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Instructions For Selecting Suitable SMR For Czech Republic

Michal Cihlář[a,b], Dana Procházková[a], Václav Dostál[a]

[a]*Czech Technical University in Prague, Prague, Czech Republic*
[b]*Research Centre Řež, Husinec, Czech Republic*

Abstract

Small modular reactors (SMRs) are a trend of recent years and one of the possible paths for a nuclear renaissance. In the Czech Republic, CEZ plans to build the first SMR at Temelin. The reactor designs under consideration include AP300 (Westinghouse), BWRx-300 (GE-Hitachi), NuScale (NuScale), Nuward (CEA, EDF, Naval Group, and Technicatome), SMART 100 (KAERI and KEPCO E&C), SMR-160 (Holtec), and UK-SMR (Rolls-Royce). An important step towards successful plan realization is the choice of the appropriate design. One method of evaluation that contributes to quality decisions, which will result in the nuclear and integral safety of the object and its surroundings is the multi-criteria method. In the presented article, we show items, which would be considered and propose further procedures for multicriteria method application.

Keywords: SMR, small modular reactor, safety, multicriteria evaluation

1. Introduction

Small modular reactors (SMRs) have been a trend in recent years and the nuclear industry is trying to achieve a nuclear renaissance with their help. The International Atomic Energy Agency defines SMRs as "small" plants with up to 300 MWe and "medium" plants with up to 700 MWe. However, the term "SMR" is more often used as an abbreviation for "small modular reactor", which is intended for series construction.

The SMR is a complex technical device that is a source of energy and thus supports the energy security of the state. In order to protect people, property, the environment, and the development of human society, SMRs must be safe technical equipment (EU, 1992; IAEA, 2021a, 2021b; OECD, 2003, 2016). Therefore, based on knowledge, when selecting an SMR type, both the parameters of the environment in which the SMR will be operated and the limits and conditions of the SMR itself must be considered (Prochazkova, 2017).

There are currently many SMRs under development by different suppliers whose concepts vary a lot (IAEA, 2010). As each site has its own specificities, the appropriate type needs to be selected for a particular site in terms of technical, economic, environmental, and social aspects (Prochazkova, 2014). This means considering many different aspects of risk management aimed at SMR safety. To realize the difficult decision, this paper presents a multi-criteria method that evaluates the main parameters of SMRs that decide the safety, performance, and utility of SMRs in a specific location.

In section 2 the background on SMRs, their advantages, and disadvantages are given. Section 3 deals with the types of safety management which SMR needs to respect. Section 4 presents examples of different SMR designs. Section 5 introduces the methods for complex problem solving, while in section 6 the specific criteria for suitable SMR selection are proposed. Section 7 summarizes the findings and concludes the paper.

2. Knowledge summary

Small Modular Reactors (SMRs) are advanced nuclear reactors. SMRs have been in development for several decades, but their development has accelerated significantly in recent years. This is due to the growing interest in nuclear power as a source of emission-free energy that could help address global warming issues. SMRs are mostly representatives of advanced Generation III+ and IV reactors. These reactors bring improvements in nuclear safety over previous generations and thus incorporate the best nuclear technology currently available.

Based on the knowledge (Hussein, 2020; IAEA, 2022; Mignacca and Locatelli, 2020; Zeliang et al., 2020), the main information is these:

