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Enabling Ukrainian higher education to ensure a sustainable and robust reconstruction of (post-war) Ukraine

Lecture

APPLICATION OF RISK-BASED APPROACH FOR BUILDING MODELS OF EMERGENCIES AND THEIR DEVELOPMENT

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Purpose and objectives of the lecture:

Goal: to learn methods of risk analysis.

Tasks: Identify safety and security problems and the level of risk of an economic entity in emergency situations.

Expected results (competencies): to analyze the security problems of complex systems that involve humans.

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Lecture plan

1. Risk as a characteristic of danger. The concept of acceptable risk.
2. Normalization of risks.
3. Assessment of the level of risk.
4. Methods of determining risk.
5. Risk management in the transport industry.

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1. Risk as a characteristic of danger

Recognizing the global nature of the dangerous processes and phenomena that humanity faced in the second half of the twentieth century and the extent of which began to threaten human civilization, the world community developed and adopted a new strategy for the harmonious development of nature and society. It takes into account two interconnected basic concepts on which the choice of ways of society's development is based: sustainable development and security.

On this basis, the concept of "zero risk" was rejected and the concept of "acceptable risk" was approved , which provides for the wide use of the principle of "foresee and prevent". It is becoming dominant in the regulation of relations in the field of industrial safety.

Policy documents have been developed that regulate the analysis and assessment of risk, declaration of safety of high-risk facilities, taking into account the level of danger and risks of losses associated with the specifics of natural phenomena and human activity.

1. Risk as a characteristic of danger

Risk is the degree of probability of a certain negative event that may occur at a certain time or under certain circumstances on the territory of a high-risk facility or outside it. **Risk** is a term that has a universal meaning; it indicates an action that can or should occur with uncertainty or uncertainty. **Risk** is the chance that something unforeseen and undesirable may happen. **Risk** is the probability of realization of a negative action in the area of human presence. Its specification can be defined in terms of probability: time, location, damage (as an assessment of the consequences of a hazard).

Object of high risk - a facility where one or more hazardous substances or categories of substances are used, manufactured, processed, stored or transported in an amount equal to or exceeding the regulatory thresholds, as well as other facilities that pose a real threat of an industrial or natural emergency.

1. Risk as a characteristic of danger

The probability of emergencies in relation to natural processes, social events, technical facilities and technologies is estimated on the basis of statistical data or theoretical studies.

$$R = \frac{N_{НП}}{N_0} \cdot R_{ДОП}$$

where R is the risk;

N_0 - total number of events per year;

$R_{ДОП}$ - acceptable risk;

$N_{ДОП}$ - number of emergency events per year;

The fundamental basis of risk analysis R(t) is formed in three main areas of life - social (N), natural (S) and man-made (T), which constitute a single complex **«human-nature-environment system»** (HNES) operating in time t:

$$R(t) = F_R\{R_N(t), R_S(t), R_T(t)\}$$

$$R(t) = F_R\{E(t), W(t), I(t)\}$$

A generalized model of the system with the definition of the role of its main components N, S, T is built in terms of the basic risk parameters **R(t)** - the probability of occurrence **P(t)** of adverse processes and events (hazards and related losses **U(t)**):

$$R(t) = F_R\{P(t), U(t)\} \quad P(t) = F_P\{P_N(t), P_S(t), P_T(t)\} \quad U(t) = F_U\{U_N(t), U_S(t), U_T(t)\}$$

Scenarios of adverse events in a complex system and quantitative risk assessment **R(t)** are determined through the parameters of the main initiating and impacting factors - flows of hazardous energies **E(t)**, substances **W(t)** and information **I(t).**

2. Risk normalization

- **Risk regulation** is a specially organized regulatory and legal activity aimed at developing and approving industrial and natural safety standards, rules and regulations for economic activities, which are determined on the basis of risk values within the limits of accepted values.
- **Regulation** is the means by which the state establishes the limits of permissible man-made activities and the limits of protection against natural hazards.
- **Risk standards** are the criterion basis for the mechanisms of regulating anthropogenic and natural safety.

