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CONTRIBUTIONS OF MODELING AND SIMULATION TO THE STUDY OF THE CRITICALITY OF COMMUNICATION IN THE URBAN ENVIRONMENT

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Abstract: *The article starts from contemporary urban realities, among which the reaction determined by news is remarkable, regardless of its mode of propagation. Against this background, the paper highlights such situations and their impact on urban functionality. A robust level of societal resilience is desired in such situations, a goal which is difficult to achieve. In this context, it is useful to have a correctly dimensioned overview of the phenomenon, that allow "what-if" analyses. The article contextualizes the role of modeling and simulation, using a specific working tool, and based on the example of the manifestation of possible situations in a city.*
Keywords: *disinformation, modeling, scenario, agents, city, criticality, resilience.*

1. OVERVIEW OF THE APPROACH FRAMEWORK

The description of the problem of interest for the present study brings to attention, on the one hand, an unprecedented dynamic of the development of the contemporary urban environment, and on the other hand, the need to design pertinent solutions to the specific challenges implicitly or explicitly manifested. The functionality of cities, seen as macrosystems, is an issue of multidisciplinary interest, with at least three fields competing for this characteristic: management, engineering, and urbanism. A contemporary challenge of interest that exceeds the classical area of administration has become urban resilience. News and fake news regarding urban events and processes also fall under the umbrella of endangering events that affect cities. If the approaches that address the dysfunction and resilience of critical urban infrastructure subsystems are more frequent, the information circuits that occur daily having as their subject the urban reality and contextualized the specific communication are less common, which constitutes a research niche prone to further exploration. Therefore, the applicable field from the point of view of the study problem is the resilience of the societal communication process, and from the point of view of the analysis of related possible solutions, the field is systems engineering.

In the specialized literature, resilience in the urban environment is placed in two categories, depending on the scope of coverage: one integrative, which concerns the city as a dynamic whole and the second category is fragmentary, comprising research in a specific field (transport, energy, water etc.) or functional process. A complex difficulty as a scientific approach is found in the first case. In both cases, as the basis of the analysis methodology at the system or subsystem level, an adequate representation of the processes, phenomena and components characteristic of the urban environment is needed, this being the prerogative of modeling techniques. Considering the quantitative side of interest associated with the constructed objective

function, simulation techniques facilitated in the implementation of appropriate software packages are those that help study the behavior of the model created under different operating conditions. The research proposed in this article belongs to the second category and it is necessary to point out that there are few studies dedicated to the resilience of communication processes in the urban environment. Communication processes occur both interorganizationally and purely humanly, which is where the research is located. The research question refers to the dynamics of producing and maintaining communication of a threatening event, using only human agents, uninfluenced by technical communication systems.

2. FROM THEORETICAL CONCEPTS TO PRACTICAL REALITIES

Urban resilience is defined in diverse ways, deriving mainly from the concept of resilience itself, in connection with the constructive and functional particularities of the urban environment. A widely cited definition posits that "Urban resilience refers to the ability of an urban system - and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales - to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity." [1, p. 40]. The fact that the urban environment essentially means a considerable agglomeration of inhabitants highlights how great the potential for communication and implicitly for disinformation is, with major effects (social networks facilitate the augmentation of negative effects) on the current functionality of urban processes (and on the consequences of the dysfunctions created by the mode of action resulting from disinformation). A prevalent example at national level, in the context, is carrying out exercises in the domain of preparing the national economy and territory for defense, through which the transition to exceptional states (mobilization, war) of society has been falsely invoked. A number (intensive in manifestation and extensive in subject) of examples at national level is also provided in the pandemic context. Beyond the conceptual differentiations between misinformation and disinformation, the common semantic essence is that there is an alteration of the communication process. This justifies the investigation of specific production mechanisms, determined effects, and the possibility of improving (up to the re-establishment of informational accuracy typical of a daily factual reality, of a correctly communicated reality) the functionality of the process between sender and receiver. From the individual level to the macro level, the way of understanding everyday information and acting accordingly (rationally and with minimal consequences) becomes a national security issue. It is also well known and accepted that there is an inverted relationship between vulnerability and resilience. Being incorrectly or insufficiently informed when an adverse event occurs creates difficulty in understanding the context and in acting to overcome that situation. Therefore, communication is a facilitator of urban resilience management, requiring high efficacy, especially in contexts that endanger the society (the case of crisis management).

