Advances in Reliability, Safety and Security, Part 8 – Kołowrocki, Magryta-Mut (eds.)
© 2024 Polish Safety and Reliability Association, Gdynia, ISBN 978-83-68136-20-3 (printed), ISBN 978-83-68136-07-4 (electronic)

Advances in Reliability, Safety and Security

ESREL 2024
Monograph Book Series

Methodology For Assessment Of Coexistence Of Power Plant With Small Modular Reactor And Its Surrounding During Operation

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Abstract

The paper deals with risks and safety of power plant with small modular reactors. Due to human society development and needs, it solves the coexistence of this power plant with surrounding. Based on present knowledge it gives methodology for assessment of coexistence of this power plant with surrounding. Because each territory has site-specific characteristics, the methodology respects this reality.

Keywords: power plant with small modular reactor, risks, safety, coexistence, assessment, methodology

1. Introduction

A power plant with small modular reactor (further ***PSMR***) is a building technical installation that is a source of energy that ensures the protection of humans and the quality of their living conditions by enabling the production of products and quality services that humans need. Therefore, it belongs to critical public assets. Current knowledge and experience show that, like any other technical installation, PSMR will cause a reaction of the territory when inserted into it. Understandably, some response of territory to PSMRs may not be favorable to humans; some unacceptable impacts are temporary (e.g. impacts of construction), others persist throughout their existence (e.g. risk of contamination by radioactive fumes) and some of them could even require the restoration of the area after the closure of operations.

The goal of every human created installation is economic development and human safety. From the point of view of current knowledge, this means that interconnected systems, which are the environment, the social system and the technological system, must be in harmony with each other, i.e. their coexistence is ensured. For PSMR, this means that it must be: long-term safe, i.e. not to endanger oneself and one's surroundings under various conditions that arise as a result of the dynamic development of the world and its parts, the developments of which, moreover, are not synergistic; and must be an asset to those around them.

2. Summary of knowledge about the safety of PSMR

Small modular reactors (SMRs) have been in development for decades. The International Atomic Energy Agency defines small, medium, and large reactors according to their electrical output; reactors up to 300 MW are classified as small reactors (IAEA, 2017). In practice, SMRs are increasingly used because: they are cheaper; and their emergency planning area is smaller compared to large nuclear power plants (OECD, 2016). A PSMR is a complex technical installation that by help of other technical systems can be used to generate electricity. It creates a stable object-oriented technical facility that is interconnected with other objects that draw electricity (IAEA, 2017). According to (Ingersoll and Carelli, 2021) there are already several different types of PSMRs (Argentina, China, France, Japan, South Korea, Canada, Russian Federation, Great Britain and USA). Their cooling is carried out with water, gas, liquid metals and molten salts. Factors that play a role in the design are: fuel production; design and fuel performance; thermo hydraulics; safety analysis; licensing; operation; and supervision. The aim is to achieve a solution that is competitive with other energy sources and ensures: and sets up such levels of I&C system safety and such PSMR security that are sufficient for licensing; sufficient performance, physical protection and a response system to unacceptable phenomena; and satisfactory waste management.

During the construction and operation of PSMR, based on knowledge and legislative requirements, it must be ensured the safety of: public assets (lives, health and security of humans, protection of property, the environment and critical infrastructures and technologies), i.e. also PSMRs; and such behavior of humans under all conditions that ensures the preservation of the coexistence of basic systems, i.e. social, environmental and technological.

From the point of view of the safety of PSMR and its coexistence with the surrounding throughout its lifetime during the operation, it is a matter of determining the size of the relevant risks and classifying them into categories: acceptable risk; conditionally acceptable risk (ALARA, ALARP), for which the necessary preventive, mitigation, reactive and recovery measures are proposed; and unacceptable risk for which either avoidance of the activity is proposed, if possible, or other prevention or crisis management measures that require higher knowledge, higher technical equipment, higher costs and higher preparedness of human resources.