- SMRs bring improvements in nuclear safety primarily through the implementation of passive safety systems that use physical principles to operate and are independent of human factors. Generation III+ reactors include mainly light water reactors such as the UK SMR, SMR-160, and BWRX-300. Generation IV includes high-temperature gas-cooled reactors, liquid metal-cooled fast reactors, molten salt-based reactors, and more;
- SMRs have a number of potential advantages over traditional large nuclear power plants. They are smaller, making them easier to build, transport components to their destination, and operate. Some SMRs are constructed from modules that can be mass-produced. This leads to reduced costs and construction time. They can also be operated in a variety of locations, including remote areas;
- SMRs can be used for a variety of purposes. SMRs can be used to generate electricity both as base load and as load balancing on the electricity grid. SMRs can be also used to produce heat for district heating, industrial heat production, or for hydrogen production. Therefore, SMRs are seen as a potentially important source of energy in the future. They can help meet the growing demand for electricity, even in countries that do not have access to traditional energy sources. SMRs also have several drawbacks. The disadvantages of SMRs can be divided into three main categories: technological challenges; economic challenges; and political challenges;
- The development of SMRs is still in the research and development phase. This means that a number of technical challenges need to be addressed before SMRs can be commercially deployed. Their implications for territorial security are not fully understood. Further research is needed to ensure how safe and reliable SMRs will be. Economic challenges include cost and financial risks. SMRs are not always cheaper than large nuclear power plants. The cost of SMRs depends on a number of factors, including reactor type, reactor size, and location. The construction itself, while cheaper than a large nuclear power plant, is still a very expensive project that poses some financial risks. The biggest policy challenges are regulation and legislation related to SMR and public support for nuclear power;
- SMR research and development is currently underway. Projects are underway in many countries around the world to develop and test commercially viable SMRs. SMRs are a promising technology that has the potential to change the future of energy. SMRs might be smaller, cheaper, and more flexible than traditional large nuclear power plants and can be used for a variety of purposes, including electricity generation, heating, and hydrogen production. Currently, over 80 SMRs are under development in many countries around the world.

3. Safety of SMR

To ensure human society's security and development, the operation of a complex technical device – an SMR – must be safe and reliably fulfill its function for a long time. It must respect safety principles (IAEA, 2006), governmental, legal, and regulatory framework (IAEA, 2016). According to present knowledge and experience in strategic risk management of complex technical facilities aimed at safety, summarized in (Prochazkova, 2018), it holds for the SMR, that its strategic risk management aimed at safety must be applied during the whole SMR life cycle:

- selection of the SMR type and the SMR location;
- design, construction, testing, and commissioning of the SMR;
- operation of the SMR including the SMR maintenance and the SMR modernization;
- decommissioning the SMR.

The processing of the 254 cases of technical facilities failures due to errors in their type selection or location revealed that these errors led to unfinished implementation, major problems in operation, and therefore, premature closure (Prochazkova and Prochazka, 2020). The main causes of the technical facility were mainly related to the knowledge and behavior of the entities managing the territory, permitting, and supervising the technical facilities in the area. Errors in technical facilities selection of type or site, shown in Figure 1 caused these technical facilities:

- have never been built or completed;
- have been built but have not been put into operation;
- have been completed, put into operation and the operation has ended prematurely because of either high operating costs (costly operation, frequent interruptions requiring costly repairs, etc.) or major conflicts with the surroundings (air contamination with gaseous hazardous substances, noise, waste, etc.);
- were completed, put into operation, and a major accident caused by the interactions between the technical part and the surroundings, which were not considered in the project, ended the operation.

For this reason, the collection of data on SMR and the method for selection of the SMR type are very important.

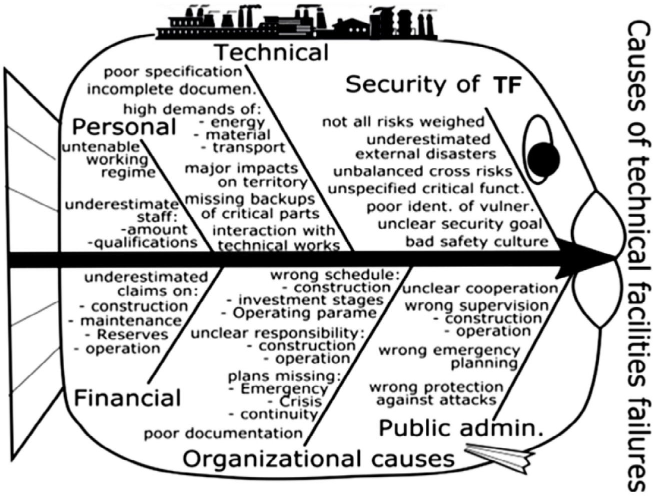

Fig. 1. The Ishikawa diagram shows the causes of technical facility (TF) failure due to bad selection of technical facility type or to a wrong technical facility location (Prochazkova and Prochazka 2020).

