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The Application of Cluster Analysis and Scaling Analysis Methods for the Assessment of Dams in Terms of Heritage Preservation

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ABSTRACT

Heritage preservation is a broad topic that affects virtually all fields of human activity. One of them is industrial heritage which is, among others, represented by the construction of dams. The assessment of such constructions, which could be important from the point of view of heritage preservation and potentially be declared cultural monuments, should be based on the analysis and historical development of the particular society. It should reveal which constructions can be found in a selected area and how they are divided. Dams include hundreds of constructions. A professional heritage officer, who is to decide whether to process and submit a proposal for the inclusion of a dam in the list of cultural heritage, thus faces the problem of how to carry out the analysis effectively. This article describes a procedure for using both cluster analysis and scaling method to categorise a set of 119 dams to be able to identify exceptional, so-called iconic, structures. By comparing the selection of significant representatives of dams created by the application of the two methods, which proved to be appropriate in terms of the industrial heritage preservation, a majority concordance is reached.

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1. Introduction

Dams constitute an effective technical means used to collect a certain volume of water and to form a reservoir. Reservoirs formed by a dam serve to redistribute volumes of water over time and stabilize flow rates downstream of the dam. They are most frequently used as a water source for agriculture, population and industry, for flood mitigation, electricity production and for navigation purposes (ICOLD 2020).

The construction of dams has accompanied the entire history of mankind since the appearance of its oldest civilizations in Mesopotamia and the Middle East, which dates back to 4000 years before Christ, and continues to this day (Smith 2009).

In the territory of the Czech Republic, the construction of dams and reservoirs is connected mainly with the construction of ponds in the 15th and 16th centuries (Broža et al. 2005). Ponds were built especially in South Bohemia and in the Pardubice region. The origins of pond construction date back to the 11th and 12th centuries. One of the oldest retention basins in the Czech lands is the pond called Máchovo Lake which was built in 1272. In 1367, the dam of the Dvořiště pond, 10 m high, was built. The first waterworks reservoir in Czech territory is the Jordán reservoir which consists of an 18 m-high dam built in 1492 and used to supply the town of Tábor with drinking water. Alongside fish farming, reservoirs were also being built for mining and, later, the metallurgical industry.

A number of ponds and small reservoirs were and still are part of sophisticated water management systems (water supply, water transfers, flood protection, etc.). To date, around 20,000 small water reservoirs and dams have been preserved (Broža et al. 2005).

The construction of dams and modern dam engineering dates back to the end of the 19th century when the primary impulse for the construction of dams was the extensive flooding of the 1890s (Broža et al. 2005). At that time, mainly masonry dams (Harcov 1904; Husinec 1939; Jevišovice 1897; Kamenička 1904; Les Království 1919; Mariánské Lázně 1896; Pařížov 1913; Pastviny 1938) were built in the Czech Republic. In the first third of the 20th century, dams based on the so-called Intze principle, designed by Professor Otto Intze from Aachen, were built in the Czech Republic as part of flood mitigation measures in mountain areas of North Bohemia.

Later, mainly concrete dams were built (Brno 1940; Březová 1934; Vranov 1936). A massive construction of concrete dams dates back to the 1950s. The largest concrete dams were built on the River Vltava (Lipno I 1960; Orlík 1963; Slapy 1957). Efforts to save cement and the

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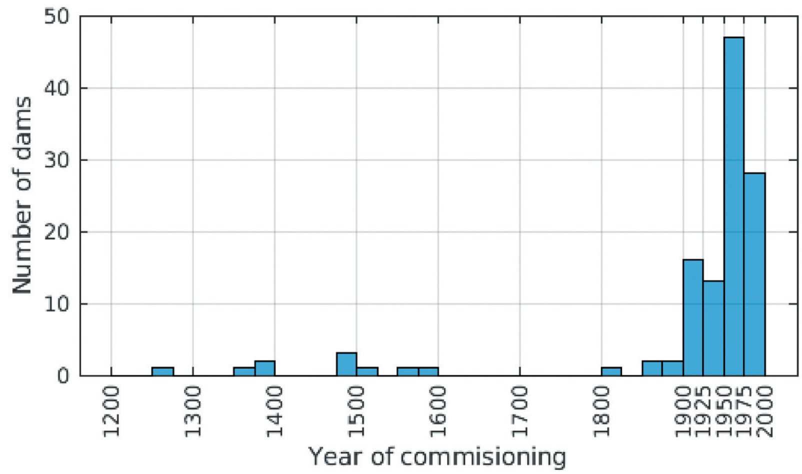

Figure 1. An overview of the number of significant dams in the Czech Republic according to year of commissioning.

depletion of profiles suitable for the construction of concrete dams led, from the late 1960s, to the construction of earth dams — dams made from local materials (Dalešice 1978; Dlouhé Stráně 1996; Nechranice 1968; Římov 1978; Slezská Harta 1997; Stanovice 1978; Želivka 1975).