To ensure the safety of both, the PSMR and the surrounding, the principles of risk-based-design and risk-based operation need to be respected (Prochazkova, 2023). When creating the countermeasures, it is necessary to: be based on scenarios of the impacts of large events; consider both, the external and the internal sources of risk; and sources of risks associated with the human factor, especially in the area of management.

3. Coexistence of PSMR and its surroundings and principles of safety management of PSMR

Coexistence generally means common existence. The need and importance of coexistence is now being considered in many technical fields as it is shown in works, e.g. (OECD, 2004; Prochazkova, 2017). The works in question show that technical installations cannot be designed as closed systems, but their surroundings must always be considered. Many studies, e.g. (Granovetter, 1985; Prakash, 2000), show that the consequences of the disruption of coexistence are sooner or later conflicts that are of a social, financial or technical nature. Works (Hall and Hay, 2005; Prochazkova, 2017) and further show that conflicts can only be avoided by proper anthropogenic management of risks in design and operation.

Therefore, in accordance with the knowledge gathered in the works (Prochazkova et al., 2018a, 2018b, 2019a, 2019b), risks must be managed in favor of the safety of the area in which PSMR is, and namely throughout its lifetime. That is, they must be managed the risks associated with the processes: selection of the type of PSMR; embedding a PSMR in the territory; designing a PSMR; construction of PSMR; operation of PSMR, including the maintenance and modernization; decommissioning of PSMR. From the point of view of human development, it is necessary that the reactions of the environment to PSMR throughout its lifetime are adequate, i.e. that the reactions in question do not create sources of risks that would significantly disrupt the conditions necessary for human life, and that human society could not cope with.

Safety-oriented engineering is a set of knowledge and skills that solve a problem, i.e. satisfy the requirements of usefulness, availability and safety, based on the principles of systemic disciplines (Prochazkova et al., 2019b) PSMR is a complex object, i.e. it is an open system of mutually interconnected open systems. As a result of the interconnections of systems with different goals, they arise from time to time phenomena that threaten humans and other public assets on which humans depend; they are occurred dangerous situations, i.e. conflicts that must be prevented, or at least managed quickly with as little loss, damage and harm as possible in the interest of the development of human society.

Based on the findings summarized in the papers (Prochazkova, 2017, 2023), to ensure the safety of the operation of PSMR a multidisciplinary and interdisciplinary approach must be applied for ensuring its: existence (ability to provide balance); efficiency (ability to cope with scarcity of resources); freedom (ability to cope well with challenges from the environment); security (the ability to protect oneself from phenomena both inside and outside); adaptation (the ability to adapt to external changes); and coexistence (the ability to change one's behavior so that the behavior responds to the behavior and orientation of other systems, and that the system does not threaten them and they do not threaten it).

From the point of view of current knowledge, it is, therefore, necessary to solve two tasks: to solve the problem of the functionality of a set of interconnected (i.e. dependent) parts of PSMR under normal, abnormal and critical conditions; and to search for critical states of PSMR that are unpredictable or are the result of a serious operator error, and under certain conditions may turn into highly unacceptable conditions, i.e. into situations in which the very existence of PSMR or even humans are threatened, and which we usually refer to as crisis conditions in common communication.

The safety of PSMR and its surroundings can only be ensured by high-quality anthropogenic management (Prochazkova, 2017, 2023). On the basis of cost-effectiveness, it is necessary to reduce risks in the most critical areas as part of prevention, as well as to prepare a response and recovery to the occurrence of risks that are not dealt with in design either due to omission or ignorance in the design and construction process, or preventive measures are very costly. This is a very costly activity, and therefore, mutual communication between owners and operators of technical installation, public administration, the public and the media is necessary (Prochazkova et al., 2019b).

