IOP Conference Series: Earth and Environmental Science

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To cite this article: A I Petrov *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **224** 012033

# Statistical Modelling of Orderliness of Regional Road Safety Provision Systems

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**Abstract.** the article considers a series of issues connected with the assessment of orderliness of regional road safety provision systems. Success in the improvement of manufacturing processes management depends a lot on the level of system orderliness. This article presents a method of statistical modeling of the orderliness of regional road safety provision systems by assessing the information entropy in the cause-effect chain «Population ($P$) – The number of vehicles ($N$) – The number of road accidents ($DTP$) – The number of deaths in road accidents ($PG$)». It was found that the range of actual values of relative entropy $H_n$ for regional road safety provision systems is [0.7161; 0.9787]. According to the results of held statistical modeling, the classification of regions of the Russian Federation by the orderliness of road safety provision systems processes was developed. During the discussion of the results an assumption, that information entropy of road safety provision systems is determined by resource availability of industry, was made.

## 1. Introduction

One of the most actual problems in the sphere of management of manufacturing processes is the complexity of the formation and maintenance of a high quality of technosphere safety in complicated human-technical systems. In these systems randomness of production processes is extremely high, while the orderliness is low.

The aim of management is to reduce the chaotic state of system functioning process. As a result, system orderliness increases. The orderliness is a system property, identifying the result of following the set of rules that structured the system and limited its changes.

Road safety provision systems are intended for creating the conditions of accident-free interaction between the subjects of vehicle systems (drivers of vehicles and pedestrians) [1, 2, 3]. Elements of road safety provision systems always include such objects as road network, road transport infrastructure, system of rules, generally accepted for use within this system. Characteristics of the orderliness of road safety provision systems allow to assess these systems.

## 2. The studied problem

Formulation of the problem that will have been being solved in this article: *«To model orderliness of technosphere safety in regional road safety provision systems»*.

The author of information theory C.E. Shannon [4, 5] introduced the concept of information uncertainty – entropy. According to C.E. Shannon, entropy characterizes missing information about the studied system. Information is the primary concept of our world, along with material, energy, space and time, and it can't be strictly defined [6].

The algorithm of problem solution:

1. define parameters of information transformation in the context of cybernetic modeling of the cause-effect mechanism of road accident rate formation. Calculate the parameters of relative information entropy in regional road safety provision systems [4, 5].
2. use statistical methods of data processing to solve the next problems:
   - construction of statistical values' distribution;
   - identification of distribution law;
   - definition of statistical parameters of these distributions.
3. classify road safety provision systems of different regions, depending on localization within a frequency range.

## 3. Problem solution and results

### 3.1. Defining parameters of information transformation and calculation of entropy for road safety provision systems

Transformation of parameters' numerical values in the cause-effect chain «Population (P) – The number of vehicles (N) – The number of road accidents (DTP) – The number of deaths in road accidents (PG)» [7, 8, 9] (fig. 1) characterizes processes of information entropy formation, i.e. characteristics of disorganization in road safety provision system.

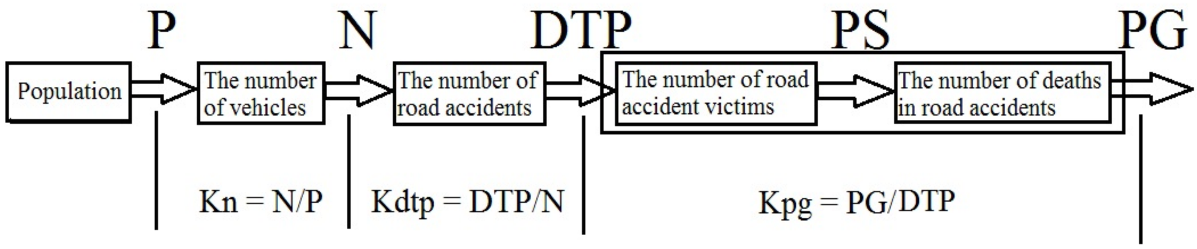


**Figure 1.** The cause-effect chain of road accident rate formation and coefficients of information transformation of road safety provision system [9]

When analyzing the transformation, the main attention is paid not to inner mechanism, working into every component of the chain, but to coefficients of informational transfer between elements (1):

$$K_n = N/P; \qquad K_{dtp} = DTP/N; \qquad K_{pg} = PG/DTP \tag{1}$$

The problem of defining the information entropy for road safety provision systems was considered earlier in articles [7, 8, 9, 10].

Calculation of relative information entropy in regional road safety provision systems is performed in the next sequence.

1. *Analyzing process' components priorities with Pareto charts* (fig. 1). The aim of this analysis is the identification of main priorities in the mechanism of road accident rate formation.