At present, mainly lower dams are being built for the purposes of land reclamation and protection of the territory from devastating consequences of floods. In the context of adaptation to climate change, which manifests itself in the Czech Republic mainly through drought, the issue of building dams serving as a source of water for the population and irrigations has come to the fore.

Dam engineering is an industry in which the most significant advances have taken place in the last 100 years. The chart in Figure 1 shows the frequency of large dams in relation to the year of commissioning.

In 1928, the International Commission on Large Dams (ICOLD) was established, which provides a forum for the exchange of knowledge and experience in the field of dam engineering. ICOLD has introduced criteria to define dams as large if they are at least 15 metres high from their lowest foundation to the crest or between 5 and 15 metres high with at least three million cubic metres of storage capacity of the reservoir. There are 119 dams in the Czech Republic that meet these criteria and can be defined as large dams. Basic data on these dams are shown in Table 1. Cluster analysis and the scaling method have been applied to them.

2. A link to cultural heritage and importance for heritage preservation

Heritage preservation is a targeted effort of a society to conserve certain parts of its movable and immovable cultural heritage, in particular constructions (OSN 1972). It is a complex, challenging and long-term project.

The International Committee for the Conservation of the Industrial Heritage (TICCIH) is the umbrella organization for industrial heritage preservation in an international context. The organization was founded after the first international conference on industrial heritage preservation had been held in Ironbridge, England, in 1973. Following an extensive and long-standing international debate, the Charter for the Industrial Heritage of TICCIH was created and published in 2003 (Douet 2012), which defines the basic principles, methods, terminology and strategy for industrial heritage preservation. In cooperation with the International Council on Monuments and Sites (ICOMOS), in 2011, the TICCIH adopted the Joint Principles for the Conservation of Industrial Heritage Sites, Structures, Areas and Landscapes (ICOMOS 2011), the content of which follows up the Charter.

According to the Charter, industrial heritage is defined as " … remains of industrial culture which are of historical, technological, social, architectural or scientific value. These remains consist of buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transport and all its infrastructure, as well as places used for social activities related to industry such as housing, religious worship or education." The Charter places particular emphasis on the identification of industrial heritage values, their documentation, recording and research, identification of threatened sites, their maintenance and protection in the context of addressing their legal protection: "They should be studied, their history should be taught, their meaning and significance should

Table 1. Database of dams in the Czech Republic.

