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Marcin Smolarkiewicz
Akademia Pożarnicza w Warszawie
e-mail: msmolarkiewicz@apoz.edu.pl

A method for measuring the uncertainty of the assessed magnitude of community outrage

SUMMARY

A quantitative, or even semi-quantitative, measurement of community outrage – introduced by Sandman as a component of socially driven risk – is difficult to perform. Nevertheless, by applying the unique methodology proposed by Wolanin, Kępka, and Telak, such measurement becomes feasible through the categorisation of emotional states and the use of social research based on assessing the sense of safety. This article discusses an original methodology that enables not only the estimation of the magnitude of community outrage but also the assessment of the uncertainty associated with its measurement. Knowledge of this uncertainty has a significant impact on risk-informed decision-making.

Key words: risk, Shannon entropy, assessment of risk uncertainty, community outrage.

Introduction

Risk perception depends both on the characteristics of risk sources and the features of hazardous events that represent the materialisation of risk (such as: type of source, voluntariness, visibility of consequences, controllability, necessity, frequency, severity of consequences, temporal distribution of consequences, uncertainty of risk assessment, geographical scope, persistence of effects, dread, and impacts on future generations), as well as on the characteristics that define – individually and collectively – the community perceiving the risk and affected by it (such as: age, gender, individual attitudes toward risk – shaped both culturally and psychologically, prior experience with risk-taking situations, inclinations, heuristics, knowledge about risk – both scientific and experience-based, inequality in risk exposure, trust, the way risk is communicated in the media, level of challenge, cognitive availability, coping ability, readiness to act, and affiliation – broadly understood – with the domain of safety). Therefore, it is necessary to incorporate the concept of community outrage, introduced into the security science literature by Sandman[1].

[1] P.M. Sandman, *Responding to Community Outrage: Strategies for Effective Risk Communication*, „American Industrial Hygiene Association" 1993.

Community outrage is understood as the sociological dimension of risk, primarily associated with the local community's sense of safety and its individual and collective acceptability of a given type of risk. When introducing this term in 1993, Sandman noted that "I like the term because it suggests strong emotions, but also suggests that they are justified. It fits well with some factors such as trust and fairness, though for others, like knowledge of a hazard or its memorability, it requires some stretching"[2]. In this way, he referred to the dual nature of risk: on the one hand, it can be determined through quantitative methods (estimating the probability and consequences of a hazardous event, expressed in the notion of expert or engineering risk), yet on the other hand, its impact on the security subject is shaped by risk perception and by the characteristics of that subject itself. This indicates that, for an accurate conceptualisation of risk in safety assessment, it is necessary to include psychological and social factors.

Sandman also recognised the duality within community outrage itself: it refers both to the circumstances that provoke a community reaction and to the reaction as such. When an institution misleads a community and the community responds with outrage, both the institution's improper actions and the community's reaction influence the actual state of affairs.

Sandman further argued that community outrage, much like computational (expert) risk, has the following properties:

- it is just as real as computational risk;
- it is measurable in the same way that computational risk is measurable;
- it can be managed just as computational risk can be managed;
- alongside computational risk, it constitutes an equivalent component of overall risk[3].

Therefore, risk assessment must account equally for community outrage and expert risk. Underestimating community outrage leads the local community to perceive risk management based solely on computational risk as inadequate, which may, in turn, intensify community outrage. In short, failing to consider community outrage in risk assessment increases risk itself. At the same time, since both components – expert risk and community outrage–are measurable, they each contain elements of uncertainty (in the sense of measurement precision), play an identical role in risk analysis, and ultimately influence the decision-making process[4].

These observations made it possible to formulate an expanded definition of the concept: *community outrage is a complex, subjective emotional reaction of society to a threat and the risk associated with it – one that does not stem solely from the (in principle) objective assessment of that risk made by experts, but also from additional psychological and sociological factors, as well as from ineffective risk communication. Alongside computational risk, it constitutes an equivalent component of risk*[5].

