logic thus stress the need to analyse social processes in terms of balancing the tension between the presence of the two opposing values in social situations. In this way, we can better understand and manage rapidly changing situations (Kosko, 1994).

Kron and Winter rely on the concept of fuzzy cube by Kosko to formalise the hybrid nature of the social event. Hybrid does not express a vagueness between two codes, but a gradual membership in the resolution of two code values. The Point M inside the square then expresses the most vague point and thus the unity of the hybrid. That is, the quantity of the hybrid expresses the same membership to the values, for example, both modern/non-modern and nature/society. M expresses the same quantity of $A \cup A'$ and $A \cap A'$. Thus, it is possible to model hybrids mathematically by using jz to express the sequential affiliation, that is, the inclusive distinction, taking into account the necessity to use form, while showing that everything corresponds to its opposite (Kron, 2015, p. 195). Thus, for example, they model the necessary and sufficient conditions of the (re)production of terror. They used one particular event to show its belonging to terror/non-terror. They addressed the value affiliation of both innocent affected but no attack/attack on the guilty and attack on the innocent/neither attack nor innocent affected (Kron & Winter, 2018, pp. 20–23).

They formulate two theses for using fuzzy logic in system theory, namely, vagueness coded and vagueness affiliation. *The vagueness of the coding* means that the assignment to one or the other party is ambiguous, and on the contrary, it is an expression of the extent to which a communication event is observed and described as, for example, legal or non-legal, that is, the code of the law does not always allow a decision on which party is right/wrong in law terms. *An affiliation vagueness* means the vagueness of a system or environment communication assignment, that is, systems are unable to reproduce a clear distinction between two code values. The code itself is vague, and the distinctions between system and environment become porous. According to them, the communication may belong partly to the system and partly to another system, which is the environment for the first system (Kron & Winter, 2009, 2011).

Thus, the authors begin by identifying the two premises underlying the use of fuzzy logic in the formalisation of self-organisation in the perspective of system theory, that is, language and complexity, as argued by Kron (2015, pp. 195–197).

4.1 | Language in fuzzy logic and in system theory

In system theory, the basic process of communication and the unit of communication is linguistic expression. Language is thus a means of shaping social reality because the consciousness of the communication partners is not mutually knowable; only the action as part of the communication can be known or observed (Luhmann, 1991, pp. 203–204).

Fuzzy logic combines mathematics with hermeneutics, which is a necessary method when researching complex systems. It allows mathematically modelling complex systems through natural language expressions (Kron, 2015, p. 196). These linguistic variables imply the expectations participants associate with an event, thereby expressing its meaning. Fuzzy models represent the representation of certain values of the inferred variables, including an expression of the degree of uncertainty.

4.2 | Complexity and self-reference system

Another common ground is an approach to the social world based on its increasing complexity and the self-referentiality of the system that reduces this complexity.

In system theory, the self-organisation of the system is determined by stimuli in the complexity of the environment. Society is differentiated into functional systems of politics, economics and science (Luhmann, 1997; Roth, 2014) with communications in loose coupling in symbolic generalised media with binary coding. This environment is indeterminate for the system, so that it is stimulated by the uncertainty of the unknowable, which it transforms into operations of its own cognition, creating a closed structure of communications and at the same time a cognitively open relative to the cognition of the environment. Meanwhile, the ways of knowing are based on a uniform logic of operations of translation from indeterminacy to determinacy, which is reproduced in the variability of situations.

Lofti Zadeh argues the importance of fuzzy logic by claiming that as complexity increases, the ability to describe these processes using only precise value characteristics decreases. Nothing is just black or white, but it is variously grey. 'The more accurately one looks at a real problem, the more obscure the solutions appear' (Zadeh, 1965). Each element of the system relates to the previous element and to the next element as well as to the whole system. The whole system is self-referential, constantly changing in relation to itself due to the reduction of chaos. Thus, fuzzy logic makes it possible to deal with social processes in their dynamics, providing a framework for approaching chaos, that is, conditions characterised by indeterminacy and unpredictability (Duignan, 1998, pp. 20–19). Using mathematical procedures, we can describe the self-organisation of a system, which is linked to the structural complexity of the system (Korotkih, 1998, pp. 36–62). The individual always acts in relation to the whole, that is, the whole is formed depending on the capabilities of its parts. Thus, the whole must be understood as the sum of the parts in the sense that at each moment the whole is always a little more than it was a moment before (Woog et al., 1998).

The advantage of fuzzy logic for the formalisation of complex systems is that it does not focus on the exact details of pre-given data, but on the relationships between data. Thus, there is no need to use causality, which is not an appropriate observation scheme in the case of complex systems, but relationships between data. This presupposes a reduction of the data, but this is not a problem if the focus is on relationships, and the point is to establish the unity of membership to the vagueness of the hybrid (Kron, 2015, pp. 195–197).

5 | FUZZY LOGIC

The concept of a system appears in different variations in all situations describing the events around us. People talk about systems of education, about systemic management in economics, about ecological systems or about social systems. In this sense, the term of a system is usually used to refer to more complex objects that can respond as a whole to stimuli from the environment. A common feature of all the situations described above is the existence of an internal structure that processes certain input quantities into output quantities.

The mathematical theory of the system is based on the Cartesian product. Let X, Y be nonempty sets. The Cartesian product of a set X, Y denoted by $X \times Y$ is the set

$$X \times Y = \{(x,y); x \in X, y \in Y\}.$$

Then the system S is any subset of the Cartesian product $X \times Y$, that is, $S \subseteq X \times Y$. The set X is called the set of inputs and its elements the inputs, Y is called the set of outputs and its elements the outputs. The subset S

represents the internal structure of the system. Mathematically, a subset of S is a relation from the set X to the set Y.

Simply put, to specify the relation S from the set X to the set Y is to select pairs of elements (x, y) and collect them into the set S. In technical fields (based on measurements), it is not a problem to unambiguously decide for any pair (x, y) whether or not this pair belongs to the set S. However, in describing social systems, one often works with vague information, for example, attitudes and mood.