4. Types of SMRs

Our research (Cihlar et al., 2023) focused on multiple reactors of different types (IAEA, 2022), Table 1. The table in question shows:

- reactor type;
- coolant type;
- the moderator used;
- thermal power;
- electrical power;
- primary circuit pressure;
- inlet and outlet temperatures of the core.

Research (Cihlar et al., 2023) has shown that SMRs differ; apart from the reactor type, coolant type, or moderator type if used any; and in many additional aspects, namely, their safety philosophy, in the number of grouped units in a single plant, in modularity, or in power.

Currently, ČEZ company (CEZ, 2023) has selected 7 possible suppliers of SMR technology for the Czech Republic. The selected technologies are based on pressurized water or boiling water reactors. An overview of the selected reactors is given in Table 2. The table contains:

- type of reactor;
- thermal power;
- electrical power;
- primary circuit pressure;
- inlet and outlet temperatures of the core;
- moderator;
- length of fuel campaign.

A comparison of the values in Table 2 shows that there are significant differences between the reactors.

Table 1. Parameters of followed SMRs.

Name	Type	Coolant	Moderator	Power	Power	I.O. Pressure	Core inlet/ outlet temperature
-	-	-	-	MWth	MWe	MPa	°C
Indian 220 MWe PHWR	HWR	Heavy Water	Heavy Water	754	236	-	249/293.4
Prismatic HTR	HTR	Helium	Graphite	350	150	6.39	322/750
EM2	GFR	Helium	N/A	500	265	13	550/850
PRISM	SFR	Sodium	N/A	840	311	0.1	-/485
ALFRED	LFR	Lead	N/A	300	125	0.1	400/480
G4M	LFR	Lead-Bismuth	N/A	70	25	0.1	-/500
CAWB	MSR	Molten Fluoride Salt	Heavy Water	100		0.1	-/560
IMSR-400	MSR	Molten Fluoride Salt	Graphite	400	194	0.1	640/700
UK-SMR	PWR	Light Water	Light Water	1358	470	15.5	295/325
BWRx-300	BWR	Light Water	Light Water	870	290	7.2	270/288
SMART 100	IPWR	Light Water	Light Water	365	107	15	296/322

Table 2. Summary of basic data on SMR reactors considered by CEZ (2023) for the Czech Republic.

Name	Type	Coolant/ moderator	Power	Power	I.O. Pressure	Core inlet/ outlet temperature	Fuel campaign
-	-	-	MWt	MWe	MPa	°C/°C	Months
AP300	PWR	Light water	900	300	(15.5)	(279/325)	(18)
BWRx-300	BWR	Light water	870	270 – 290	7.2	270/288	12-24
NuScale	PWR	Light water	160	50	12.75	258/283	24
Nuward	PWR	Light water	540	170	15	280/307	24
SMART 100	PWR	Light water	365	107	15	296/322	30
SMR-160	PWR	Light water	525	160	15.5	243/321	24
UK-SMR	PWR	Light water	1358	470	15.5	295/325	18-24

5. Method of selecting a suitable solution to a complex problem

Firstly, we give several methodical comments to multicriterial assessment and after this, we describe the approach that we use in our case.

5.1. Multicriterial assessment

According to knowledge summed in (Beton and Stewart, 2001; EPA, 1979; Figueria, 2005; Prochazkova, 2011):

- multicriterial methods have been developed since the 60's of last century;
- for the use of multicriterial methods, it is necessary to create a set of criteria and a scale for the assessment;
- at present, they are used:
  - simple methods such as decision matrixes, boundary graphs, and multicriterial evaluation methods using the hierarchy of criteria, a method that uses a multipurpose tree of the criteria hierarchy, pairwise comparison method, scoring method, etc.
  - sophisticated as DELPHI, AHP (Analytical Hierarchal Process), a method based on a partial utility function, MCDA (Multiple Criteria Decision Making), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS); Ideal Point Analysis (IPA); Aggregation Preferences (AGREPREF); Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE); Markov Chain (MC); Multi-Objective Genetic Algorithm (MOGA); a Multiplicative Intuitionist Linear Logic (MILL) etc.