An acceptable level of risk is a risk that is less than or equal to the maximum permissible level, while a minimum level of risk is a level of risk below which further risk reduction is economically unreasonable.

The question of the level of permissible or acceptable risk is the most important in decision-making. It is worth emphasizing that the choice of the value of the acceptable level of individual risk largely depends on the economic situation of countries.

2. Risk normalization

The benchmark for determining the levels of acceptable risk in Ukraine is the risk values accepted in economically developed countries, which are:

minimum risk - < 10^{-8};

maximum permissible risk - < 10^{-5}.

A risk value that is less than or equal to the minimum is considered absolutely acceptable. In other words, any activity with such a low-risk value is acceptable and does not require any additional efforts to mitigate it, and therefore may not be monitored by the relevant supervisory authorities.

A risk that exceeds the maximum permissible value is considered absolutely unacceptable. For each sector of the economy, hazardous production activity, territory, type of man-made or natural object, the standards of minimum and maximum permissible risk levels are determined, which should be within similar national values.

3. Assessment of the risk level

A ***risk model*** **is**a verbal (a given description of the sequence of events or occurrences) or mathematical expression of the probability of a threat to the desired planned functioning of the object of assessment. A typical risk model is a generalized model that takes into account only the basic, fundamental groups of factors that can lead to a hazard.

The risk concept includes two elements - **Risk Assessment** and **Risk Management.**

Risk assessment is a scientific analysis of the genesis and extent of risk in a particular situation, while ***risk management*** is the analysis of a risk situation and the development of a solution aimed at minimizing the risk.

The **risk to human health** (or ecosystem) associated with environmental pollution occurs **under the following necessary and sufficient conditions**

1) **the existence of a risk source** (a toxic substance in the environment or food, or an enterprise producing products containing such substances, or a technological process, etc;)

2) **the presence of this source of risk in a** certain **dose or concentration harmful to human health**;

3) **a person's susceptibility to the effects of the mentioned dose of a toxic substance**. These conditions together constitute a real threat or danger to human health.

3. Assessment of the risk level

Risk assessment is a set of actions aimed not only at assessing, but also at analyzing and identifying the mechanisms of occurrence of phenomena that have a strong impact on a person's lifestyle and health, in order to prevent or counteract deviations, threats, harm, losses, etc.

The first stage of risk assessment is the actual *identification of the hazard* - for example, in the case of air pollution, it includes accounting for all chemicals that pollute the surrounding air, determining the toxicity of the chemical to humans or the ecosystem.

The second stage - *exposure assessment* - is designed to estimate the number and type of people exposed to a particular stressor, along with the magnitude, route of exposure, duration and time of exposure.

The third stage, the *expected effects assessment*, determines the magnitude of adverse effects that are likely to occur at given levels of exposure to the risk factor.

The fourth stage is *risk characterization*, which involves assessing possible and identified adverse effects; analyzing and characterizing the uncertainties associated with the assessment; and summarizing all risk assessment information.

3. Assessment of the risk level

Identification of risk factors

The first step in risk assessment is to **identify the most serious sources of danger (risk factors) and rank them** in order to determine the real threat to humans and the environment based on risk mapping; determine the thresholds of stability of technical and environmental systems; and use simulation modeling.

As a rule, when characterizing the causes of man-made or environmental disasters, factors of **technical, technological and organizational nature** are distinguished. Particular attention is paid **to the human factor.**

The causes of disasters should be sought not only at the micro but also at the macro level, analyzing the entire complex of contradictions that arise in the national economy and are associated with a deep crisis in the economy, accompanied by **a crisis in virtually all spheres of society - environmental, political, social and spiritual.**

3. Assessment of the risk level

The third stage is the assessment of expected effects, which determines the magnitude of adverse effects that may likely occur at given levels of exposure to the risk factor.

Risk assessment is carried out to determine the expected values of losses from exposure to a given risk stressor and to assess whether these consequences are significant enough to require enhanced ("increased") management (or regulation) in the situation under consideration.

Since the problem of human life safety is considered, the object of hazard probability assessment is the «human-machine-environment» (HME) system, where a person is the main element of forecasting both as a subject and an object of risk.