To ensure safety in accordance with current knowledge and experience, summarized in works (Prochazkova 2017, Prochazkova et al. 2019b), it is necessary to: firstly, to know the sources of risks; evaluate their harmful potential (i.e. identify the hazards posed by the phenomena in question and the distribution of their impacts) in individual locations; determine the size of possible losses and damages depending on the distribution of public assets; select appropriate measures to mitigate the impacts of risks; and ensure timely implementation of measures (risk management plan). Since 1989, the comprehensive Total Quality Management – TQM (Zairi 1991) technique has been used in the European Union to manage the safety of complex facilities, which was confirmed by the Maastricht Treaty (EU, 1992).

At present, when the automation of technical installations is on the rise, the management of technical installations is understood as a conscious way of applying the theoretical and practical knowledge either by a person (a manager) or by a control system that a person has put together (Prochazkova et al., 2019b). The control system in question performs activities according to the information it obtains from sensors and logical links that are embedded in software created by humans; it is referred to as I&C (information and control) system.

The basic principle of management of risks of PSMR is: qualified interconnection of technical, organizational, financial, personnel, social, knowledge areas; and clearly defined roles and responsibilities for all those involved. Therefore, the safety management system of PSMR affects a number of areas, i.e. technical, military, legislative, financial, economic, social, environmental, educational, research, etc. Based on the knowledge summarized in (Prochazkova, 2023; Prochazkova et al., 2019b), to ensure the safe operation of PSMRs, it is necessary to: use an integrated management system of PSMR according to ISO 9000 series, which is based on management of safety 7 processes - Figure 1; details in (Prochazkova, 2023); risk management plan according to ISO 31000; and proactive preventive maintenance (EPRI, 2001).

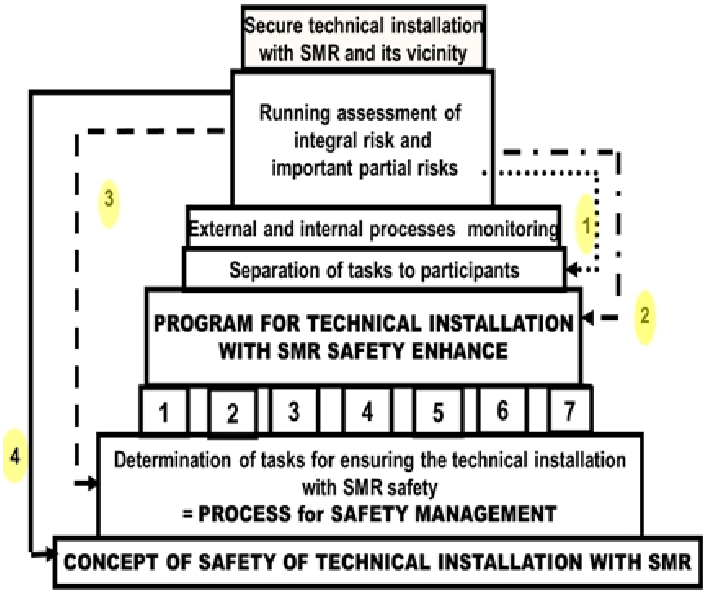

Fig. 1. Model of safety management of set of technical installations powered by the SMR with automated control (Prochazkova, 2023). Processes: 1- conception and management; 2 - administrative procedures; 3 - technical matters; 4 - external cooperation; 5 - emergency preparedness; 6 - documentation and investigation of accidents; 7- cyber security. Feedbacks: numbers 1-4 in a yellow circle.

4. Data and method of their processing

Based on the results of the research described in the work (Prochazkova et al., 2019b), the known sources of risk for the technical installations (to which nuclear facilities belong) during the operation are: natural disasters; failure of external critical infrastructures; internal disasters; internal infrastructure failures; technical failures; cybernetic failures; human errors; organizational accidents; terrorist attacks; and failure of public administration surveillance. In the management of the risks in question, it is important both, the integral safety of PSMR and its surroundings and the competitiveness of PSMR and the provision of energy service to the area in a longer period of time.