- the multicriterial assessment is intended to identify the most suitable solution, not to enforce it at any cost.

5.2. Description of methods used for SMR type selection

From the data presented above, it is clear that SMR types differ in many areas that are not easily comparable. Therefore, deciding on an appropriate solution for the Czech Republic is not a simple matter, as it must be based on a comprehensive systemic evaluation (Prochazkova, 2011). From a methodological point of view, it is a multi-criteria evaluation that assesses the contribution of a given technology to society according to its impacts and benefits based on criteria from all areas of society's life (technical, ecological, social, economic, legal). The different aspects cannot be artificially separated from each other, as they are interconnected in a complex web of subtle linkages reflecting the real-world contexts of different areas of society. For this reason, it is necessary to create a comparative platform so that the results are logical, conclusive, and repeatable. In harmony with the demand for technology assessment characterized in (EPTA, 2009; USA, 1992) we use several sets of criteria in our evaluation, namely:

- satisfaction assessment criteria;
- technical feasibility assessment criteria;
- criteria comparing the level of substantive solutions with the rest of the world;
- economic criteria (cost-benefit analysis);
- criteria for the impacts of technology and its feedback on human health, the environment, waste, and society;
- criteria for material and energy requirements as well as sources of raw materials.

A decision support system (Prochazkova, 2011) promotes an analytical style of decision-making against heuristic decision-making and improves decision-making in the case of complex systems when a strategy of multicriteria decision-making is built into it.

Decision-making is prepared by a team of competent experts (Prochazkova, 2011) who:

- have their own professional results in the area to which the problem under consideration falls;
- are able to synthesize knowledge, and understand a problem in a broad context;
- are unbiased and independent.

The assessment of the competence of experts in assessing a given issue has its own rules, which are contained in the professional literature and in many countries, e.g., the USA, Japan, and the EU, in legislation.

In cases where the problem to be decided is complex, i.e., it spans multiple areas, we use methods to support decision-making (Prochazkova, 2011), which are: a method using a hierarchy of criteria tree; a method that uses a multi-purpose tree of the criteria hierarchy; pairwise comparison method; scoring method; and a method based on a partial utility function. The methods in question usually consist of 4 methods, namely: problem identification method; method of problem analysis and problem structuring; method of creating variants of the solution; and the method of evaluating variants. We divide them into quantitative and qualitative. Basic quantitative methods include: basic and descriptive statistics; calculation of probability; decision analysis; quality management; leveling methods; regression analysis; linear programming; inventory management; project management; simulation; and financial decision-making.

In Czech practice (CVUT, 2023), the method using the Multi-Attribute Utility Theory (Keeney and Raiffa, 1993) based on the vulnerability assessment of individual elements of the system has proven to be effective. It is used in strategic management when it is a long-term solution. During the evaluation, a relatively complex system of links is classified, in which the effect of individual factors on the resulting effect cannot be quantified. The overall rating is, therefore, relative and may be influenced by the subjective approach of individual evaluators. It is, therefore, advantageous if the evaluation is carried out by several independent experts. The evaluation results are valid only for the system being evaluated and it is not possible to compare the results of the evaluation of different systems assessed separately. Therefore, in the USA and some other countries, expert methods for these complex assessments are being codified.

Multi-criteria evaluation based on a decision support system includes:

- creation of a purpose-oriented set of evaluation criteria;
- weighting the evaluation criteria;
- determination of sample/cut-off values by evaluation criteria;
- evaluation of the achieved results of the variants (e.g., impacts, benefits, damages, losses, injuries), is a partial evaluation of each item, which will then be decisive in the overall evaluation;
- assessment of the risk associated with the application of the selected method of item evaluation;
- specify the preferred order of variants;
- recommendation of the best option.