Sandman identified a number of variables that constitute the components of community outrage, most of which derive directly from risk perception and risk communication. In his analysis, he focused on 12 variables which, in his view, dominate in most risk-related inter-

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[2] Ibidem, p. 7.

[3] Ibidem, p. 9.

[4] J. Wolanin, P. Kępka, O. Telak, *How outrage can be quantified in risk assessment*, „Nowa Polityka Wschodnia" 2023, 1(36), pp. 141–160, DOI: 10.15804/npw20233607.

[5] M.M. Smolarkiewicz, *O teorii ryzyka w bezpieczeństwie*, Wydawnictwo APoż., Warszawa 2025 p. 414.

actions[6], and he also discussed 8 additional, somewhat less significant ones[7]. All of these correspond to the previously mentioned characteristics of risk sources and the traits – both individual and collective – of the community that perceives and is affected by the risk. In addition to these characteristics, Sandman pointed to several aspects of the risk management process that may influence community outrage:

- moral significance;
- effectiveness of risk communication;
- the impact of risk on vulnerable social groups;
- the possibility of completely eliminating the risk versus merely reducing it;
- in the case of fatalities resulting from a hazardous event, the possibility of identifying the victims.

In Polish security science literature, the term community outrage was introduced by Wolanin[8]. In subsequent years, he devoted considerable attention to assessing the possibilities of measuring and incorporating community outrage into the risk assessment process. As Wolanin emphasized, in individual awareness – and particularly in the collective perception of local communities – threats are often either downplayed, leading to apathy, or excessively magnified. Although the perception of threats is subjective, it constitutes, as Sandman argued, an element of reality equally significant as the physical presence of the threats themselves. This is a crucial issue for understanding the differences in risk assessment between experts – including entities responsible for public safety and order – and the local community[9]. Experts typically rely on quantitative methods to analyse hazards, estimate the probability of hazardous events, and determine their consequences. They often regard such emotion-free methods as the only objectively valid assessment of a situation, with accuracy depending solely on the precision of calculations. For this reason, they tend to consider public perceptions negligible, viewing them as subjective impressions based on myths, vague memories, or exaggerated judgments[10].

The author proposed linking community outrage, which represents the sociological (and psychological) dimension of risk – primarily associated with the sense of safety and the subjective acceptability of a given type of risk – with expert risk according to the following formula[11]:

$$R = R_{eks} + SW \tag{1}$$

where:

R is a total risk,

R_{eks} – expert risk (the product of: probability of occurrence – p, and consequences of the hazardous event – S),

SW – community outrage.

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[6] P.M. Sandman, op. cit., p. 13.

[7] Ibidem, p. 72.

[8] J. Wolanin, *Zarys teorii bezpieczeństwa obywateli*, Danmar, Warszawa 2005.

[9] Ibidem, p. 96.

[10] Ibidem, p. 97.

[11] M.M. Smolarkiewicz, *Teoria matryc stowarzyszonych i N-wymiarowa matryca bezpieczeństwa – nowe metody wspomagania decyzji na potrzeby zarządzania kryzysowego*, Wydawnictwo WSZiP, Warszawa 2013, p. 94.

Author noted that the *plus* sign in equation (1) can be interpreted mathematically only if community outrage can be expressed on at least an interval scale (which enables addition). Such an approach, however, is imprecise and does not provide a general solution to the problem of additivity between engineering risk and community outrage.

In one of his later works, Wolanin states that "the question of whether community outrage can be measured at all also requires resolution"[12], referring to the existence of two main indicators of community outrage, namely: the *emotional state* and the *behaviour correlated with it*[13]. In line with Wolanin's postulate[14], equation (1) should be understood as representing a quasi-generalised form of risk, incorporating all possible aspects. Since the risk-perception aspect within a community is linked to the emotional state of the population constituting that community, risk can be expressed in the following general form[15]:

$$Risk = f(R_{eks}, SW) \tag{2}$$

where:

f is a risk function whose value depends on expert risk (R_{eks}) and community outrage (SW).