Since PSMR is a critical infrastructure object, from the point of view of the safety of the State and its inhabitants, it is necessary to ensure and maintain its long-term safe operation. Therefore, when compiling the requirements for the safety management of PSMR, it is necessary to consider the research results summarized in the work (Prochazkova et al., 2019b), namely: one of the causes of accidents and failures of technical facilities in 80% of cases is human error at their management or at response to accidents or failures; and 80% of accidents and failures of technical installations are caused by a combination of external/internal/external and internal harmful phenomena that have occurred in a short period of time, although these harmful phenomena alone are not capable to cause an accident or failure. For this reason, the integral safety management of PSMR is necessary to use, which is implemented as an integrated management of 7 processes (Prochazkova, 2023) and their interconnection, which is codified by ISO 9000 series standards.

The application of risk management tools depends not only on knowledge, but also on finances and responsibilities, as specific measures are costly and require the participation and synergy of activities of workers of PSMR. Therefore, it is necessary to consider that the competencies and responsibilities that make the necessary resources available for measures and activities for the management and settlement of risks in favor of safety depend on the level of the organizational structure, which represents a hierarchical arrangement of superior-subordination relationships and resolves mutual competences, links and responsibilities. Of course, the mobilization of large financial and other resources for risk management and settlement is only at the highest hierarchical level. Therefore, we consider the organizational structure of PSMR as follows: top management; senior management – it manages and is responsible for projects (e.g. the result of a set of several production lines – a system associated with a nuclear reaction, a cooling system, power generation, etc.); middle management – it manages and is responsible for processes (individual production lines, composite components – reactor, generator, individual cooling systems, etc.); technical management – it manages and is responsible for the operation of individual technical equipment; and personnel (critical and supportive) – it carries out and is responsible for carrying out technical activities.

Since ensuring the safety of PSMR is not just a technical issue, but a multi-sectoral one, it is necessary to use a multi-criteria tool for risk decision-making, which is a decision support system (Prochazkova, 2011). When compiling the methodology for assessing the coexistence of PSMR and its surroundings, we use common sense, i.e. the coexistence in question is ensured when the operation of PSMR is safe and profitable and is of long-term benefit to the surroundings, i.e. the costs incurred to settle the risks associated with its operation by the public administration (losses) are significantly lower than the benefits for the surroundings.

5. DSS for deciding on risks of PSMR

Based on the research summarized in the work (Prochazkova et al., 2019b), they are considered when compiling the DSS, assess: the method of considering the risks and their sources at different levels of the organizational structure; the level of safety achieved in given design of PSMR; the technical level of the operational measures put in place; material and energy demands; speed of implementation of the necessary measures to support the operation; personnel requirements; information security requirements; financial claims; responsibility claims; and as well management requirements of all those involved (i.e. both, the management of PSMR and the management of the territory).

Based on the requirements for working with the risks of technical installations listed in (Prochazkova et al., 2019b), a checklist for assessing the risks associated with the operation of PSMR is compiled in Table 1 with the philosophy, the higher the risk, the lower the safety of PSMR, which also means a lower degree of coexistence of PSMR with the surroundings. For practical application, two scales are assigned to the checklist: the scale in Table 2 is intended to ensure commensurability in the assessment of the individual criteria in Table 1 using the classification scale (0-5) and the concept "the higher the value, the higher the risk (Keeney and Raiffa, 1993), i.e. the lower the coexistence of PSMR with its surroundings; and a second scale for the evaluation of integral risk by help of checklist in Table 1 based on the principle that was introduced into ČSN standards in the 1980s (Prochazkova, 2013), Table 3.

Table 1. Checklist for assessing the risk associated with the coexistence of PSMR with its surroundings in operation. A- rating, N – note. Number of criteria n = 339.