Against this background, it is obvious that it is not easy to translate the reality of communication specific to a perilous event happening in an urban context into a working model that allows, through essentialization, conceptualization, or abstraction, a mathematized treatment in order to determine conditionings or ways to improve identified deficiencies. It is reiterated that there are numerous and diverse qualitative and quantitative aspects specific to communication in the urban environment. At least the following aspects are of interest: the typology of communication from the perspective of the content of the message, the context that triggers communication and influencing mechanisms, the typology of participants in the communication process (age, education, profession etc.), the characteristics of the means

(media, IT etc.) of communication, the impact produced by communication, whether the participants in the discussion know each other beforehand or not etc. The following theoretical models of human communication have an essential place in the socio-human disciplines: perspective-taking, managing common ground, theory of mind, imputing one's knowledge to others [2]. As a process, communication becomes resilient after being affected, especially in crisis situations, if the mechanisms of production and functioning in the sender-receiver framework are understood from multiple perspectives.

A special class of models are conceptual models defined as "*abstract, simplified representations of real-world systems, serving as a tool for analyzing a given problem or solution through understanding, communicating, and reasoning*." [3, p. 4]. More specifically, Steven M. Manson emphasizes that "*a simulation model represents key features of a system like a city or economy as a computer program that takes data as input, executes the underlying software, and produces output data for analysis*." [4, p. 207]. Consequently, the success of such an initiative is conditioned, subsumed to the question of how much is too much in the application of modeling and simulation, by the following main factors: what precisely (context) we select as essential from a certain reality of interest, the level of detail of the object of the context, and the proposed objective function.

3. FROM THEORETICAL CONCEPTS TO PRACTICAL REALITIES

A medium-sized city in Romania was chosen as the context of communication, meeting the conditions of interest for the issue of urban resilience and the manner in which communication processes occur in this framework. Specifically, an area of the city of Sibiu was chosen (Fig. 1), where institutions with different and diverse typological audiences are present: university, primary school, bank and private clinic. It is clear that at different times of the day the occupancy of these organizations is different and, implicitly, so is the quantity and quality of the determined communication processes.

The possibility of influencing communication is particularly great through the presence and contact of groups created at a given time in these organizations, which are at the same time groups with a distribution of different ages (pupils/elementary school students, students, adults).



Fig. 1. Disposal of case studies organizations [5]

The way of propagating communication, in different work scenarios containing characteristics of the chosen area, is of interest.

The NetLogo platform was selected as the environment for creating the model, being suitable for modeling and simulating social phenomena. A deficiency brought to attention in the specialized literature [6] is the limitation of achieving advanced optimizations or interoperability with artificial intelligence applications. In terms of use, this platform is characterized by the following main features [7]: it has predefined different applications in its own library, applications that can be accessed in the existing form but also improved; modeling is based on *turtle*-type agents; the platform allows the explicit representation of individual actors (called *turtles*), of the spatial environment (*patches*) and of the dynamic relationships that arise from the interaction rules.

For the present study, NetLogo was used as the main model building tool, due to its ability to: simulate realistic social interactions between agents with distinct age and behavioral characteristics; integrate urban structures (built-up areas, streets, public institutions) in an intelligible two-dimensional form; test scenarios in which the nature of the disruptive event (military threat, fire, human strike) influences the behaviors of agents; measure quantitative indicators relevant to communication resilience, such as the number of misinformed people, distribution by age group and institution of origin.

The model developed in NetLogo aims to simulate how information – whether correct or erroneous – propagates in a delimited urban space, through direct interactions between people who transit or occupy different public institutions. The model is based on a simplified representation of a real area in the municipality of Sibiu, where four institutions with distinct functions are located: the school (red color in the model), the university (black color in the model), the clinic (purple color in the model) and the bank (green color in the model). Each institution simultaneously hosts people from three demographic categories: pupils, students and adults.