Of course, the creation of a purpose-oriented set of evaluation criteria has the greatest impact on the final evaluation. The essence of the creation of criteria lies in a careful knowledge of the object of evaluation and in the system of understanding its structure and function. The set of criteria must be complete and the essential properties of the evaluated objects must also be known. Otherwise, the overall result is usually distorted. The act of selecting and arranging the evaluation criteria is a complex and demanding process that cannot be replaced procedurally (i.e. by a determined algorithm). An integral part of it is the classification of possible criteria. The commensurability of the evaluation of criteria from different areas is achieved by using the utility values of the item for the problem being decided. An example of a table for achieving commensurability is e.g., Table 3 (Prochazkova, 2013). The result of multi-criteria decision-making is usually a certain consensus (Prochazkova, 2011).

Table 3. Value scale for classifying the disaster impacts.

Area	Value scale for primary impacts	Note
Social	1 – fewer than 50 people are affected 2 - 50-500 people are affected 3 - 500-5000 people are affected 4 - 5000-50,000 people are affected 5 – 50,000 -500,000 people are affected 6 - More than 500,000 people are affected	For technological disasters, these figures need to be reduced in order to comply with the legislation, which sets a limit of 1 death every 10 years.
Technical and economic	1 - damages up to 5000 CZK 2 - damages 5000 – 50,000 CZK 3 - damages 50,000 - 500,000 CZK 4 - damages 500,000 – 5 000,000 CZK 5 - damages 5 000,000 – 50 000,000 CZK 6 - damages of more than 50 000,000 CZK	When used in strategic planning, it is necessary to consider the facts with which the UN works (Prochazkova 2007), i.e. the limit value for damage is a tenth of the annual budget and that the occurrence of damage greater than a tenth of the budget for three years in a row is devastating for the entity.
Infrastructures	1 - fewer than 50 people are affected by the service outage 2 - 50 - 500 people are affected by the service outage 3 - 500 - 5000 people are affected by the service outage 4 - 5000 – 50,000 people are affected by the service outage 5 - 50,000 – 500,000 people are affected by the service outage 6 - more than 500,000 people are affected by the service outage	Depending on the type of infrastructure, the duration of the service outage still needs to be considered. Currently, durations of 3 hours, 6 hours, 1 day, 3 days, and 14 days are being tested for vital infrastructures. At the same time, wherever people's lives are at stake, infrastructures are backed up in some way to ensure people's survival.
Environment	1 - little damage to the environment 2 - Environmental damage that nature balances over time 3 - moderate damage to non-renewable natural resources and nature reserves 4 - moderate damage to non-renewable natural resources and nature reserves 5 - irreversible damage to non-renewable natural resources and nature reserves 6 - the devastation of the landscape, non-renewable resources, nature, and nature reserves nature resources and nature reserves	

6. Proposal of criteria for selection of suitable SMRs for the Czech Republic

The selection of a suitable reactor will be a crucial step not only for the successful implementation of the construction project, but also for the subsequent expansion of SMRs and their long-term safe, reliable, and economical operation. Based on the above-mentioned method based on MAUT (Keeney and Raiffa, 1993), the IAEA requirements (IAEA, 2006, 2016, 2021a, 2021b), the knowledge gained from the analysis of available data, which are mentioned above, and practical experience (CVUT, 2023), we propose to use the decision support system shown in Table 4 for the selection of the SMR type and evaluate it according to Table 5. The selection of criteria in Table 4 is based on demands on reactor safety that are given (CEZ, 1997; IAEA, 2000; US NRC, 2015) and experiences obtained by study of nuclear accidents (Prochazkova et al., 2020).

We propose to rate the criteria in Table 4 at 1,2,... 5 with the provision that the higher the value, the lower the acceptability. In addition, for the correct evaluation of Table 4, it is necessary to establish an evaluation team that meets the criteria referred to in paragraph 5. At the same time, it is necessary to appoint a team member who will resolve conflicts, i.e. cases where the evaluations of individual members of the expert team will have a large variance. To complete the answers to the questions in Table 4, you need to create a scale for the commensurability of the answers, which is similar to the scale in Table 3 because the questions are not from the same discipline - they are technical, economic, environmental, social and societal, and it is a very specific area.