Criterion	A	N
Risks associated with the top management of a PSMR – 139 items		
The rate with which the top management of PSMR understands and realizes responsibility for the integral safety of PSMR.		
The rate with which the top management of PSMR and the management documents for the operation of PSMR consider the impacts of disasters that are possible in the area at the operation of PSMR and carry out remedy deficiencies.		
………		
Risks associated with project management– 52 items		
The rate with which management of projects in PSMR understands and realizes responsibility for the safety of projects of PSMR.		
The rate with which management of projects in PSMR and management documents for realization of projects consider the impact of project management errors on effective management of safety of projects in PSMR and carry out remedy deficiencies.		
……….		
Risks associated with process management– 52 items		
The rate with which management of processes in PSMR understands and realizes responsibility for the processes safety of PSMR.		
The rate with which the managements of processes in PSMR and management documents for realization of processes consider the impact of errors in management of safety of processes at operation of PSMR and carry out remedy deficiencies.		
……		
Risks associated with management of technical equipment – 35 items		
The rate with which the management of specific technical equipment of PSMR understands and realizes responsibility for the safety of specific technical equipment of PSMR.		
The rate with which the management of specific technical equipment of PSMR and the management documents for the control of technical equipment consider the impact of technical management errors in the field of maintenance and quality control on the operation of PSMR and carry out remedy deficiencies.		
……..		
Risks associated with behavior of personnel of PSMR – 12 items		
The rate with which critical personnel of PSMR performing the specific work tasks at operation of PSMR understand and realize responsibility for the safety of the operations tasks.		
The rate with which critical workers of PSMR performing the specific works tasks connected with safety at operation are trained.		
………		
Risks associated with behavior of contractor personnel in PSMR – 5 items		
The rate with which the personnel of the contractor in PSMR performing the work tasks at operation of PSMR have responsibility for the safety of work tasks.		
The rate with which the personnel contractor in PSMR performing the work tasks at operation of PSMR must respect rules of safety culture.		
…..		
Risks associated with behavior of visitors to PSMR - 5 items		
The rate with which a person who visits PSMR at its operation is responsible for the safety of his/her behavior.		
The rate with which a person who visits PSMR at its operation must comply with the rules of safety culture.		
……..		
Technical safety risks - 13 items		
The rate with which the technical safety of critical components in PSMR is ensured: reactor; reactor vessel; heat exchanger; fuel; refrigerant tank; main circulation pump; pipes for steam discharge to the secondary circuit; refrigerant replenishment system; residual heat dissipation system; and containment with respect to the impacts of disasters that are possible in PSMR and in its surroundings.		
The rate with which the technical safety of the interconnections of critical components of primary circuit of P SMR is ensured with regard to the impacts of disasters that are possible in PSMR and in its surroundings.		
….		
Risks associated with cybersecurity – 5 items		

The rate with which the hardware of information system of PSMR supporting the organization and operation is secured against the impacts of disasters that are possible in PSMR and its surroundings so that the operation of power plant with SMR is not disrupted.

The rate with which the software of information system of PSMR supporting the organization and operation respects the impacts of disasters that are possible in PSMR and its surroundings so that the operation of PSMR is not disrupted.

…..

Risks associated with supporting a management system of power plant with SMR, i.e. with I& C – 10 items

The rate with which I&C system of PSMR is safety-oriented, i.e. it is an integral part of SMS (safety management system).

The rate with which I&C system of PSMR is able to deal with the impacts of disasters that are possible in PSMR and its surroundings so that the operation of PSMR is not disrupted.

……

Risks associated with legislation and public administration supervision of PSMR – 11 Items

The rate with which valid legislation requires from the operator and owner of PSMR to ensure the integral safety.

The rate with which public administration ensures the quality of risk and safety education.

The rate in which the public administration supervises the integral safety of PSMR.

……..

TOTAL

Table 2. Value scale to ensure the commensurability of evaluation of criteria in Table 1 at determining the risk rate that an operating PSMR poses to its surroundings; it is designed by analogy with the scales given and described in work (Prochazkova, 2013); p – annual insurance, ABT – annual budget of the territory.