Each person is modeled as an autonomous agent, characterized by the following properties: age group (pupil, student, adult), with differentiated interaction probabilities and different reactions when they become misinformed; informational state (misinformed/non-misinformed); initial organization of membership, determined by adjustable percentages for each time period of the day; movement rules, which assume continuous movement, avoiding walls and exclusive use of doors for entry/exit; interaction rules, which determine the information exchange when two agents are in proximity.

The environment is made up of: delimited institutional areas (school, university, hospital, bank); streets widened by two units to allow large flows of people; chromatically marked doors, through which only transits are allowed; labeled areas, inaccessible to agents, to avoid visual overlapping with the names of the institutions.

An agent can transmit erroneous information to another agent if: there is a short distance (patch-adjacent); the discussion event occurs either spontaneously or according to age affinity (more likely interactions between agents in the same category); the global spread probability (spread-chance) is satisfied.

The working model includes three different hotspots of disinformation, depending on the proposed scenario: *scenario A* – military threat (terrorist attack) with the initial hotspot being the bank; *scenario B* – fire hazard (fire), with the initial hotspot being the bank; *scenario C* – strike, with the initial hotspot being the school, university and bank, considered simultaneously. In real time, the model thus designed calculates: the total number of misinformed people; the number of misinformed pupils/students/adults; the level of misinformation in each institution; the temporal evolution of disinformation, through a graph updated per minute; the simulation time, considering that *1 tick = 1 minute*. The model stops automatically after 30 simulated minutes, which allows for uniform comparison between

scenarios and time intervals. Through this structure, the model provides an appropriate experimental platform for: testing the resilience of communication by reporting to different types of events; exploring how urban structure, mobility and social architecture affect the spread of rumors; identifying the most vulnerable institutions and groups; generating recommendations for crisis management in an urban context.

The starting quantitative data refers to the existence of a number of people in different institutions at different times of the day.

4. RESULTS

4.1 *Scenario A* analysis

Scenario A simulates the propagation of false information regarding the existence of a military danger (discovery of a suspicious package) in the area of the "T" intersection. In this context, the model assumes reactions adapted for the three categories of population: pupils, students and adults. Misinformed students tend to be removed / to evacuate the buildings, most adults stay away from the intersection, and some students approach the central area (curiosity / filming). Also, the initial starting point of the rumor is defined by a hotspot – a place where disinformation appears and from which it spreads to other institutions. In *Scenario A*, the hotspot is the bank. This functions as the generating nucleus of the propagation, its role varying in intensity depending on the population density and the mobility specific to each time interval.

The following are the results for the intervals 09.00, 15.00 and 19.00.

At 09.00, the population is concentrated mainly in the school and the bank. After 30 minutes of simulation, 2047 misinformed people are found, distributed differently by age (pupils - 961, students - 557, adults - 529) and by institution (school - 964, university - 468, bank - 272, clinic - 221). The initial hotspot of the rumor (the bank) produces a rapid wave of transmission to the school, especially because the students are numerous and react by evacuating, generating an intense flow of people between the entrances of the institutions. In this configuration, the bank functions as the primary focus, but the school becomes a major secondary focus due to the high density and collective movement of students. The high mobility of adults, in contact with the evacuated students, facilitates the spread of the rumor in the university and hospital.

Context time 15.00 coincides with the highest level of human activity in the entire model. During this interval, the university and the bank are the most populated institutions. After 30 minutes of simulation (Fig. 2) the result is 2500 misinformed people distributed differently by age (pupils - 672, students - 950, adults -878) and by institutions (school - 661, university - 865, bank - 764, clinic - 86).