Table 4. A decision support system for selecting a suitable SMR using a multi-criteria method that is based on the greatest utility; 1-7 refer to the reactors described in Table 2.

Criterion	1	2	3	4	5	6	7
Assessment of performance in terms of conditions and needs of practice in the Czech Republic							
Assessment of I.O. pressure from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of the range of outlet and inlet temperature from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of the availability of the type of coolant in terms of conditions and needs of practice in the Czech Republic							
Assessment of the length of the fuel cycle from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of the complexity of the refueling procedure from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of containment safety from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of the number of backups of critical components from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of nuclear fuel safety from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of the availability of nuclear fuel from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of reactor space requirements from the point of view of conditions and practical needs in the Czech Republic							
Assessment of the spatial requirements of a power plant with a given type of reactor from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of the requirements of a power plant with a given type of reactor on the shape and structure of the foundation slab from the point of view of the conditions and needs of practice in the Czech Republic							
Assessment of the reactor's professional level and safety functions							
Assessment of the professional level of the steam generator and its safety functions							
Assessment of I.O. safety from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of the safety of the interconnection of the primary and secondary circuits from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of the expertise of systems that ensure safety							
Assessment of the professional level of safety-related systems							
Assessment of the professional level of the pressure vessel							
Assessment of the professional level of configuration of critical components of a nuclear facility							
Assessment of the professional level of the reactor control system							
Assessment of the expert level of application of inherent safety							
Assessment of the professional level of defense-in-depth							
Assessment of the professional level of backups							
Assessment of maintenance requirements							
Assessment of the professional level of technical systems that help manage incidents and accidents							
Assessment of service requirements from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of the professional level of spent fuel management							
Assessment of the professional level of protection against vibrations, earthquakes, storms, landslides, floods, and aircraft crashes							
Assessment of the results of the reactor operation test							
Assessment of initial costs in terms of conditions and needs of practice in the Czech Republic							
Assessment of operating costs from the point of view of conditions and needs of practice in the Czech Republic							
Assessment of nuclear fuel storage and spent fuel storage requirements							
Assessment of demands for electricity supply from the external grid							
Assessment of affordability of reactor in terms of conditions and needs of practice in the Czech Republic							
TOTAL							

Table 5. Value scale for determining the degree of acceptability of the reactor in the Czech Republic; *N* = five times the number of criteria in the decision support system for the item.

Rate of acceptability	Value in % *N*
Negligible -5	More than 95 %
Low – 4	70–95 %
Medium – 3	45–70 %
High – 2	25–45 %
Very high – 1	5–25 %
Extremely high – 0	Less than 5 %

7. Conclusion

Small modular reactors (SMRs) can be a new impetus for nuclear energy. In the Czech Republic, the ČEZ company is considering their construction. The seven reactors currently in the pipeline are AP300 (Westinghouse), BWRx-300 (GE-Hitachi), NuScale (NuScale), Nuward (CEA, EDF, Naval Group, and Technicatome), SMART 100 (KAERI and KEPCO E&C), SMR-160 (Holtec), and UK-SMR (Rolls-Royce). Our research showed that these reactors differ in many respects, such as the type of reactor (PWR/BWR), the philosophy of concept (integral, loop, multi-modular, etc.), electrical output (50-470 MWe), and others.

To select a suitable solution, we have designed criteria based on a multi-criteria approach. For the specific application of the methodology, we are now compiling:

- a questionnaire for suppliers of individual SMRs, in which we ask for the data we need to evaluate Table 4
- and a team of specialists who have the ability to professionally evaluate the monitored reactors according to the criteria in Table 4.

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References

Beton, V., Stewart, J.T. 2001. Multiple Criteria Decision Analysis.

CEZ. 1997. Safety report for Temelin nuclear power plant. CEZ, Praha.