However, for this type of information, the required unambiguity may not be met. The possibility of working with this type of information is offered by the means of fuzzy mathematics. Thus, the sets X and Y can be expressed as fuzzy sets. They represent the internal structure of the system S by means of a fuzzy relation (fuzzy similarity is used in this paper).

When there is ambiguity in the data or in the system being represented, fuzzy logic is especially helpful. This is particularly true in socio-economic sciences, where there are frequently a variety of factors at play that can affect results but may not always be clear-cut or simple to quantify. By providing for the representation of unsure data, fuzzy modelling can aid in addressing this ambiguity. Numerous social and economic phenomena can be represented using fuzzy modelling (Çelikyılmaz & Türkşen, 2009).

Fuzzy logic uses language words and fuzzy sets to describe social events, making it easier to understand social science research. It is possible to combine complex social events, including those with nonlinear connections between variables, which can then be studied using fuzzy modelling (Rostamabadi et al., 2020). Thus, fuzzy description allows us to better express the internal structure of the SST, which then allows us to predict future states of the system more accurately.

6 | RESEARCH PERSPECTIVE ON THE FORMALISATION OF SELF-ORGANISATION

Kron and Winter's approach was stimulating for the formalisation of self-organisation in the presented paper. We agree with the view that social events should be observed as hybrid and not dichotomous. We also agree that in this respect, Luhmann's concept of form needs to be complemented by introducing another concept, allowing for various degrees of uncertainty. The initial operative function of form is then to mark distinctions according to the structural unity of operations. However, we do not build on a fuzzy cube and membership to two distinctions, but we focus on the formalisation of self-organisation by modelling what stimuli in the environment the system refers to,

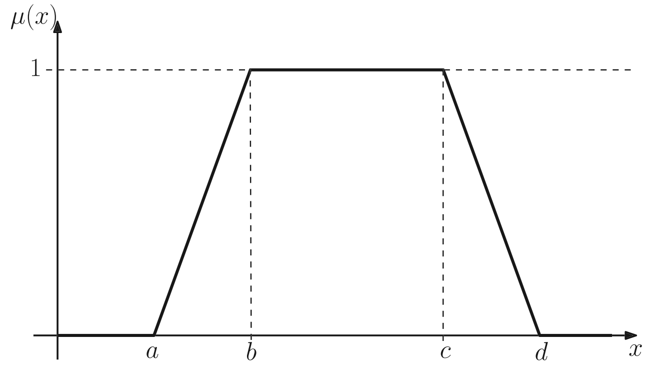

FIGURE 1 Fuzzy grade of membership.

or what is the external reference, and how it transforms them into internal operations, or the self-reference. Based on the observation of these processes, it is then possible to infer a certain structural uniform pattern of the system that shows the observation of past operations and the simultaneous observation of the environment. The structure therefore does not express the static state of the system, but the pattern of its dynamics. We illustrate the approach presented here with the case of restaurant behaviour during a pandemic period.

It is not necessary to encompass and explain all the factors that explain some behaviours, but only what is observed in the system's communications and in what way. Thus, the fuzzy model will mainly show how the uncertainty between two values of a certain primary code is expressed in the language. Through the structural uniform patterns, on the one hand, the semantically different operations of the environment are observed, and on the other hand, they are transformed into operations. For example, a new measure of prevention in a firm against the spread of Covid-19 will lean towards health/non-health values at different degrees of membership given the unity transformations of environment stimuli under the structural unitary formula in the membership of the profit/non-profit code.

7 | METHODOLOGY

7.1 | Fuzzy reasoning

Fuzzy logic is a theoretical system, but a more significant aspect is that it is a way of thinking and a range of methods for proposed logical considerations that show how the imperfection and uncertainty of social reality can be addressed (Abdullah et al., 2012; Selerio et al., 2021). The founder of the fuzzy logic is Zadeh (1965), who formulated the field based on the more-value logic and the fuzzy set theory.

A fuzzy set theory is based on the premise that the key elements of human thinking are not numbers but words (Pask et al., 2017; Zadeh & Polak, 1969).

The most important feature of human thinking is the extraction from masses of data of only such items of knowledge which are relevant to the task at hand, (Dohnal, 1992; Dubois, 2014; Dubois et al., 2003). Fuzzy reasoning is based on a very similar principle (Hüllermeier, 2017).

There are many different fuzzy reasoning algorithms based on reasoning algorithms of differing levels of sophistication (Cox, 1995; Dubois & Prade, 1980). However, many of these algorithms are too complex and difficult to understand to widely use (Ghodousian et al., 2018) because MC experts will only be willing to accept fuzzy-based arguments if these fuzzy algorithms are not prohibitively theoretically demanding (Spolaor et al., 2020). Therefore, the following presentation of fuzzy reasoning is based on a tested and simple algorithm, (Liu & Yu, 2009; Vesely et al., 2016).

A linguistic value is a 'value' that is given by words, for example, very low, low, medium, high and around 5°C. A linguistic value of a monitored variable is transformed into a fuzzy set by the specification of a *grade of membership*. For example, a verbal value around 5°C of the variable temperature is transformed into a fuzzy set by the grade of membership function μ given in Figure 1. A typical fuzzy set 5C of the linguistic value around 5°C of the variable temp is

$$b < \text{temp} < c \tag{1}$$

where (see Figure 1)

$$\mu_{5C}(temp); temp \in [0;\infty] \tag{2}$$

is the grade of membership of the numerical value temp in fuzzy set 5C. There are two fuzzy intervals, namely (see Figure 1)

$$a < temp < b, c < temp < d \tag{3}$$

These intervals represent such numerical values *temp*, which belong partially to the fuzzy set 5C. There are two intervals of numerical values of *temp*, which belong to the fuzzy set 5C with the grade of membership zero:

$$[0;a], [d;\infty] \tag{4}$$

A traditional fuzzy model is a set of m n-dimensional conditional statements (see, for example, Dohnal, 1996).

TABLE 1 Statements.