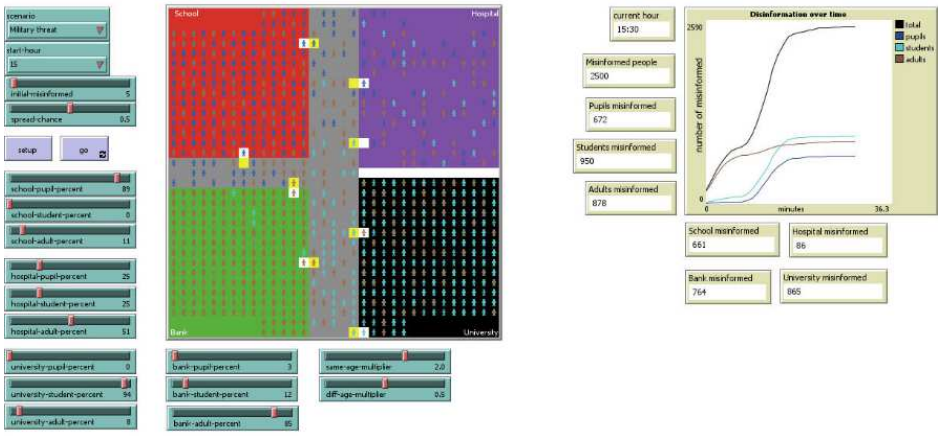

Fig. 2. *Scenario A* simulation results at 15.30

The hotspot located in the bank has the maximum impact of the day at this time. Demographically, students are the dominant group and show ambivalent behavior (some avoid the central area, some approach it out of curiosity). This generates frequent crossings between institutions, which transforms the university into the main receiver of the rumor. Practically, the bank (hotspot) simultaneously feeds: the school – through the traffic of students in transit; the university – through the intense movement of students; secondary institutions – through adults crossing the street space. Thus, the time point 15.00 highlights the strongest amplification of the hotspot effect, generating a maximum level of disinformation.

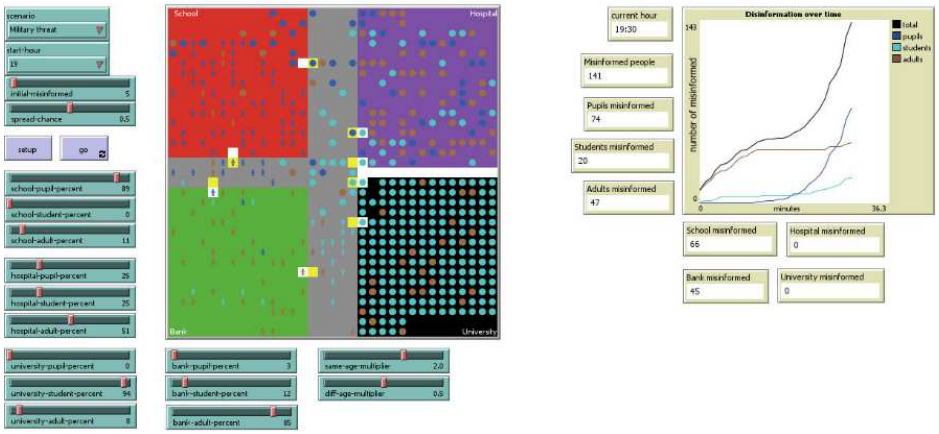

Fig. 3. *Scenario A* simulation results at 19.30

At 19.00, the population density is reduced in all institutions. After 30 minutes (Fig. 3), there are 141 misinformed people distributed differently by age (pupils - 74, students - 20, adults - 47) and by institution (school - 66, university - 0, bank - 45, clinic - 0). During this interval, the hotspot in the bank generates a localized effect, limited almost exclusively to the school and the bank. The low mobility and low presence of students determine a dramatic decrease in propagation. Institutions located further from the hotspot (the university and the hospital) remain practically unaffected, which indicates that under conditions of low traffic, the rumor does not exceed the area of institutions with an active presence.

4.2 *Scenario B* analysis

Scenario B simulates the propagation of false information regarding the existence of a fire caused by the transport of hazardous materials in the area of the "T" intersection. In this context, the model assumes the same reactions adapted for the three population categories: all misinformed people exit through the doors and move away from the central patches (where the fire is). In this scenario, the hotspot is also considered to be the bank. This functions as the generating nucleus of the propagation, its role varying in intensity depending on the population density and the mobility specific to each time interval.