i	Dam name	Type according ICOLD	Height above foundation [m]	Reservoir volume [$10^6 m^3$]	Year of commisioning	Note	Listed as cultural heritage
1	Labská	PG	41.5	2.9	1916	masonry	
2	Les Království	PG	41.0	7.3	1919	masonry	yes
3	Rozkoš	TE	26.4	76.2	1972	embankment	
4	Pastviny a Nekoř	PG	38.5	10.8	1938	masonry	
5	Hvězda	TE	10.6	3.5	1378	embankment	
6	Hamry	TE	17.4	3.6	1912	embankment	
7	Seč a Padrty	PG	42.0	21.8	1934	masonry	
8	Křižanovice	PG	31.7	2.0	1953	concrete	
9	Práčov	TE, PG	17.1	0.4	1952	embankment, concrete	
10	Pařížov	PG	31.0	1.7	1913	masonry	yes
11	Vrchlice	VA	40.8	9.8	1970	concrete	
12	Velký rybník	TE	15.8	0.4	1852	embankment	
13	Josefův Důl	TE	44.0	22.6	1982	embankment	
14	Souš	TE	25.0	7.6	1915	embankment	
15	Bílá Desná	TE	17.9	0.4	1915	embankment	yes
16	Mšeno	PG	20.0	2.8	1909	masonry	yes
17	Harcov	PG	19.0	0.7	1904	masonry	yes
18	Bedřichov a Rudolfov	PG	23.5	2.1	1906	masonry	yes
19	Fojtka	PG	16.0	0.3	1906	masonry	
20	Mlýnice	PG	22.0	0.3	1906	masonry	
21	Lipno I	TE, PG	25.8	309.5	1960	concrete	
22	Lipno II	TE, PG	19.5	1.7	1960	concrete	
23	Hněvkovice	PG	33.5	21.1	1991	concrete	
24	Orlík	PG	90.5	716.5	1963	concrete	
25	Slapy	PG	67.5	269.3	1957	concrete	
26	Štěchovice	PG	31.0	10.4	1945	concrete	
27	Homole	PG	15.0	0.5	1947	concrete	
28	Římov	ER	55.7	33.8	1978	embankment	
29	Humenice	ER	20.0	0.8	1988	embankment	
30	Jordán	TE	22.0	3.0	1492	embankment	yes
31	Husinec	PG	34.1	6.6	1939	masonry	
32	Velké Dářko	TE	7.6	4.2	1480	embankment	
33	Chotěboř	TE	15.0	0.4	1959	embankment	
34	Sedlice	PG	27.0	2.2	1927	masonry	yes
35	Trnávka	TE	20.0	6.7	1981	embankment	
36	Němčice	TE	17.0	1.2	1980	embankment	
37	Želivka	TE	58.0	309.0	1975	embankment	
38	Lučina	ER	26.2	5.8	1975	embankment	
39	Hracholusky	TE	39.1	56.7	1964	embankment	
40	České Údolí	TE, PG	12.6	5.3	1972	embankment, concrete	
41	Nýrsko	ER	36.0	20.8	1969	embankment	
42	Klabava	TE	15.0	5.7	1957	embankment	
43	Klíčava	PG	50.2	10.4	1955	concrete	
44	Žlutice	TE	30.0	15.6	1968	embankment	
45	Láz	TE	15.0	1.0	1822	embankment	
46	Pilská u Příbrami	TE	19.0	1.9	1853	embankment	
47	Obecnice	TE	16.0	0.7	1964	embankment	
48	Záskalská	TE	17.0	0.7	1960	embankment	
49	Suchomasty	TE	16.0	0.5	1959	embankment	
50	Hostivař	TE	16.0	1.8	1963	embankment	
51	Rožmberk	TE	14.0	6.2	1590	embankment	
52	Staňkovský rybník	TE	15.0	6.3	1554	embankment	
53	Dvořiště	TE	11.0	6.7	1367	embankment	
54	Horusický rybník	TE	11.0	4.0	1512	embankment	
55	Velká Holná	TE	12.0	5.5	1384	embankment	
56	Dehtář	TE	11.0	6.5	1479	embankment	
57	Skalka	ER, PG	17.0	19.6	1964	embankment, concrete	
58	Jesenice	TE	23.8	60.2	1961	embankment	
59	Horka	TE	48.0	21.4	1970	embankment	
60	Tatrovice	TE	30.0	1.8	1969	embankment	
61	Mariánské Lázně	PG	19.9	0.3	1896	masonry	
62	Podhora	TE	12.0	3.0	1956	embankment	
63	Březová	PG	38.6	5.7	1934	concrete	
64	Stanovice	ER	62.5	27.8	1978	embankment	
65	Kadaň	PG	18.4	2.8	1971	concrete	
66	Nechranice	TE	47.5	287.6	1968	embankment	

(*Continued*)

Table 1. (Continued).