Supplier	Satisfaction (*RI*)
1	High (*H*)
2	Medium (*M*)
3	Medium (*M*)
4	Small (*S*)

TABLE 2 Dictionaries of the variable *RI*.

RI	*a*	*b*	*c*	*d*
Small (*S*)	0	0	10	20
Medium (*M*)	10	20	20	30
High (*H*)	20	30	50	90

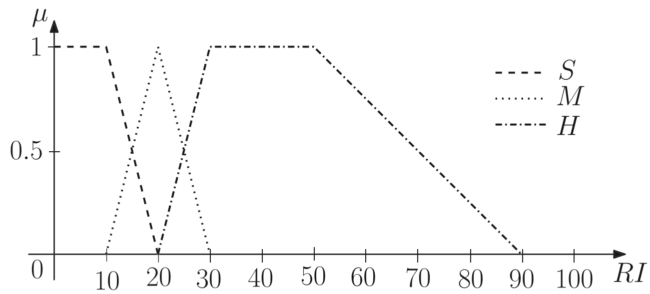

FIGURE 2 Grade of membership of *RI*, see Table 2.

$$\begin{aligned} &\text{if } A_{1,1} \text{ and } A_{1,2} \text{ and ... and } A_{1,n} \text{ then } B_1 \\ &\text{if } A_{2,1} \text{ and } A_{2,2} \text{ and ... and } A_{2,n} \text{ then } B_2 \\ &\vdots \\ &\text{if } A_{m,1} \text{ and } A_{m,2} \text{ and ... and } A_{m,n} \text{ then } B_m \end{aligned} \tag{5}$$

where fuzzy sets

$$A_{i,j}, B_i \text{ for } i = 1,2,...,m \text{ and } j = 1,2,...,n \tag{6}$$

are one-dimensional fuzzy sets and can be easily specified or/and modified using points a, b, c, d of a variable X_j (see Figure 1).

The model (5) represents a function.

$$B_i = f_i(A_j) \tag{7}$$

where A_j is the jth independent variable and B_i is the dependent variable.

Therefore, the model (5) is replaced by the following matrix $(m \times n + 1)$:

$$\begin{matrix} A_{1,1} \ldots A_{1,n} \; B_1 \\ A_{2,1} \ldots A_{2,n} \; B_2 \\ \vdots \\ A_{m,1} \ldots A_{m,n} \; B_m \end{matrix} \tag{8}$$

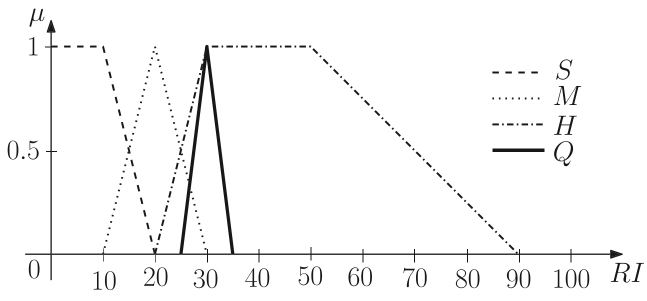

FIGURE 3 Grade of membership of Q, see (10).

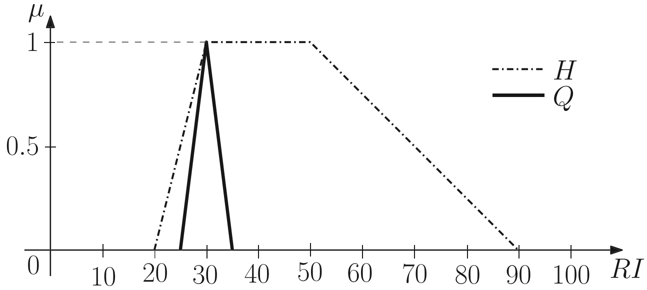

FIGURE 4 Fuzzy similarity between Q and first supplier.

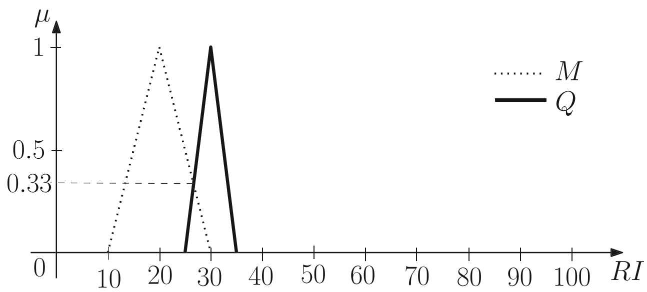

FIGURE 5 Fuzzy similarity between Q and second and third supplier.

7.2 | Fuzzy similarity

A similarity s of two n-dimensional fuzzy sets V, W is

$$s(n,V,W) = \min\left(\max\left(\min\left(\mu_V\left(x_j\right),\mu_W\left(x_j\right)\right)\right)\right) \quad (9)$$

where $j = 1, 2, ..., n$ and x_j is a concrete value of a monitored variable X_j.

The similarity $s \in [0;1]$, $s = 0$ means there is no similarity of the fuzzy sets V a W, $s = 1$ means there is 100% similarity, that is, the fuzzy sets V and W are identical.

For example, a customer decides between four suppliers. The criterion is satisfaction with the supplier's focus on sustainability. Satisfaction (*RI*) is determined based on references, see Table 1. This table represents statements of the model (8), where $n = 1$, $m = 4$.

Verbal evaluation of satisfaction (small, medium, and high) is quantified using fuzzy sets. The fuzzy sets, see Table 2, are dictionaries for the variable *RI* in Table 1. Their graphical representation is shown in Figure 2.

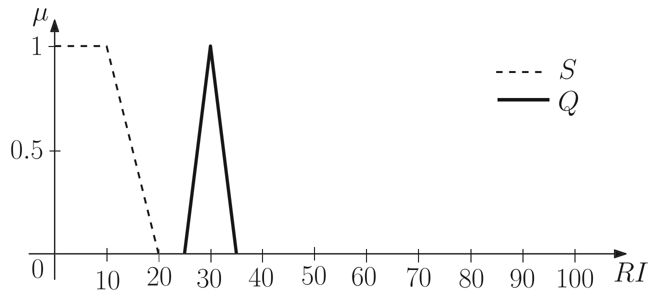

FIGURE 6 Fuzzy similarity between Q and fourth supplier.