According to equation (2), influencing the value of risk in this approach involves not only reducing the probability of a hazardous event or limiting its consequences (risk control), but also lowering the level of community outrage. Taking into account the previously discussed aspects of risk, and modifying the risk formula in line with Aven's[16] definition of quasi-generalised risk, the expression can be written in the following form[17]:

$$R_u = f(U, A, C, K, SW) \tag{3}$$

where:

R_u is quasi-generalised risk,
U – uncertainty, measured by the probability or possibility of occurrence of a hazardous event (denoted as A)
C – onsequences resulting from the occurrence of the event,
K – uncertainty associated with expert knowledge,
SW – community outrage.

Taking into account the fact that expert knowledge is not always scientifically validated, and that the risk manager also possesses knowledge K_m, which is not identical to expert knowledge, quasi-generalised risk can also be expressed as follows[18]:

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[12] J. Wolanin, *Inżynieria w bezpieczeństwie wewnętrznym*, Szkoła Główna Służby Pożarniczej, Warszawa 2020.

[13] N. Grądzka, *Wpływ społecznego wzburzenia na wartość ryzyka*, master thesis, supervised by J. Wolanin, Szkoła Główna Służby Pożarniczej, Warszawa 2018 (unpublished).

[14] J. Wolanin, *Inżynieria w bezpieczeństwie…*, op. cit.

[15] Ibidem.

[16] T. Aven, *On the link between risk and exposure*, „Reliability Engineering and System Safety" 2012, 106, pp. 191–199, DOI: 10.1016/j.ress.2012.06.004.

[17] J. Wolanin, *Inżynieria w bezpieczeństwie…*, op. cit.

[18] A. Bralewski, J. Wolanin, *Metodyka oceny ryzyka zdarzeń z udziałem LNG*, Szkoła Główna Służby Pożarniczej, Warszawa 2020, p. 45.

$$R_u = f(A', C, Q, K, SK, K_m) \quad (4)$$

where:

R_u is quasi-generalised risk,,
A' – hazardous event,
C – onsequences resulting from the occurrence of event A',
Q – uncertainty related to the occurrence of the event and its consequences,
K – expert knowledge,
K_m – knowledge of the risk manager,
SK – trength of scientific confirmation of expert knowledge.

A joint consideration of the dependencies represented by equations (3) and (4) allows the following definition to be formulated:

$$R_u = f(A', C, Q, K_u, SW) \quad (5)$$

where:

R_u is quasi-generalised risk,,
A' – hazardous event,
C – onsequences resulting from the occurrence of event A',
Q – uncertainty related to the occurrence of the event and its consequences,
$K_u = f(K, SK, K_m)$ generalised knowledge, resulting from confronting the risk manager's knowledge (K_m) with expert knowledge (K), whose strength is determined by the scientific evidence supporting it (SK),
SW – community outrage, representing the broadly understood social component of risk.

Measuring the level of community outrage quantitatively is not straightforward; nonetheless, it is always influenced by the adopted viewpoint or perspective [19]. As the author notes, in safety assessment – particularly in assessing the sense of safety understood through the lens of community outrage – it is necessary to account for how the state of safety (which can be measured indirectly through risk assessment) is perceived by experts, as opposed to how it is perceived by the local community to whom this state applies [20]. Reducing the level of community outrage is possible through the use of specific tools, including transparency policies, consultation, education, and negotiation techniques – all of which form elements of effective risk communication.