After 30 minutes of simulation, the result is 1832 misinformed people, distributed differently by age (pupils - 915, students - 504, adults - 413) and by institution (school - 962, university - 470, bank - 268, clinic - 8). In *scenario B* ("Fire"), the initial focus of misinformation is the bank, from where the 5 initially misinformed people trigger an evacuation behavior for all age groups. At 09:00, the population structure is strongly oriented towards the presence of students in the school and students in the university, and the streets of the intersection considered function as transit areas between the bank and the other buildings. Although the bank is the hotspot, after 30 minutes of simulation, most of the misinformed people are found in the school and the university. This suggests that, in the context

of a fire hazard, the rumor spreads rapidly along the evacuation corridors and through doors, especially affecting groups in high-density buildings (school, university), while the hospital remains almost completely protected (very few misinformed people and very little direct interaction with the hotspot).

At 15.00, the total number of people in the model is higher, and the institutional composition changes: the university and the bank become much more populated, and students are still present in the school. The initial focus of disinformation remains the bank, but, unlike the 09.00 results, here the bank retains a much higher share of misinformed people, comparable to the university and superior to the school. The simultaneous evacuation of several buildings produces a strong crowding on the streets, which favors contact between adults and students and leads to an almost balanced distribution of disinformation between the three major organizations (school – bank – university). The medical unit remains almost unaffected in this case as well, which indicates that its relatively more peripheral positioning in relation to the hotspot and the main evacuation flows reduces exposure to the rumor.

In the evening, at 19.00, the population present at the intersection is much smaller, and students are almost absent from their buildings. Disinformation remains almost entirely concentrated around the hotspot – the bank, with very little "leakage" to other institutions. This suggests that, in the absence of large flows of people and intense mobility between buildings, even a rumor about an immediate danger, such as a fire, fails to spread significantly throughout the rest of the system. Evacuation behavior remains active (Fig. 4), but it occurs mainly inside and on the periphery of the bank, without generating chains of informational contagion, due to limited inter-institutional contacts.

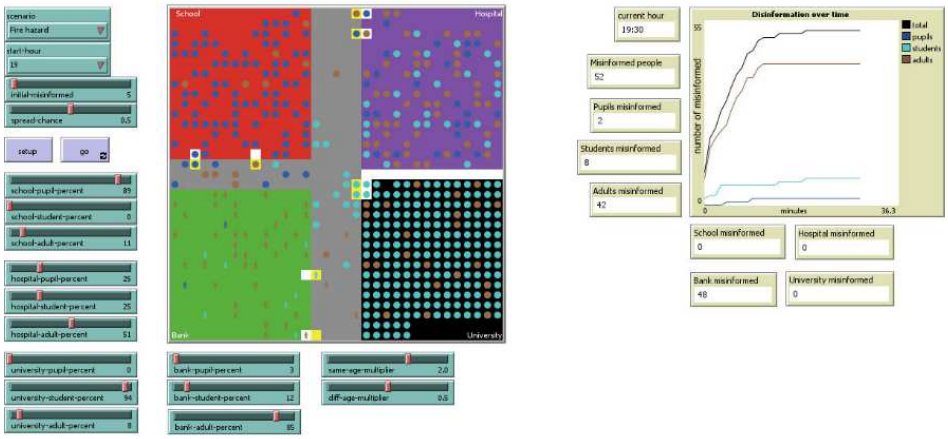

Fig. 4. *Scenario B* simulation results at 19.30

The data consistently indicate the central role of the bank as a misinformation hotspot and how the temporal structure of the population amplifies or diminishes the effects of the rumor. At 09.00 and 15.00, the high density of people in buildings and on the streets turns the message about the fire danger into an almost universal "signal", which spreads rapidly through local contact, despite the fact that all age groups adopt the same behavioral strategy of evacuation.

At 09.00, the evacuation transfers the misinformation from the hotspot to the school and university, numerically dominated by pupils and students; they appear as the main information "vectors", especially on the routes between the bank and the university campus. At 15.00, the increase in the presence of adults and students in the bank and the university leads to a redistribution of informational contagion: the bank is no longer only the origin, but also one of the main poles of accumulation, along with

the university, which suggests a feedback between the density of people, the flows of evacuation and the intensity of interactions.