Area	Risk rate	
	Classification	Comment
Social	0	Up to 50 people are affected by an accident or failure of PSMR
	1	50-500 people are affected by an accident or failure of PSMR
	2	500-5000 people are affected by an accident or failure of PSMR
	3	5000-50000 people are affected by an accident or failure of PSMR
	4	50000 -500000 5000-50000 people are affected by an accident or failure of PSMR
	5	More than 500,000 people are affected by an accident or failure of PSMR
Technical and economic	0	An accident or failure of PSMR will cause damage up to 0.5 p
	1	An accident or failure of PSMR will cause damage equal to p
	2	An accident or failure of PSMR will cause damage greater than p and less than 0.005 ABT
	3	An accident or failure of PSMR will cause damage between 0.005 ABT and 0.075 ABT
	4	An accident or failure of PSMR will cause damage between 0.75 ABT and 0.1 ABT
	5	An accident or failure of PSMR will cause damage greater than 0.1 ABT
Environment	0	An accident or failure of PSMR power plant will cause little damage to the environment
	1	An accident or failure of PSMR will cause damage to the environment that will be offset by nature over time
	2	An accident or failure of PSMR will cause little damage to the environment
	3	An accident or failure of PSMR will cause moderate damage to non-renewable nature resources and nature reserves
	4	An accident or failure of PSMR will cause irreversible damage to non-renewable nature resources and nature reserves
	5	An accident or failure of PSMR will cause devastation to the landscape, non-renewable nature resources and nature reserves

Table 3. Value scale to determine the degree of coexistence of PSMR and its surroundings; N = five times the number of criteria in Table 1, i.e. N = 1695

Risk rate of PSMR	Values in **% N**
Extremely high – 5	More than 95%
Very high – 4	70–95 %
High – 3	45–70 %

Medium – 2	25–45 %
Low – 1	5–25 %
Negligible – 0	Less than 5%

The evaluation of a specific case, i.e. the evaluation of a set of expected variants of operation of PSMR according to Table 1, must be carried out independently by a team of specialists from different departments; in practice (Prochazkova et al., 2019b), in practice it works a team consisting of: public administration officer responsible for safety of territory; public administration officer responsible for supervising the operation of technical installations; representative of PSMR responsible for risk management; representative of expert institution for assessing the safety of technical installations – e.g. from a technical inspection; Nuclear Regulatory Body representative; and representative of Integrated Rescue System responsible for responding to accidents and failures of technical installations. The resulting value for each criterion is the median, and in the event of a large variance of values for any criterion, it is necessary for the public administration officer responsible for the safety of the territory to ensure further investigation, at which each evaluator communicates the justification for his/her evaluation in the case in question and the resulting evaluation is determined on the basis of a panel discussion or brainstorming

Based on the modern approach that we have already used in the work (Prochazkova et al., 2019b) and in accordance with the work (Hezoucky, 2006; Hollnagel, 2012; Leveson, 2004; Stein et al., 2003), we consider the tolerable risk expressed by the ALARP principle (as low as reasonable possible) (EU, 2006) in the given context, i.e. the case where PSMR has benefits and at the same time there are associated impacts (losses, damages and injuries to protected assets) that PSMR and its surroundings can handle through continuous risk management aimed at safety. The tolerance limit (i.e. the boundary between tolerable and unacceptable risk) is defined as a quantitative property (Prochazkova, 2011), which is used, for example, by the UN and Swiss Re, namely the limit of unacceptability is a tenth of the utility value of PSMR.

On the basis of this requirement, in accordance with the works (Ben-Gal, Katz and Bukchin, 2015; Berman, Krass and Menezes, 2009; Chapman, 2009; FEMA, 2007; Gayford E. and Gayford C., 1979; Portny, 2007; Price, 2005; Prochazkova et al., 2019b; Tatum, 1987), using the integrated approach and other assumptions mentioned above, we get the condition for the highest possible annual losses of PSMR caused by the implementation of ***RZE*** risks in the form of

$$RZE < 0.1 \sum_{i=1}^{n} \frac{k_i \, HE}{5\,T}, \qquad (1)$$

Where ***HE*** is the utility value of PSMR, k_i is the resulting the risk source assessments in Table 1, n is the number of risk sources in Table 1 (i.e. $n = 339$ in this case) and T is the lifetime of PSMR. If the condition given by equation (1) is not met, then the risk is not tolerable, i.e. coexistence is not ensured and operation of PSMR should be changed, i.e. either a new option or additional risk reduction measures should be requested, followed by a further assessment of the design. If the requirement given by equation (1) is met, the evaluation of coexistence can be continued.