Even if community outrage can be measured using scientific methods, its measurement requires not only estimating its magnitude but also determining (measuring) the uncertainty associated with that measurement – so as to assess the reliability and usefulness of the resulting calculations. This issue has not been addressed to date, which leads to the research question formulated for the purposes of this article: *How can the measurement uncertainty*

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[19] M. Smolarkiewicz, P. Zych, *Ocena poziomu bezpieczeństwa w powiecie przysuskim w perspektywie ekspertów i społeczności lokalnej*, „Zeszyty Naukowe Pro Publico Bono" 2022, 1(1), pp. 273–294. DOI: 10.5604/01.3001.0016.1979.

[20] M.M. Smolarkiewicz, *Odstępstwa od teorii oczekiwanej użyteczności a analiza ryzyka w sytuacjach kryzysowych* [in:] *Zarządzanie bezpieczeństwem w sektorze publicznym i biznesie*, Wydawnictwo WSAiB, Gdynia 2009.

of community outrage be assessed, assuming that a quantitative or semi-quantitative measurement of its magnitude is possible?

Research methodology

With the identity and methodological foundations of safety science in mind, this study employed both theoretical and empirical research methods. The theoretical methods included literature analysis and critique, conceptual analysis, and theoretical modelling. The empirical methods comprised a diagnostic survey, a case study, and statistical techniques. All of these methods required the concurrent use of methods of intellectual inquiry, namely: analysis and synthesis, deduction and (incomplete) induction, abstraction, comparison, as well as generalisation and inference.

Results of the study with discussion

It appears that one of the most challenging situations requiring the determination of uncertainty in risk estimation arises when assessing community outrage, a measurement that is neither simple nor intuitive. One of the earliest studies in this area was the author's publication[21], which explored the possibility of applying Zadeh's fuzzy logic to this purpose[22]. Another, and still one of the few works attempting a quantitative analysis of community outrage by deriving empirical profiles of "emotional" risk, is the study by Wolanin, Kępka, and Telak, whose key considerations are presented later in this subsection. The authors of that study, assuming that risk has two dimensions – an objective one (expert, engineering) and a subjective one (related to risk perception, of which community outrage is one measure) – define risk using the following formula[23]:

$$R = R_0 \cdot \alpha \tag{6}$$

$$\alpha = 1 + \frac{\beta \cdot W(J_i) \cdot n}{N} \tag{7}$$

where:

α is a dimensionless coefficient accounting for community outrag,
β – he proportion of the studied population expressing a given emotional state J_i,
$W(J_i)$ – the community outrage coefficient characterising the emotional state of the population,,
n – the number of individuals required to undertake specific actions in response to a given threat,
N – the total number of individuals in the studied population.

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[21] M.M. Smolarkiewicz, *Entropia Shannona jako parametr charakteryzujący stan bezpieczeństwa*, „Zeszyty Naukowe SGSP" 2010, 40, pp. 47–57.

[22] L. Zadeh, *Fuzzy sets*, „Information and Control" 1965, 8, pp. 338–353; idem, *The concept of a linguistic variable and its application to approximate reasoning–I*, „Information and Science" 1975, 8, pp. 199–249.

[23] J. Wolanin, P. Kępka, O. Telak, op. cit., pp. 145–146.

As the authors of the study note, an emotional state may be expressed in many ways[24]. For the purposes of their analysis, they introduced a categorisation consisting of five emotional states associated with the presence of a risk source J_i, for i = 1, 2, 3, 4, 5, namely:

- apathy – the existing risk source is irrelevant and evokes indifference;
- irritation – the existing risk source causes nervousness and dislike;
- anger – the existing risk source evokes a strong sense of indignation;
- rage – the existing risk source evokes intense anger and/or fury;
- fear – the existing risk source induces uncontrolled fear.