TABLE 3 Fuzzy similarities.

Supplier	*RI*	Fuzzy similarity (s), see (9)
1	H	1
2	M	0.33
3	M	0.33
4	S	0

The customer has their own level of satisfaction (10) that suppliers should meet. This level of satisfaction can be seen as a query (Q).

$$\begin{array}{cc} a\,b & c\,d \\ 25\,30 & 30\,35 \end{array} \quad (10)$$

The graphical representation of the query (Q) is shown in Figure 3.

The fuzzy similarities of the query Q (10) with the level of satisfaction with individual suppliers, see Table 1, can be determined by (9) for $n = 1$. A graphical background of the fuzzy similarity is shown in Figures 4–6.

The numerical expression of fuzzy similarities from Figures 4–6 is seen in Table 3.

Table 3 shows that the first supplier (fuzzy similarity equal to 1) fully suits the customer's conditions. For the second and third supplier the fuzzy similarity is small. The fourth supplier does not suit because the fuzzy similarity is zero.

Defuzzification is a special operation that transforms a fuzzy set to a specific value. A widely used method of defuzzification is the method *COG* (*Centre of Gravity*):

$$T = \frac{\sum_i x_i \mu_i}{\sum_i \mu_i}. \quad (11)$$

The resulting value T represents the position of the centre of gravity of the area, which delineates a graphical representation of the degree of jurisdiction.

In this example, only one criterion/variable was taken. It is very easy to extend this issue to several variables. Moreover, this approach may not only be used for selection, but also for comparison, for example, finding out dependence between variables, as seen in the following section where it serves as a replacement for classical statistical methods if the basic prerequisites for their use are not met.

8 | ILLUSTRATING CASE: SELF-ORGANISATION OF CZECH RESTAURANTS UNDER LOCKDOWN DURING COVID-19 PANDEMIC

The example selected for fuzzy modelling is solutions to dealing with the lockdown state by Czech restaurants during the so-called second wave of Covid-19 (January 2021–May 2021).

Restaurants are organised systems that communicate in the form of decisions and can communicate in many codes, choosing a dominant orientation towards a specific functional system (Luhmann, 2000; Martens, 2006, p. 97). They are not part of functional systems, but are structurally coupled to them (Luhmann, 2000, 397ff.; Knudsen, 2012). In this sense, Andersen characterises organisations as polyphonic. Organisations are a 'container' for multiple functional systems, but in a single communication act of connection only one encoding can be selected (Andersen, 2003, p. 162). According to this, restaurants as firms communicate with relatively low uncertainty and thus sufficient probability in the medium of money (cf. Luhmann, 2000, p. 405) and thus in the code profit/loss, but in addition to this, they also communicate in other codes such as health/non-health. However, this is true for communication in a stable probabilistic environment. In our approach, we observe how the uncertainty of the economic code changed during the Covid-19 pandemic, that is, in a highly unstable environment. The self-organised system then provides an example of a shared strategy of many restaurants in the time of a pandemic. The restaurants as organisations were each other's environment but had a shared strategy.

Lockdown was communicated in the form of restaurants' communications that applied to the differences between restaurants and the environment in dealing with uncertainty. These organisations can refer to stimuli of different function systems (healthy, economic and science) and communicate them according to premises with economic primary code and strengthening codes. For a clear demonstration of our approach, we chose references to the political system, as it was arguments with political significance that appeared most frequently in the media space.

During the defined period of the lockdown, restaurants were completely closed to public entry or opening times were limited, but it was possible to deliver food or operate so-called pick-up windows. Overall, we can identify three ways of lockdown solving.

(1) The first way to deal with the lockdown is to offer food delivery and the operation of so-called 'pick-up windows'. Many restaurants have adapted flexibly to the situation and have used and developed this limited business option.

(2) The second way of doing things was to run restaurants illegally. This meant that the restaurants 'were closed formally', but private visits could be arranged for groups of people.

(3) The third way of doing this was political protests, primarily demanding the immediate opening of operations. Several companies set up the initiative 'Otevřeme Česko—Chcípl pes', which later announced the formation of a political movement. The movement organised public protests, called for the resignation of the government, compensated for all the financial damage, argued for necessity, based the observance of preventive measures on a voluntary basis, promoted equal rights for vaccinated and non-vaccinators alike, declared as representatives of all ordinary people and common sense, criticised restrictions on the free movement of people, business and lifestyle.

These three modes of practice thus represent argumentative forms of self-organisation of restaurants in the lockdown era. Or they also represent the problem of profit production and the ways of solving it.

Our approach was based on an analysis of reports that contained information on restaurants' approaches to dealing with lockdown. It should be stated upfront that this is an illustration to provide suitable data for fuzzy modelling, to test the proposed approach and to draw out issues for further development of the approach. In the analysis, we focused on the statements that represented the restaurants' reasoning for proceeding in certain ways; in other words, we observed how restaurants observe the environment and their own processes at the same time. In these claims, restaurants reported on their own decisions and argued why they did so. That is, we ascertained self-reference and other reference.

The individual statements come from a combination of electronic and print sources published in the Czech Republic. The individual statements were obtained in two phases.

The elicitation of individual statements was conducted in two phases. In the first step, articles focusing on restrictive measures concerning restaurants were searched in printed journals. These restrictive measures have been taken by the government or other institutions in the context of the Covid-19 pandemic. In these articles, individual reactions and statements made by restaurants

TABLE 4 Argumentative claims.