i	Dam name	Type according ICOLD	Height above foundation [m]	Reservoir volume [$10^6 m^3$]	Year of commisioning	Note	Listed as cultural heritage
67	Přísečnice	ER	57.6	54.7	1976	embankment	
68	Kamenička	PG	44.5	0.7	1904	masonry	
69	Křímov	PG	48.0	1.5	1959	concrete	
70	Jirkov	ER	55.6	2.8	1965	embankment	
71	Jezeří	PG	23.1	0.1	1904	masonry	yes
72	Újezd	TE	17.5	8.4	1982	embankment	
73	Janov	PG	53.1	1.7	1914	masonry	yes
74	Loupnice	TE	17.0	1.3	1959	embankment	
75	Fláje	CB	55.5	23.1	1963	concrete	yes
76	Máchovo jezero	TE	10.0	7.9	1272	embankment	
77	Chřibská	TE	26.1	1.2	1924	embankment	
78	Větřkovice	TE	17.5	1.1	1976	embankment	
79	Slezská Harta	ER	71.6	218.7	1997	embankment	
80	Kružberk	PG	42.0	35.5	1955	concrete	
81	Lobník	TE	19.6	1.3	1955	embankment	
82	Šance	ER	65.0	61.8	1970	embankment	
83	Morávka	TE	44.9	12.1	1964	embankment	
84	Olešná	TE	16.0	4.4	1964	embankment	
85	Žermanice	PG	38.0	25.3	1958	concrete	
86	Těrlicko	TE	28.0	27.4	1963	embankment	
87	Nemilka	ER	17.7	1.6	1970	embankment	
88	Karolinka	ER	47.0	7.4	1985	embankment	
89	Bystřička	PG	36.0	4.6	1912	masonry	yes
90	Horní Bečva	TE	18.0	0.7	1944	embankment	
91	Plumlov	TE	18.0	5.5	1933	embankment	
92	Opatovice	ER	46.5	10.1	1972	embankment	
93	Slušovice	TE	33.9	9.9	1976	embankment	
94	Fryšták	TE	15.0	3.0	1938	embankment	yes
95	Bojkovice	TE	19.0	1.0	1966	embankment	
96	Luhačovice	TE	19.0	2.7	1930	embankment	
97	Ludkovice	TE	18.0	0.7	1968	embankment	
98	Landštejn	ER	26.1	3.3	1973	embankment	
99	Nová Říše	ER	24.1	3.1	1984	embankment	
100	Vranov	PG	59.0	132.7	1934	concrete	
101	Znojmo	TE, PG	20.0	4.3	1965	embankment, concrete	
102	Jevišovice	PG	25.0	0.6	1896	masonry	yes
103	Hubenov	TE	25.0	3.4	1972	embankment	
104	Mostiště	ER	41.7	11.9	1961	embankment	
105	Vír I (a Vír II)	PG	76.5	56.2	1957	concrete	
106	Brno	PG	34.0	17.7	1940	concrete	
107	Letovice	TE	29.1	11.6	1976	embankment	
108	Boskovice	ER	44.0	7.0	1990	embankment	
109	Nové Mlýny-UR	TE, PG	6.6	14.3	1988	embankment, concrete	
110	Nové Mlýny-MR	TE, PG	7.2	32.1	1988	embankment, concrete	
111	Nové Mlýny-LR	TE, PG	10.3	84.0	1988	embankment, concrete	
112	Koryčany	TE	25.0	2.6	1958	embankment	
113	Dalešice	ER	100.0	126.9	1979	embankment	
114	Mohelno	PG	48.7	17.1	1979	concrete	
115	Dlouhé Stráně-LR	ER	57.6	3.4	1996	embankment	
116	Dlouhé Stráně-UR	ER	28.0	2.7	1996	embankment	
117	Výrovice	TE	17.2	4.2	1983	embankment	
118	Těšetice	TE	15.3	0.9	1983	embankment	
119	Kožichovice	TE	18.6	0.7	1984	embankment	

Note: TE — Earthfill dams; ER — Rockfill dams; PG — Gravity dams; VA — Arch dams; CB — Buttress dams.

be probed and made clear for everyone, and the most significant and characteristic examples should be identified, protected and maintained, in accordance with the spirit of the Venice Charter, for the use and benefit of today and of the future (ICOMOS 1964)."

The TICCIH's materials and annual reports (more on www.ticcih.org) provide a current overview and appropriate signpost of activities of individual states and research teams in the area of documentation, assessment and protection of industrial heritage sites.

Foreign examples of practical protection and restoration of such constructions include the Ruhr area (Emscher Park project, more on www.iba.nrw.de) and industrial centres with significant industrial history and its evidence (Ironbridge, New Lanark, Manchester, Liverpool, Brussels or Lodz), which can be documented by an illustrative selection of literature (Miller and Wild 2007; Jones 2007; Giles 2007).

Among long-term editorial projects, the series England's Living History (more on www.countrysidebooks.co.uk) and the Shire Album, dedicated to industrial heritage and technologies in various industrial sectors (more on www.shirebooks.co.uk), can be mentioned. A specialist German magazine called Industrie-kultur (more on www.industrie-kultur.de) covers not only domestic but also foreign topics (for example, Volume 2 from 2002 was devoted to the Czech Republic's industrial heritage).