Each category was assigned a community outrage value expressed as an outrage coefficient $W(J_i)$, adopting the following assignments: for J_1 = „apathy" – $W(J_1)$ = 0, for J_2 = „irritation" – $W(J_2)$ = 0,1, for J_3 = „anger" – $W(J_3)$ = 1, for J_4 = „rage" – $W(J_4)$ = 10, for J_5 = „fear" – $W(J_5)$ = 100. During the study, due to the statistical significance of the results, the categories "irritation" and "anger" were merged. Survey research was then conducted to examine the influence of five selected risk sources (potentially constructed or established near the respondents' place of residence) on the level of community outrage. Based on the significance of the collected data, four of these sources – symbolically labelled A, B, C, and D for the purposes of this publication – were analysed further. In addition to evaluating their potential emotional state, respondents assessed the actions they would take in relation to each risk source, choosing from a three-element set: take action to eliminate the risk source, leave their place of residence, or do nothing. Using the survey results as statistical data, it was possible to calculate the cumulative probability distribution function for each emotional state and subsequently determine the probability of exceeding a given emotional state in relation to increasing risk. The results of these calculations were expressed as a multiple of the expert risk R_0 (Table 1).

Tabela 1. Increase in risk as a function of emotional states for selected haza

Emotional state	**Increase in Risk**			
	A	**B**	**C**	**D**
apathy	1,00 R_0	1,00 R_0	1,00 R_0	1,00 R_0
anger	1,17 R_0	1,05 R_0	1,47 R_0	1,28 R_0
rage	1,28 R_0	1,21 R_0	2,76 R_0	2,61 R_0
fear	2,54 R_0	6,00 R_0	3,78 R_0	2,93 R_0

Source: J. Wolanin, P. Kępka, O. Telak, op. cit., pp. 155–156.

[24] L.F. Barrett, *Categories and their role in the science of emotion*, „Psychological Inquiry" 2017, 28(1), pp. 20–26, DOI: 10.1080/1047840X.2017.1261581; M.B. Petersen, *Distinct emotions, distinct domains: Anger, anxiety and perceptions of intentionality*, „Journal of Politics" 2010, 72(2), pp. 357–365.

The authors then calculated the average risk R_{av} according to the formula[25]:

$$R_{av}^{i} = \sum_j p_j \cdot R_j \tag{8}$$

where:

R^{i}_{av} is average risk for the *i*-th hazard source, $i = 1, 2, 3, 4$;

p_j – the weight (β), i.e., the share of the sampled population indicating a given emotional state;

R_j – he increased risk associated with a given emotional state, j ∈{apathy, anger, rage, fear}, including a measure of uncertainty of the statistical data (the given emotional-risk profile), expressed by the statistical entropy *H(Z)*, computed for each hazard source according to the formula[26]:

$$H(Z) = -\sum_{i=1}^{n} P(A_i) \cdot log_2 P(A_i) \tag{9}$$

where:

Z is a set of mutually exclusive events $A_1, \ldots, A_n$, with cardinality n,

$P(A_i)$ – the probability of event A_i.

If statistical entropy expresses the degree of disorder within a probability distribution, then in the case of emotional-risk profiles it becomes a measure of the diversity of emotional states. It reaches its maximum value for a distribution dominated by a single emotional state, and its minimum value for a uniform distribution (indicating the absence of emotions triggered by the disclosure of a risk source). By additionally calculating the relative randomness index ω_H, using the formula:

$$\omega_H = \frac{H(Z)}{H_{max}(Z)} \tag{10}$$

where:

$$H_{max}(Z) = log_2(n) \tag{11}$$

it may be considered (with a substantial approximation and under all previously adopted assumptions) a conventional measure of community outrage. Table 2 presents the research results taken from the study by Wolanin, Kępka and Telak[27] – columns 1–3 – together with the relative randomness index ω_H calculated by the author (columns 4 and 5).