Forms of lockdown in restaurants referencing to the political system	Absolute frequency
We will not respect the earlier closure of restaurants (until 8 PM) and will be open in protest.	50
We will open despite the government decree because we object to the absurdity of these decrees.	40
Restaurants need help from the government as well as spas and hotels. Otherwise, mass redundancies, the demise of many restaurants, the loss of motivation and the livelihood of many traders.	42
We resent the government's rhetoric because it doesn't deal with restaurants at all, it only cares about spas, industry.	40
Organise a protest march against the government and its regulations.	40
We want a long-term restaurant support programme for loss relief—we want to extend the antivirus programme, we want a VAT reduction, we want a legalisation of tips.	15
We want loss compensation from this year.	20
Closing at 22 p.m. will destroy us. Asking for an extra hour.	40
Restaurateurs advise each other on how to circumvent government measures and have an 'officially open restaurant space that is not public' ... entry only for opponents of government measures, a petition site on restaurant premises.	15
We are forming the protest movement 'we will open the Czech Republic'.	18

TABLE 5 Variables.

Variable	Media
X_1	*Compliance with regulation*
X_2	*Employees reduction*
X_3	*Service extensions*
X_4	*Complete shutdown*
X_5	*Relevant information from the government*
X_6	*Adequate compensation from subsidy programmes*
X_7	*Economic outcome*

in response to the Covid-19 restrictions were identified. These statements are formulated in Table 4.

As the second step, the individual statements in the Czech language were entered into a Google search engine and electronic resources dealing with the issue were found. These were articles coming from news and government websites. The number of occurrences of the statement was then counted in each result (article). The restaurants' argumentative claims were categorised into the following groups, which represent generalised forms of lockdown.

These forms had to be operationalised into several variables for modelling purposes. This means that each form contains several variables. Table 5 shows the variable and media (measures).

These steps were followed by the definitions of the variables. Based on the first statement 'We will not respect the early closure of restaurants (until 20:00) and will be open in protest', the second statement 'We will be open despite government regulations because we object to the absurdity of these regulations' and the fifth statement 'We will organize a protest march against the government and its regulations', the variable X_1, *Compliance with regulations*, was created.

The third argumentative statement 'Restaurants need help and relevant information from the government, just like spas and hotels, otherwise there will be mass layoffs, the disappearance of many restaurants, and the loss of motivation and livelihood of many tradespeople' forms the variable X_5—*Relevant information from the government*.

The seventh statement 'We require compensations for the loss of this year' forms the variable X_2—*Reduction in the number of employees*—because restaurants have to lay off their employees as a result of high losses.

Based on the sixth statement ' We want a long-term program to support restaurants to relieve losses - we want to expand the Antivirus program, we want to reduce VAT, we want to legalize tipping' the variable X_6—*Adequate compensation from subsidy programmes*—was defined.

Regarding Requirement 8, 'Closing at 10 pm will destroy us. We ask for an extra hour' variable X_3 was defined.

The variable X_4 was defined based on the ninth statement 'Restaurateurs advise each other on how to circumvent government measures and have an (officially open restaurant space that is not public) entry only for opponents of government measures, a petition site on restaurant premises' and 10th statement 'we are forming the protest movement "We will open the Czech Republic"'.

The shapes of membership function were set for each variable based on the expert estimation of the authors of the article. For the variable X_1—*Compliance with regulations*—the shape of the membership function for the expression 'yes' and 'no' was set equally in the context of the frequent occurrence of statements concerning this

TABLE 6 Dictionaries.

Variable	Expression	*a*	*b*	*c*	*d*
X_1	No (N)	0	0	0.5	0.7
	Yes (Y)	0.3	0.5	1	1
X_2	No (N)	0	0	0.5	0.7
	Yes (Y)	0.3	0.5	1	1
X_3	No (N)	0	0	0.3	0.5
	Yes (Y)	0.2	0.5	1	1
X_4	No (N)	0	0	0.5	0.7
	Yes (Y)	0.3	0.5	1	1
X_5	No (N)	0	0	0.3	0.5
	Yes (Y)	0.2	0.5	1	1
X_6	No (N)	0	0	0.4	0.7
	Yes (Y)	0.6	0.8	1	1
X_7	Loss (L)	−1	−0.5	0	—
	Zero (Z)	−0.3	0	0.3	—
	Profit (P)	0	0.5	1	—

TABLE 7 Fuzzy statements.

	Variables						
Statements	X_1	X_2	X_3	X_4	X_5	X_6	X_7
S1	Y	Y	Y	N	Y	Y	P
S2	N	N	N	Y	N	N	L
S3	Y	N	N	N	N	Y	Z
S4	Y	N	N	Y	N	N	L
S5	Y	N	Y	N	N	Y	P

variable see Table 4. The aim was to highlight the fact that many restaurants in extreme conditions (Covid-19) tend to incline towards behaviours that do not comply with regulations, even though in normal conditions, the shape of the membership function for the expression 'no' would be rather close to zero. The variable X_2—*Employee reduction*—also emphasises the risk of redundancy in connection with a possible loss. Under normal conditions, the demand for labour in the catering sector in the Czech Republic is high. During the Covid-19 pandemic, the situation changed, and some restaurants had to close despite financial support from the government. For this reason, the area of the membership function was defined the same for the positive and negative variants. For variable X_3, the emphasis was placed on the situation where restaurants, due to closing as early as 10 PM, were forced to respond by expanding their services. Here, therefore, the shape of the membership function for the expression 'yes' has a larger area than for the variant 'no'. For the variable X_4—*Complete shutdown*—it is taken into account that such a scenario can realistically occur in extreme conditions such as the Covid-19 pandemic. Therefore, the membership function for the expression 'yes' has the same area as for the variant 'no'. Variable X_5—*Relevant information from the government*—takes into account that appropriate and up-to-date information allows restaurants to better respond to changing conditions and attempt to minimise their costs. In this case, the area of the membership function for the 'yes' expression was set larger than for the 'no' scenario. For the last independent variable X_6—*Adequate compensation from subsidy programmes*—some have been proven to have a positive impact on restaurants in the short term and could effectively help. However, from a longer term perspective, the government cannot subsidise restaurants because the cost for the state budget is too high. For this reason, the area of the membership function for the 'yes' option has been set smaller than for the 'no' option.