The main risk factors are as follows

- ***person's knowledge*** (general and professional)
- $$Z = \{z_1, z_2, ..., z_{jc}\}$$
- ***psychophysiological capabilities of a person*** (parameters of its physiological and psychological functions)

$$P = \{p_1, p_2, ..., z_l\}$$

- ***technogenic environment*** (industrial or domestic)

$$V = \{v_1, v_2, ..., v_n\}$$

- ***natural factors*** environmental factors (poorly controlled or uncontrolled), the superposition of which leads to the emergence of hidden "weaknesses"

$$E = \{e_1, e_2, ..., e_m\}$$

3. Assessment of the risk level

Each initial coordinate of the system state y_i, that affects the risk of the entire HME system is a function of all the impacts $y_i = F_i(P, V, E, Z)$. In addition, **P=P(t), E=E(t),** and, as a consequence,

$$y_i = F_i(P(t), V(t), E(t), Z(t))$$

Джерела "невпевненості", які ведуть до прояву ризику

human health (r_1),

society (r_2),

technogenic environment (r_3),

natural environment (r_4).

- Overall risk $R = \sum r_i$, where ***ri*** - is the probability of events deviating from expected conditions.
- If we take into account that each of the risk sources can, in turn, be quite complex, the typical model becomes the sum of the probabilities of deviations in the functioning of the entire HME system.

For example, the risk of damage to human health r_1 has components: physiological (q_{11}), psychological (q_{12}), socio-economic (q_{13}) etc.

Thus $r_i = \sum q_{ij}$, and then $R = \sum Sq_{ij}$

Methods for determining risk

Risk assessment, i.e. the probability of a risk event occurring, can be **quantitative or qualitative**. The quantitative determination of the risk level is objective in nature, as it is based on a certain statistical basis. A qualitative risk assessment determines only the degree of probability of a risk event and the number of losses from it.

- ***The method of analogies*** involves using data from other projects that have already been completed. This method is used by insurance companies, which constantly publish data on the most important risk areas and costs incurred.
- ***Statistical method.*** The most commonly used method is statistical testing (Monte Carlo method). The advantages of this method include the ability to analyze and evaluate different ways of project implementation.
- ***The expert method,*** which is known as the method of expert estimates, can be implemented by studying the opinions of experienced managers and specialists. In doing so, it is advisable to establish indicators of the most acceptable, critical and catastrophic losses, taking into account both their level and probability.
- ***The calculation-analytical method*** is based on theoretical concepts. However, applied risk theory is well developed only for insurance and gambling risk.

4. Methods for determining risk

- ***Engineering.*** As a rule, this approach is the calculation of accident probabilities. The main efforts are directed at collecting statistical data on accidents and related emissions of toxic compounds into the environment.
- ***Modeling.*** Mathematical models of processes are developed that lead to undesirable consequences for humans and the environment when using harmful chemicals**.**
- ***Expert approach*****.** When using the first two approaches for risk assessment, there are often cases when there is not enough statistical data or some fundamental dependencies are not entirely clear. The source of data is experts. They are tasked with probabilistic assessment of certain events related to risk analysis.
- ***Sociological*****.** This method is used to determine the perception of a particular risk by the population and its individual groups. There are widely known studies that have determined the risk assessment for various types of activities given by people in a sociological survey. Interesting effects were found. For example, people prefer voluntary risk (e.g., mountain climbing, smoking) to forced risk. They are more willing to take risks if they can influence them.

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Expert method of risk assessment

Algorithm of application :

1. Determine the range of experts who have the necessary qualifications and experience to assess the level of this risk.
2. Determining the list of factors that determine the level of risk and the weighting of each of them for a generalized risk assessment.
3. Determine the correspondence between the nature of the factors and the level of risk (in points). Obtain an expert table for risk assessment (factor map).