At 19.00, the same rule of behavior – evacuation – produces a practically opposite effect: in the absence of crowds, the rumor remains localized around the hotspot, and the intersection no longer functions as a "network" of propagation, but as a largely empty space, in which disinformation has nowhere to circulate.

4.3 *Scenario C* analysis

In *Scenario C*, disinformation is initiated simultaneously in three hotspots: bank, school, and university, reflecting a social context in which rumors of a human strike are propagated in multiple community centers. Unlike *scenarios A* and *B*, this scenario involves a high level of social interest and a mixed reaction: students tend to participate, adults exhibit divergent behaviors, and students are protected and move away from the central area.

At 09.00, the school population is at its maximum quantitative level, and the active hotspot in the school produces an acceleration of the spread. Although the university is another hotspot, the high density of students makes the school the epicenter of the propagation. Adults, who have mixed behaviors (avoidance or participation), represent a secondary channel, while students – prone to "getting closer to the center" – amplify the transmission in the area of the university.

At 15.00, the university campus has the highest population density, and students are the category with the highest natural "join-strike" predisposition, i.e., intentional movement toward the center and increased interactions. The effect of the university hotspot thus becomes decisive (Fig. 5). The bank, although lacking a large population, receives a secondary wave of disinformation through the mobility of students and adults crossing the intersection.

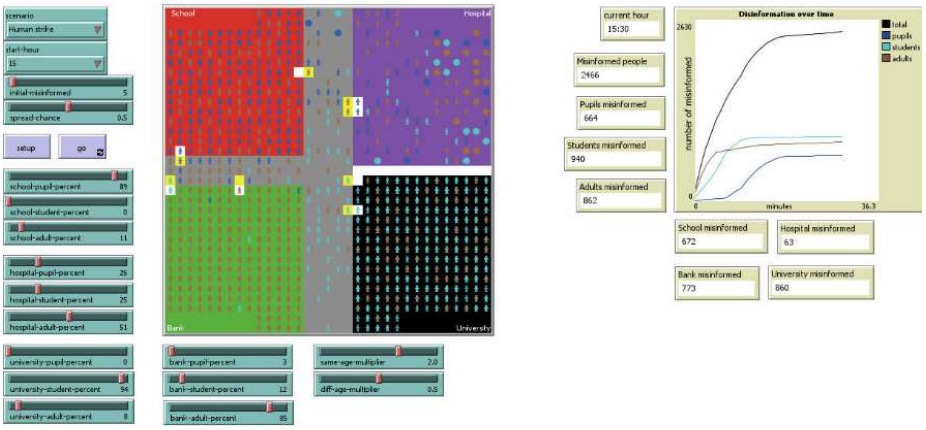

Fig. 5. *Scenario C* simulation results at 15.30

After 30 minutes of simulation, 2466 misinformed people are found, distributed differently by age (pupils - 664, students - 940, adults - 862) and by institution (school - 672, university - 860, bank - 773, clinic - 63).

At 19.00, the general density in all buildings is reduced, except for the university. Although there are three hotspots, only the one in the university remains effectively active, because the rest of the population is too sparse to maintain transmission. There are few students at this time, and adults tend to avoid the center, which limits interactions. The scenario becomes dominated exclusively by student behavior.

The analysis shows a distinct mechanism from *scenarios A* and *B*: the multiplicity of hotspots massively amplifies the spread, but only when the density is sufficient; student behavior ("join-strike") is the most influential propagation factor, even exceeding the microsocial probability of contagion; students are only majorly impacted when the school population is dense (at 09.00); adults have a

secondary role, as avoiding the center reduces interactions; the hotspot effect is strongly dependent on the time of day, local density, and the way groups cross the intersection.

5. DISCUSSION AND CONCLUSIONS

At each moment of the day (09:00, 15:00, 19:00) instantiated within each scenario (A, B, C), some reflected in the corresponding graphs (shown in the text of the article) determined as a result of the simulation, relative to the total number of the population considered, differences appear in the two categories (age groups and institutional affiliation). These differences represent human groups that are on the street, in the vicinity of the institutions (organizations) considered, are misinformed, are counted in their age category but, not being in any building in that context, do not appear on the respective counters generated by the software product used.