A set of five fuzzy statements was generated using the dictionary (Table 6, see Table 7). For variables X_1–X_6, the universe was defined on the interval [0; 1]. For each variable from the perspective of the restaurant owners, the meaning of the extreme points of the universe is explained in the following text. For the variable *Compliance with regulation*, the number 0 means unwillingness to comply with any rules, the number 1 means willingness to comply with all rules. For the variable *Employees reduction*, the number 0 indicates the decision not to reduce the number of employees, and the number 1 indicates the decision to reduce the number of employees. For the variable *Service extensions*, the number 0 indicates the decision not to extend services, and the number 1 indicates the decision to extend services. For the *Complete shutdown variable*, the number 0 indicates a decision not to shut down, and the number 1 indicates a decision to shut down. For the variable *Relevant information from the government*, the number 0 indicates a lack of relevant information, and the number 1 indicates sufficient relevant information. For the variable *Adequate compensation from subsidy programmes*, 0 indicates inadequate compensation, and 1 indicates adequate compensation.

For variable X_7, the universe from the perspective of restaurant owners was defined on the interval [−1; 1]. The number −1 indicates a loss threatening the future operation of the business, and the number 1 indicates a gain allowing for future expansion.

The definition of the dictionary and fuzzy rules is an expert formulation of the authors based on electronic news websites monitored in 2020 and 2021. Namely, the following news and government websites were analysed

TABLE 8 Fuzzy query.

Variable	*a*	*b*	*c*
X_1	0.25	0.5	0.7
X_2	0.3	0.5	0.6
X_3	0.4	0.6	0.8
X_4	0.6	0.8	1
X_5	0.2	0.4	0.6
X_6	0.4	0.65	0.9

TABLE 9 Fuzzy similarity.

Economical outcome—expressions	Fuzzy similarity
Loss	0.25
Zero	0.187
Profit	0.115

(www.lidovky.cz, www.idnes.cz, tn.nova.cz, seznamzpravy.cz, irozhlas.cz, www.mzcr.cz or www.mvcz.cz). The individual articles contained verbal formulations such as most restaurants are going to limit their operations, and most restaurants consider the information from the government insufficient. It is because of the vagueness of this input information that a fuzzy approach was taken.

The intervals in Table 6 are the results of a discussion with experts, in this case, a discussion among authors of the article based on the aforementioned analysis of reports. To check, they are subjected to a sensitivity analysis. The sensitivity analysis proved that the interval quantification is not very sensitive, and therefore, potential deviations from the values in Table 6 have little effect.

Our query is when there was a certain political statement and restaurants responded in a certain way, according to restaurants' statements, what was the economic outcome? The aforementioned query can be rewritten as a fuzzy query (Table 8).

The fuzzy *similarity of the query to the dependent variable* X_7 (*economical outcome*) based on statements is shown in Table 9.

For ease of interpretation and practical application, results need to be defuzzificated. One option is to calculate the centre of gravity of the newly formed fuzzy set. The coordinates of the peak points of this set are shown in the table below.

On the basis of coordinates listed in Table 10 the centre of gravity (11) is calculated. The final value of the centre of gravity is −0.029. Because the value is negative, it means there was a loss for restaurants. This gravity centre is a sought-after uniform distinction, so we can say that the uniform distinction of the forms of lockdown in Czech restaurants was the approach that 'government announcements mean loss'. In other words, 'if we behave as the government dictates, we're going to have a loss'. Thus, restaurants were looking for a way to make profits and they were arguing their practices as a solution to the losses they were facing.

According to Kron and Winter (2009), it is necessary to consider uncertainty when studying social systems. While analyzing fuzzy systems, two types of vagueness must be taken into account. First, we need to consider vagueness related to the binary coding of social systems, that is, not every communication event can be assigned to one code value vagueness—this type of vagueness should be referred to as coding vagueness. Second, and as a consequence of the first vagueness, not every communication event belongs unambiguously to a system, but may cross the system-environment boundary and thus belong to different systems simultaneously—this type of vagueness is referred to as affiliation vagueness (Kron & Winter, 2009).

So the vagueness of the described fuzzy system will be assessed. The vagueness of affiliation will be used to describe this vagueness of system because by Kron and Winter (2009), this vagueness implies the vagueness of coding too. Communication is defined through the degree of affiliation. Thus, it takes values from the interval [0,1]. The number 0 means that the communication is not an element of the system, and the number 1 means that the communication is definitely an element of the system. Numbers from the interval [0,1] indicate that communication is not a clearly defined element of the system. The vagueness of affiliation could also be calculated as fuzzy entropy (Kron & Winter, 2009).

In our case, we want to find out the vagueness of the fuzzy system defined by Tables 5–7. The variable of our interest is variable X_7 (*Economic outcome*). Three expressions/faces have been defined for this variable: loss, zero and profit, see Table 6. Using fuzzy similarity, the degrees of affiliation of the fuzzy query to each expression of the variable X_7 were calculated, see Table 9. With respect to the defined expressions of the variable X_7, the studied system can be understood as a set of points in the Cartesian system of three coordinates [loss, profit, zero]. The current state is then represented by a Point A. The coordinates of this point are A [0.250,0.115,0.187]. A graphical representation can be seen in Figure 7.

By modification of the approach by Kron and Winter (2009), the vagueness of affiliation is calculated as the quotient of the distance between A to the plain ρ and the distance of A to the origin of the coordinate system [0,0,0], which can be calculated by the basic relations of analytic geometry. Considering that the affiliation can

TABLE 10 Coordinates of the peach point.