Factors that determine the level of risk	Risk level (high, moderate, low)
Factor 1	Description of the nature of the action of each factor at the risk of the appropriate level
Factor 2	

Factor determining the level of risk	*Risk level*					
	High		Medium		Low	
	Nature of the factor	Number of points	Nature of the factor	Number of points	Nature of the factor	Number of points
Factor 1	Description of the factors manifestation	$(N_2+1)-N_3$	Description of the factors manifestation	$(N_1+1)-N_2$	Description of the factors manifestation	$1 - N_1$
Factor 1						
….						
Factor n						

The number of points assigned to each factor

1. Gathering information about the nature of the impact of certain factors. For this purpose, use surveys, familiarization with operational and statistical information, observation, etc.
2. Conduct a scoring assessment of each risk factor using the factor map developed earlier.
3. Qualitative determination of the risk level by calculating the total number of points for each risk factor, taking into account its weighting factor.

4. Methods for determining risk

Model method of risk assessment

Development of a model for risk assessment involves:

1. determining the key indicator that will be used to assess the effects of risk factors;
2. selection of factors that determine the risk of changes in the key indicator, in the form of a formula or by determining the model parameters;
3. establishing a quantitative relationship between the change in factors and the value of the key (final) indicator.

Method of sensitivity analysis

The sensitivity of an event to its individual parameter is calculated as the ratio of the previous (initial) event result to its new value when the relevant parameter is changed. The event sensitivity indicator to a particular parameter is calculated as the ratio of the previous event result to its new value when the corresponding parameter changes. Calculation and comparison of the event sensitivity indicators to changes in its individual parameters allows you to identify the most important event parameters, the change of which has the greatest impact on the change in the final result.

The scenario analysis method involves simultaneously changing several variable parameters of an event. In this way, alternative scenarios for the realization of the event are created, which correspond to different assumptions regarding the effect of certain factors. As a rule, a basic (realistic), optimistic and pessimistic version of the event scenario is considered.

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Risks in road transport

In road transport, the amount of risk is most often determined by the probability of road traffic accidents (including fatalities), which can be determined with a sufficient degree of accuracy from statistical data.

RISK FACTORS FOR ROAD ACCIDENTS

Factors affecting the level of risk

-economic;
-demographic;
-factors affecting travel time correlation of high-speed traffic with the vulnerability of road users).

Risk factors that affect the likelihood of an accident

-speeding;
-physiological aspects;
-driving in the dark-technical condition of the vehicle;
-deficiencies of roads;
-insufficient visibility.

Risk factors affecting the severity of an accident

-the degree of human endurance;
-exceeding the speed limit;
-failure to use seat belts and protective helmets;
-presence of alcohol in the blood;
-insufficient engineering support of road structures).

Risk factors that determine the severity of post-traumatic complications

-delays in detecting an accident;
-fire;
-leakage of harmful substances;
-difficulties in rescuing people during evacuation;
-lack of adequate medical care.