6. Methodology for assessing the coexistence of PSMR and its surroundings

When deciding on the operation of PSMR from the point of view of the requirement to ensure coexistence, it is necessary that PSMR is not loss-making for the territory during the operation, i.e. that its benefits for the territory are greater than the costs incurred by the public administration to manage the risks associated with its operation. Therefore, another condition for assessing the degree of coexistence is obtained when evaluating the benefits of PSMR according to Table 4 with the help of Tables 5 and 6.

Table 4. Checklist for assessing the benefits of PSMR for surroundings. A – evaluation result, N note. Number of criteria n = 10.

Criterion	A	N
The operated PSMR will increase the education of the population in the area.		
The operated PSMR will increase the possibility of employment of the population in the area.		
The operated PSMR will increase the level of services in the area.		
The operated PSMR will increase the public welfare in the area.		
The operated PSMR will contribute to the development of basic infrastructures in the area.		
The operated PSMR will increase the prestige of the area.		

The operated PSMR will contribute to the cultural development of the area.

The operated PSMR will improve the situation in the social domain in the area (according to auxiliary Table 5).

The operated PSMR will improve the situation in the technical and economic situation in the area (auxiliary Table 5).

The operated PSMR will improve situation in area of environmental protection and public well-being in area (auxiliary Table 5).

Table 5. A value scale to determine the degree of benefit that PSMR has for its surroundings; designed by analogy with the scales given in the work (Prochazkova, 2013); ABT – Annual Budget of the Territory.

Domain	Benefit rate	
	Classification	Comment
Social	0	Fewer than 50 people will benefit from PSMR.
	1	PSMR will benefit 50-500 people.
	2	PSMR will benefit 500-5000 people.
	3	PSMR will benefit 5000-50000 people.
	4	PSMR will benefit 50000-500000 people.
	5	More than 500,000 people will benefit from PSMR.
Technical and economic	0	PSMR will bring 0.005 ABT to the territory budget.
	1	PSMR will bring 0.005-0.01 ABT to the territory budget.
	2	PSMR will bring 0.01-0.025 ABT to the territory budget.
	3	PSMR will bring to the territory budget.
	4	PSMR will bring 0.026-0.05 ABT to the territory budget
	5	PSMR will bring more than 0.075 ABT to the territory budget.
Environment and public welfare	0	PSMR will contribute less than CZK 500 per year to environmental protection and increase public welfare.
	1	PSMR will contribute CZK 500-5000 per year to environmental protection and increase public welfare.
	2	PSMR will contribute CZK 5000-50000 per year to environmental protection and increase public welfare.
	3	PSMR will contribute CZK 50000-500,000 per year to environmental protection and increase public welfare.
	4	PSMR will contribute CZK 500,000-5,000,000 per year to environmental protection and increase public welfare.
	5	PSMR will contribute more than CZK 5,000,000 per year to environmental protection and increase public welfare.

Table 6. A value scale to determine the degree of benefit of PSMR for its surroundings; N is a number equal to five times the number of criteria in Table 5, i.e. N = 50.