CEZ. 2023. Small Modular Reactors. https://www.cez.cz/cs/nove-jaderne-zdroje/male-modularni-reaktory

Cihlar, M., Prochazkova, D., Endrychova, A., Junek, M., Komrska, J., Smolik, V., Spacek, J., Dostal, V. 2023. SMR reactors for the Czech Republic. In: Řízení rizik procesů, zařízení a složitých technických děl zacílené na bezpečnost 2023. ISBN 978-80-01-07239-4. CVUT, Praha, 22-34.

CVUT. 2023. Proposals for technical solutions. In: Archives. Archive. CVUT, Praha.

EPTA. 2009. https://eptanetwork.org/database/projects?start=0

EU. 1992. Maastricht Treaty. C 191, 29.7, 1–112. EU, Maastricht.

Figueria, J., Greco, S., Ehrgott, M. Multiple Criteria Decision Analysis: State of the Art Surveys. Springer, New York. doi:10.1007/b100605 2005

Hussein, E. M. A. 2020. Emerging small modular nuclear power reactors: A critical review. In Physics Open 5. doi:10.1016/j.physo.2020.100038

IAEA. 2000. Safety of Nuclear Power Plants. No. NS-R-1. IAEA, Vienna.

IAEA. 2006. Fundamental safety principles. No. SF-1. ISBN 92-0-110706-4. IAEA, Vienna.

IAEA. 2020. Advances in Small Modular Reactor Technology Developments. A Supplement to: IAEA Advances Reactors Information System. IAEA, Vienna. http://aris.iaea.org.

IAEA. 2021a. Small Modular Reactors: flexible and Affordable Power Generation. IAEA, Vienna. www.iaea.gov/topics/small-modular-reactors

IAEA. 2021b. Benefits and Challenges of Small Modular Fast Reactors. IAEA-TECDOC 1972. ISBN 978-92-0-124021-7. IAEA, Vienna.

IAEA. 2022. Advances in Small Modular Reactor Technology Developments: A supplement to the IAEA Advanced Reactor Information System (ARIS). IAEA, Vienna.

Keeney R. L., Raiffa H. 1993. Decisions with Multiple Objectives: Preferences and Value Trade-Offs. J. Wiley & Son, New York.

Mignacca, B., Locatelli, G. 2020. Economics and finance of Small Modular Reactors: A systematic review and research agenda. In Renewable and Sustainable Energy Reviews 118. doi:10.1016/j.rser.2019.109519

OECD. 2016. Small modular reactors: nuclear energy market potential for near-term deployment. OECD/ NEA, Paris.

Prochazkova, D. 2007. Methodology for estimating the costs of property restoration in areas affected by natural or other disasters. SPEKTRUM XI, Ostrava.

Prochazkova, D. 2011. Methods, Tools and Techniques for Risk Engineering. ČVUT, Praha.

Prochazkova, D. 2013. Fundamentals of critical infrastructure safety management. ČVUT, Praha.

Prochazkova, D. 2014. Disaster risks and engineering procedures for disaster management. ČVUT, Praha.

Prochazkova, D. 2017. Principles of risk management of complex technological facility. ČVUT, Praha. doi:10.14311%2FBK.9788001061824

Prochazkova, D. 2018. Analysis, management and settlement of risks connected with technical facilities. ČVUT, Praha. doi: 10.14311%2FBK.9788001064801

Prochazkova, D., Prochazka, J. 2020. Risk management at technical facilities type and site selection. ČVUT, Praha. doi: 10.14311%2FBK.9788001067185

Prochazkova, D., Prochazka, J., Dostal, V. 2020. Causes of disasters with presence of radioactive substances. In: Proceedings of the 30th European Safety and Reliability Conference and 15th Probabilistic Safety Assessment and Management Conference. Research Publishing, Singapore, 1584-1592.

USA. 1992. Public Law 92-484. Technology Assessment Act. US government, Washington.

USNRC. 2015. The standard review plan. NUREG-080. USNRC. Washington.

Zeliang, C., Mi, Y., Tokuhiro, A., Lu, L., Rezvoi, A. 2020. Integral PWR-Type Small Modular Reactor Developmental Status, Design Characteristics and Passive Features: A Review. In Energies 13. doi:10.3390/en13112898