Based on the analysis by Wolanin, Kępka and Telak, it was possible to calculate the uncertainty of community outrage assessment ($\Delta\omega_H$) using the following formulas[28]:

$$\Delta H(X) = \sum_{i=1}^{n} \left| log_2(P_i) + \frac{1}{ln\,2} \right| \cdot \Delta P_i \tag{12}$$

$$\Delta P_i = z_{1-\frac{\alpha}{2}} \cdot \sqrt{\frac{p_i(1-p_i)}{n_i}} \tag{13}$$

he results of these calculations are also presented in the last column of Table 2. This uncertainty is of both epistemic and aleatory character[29].

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[25] J. Wolanin, P. Kępka, O. Telak, op. cit., p. 155.

[26] M.M. Smolarkiewicz, *Entropia Shannona…*, op. cit.

[27] J. Wolanin, P. Kępka, O. Telak, op. cit.

[28] M.M. Smolarkiewicz, *Entropia Shannona…*, op. cit.

[29] M.M. Smolarkiewicz, *O teorii ryzyka…*, op. cit., p. 685 and following.

Tabela 2. Risk characteristics accounting for the increase in average risk associated with community outrage expressed through emotional state

	Average risk	**Emotional state corresponding to the average risk**	**Entropy *H* (diversity of the emotional state)**	**Relative randomness index $\omega_H \pm \Delta\omega_H$**
1	2	3	4	5
A	1,20 R_0	more than apathy	1,253	**63% ± 64%**
B	1,811 R_0	more than apathy	1,232	**62% ± 69%**
C	1,766 R_0	more than rage	0,88	**44% ± 93%**
D	1,346 R_0	more than anger	1,33	**50% ± 102%**

Source: columns 1–3 based on Wolanin, Kępka, Telak[30], 2023, p. 158), columns 4 and 5 – author's own elaboration[31].

Summary and conclusions

The quantitative method for representing community outrage (together with the uncertainty of its measurement) demonstrates that community outrage plays a significant role not only in risk perception but also as a substantive component incorporated into the numerical value of risk – and, importantly, it can indeed be calculated. Conducting this type of research is challenging, among other reasons, due to the necessity of precisely formulating questions in social surveys concerning emotional states, as well as the need to distinguish between the assessment of natural and anthropogenic hazards[32]. A weakly differentiated shape of the emotional-risk profile, resulting from limited perception of distinctions between emotional states, causes the quantitative estimation of the uncertainty of the derived risk – uncertainty that is predominantly epistemic, since it is associated with knowledge and risk perception – to be of limited reliability. In the analysed example, the value of uncertainty for all assessed hazard sources exceeded 50%, in two cases approaching 100% (Table 2, colum „$\omega_H \pm \Delta\omega_H$"). This does not invalidate the conclusions formulated earlier; it merely indicates the limitations of the applied method.

[30] J. Wolanin, P. Kępka, O. Telak, op. cit., p. 158.
[31] M.M. Smolarkiewicz, *O teorii ryzyka…*, op. cit., p. 696.
[32] J. Wolanin, P. Kępka, O. Telak, op. cit., p. 158.

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STRESZCZENIE

Marcin Smolarkiewicz

Metoda pomiaru niepewności szacowanej wielkości oburzenia społeczności

Ilościowy, a nawet półilościowy pomiar oburzenia społeczności – wprowadzony przez Sandmana jako składnik ryzyka społecznie uwarunkowanego – jest trudny do uzyskania. Niemniej jednak dzięki zastosowaniu unikalnej metodologii zaproponowanej przez Wolanina, Kępkę i Telaka, taki pomiar staje się możliwy dzięki kategoryzacji stanów emocjonalnych i wykorzystaniu badań społecznych opartych na ocenie poczucia bezpieczeństwa. W artykule omówiono oryginalną metodologię, która umożliwia nie tylko oszacowanie wielkości oburzenia społeczności, ale także ocenę niepewności związanej z jego pomiarem. Znajomość tej niepewności ma istotny wpływ na podejmowanie decyzji w oparciu o ryzyko.

Słowa kluczowe: ryzyko, entropia Shannona, ocena niepewności ryzyka, oburzenie społeczności.

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