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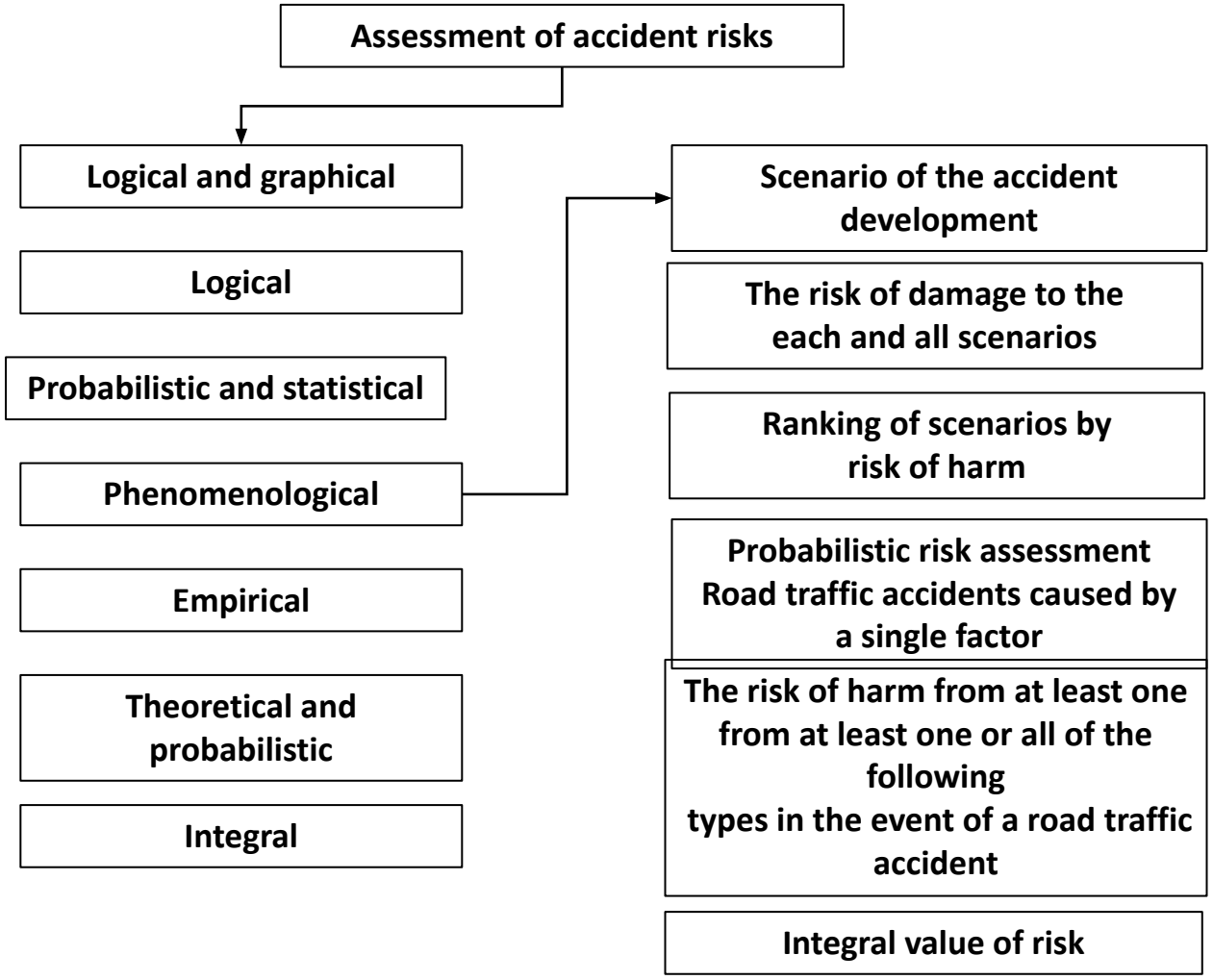
Modeling of road accident risks



Flowchart of the road traffic accident risk modelling process

When mathematically modeling risk, it is most generally represented as a function of two components:

$$R=P/C,$$

The first is the frequency of the event (**P**), which in our case is expressed as the number of road accidents per unit of time. The second is the consequence (**C**), which is a measure of the harmfulness of the accident. Consequences can be expressed in different ways depending on the type of analysis (number of people killed or injured, amount of damage, etc.).

Risks of cargo transportation

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The most common risks are divided into the main phases of cargo transportation.

1. **The phase of packaging and preparation of cargo for loading.**
2. ***The phase of loading and securing the cargo in the truck, if necessary, weighing, sealing.***
3. ***The phase of cargo transportation.***
4. ***The phase of temporary storage.***

The phase of unloading the cargo (its acceptance by the recipient).

Risks in road freight transportation

Risks in road transport	Risks of vantage transport
-technical risks; -operational risks caused by the human factor; -risks of an accident caused by other participants in the transportation process.	- risks at the stage of packing and preparation of cargo for loading; -risks of loading and securing the cargo in the truck, if necessary, weighing and sealing; -risks at the stage of cargo transportation; -risks at the stage of temporary storage; -risks at the stage of cargo unloading.