2. *Assessment of weight coefficients for chain elements by means of evaluation of positive of every component.* The algorithm of weight coefficients $w_i$ definition on the example of the final coefficient of information transfer in the chain «Population (*P*) – The number of vehicles (*N*) – The number of road accidents (*DTP*) – The number of deaths in road accidents (*PG*)»:

$$K_{HR} = PG/P = K_n \cdot K_{dtp} \cdot K_{pg} \tag{2}$$

As an estimate we take the value $Q = \ln(1/K_{HR})$, so (3):

$$Q = Q_n + Q_{dtp} + Q_{pg} = \ln(1/K_n) + \ln(1/K_{dtp}) + \ln(1/K_{pg}). \tag{3}$$

Analysis of relation (3) shows that share of each summand $w_i$ (3) equals to:

$$w_i = \frac{\ln(1/K_i)}{\sum_{i=1}^{3} \ln(1/K_i)}. \tag{4}$$

3. *Assessment of information entropy* $H$ *for road safety provision systems [9] as characteristic of technological process orderliness* (5):

$$H = -\sum_{i=1}^{n} w_i \cdot \ln w_i, \tag{5}$$

where *n* – number of system components (in our case *n* = 3);
$w_i$ – weight coefficients, fulfilling condition of normalization, $\sum_{i=1}^{n} w_i = 1$.

In system problems besides entropy *H* also the concept of relative entropy $H_n$ (6) is used:

$$H_n = H/H_{\max} = H/\ln(n). \tag{6}$$

## 3.2. Statistical modeling of orderliness of road safety provision systems

After calculation of relative entropy $H_n$ in regional road safety provision systems, it is necessary to model the distribution of its values (fig. 2). The analysis shows that many factors have an impact on the formation of relative entropy $H_n$ in regional road safety provision systems because all values (83 regions in 2013) are described by Gauss's law. Range of actual values of $H_n$ is [0.7161; 0.9787].

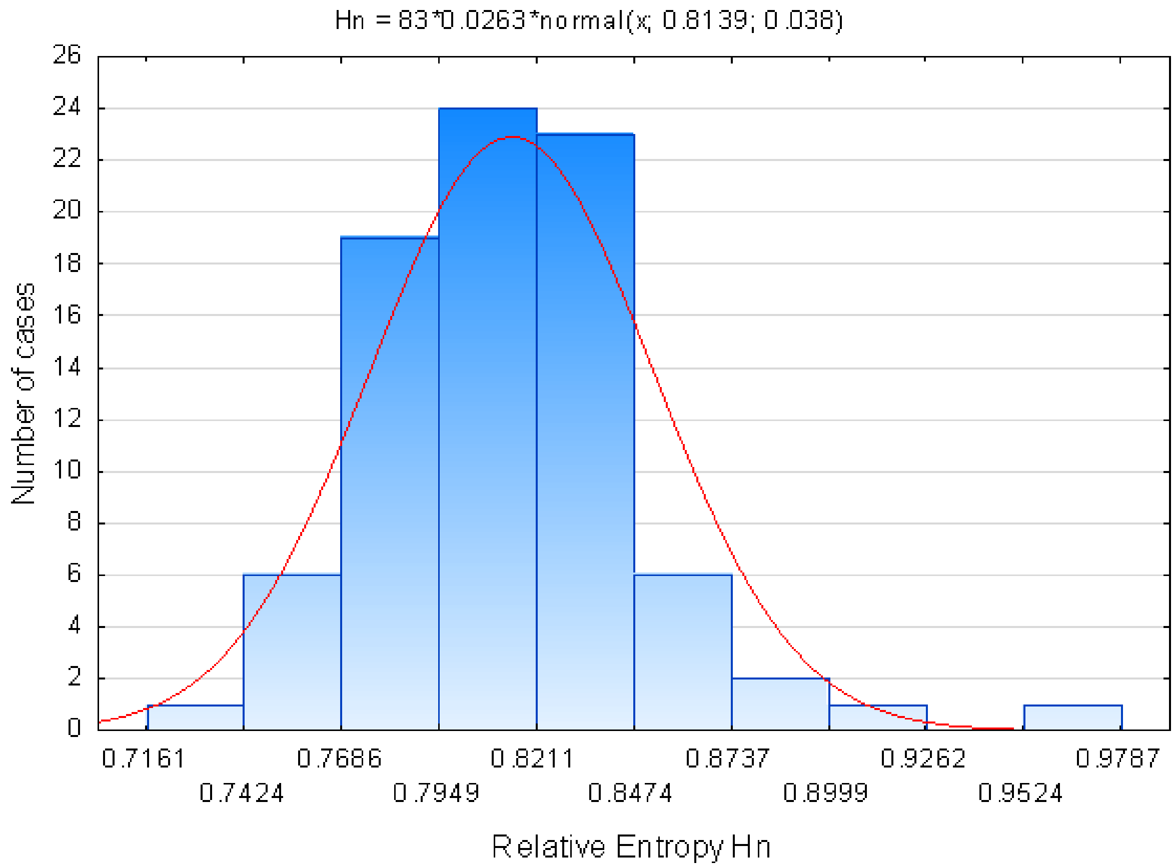


**Figure 2.** The distribution of calculated values of relative entropy $H_n$ in regional road safety provision systems of Russian Federation

It is important to remember that orderliness $O$ and disorganization, evaluated by entropy $H$ – two states of system functioning process. Therefore, chaos distribution $DH = 1 - DO$, where $DH$ – share of orderliness in system [10].