It is useful to specify, for a better understanding of the framework modeled for simulation, correlated with the research niche assumed by the research team, that correctly informed individuals were not considered in the representations designed and operationalized in the simulation. The reasoning was that those who were not correctly informed (with the necessary nuances considered generally included because they require additional detail that may be the subject of another study) are the hard component of communication effectiveness, which determines (of course, in relation to correctly informed individuals) the overwhelming resilience of communication (how many *negatives* must be overcome by *positives* for correct communication in a given context or a return to normality when the *negative* component is predominant).

Scenario A demonstrates that a military threat (terrorist attack) produces an intense mobility dynamic, characterized by: rapid evacuations (pupils); intense inter-institutional mobility (students); avoidance reactions with residual exposure (adults); an essential role of the initial hotspot (the bank) in determining the direction of information propagation. The time point located at 15.00 highlights the maximum capacity of the hotspot to drive the rumor spread throughout the system, while at 19.00 it has a strictly local effect.

The "Fire" scenario reveals that, in a context of immediate physical danger, disinformation functions in the model as a trigger for uniform evacuation, common to all age groups. The effect on propagation is not determined so much by differences in reaction between groups (everyone evacuates), but rather by the density and spatial distribution of the population at different times of the day. When the intersection of evacuation flows between the hotspot (bank) and the other buildings is intense (at 09.00 and especially at 15.00), the rumor produces a massive spread, with the predominant involvement of pupils and students in the morning and students and adults in the afternoon. In contrast, in conditions of low traffic (at 19.00), the same disinformation remains almost completely confined to the hotspot, being unable to generate a generalized panic. In broader terms, the results suggest that, for the fire hazard scenario, the vulnerability of the system does not derive only from the existence of a misinformation hotspot, but from the coincidence between this hotspot and the moments of maximum crowding and population mobility around the intersection.

The "Human Strike" type scenario demonstrates that the spread of social information is strongly dependent on the structure and collective behavior, not just on the probability of contagion. The three initial hotspots produce a strong acceleration only during periods of high mobility and density, especially in the university. Student behavior is the most influential propagation factor, transforming the university into the epicenter of disinformation at all times when the population is present. At 09.00 the school dominates, at 15.00 and 19.00 the university dominates. The final result emphasizes that a hotspot is not enough, a critical mass of individuals prone to move towards the center and interact socially is also necessary. Thus, *Scenario C* highlights the typical dynamics of rumors emerging from social movements: they grow where collective motivation and density are simultaneously high.

Returning to the general framework proposed in sections 1 and 2, it can be concluded that the

nature of information (perceived criticality) completely determines collective behavior, communication actively contributing to the quality of this behavior. The study undertaken provides arguments for the development of specialized studies in the field of critical infrastructure security and their resilience by also considering some soft aspects of systemic interfaces determined by such contexts. The limitations of the present research method pertain to the fact that certain moments from a specific area are instantiated. Using tools (from the AI spectrum) that can analyze much larger amounts of data from extended areas (e.g. a central tourist market of the city, a stadium or an airport), including the concatenation of events in different geographical areas of the city, it is possible to draw general conclusions on behaviors and communication in crisis situations.

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Contribuții ale modelării și simulării în studierea criticității comunicării în mediul urban

Rezumat: Articolul pornește de la realități urbane contemporane, între care este remarcabilă reacția determinată de știri, indiferent de modul lor de propagare. Sunt evidențiate astfel de situații și impactul lor asupra funcționalității urbane. Societal se dorește un nivel robust de reziliență în astfel de situații, deziderat dificil de atins. În acest cadru este util a avea o imagine de ansamblu asupra fenomenului, corect dimensionată, pentru a permite analize de tip *what if.* Articolul demonstrează rolul modelării și simulării în acest context, folosind un instrument de lucru specific, pe exemplul manifestării unor situații posibile într-un oraș.

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