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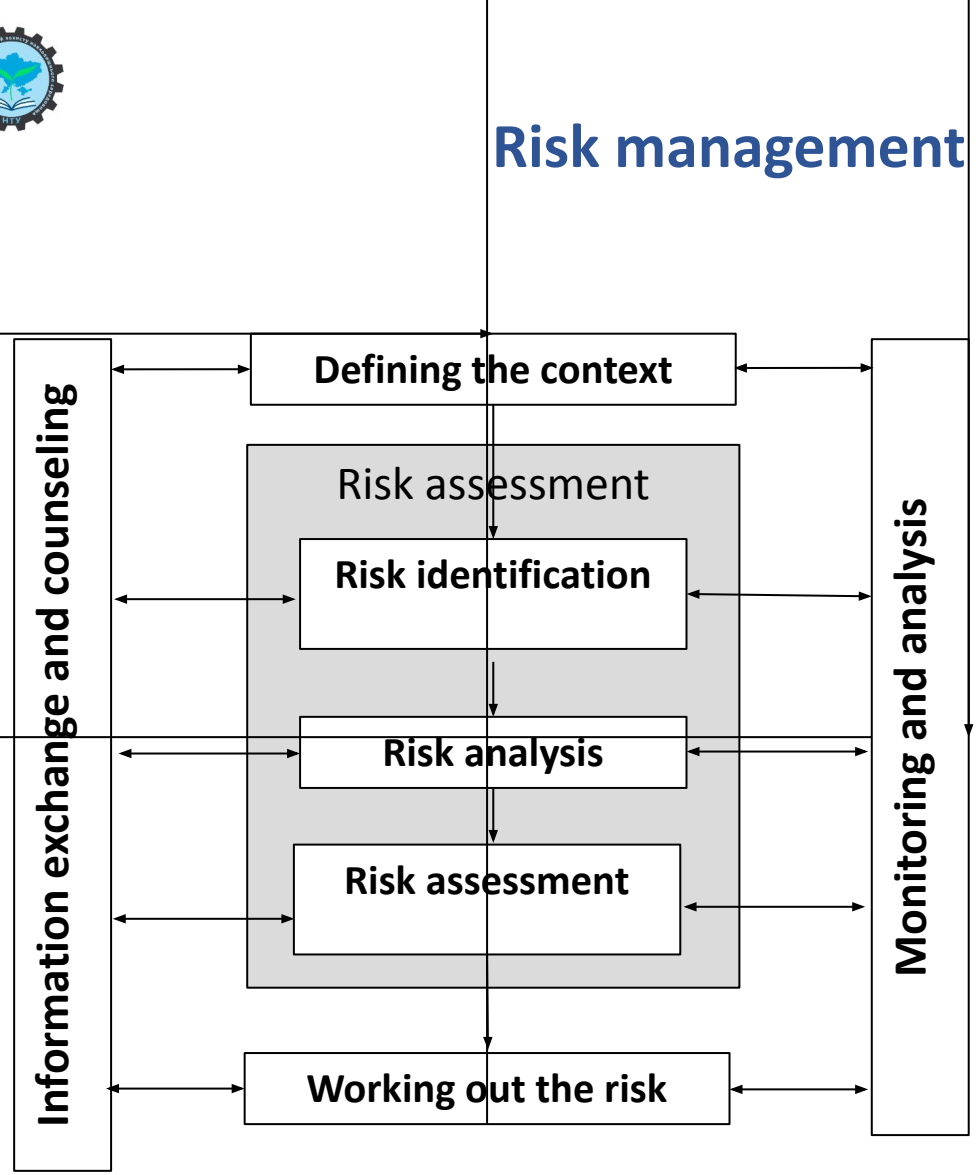
Risk management in transportation processes



1. Determining the parameters of an existing or predicted situation in transportation processes.
2. Risk analysis in transportation. The information basis of the risk management process is its analysis. The main purpose of the analysis is to form a holistic picture of risks and the extent of potential liability.
3. Comparison of the analysis data with the maximum permissible levels of danger. After comparing the obtained values of risk indicators with the maximum permissible values (levels of acceptable risk), a risk management strategy and measures to reduce it are developed.
4. Justification of the transport process risk management program.
5. Deciding on the degree of sufficiency of the planned measures. After selecting a certain set of measures, a decision is made on the degree of their sufficiency.
6. Monitoring of results: This process provides feedback to the risk management system and allows taking measures to improve it.

Thank you for your attention!