### 3.3. Classifying of Russian Federation regions by degree of orderliness of road safety provision systems.

Approach to the classification of regions by the orderliness of road safety provision systems is based on accounting features of the probability density of random variable normal distribution (fig. 3).

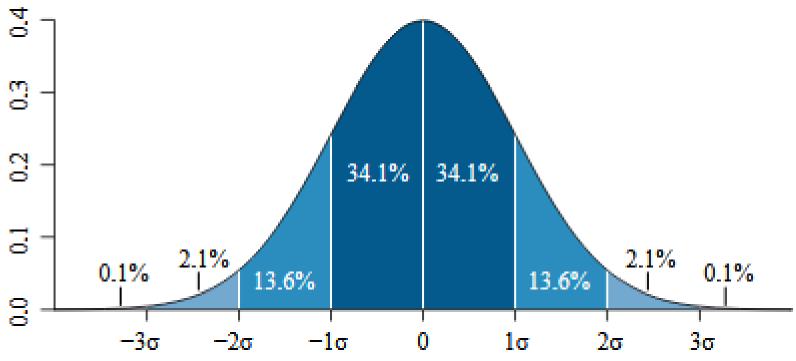


**Figure 3.** The chart of the probability density of normal distribution and the percentage of hitting of the random variable on segments, equal to the standard deviation [11]

In our case, the random variable is the value of relative entropy of road safety provision systems in the regions of the Russian Federation. 68.2 % of all cases must locate in the range [ã – σ; ã + σ], where ã = expected value $H_n$ (34.1 % to the left and to the right of the expected value of $H_n$). 15.9% cases of $H_n$ formation must locate to the left and to the right of the specified range. Thus, it is suggested to classify Russian regions by the orderliness of road safety provision systems on four groups (table 1).

**Table 1.** Classification of regions of the Russian Federation by the degree of orderliness of road safety provision systems

| Class of region by degree of orderliness of road safety provision systems | Range of values of relative entropy $H_n$ of road safety provision systems | Number of Russian regions | Specific example of Russian region |
|---|---|---|---|
| Relatively low level of orderliness of road safety provision systems | [0.8519; 0.9787] | 9 | Republic of Dagestan ($H_n$ = 0.9787) |
| Level of orderliness of road safety provision systems is below the average | [0.8140; 0,8519] | 31 | Saint-Petersburg ($H_n$ = 0.8404) |
| Level of orderliness of road safety provision systems is above the average | [0.7759; 0.8139] | 29 | Moscow ($H_n$ = 0.8110) |
| Relatively high level of orderliness of road safety provision systems | [0.7161; 0.7759] | 14 | Moscow region ($H_n$ = 0.7310) |

## 4. Discussion of the results

The question, why road safety provision systems of different regions of the Russian Federation are characterized by different levels of the orderliness is quite important for discussion [10, 12].

Pareto chart of values of relative entropy $H_n$ distribution and entropy $H$ are closely interconnected. Structure identification of normalized Pareto chart *(y)* shows that it has the appearance (7):

$$y = 1 - (1 - x)^g, \tag{7}$$

where x = $r_i/r_{max}$
$r_i$ и $r_{max}$ – current and maximal rank respectively ($r_{max}$ = n);
n – number of components on system;
g – indicator (in general case depending on *x*).
It means that weights $w_i$ are predetermined by indicator g (8):

$$w_i = \left(1 - \frac{r_{i-1}}{r_{\max}}\right)^g - \left(1 - \frac{r_i}{r_{\max}}\right)^g, \tag{8}$$

Considering relation (5), the connection between $g$ and $H$ become evident.

What is the physical meaning of indicator $g$ ? Presumably – resource availability of road safety provision systems. The term resource availability should be understood as financial and resource provision of events for road safety enhancement. Possibly resource availability includes the wider set of circumstances such as the general level of transport culture of the population. Because the transport culture of population forms in the specific environment, then we can state that factors of impact on indicator $g$ include social-economic factors that form the population quality of life [13].

## 5. Conclusion

Assessment of orderliness of road safety provision systems of extremely important for the successful execution of The Federal target program "Increase in Traffic Safety in 2013 – 2020 [3] and preparation for practical implementation of Strategy in road safety of Russian Federation up to 2030 [14]. The aim of this Strategy is not only the decline of road accident rate but also its spatial alignment. To achieve the goal instrument of assessment of orderliness degree of regional road safety provision systems is required. Method of entropic assessment of system orderliness can successfully be that instrument.

According to the results of the research, the next conclusions can be made.

1. Statistical modeling of the orderliness of technosphere safety in regional road safety provision systems shows the wide dispersion of its values in different Russian regions.
2. Range of actual values of relative entropy $H_n$ for regional road safety provision systems is [0.7161; 0.9787].
3. According to the results of statistical modeling of the orderliness of technosphere safety in the road safety sphere, it was suggested to classify regional systems on 4 groups.
4. During the discussion of reasons for road safety provision systems orderliness diversity, the assumption on its connection with resource availability was made. This hypothesis should be checked out additionally.

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