Degree of benefit of PSMR for the surroundings	Values in % N
Extremely high – 5	More than 95 %
Very high -4	70–95 %
High – 3	45–70 %
Medium -2	25–45 %
Low -1	5–25 %
Negligible – 0	Low than 5 %

Based on practical experience and knowledge and examples in the work (Bruce, 2003), using the integrated approach and assuming that all benefits determined according to Table 4 have the same probability of occurrence, we obtain a formula for determining the expected annual yield of PSMR ***PRZE*** in the form

$$PRZE = 0.7 \sum_{i=1}^{n} \frac{k_i\, CPE}{5\, T}, \qquad (2)$$

in which ***CPE*** is the total useful yield of PSMR over its lifetime, k_i is the individual ratings in Table 5, n is the number of benefit sources in Table 4 (i.e. n = 10 in this case) and T is the lifetime of PSMR. The expected annual net income of PSMR ***RPE*** for the territory is determined by the relationship

$$RPE = PRZE - A - RPNE, \quad (3)$$

where A is the annuity and ***RPNE*** is the expected operating cost of PSMR. The basis for the decision on the acceptability or unacceptability of operation of PSMR is the result of the difference ***RR*** between the permissible maximum annual losses of PSMR, caused by implementation of risk and expected net annual revenues, i.e.

$$RR = RZE - RPE. \quad (4)$$

The assessment uses the limits of risk acceptability or unacceptability, which are used, for example, by the UN and Swiss Re, namely the amount of annual premiums for protected assets in the territory (***PRE)*** and a tenth of the annual budget of the territory (*ABT*), which ensures development in the territory. According to this rule, we compare three quantities in practice: the difference between the annual losses of PSMR due to the realization of risks and the expected annual net return of PSMR (*RR*); annual premium PSMR (*PRE*); and the Annual Territorial Budget (*ABT*).

Based on the scoring the results, the category to which the risk associated with PSMR belongs in a given case shall be determined according to the methodology described in (Prochazkova et. al., 2019b) as follows:

- $RR < PRE$, so the risk of operation of PSMR is acceptable for the territory,
- $PRE < RR < 0.1\ ABT$, so the risk of operation of PSMR is conditionally acceptable (tolerable) for the territory,
- $RR > 0.1\ ABT$, so the risk of operation of PSMR is unacceptable for the territory.

In the first case (the revenues are greater than the losses, or the losses are covered by insurance premiums), PSMR can be operated. In the other case, it is necessary to require response measures in the management of operation of PSMR leading to risk reduction and to ensure mitigation, reactive and restorative measures (Prochazkova et al., 2019b) as part of continuous targeted risk management aimed at ensuring a safe PSMR and the coexistence of PSMR with its surroundings. In last case, i.e. in the case of an unacceptable risk, it is necessary to carefully consider the conclusion – either risk avoidance, i.e. non-implementation or cessation of operation of PSMR, or request for further preventive and mitigation measures leading to increased safety of PSMR (it is necessary to require the application of: higher knowledge; better technical equipment; higher costs on protective systems; ensuring higher readiness of human resources, etc.) and then a new coexistence assessment (Prochazkova, 2013, 2017; Prochazkova et al., 2019b).

7. Conclusion

Each PSMR consists of elements, components, systems and their interconnections. Due to the management system, which is increasingly automated, it is socio-cyber-physical in nature. Many of these items ensure the performance of basic functions and either provide or support the provision of safety. As an engineering system, it is characterized by the structure, hardware, procedures, environment, information flows, organization, and interfaces between these components. The basic element of its safe operation in the field of technical solutions is the application of safe (i.e. reliable, functional and non-endangering itself and its surroundings) technical elements, their qualified interconnection and operating mode allowing safe (i.e. reliable and trouble-free) operation, timely and proper maintenance (proactive preventive), backup of priority parts of technical equipment, use of various backup principles and thoughtful deployment of reserves in the territory. However, the aspects important for the operation of PSMR are very diverse, in particular: knowledge and technical capabilities that determine the capacity of PSMR and its technical facilities; organizational and legal matters that allow the operation of PSMR and technical facilities at a certain level of safety in the territory and at a time; and financial, personal, social and political at the national and international levels. Therefore, the above-mentioned methodology for assessing the coexistence of PSMR with its surroundings in a long time interval is quite complex.

Acknowledgements

Authors thank for support to TAČR project No TK05010146.

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