I	1	2	3	4	5	6	7	8
x_i	−1	−0.875	−0.125	−0.094	0.406	0.442	0.942	1
μ_i	0	0.25	0.25	0.187	0.187	0.115	0.115	0

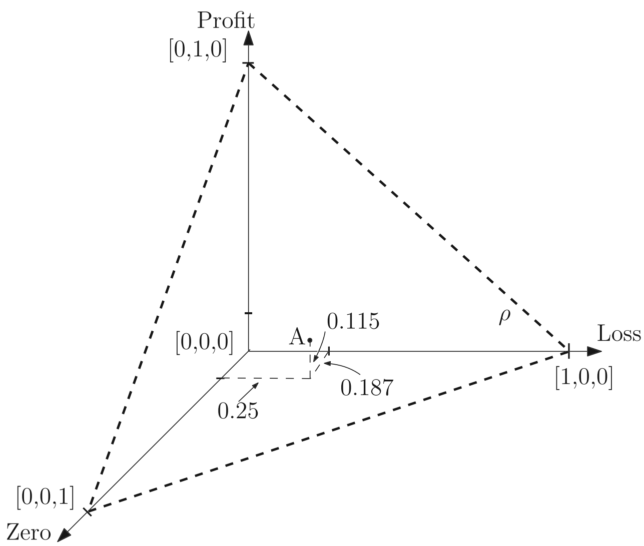

FIGURE 7 Vagueness of affiliation.

take numbers from the interval [0,1], the equation of the plane ρ is

$$\text{Loss} + \text{Profit} + \text{Zero} - 1 = 0. \tag{11}$$

Then we calculate the vagueness of affiliation as

$$\text{Vagueness of affiliation (A)} = \frac{d_{A\rightarrow\rho}}{d_{A\rightarrow[0,00]}} = \frac{\frac{|1\cdot 0.25 + 1\cdot 0.115 + 1\cdot 0.187 - 1|}{\sqrt{1^2+1^2+1^2}}}{\sqrt{0.25^2+0.115^2+0.187^2}} \doteq 0.778. \tag{12}$$

Coordinates of point A [0,0,0] indicate that no order is expressed in the system. Point A means the economic order of the communications in the restaurants (organisations). The coordinates of this point correspond to the fuzzy similarities given in Table 9, which can be explained by the extreme conditions in which restaurants found themselves during the Covid-19 pandemic. The communication of the different government measures was haphazard, and restaurants reacted rather haphazardly in an attempt to survive (0.778). It was difficult for restaurants to plan economic activities to be profitable.

9 | DISCUSSION

Our model is useful for governmental managing social changes like the pandemic, but also for managing evolutionary changes in the economic system. It allows us to explain and understand the behaviour of organisations in relation to the environment.

Based on the similarity of the variables, we then expressed the predominant space given to the self-reference and the foreign reference. We found that in the restaurants at the time of the lockdown, profit–loss labelling was prevalent in addressing the problem of government regulation.

The finding itself is not so surprising. However, it is interesting that the same results can be achieved with a lack of input data, where finding and confirmation of a relationship using classical statistical methods is difficult (Madhavaram & Hunt, 2008).

Small entrepreneurial firms such as restaurants have to face the obstacle of being constrained by very limited financial resources in comparison with large enterprises (Chaston, 2010). Restaurants may not have such large financial reserves compared with large enterprises. Therefore, it is necessary for them to optimise financial resources, human resources, materials and equipment or time as much as possible. For this reason, timely and relevant information regarding government action on Covid-19 is often an existential issue for these types of firms.

Fewer information intensive methods of analysis often achieve more realistic results in cases where the system which is being modelled is very complex. These complex tasks are usually studied at different levels of accuracy because more precise knowledge is available. As the first approach for a decision of complex tasks, experts use experiences represented by common sense instead of mathematical models.

Further development of this approach in system theory may be beneficial for the following reasons:

- Fuzzy logic for interpretations of social processes according to concepts of system theory provides methodological means that are readable for many scientific disciplines, but also for other societal areas such as business, public sector and technological areas.
- With fuzzy logic, we can formalise and explore what meaning concepts are shaped by social systems, and

what space they occupy in systems' communications and how they relate to each other.
- System theory and fuzzy theory are based on polyvalence and therefore provide an alternative to the monopoly of probability and ontologisation in science.

Using fuzzy logic in system theory can provide a beneficial combination of theory and methodology. Thus, to represent a way of studying the self-organisation of processes with the assumption of meaning or value uncertainty and variability, we can depict the social reality of systems as files with unclear boundaries, because we are only able to obtain vaguely expressed data.

With means of fuzzy logic, we can represent the vagueness and level of expectations of our own, and at the same time the expectations of the opposing parties we observe in communications. Thus, the structure of expectations is duplicated, and the expectations of the system, that is, the restaurants, are shaped by the expectation of communication of the observed parties, which in our case were the government and its political announcement.

10 | CONCLUSION

In the paper, we have shown how the integration of fuzzy logic concepts and system theory can be used to formalise the processes by which systems self-organise with reference to the environment. We asked the following research questions. Research question 1: How can we model the self-organisation of the system in a complex environment? That is, how can we at the same time model the processes of reference to the environment and self-reference, that is, reference to the operations of the system? Research question 2: How can we model in fuzzy logic the unity of self-organisation by which the system reduces the complexity of the environment? We have illustrated our approach with the example of formalising self-organisation of restaurants during the Covid-19 pandemic.

Regarding research question 1, it is possible to observe the relationship of restaurants with their environment. It means that we can formalise how restaurants observe environmental stimuli and how they transform them into internal system operations. It is not necessary to encompass and explain all the factors that explain some actions, but only what is observed in what way in communications, as this shapes social reality. The model thus illustrates what environmental stimuli are relevant to the system. In connection with the above-mentioned, we can move on to answering research question 2. System theory helped us to explain the unified logic of restaurant behaviour, while fuzzy logic provided methods to formalise this structural unity.

The work of Kron and Winter was stimulating for our approach. We build on these authors by focusing on modelling self-organisation in terms of the relation of uncertainty to the environment, which the system observes by gradual belonging to binary codes. In other words, indeterminacy is implied in gradual distinctions between two values of a particular code, and these distinctions are based on the structure of the system. At the same time, we thus model the structural unity or order of self-organisation of the system.

An example of restaurant behaviour during Covid-19 pandemic is only to illustrate the use of the fuzzy approach for modelling. It represents how these organised systems self-organised in references to environment.

Restaurants argued their decision on the grounds that any announcement by the government regarding Covid-19 means a loss. This is the positive side of the code, that is, profit because restaurants did what made them a profit. The negative side is associated with the risk of loss. In fact, these practices varied according to the uncertainty with which restaurants associated profit/loss production primarily with government announcements. Thus, the point is not to say that restaurants were more likely to comply or not comply with the measures, but that the variability in their behaviour balanced between these code values.

It is then necessary to observe how the limit of observation is shifting, that is, how the ways of communication are changing. We can ask whether communication will move towards a state where, ‘paradoxically’, political statements will mean gain and non-compliance will mean loss, or whether this ‘turn’ will not happen. This state could arise, for example, if the failure to address the spread of a pandemic causes employees and customers to become ill, so that the loss will be argued on these grounds and the medium of health will be central to the behavioural argument.

Our approach thus formalises the importance in the behaviour of restaurants of different functional areas such as science, health and politics. This is where the recursiveness of the system comes into play, as it is possible to formalise and trace what importance these social spheres or functional systems had in the past and how they might be referred to in the future. In the case, this means that the government is not accepted as a credible actor for the execution of regulatory and executive power, and if its regulations threaten the existence of restaurants, they begin to comply with the regulations only formally, and the regulations are circumvented. However, these assumptions of our model need to be further verified by other procedures.

Pandemics can cause short-term damage such as fiscal shocks. In the long term, economic growth may be reduced (Madhav et al., 2017). A pandemic is a threat to civilisation. Therefore, its occurrence is of interest not only to the natural sciences but also to the humanities. A pandemic is a social phenomenon with important human, socio-economic and cultural consequences (Schwaninger & Schoenenberger, 2022). Emergency preparedness and operations are important for restaurants. In the case of the Covid-19 pandemic, this is a must. There is a need to study industry-wide responses so that restaurants can prepare contingency plans in the event of another pandemic wave or similar situation occurring in the future.

Our model can be further extended to formalise references to different functional media of health, power and money. Research is then concerned with observing how certain behaviours are argued and interpreted, and what relevance they have in solving restaurants' problems such as the distribution of power, scientific or lay truth, and health. Regarding the case, restaurants attribute the value of profit/loss with varying degrees of uncertainty to compliance/non-compliance with measures as self-reference and argue for it with varying degrees of uncertainty by maintaining the health of employees and customers, political proclamations or laws or scientific knowledge as extraneous reference.

The limitations of this conceptual paper can be seen in its focus on the territory of the Czech Republic and the hospitality sector. Therefore, further research will focus first on Central Europe and then on the territory of the European Union. The combination of fuzzy logic and system theory will be worth using in other social-economic fields that shape and have impact on the population in the European Union. For example, the impact of the war in Ukraine on the economic, social and political aspects of our existence seems to be an appropriate use of fuzzy modelling within the system theory. We believe that the application of fuzzy logic in system theory should be further developed. Another limit, given that it is a conceptual article, is a broader discussion of whether Luhmann's theory is dichotomic or, on the contrary, its interpretation corresponds to the uncertainty of the differentiation of the social world. But this topic would certainly be beneficial to discuss in a separate paper. In this respect, it would also be beneficial to discuss in more detail the conceptualisation of the vagueness of the social world in the theories of Latour, Beck and other authors, as well as the empirical work of Kron and Winter.

On the contrary, we see the following contributions of this paper.

When there is ambiguity in the data or in the system being represented, fuzzy logic is especially helpful. This is particularly true in socio-economic sciences, where there are frequently a variety of factors at play that can affect results but may not always be clear-cut or simple to quantify. By providing for the representation of unsure data, fuzzy modelling can aid in addressing this ambiguity. Fuzzy logic can deal with the imprecise and unsure data that social networks frequently include. Numerous social and economic phenomena can be represented using fuzzy modelling (Çelikyılmaz & Türkşen, 2009).

Fuzzy logic enables to transform language statement into mathematical models to describe social events, making it easier to understand social-science research and it is possible to combine complex social events, including those with non-linear connections between variables, which they can be then studied using fuzzy modelling (Rostamabadi et al., 2020).

Fuzzy reasoning algorithms can teach computers to use verbal descriptions like humans. Apart from the Covid-19 situation, the managerial implications of the article should be seen in the light of the fact that the proposed tool can be broadly used for additional fields in social and political decision-making process by defining goal variables related to economic development. More specifically, the tool can be used to determine the importance of individual information related to the war in Ukraine on the economic and social aspects of life in the European Union.

Fuzzy logic provides a mathematical basis for the uncertainty of social processes and in combination with system theory very well and comprehensively describes social phenomena so that their meaning and uniform operational and cognitive logic are evident. The creation of dictionaries (fuzzification) involves a certain degree of subjectivity, as experts often draw on their own experience and knowledge in their chosen field. The robustness of the fuzzy model thus created can be checked by sensitivity analysis.

The model allows us to take advantage of the specificity of system theory, namely, the process view of organisations.

In this approach, it cannot be assumed that systems and environments are static and given, so our aim was not to create a methodological means of understanding what the reality of restaurant behaviour is, but how it is shaped. Our model made it possible to depict not only the meaning given to certain processes in the system but also the context of the environment, that is, how the systems refer to the environment, thereby shaping the environment. The point of centrality ultimately revealed what was a key proposition, and it is a structural unity how the paradox in observing both values of code is handled.

Our ambition was to provide a different perspective on cognition than that established in mainstream theories of social sciences, in which structure is considered something stable and where operations change. It is a projection into the past, where past operations are used as projections into the future. Thus, the system reduces the complexity of the environment while increasing its own complexity. Thus, if we describe and explain the structure of a system, we can also infer what further expectations will be implied in communications; hence, we can predict the behaviour of systems.

We have thus shown the research potential in combining Luhmann's theory, specifically the concept of self-organisation, with fuzzy logic. By doing so, we want to contribute to the extension of self-organisation as a concept in the social sciences. We also hope to simultaneously contribute to the expansion of formalisation in the social sciences, as it can provide a useful means of representing social processes and explaining them.

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