As to the methodological approach of assessing the significance of historical water management constructions (and industrial constructions in general) from the perspective of heritage preservation in the world, their architectural and urban value, degree of authenticity and historical background are generally accentuated. In the case of dams, Kreuzer (2011) and Ioannidis and Koutsoyiannis (2017) added that these water constructions are aesthetically impressive and can even create entire landmark. However, efforts to identify and highlight the technical and technological values of industrial objects and to integrate these criteria into the process of assessing the significance of individual constructions are becoming increasingly common. The American Society of Civil Engineers (ASCE) grants the designation of ASCE Historical Civil Engineering Landmark (ASCE 2020) to projects (constructions) that illustrate the creativity and innovativeness of civil engineering worldwide, at least at a national level. One of the nomination criteria for granting the award is the assessment of whether the construction constitutes a "significant facet of civil engineering history" and the project must also have "some uniqueness or used a unique or significant construction or engineering technique". The Ministry of Education, Culture and Sport of the Government of Spain (2012) uses one of the few assessment methodologies for historical WM constructions which consists of "12 criteria and 36 variables that make up the categories of intrinsic values, heritage values, and potential and feasibility values". This methodology was used for the assessment of historical irrigation systems (Hermosilla and Mayordomo 2017; Hermosilla and Peña 2010), and on drainage tunnels or qanats (Hermosilla and Iranzo 2014).

Douet (2018) included the dams and reservoirs as one of the main priorities of the heritage of water industry and industry itself. Large dams or big water reservoirs are specific constructions composed of two main parts — the structure of the dam "wall", and the water mass (water lake/reservoir), which, both together, create a specific landscape with large spatial consequences to the environment and human society (Kreuzer 2011). Because of that, the value of entire dam's landscape is very hard to evaluate, and it is a great task for heritage preservation around the world. For example, monument protection in the United States is governed by the Section 106 of the National Historic Preservation Act (McClain, Lindloff, and Baer 2008). Regarding dams, McClain, Lindloff, and Baer (2008) describe the process of assessing dams or their components as cultural monuments if they are to be removed or if they are proposed for registration in National Register. The procedure is in accordance with section 106 of the National Historic Preservation Act, which establishes a preservation officer that evaluates whether or not a work should be protected and registered in the National Register. Usually, if a dam is to be inscribed on the National Register, it should be at least 50 years old. McClain, Lindloff, and Baer (2008) states that it is possible to protect a dam in modes called preservation in service, adaptive reuse, partial preservation or avoidance (no preservation). The same approach is applicable also to other objects like bridges, mills, industrial halls, etc.

Nowadays heritage preservation practises target especially on the construction of the dam, because it can be relatively easily described and evaluate (there is often a project documentation with all parameters of the dam, etc.), and Douet (2018) mentioned the dam design and architectural design of water infrastructure as the values of heritage significance. Nevertheless, the main problem is the setting of evaluation criteria for heritage preservation. UNESCO defines six ordinary criteria for choosing World Heritage, which highlights the extraordinary structures and unique solutions reflecting the specific natural conditions, cultural traditions, and technological stage of civilization through the human history (OSN 1972). The Government Office of Environment and Heritage of New South Wales in Australia-based assessment of hydroelectric facilities on historical, associative, aesthetic and social significance, together with research potential, rarity, representativeness and integrity (NSW 2008). In Vermont (USA) developed categories to determine the relative importance of one dam to another dam based on the age of a particular dam, the historical consequences with surrounding, the functions and intrinsic physical characteristics of a dam, and the historical integrity of a dam (McClain, Lindloff, and Baer

2008). Finally, Kuban and Pretelli (2019) presented the guidelines how to assess the industrial heritage of hydroelectric plants in Italy based on six main criteria: 1) age value and historic value; 2) technological value; 3) architectural/artistic value; 4) integrity; 5) social and economic value; and 6) environmental and/or structural safety.

Additionally, the critical analysis or the cost-benefit analysis is widely applied approach during the evaluation of heritage preservation. The aim is to assess a role and possible benefit for the society and nature by the preserving from particular construction to entire landscape. Nocca (2017) proposed nine categories to assess the multidimensional benefits of heritage conservation or regeneration consist of: 1) tourism and recreation; 2) creative, cultural and innovative activities; 3) typical local productions; 4) environmental and natural capital; 5) social capital/cohesion and inclusion; 6) real estate; 7) financial return; 8) cultural value of properties/landscape; and 9) wellbeing. The benefit analysis can be very helpful during the final step considering the supposed heritage value of particular structure, and should be included.

2.1. Current practices and requirements of heritage preservation in the Czech Republic

The National Heritage Institute in the Czech Republic is governed by Act No. 20/1987 Sb. on heritage preservation, which, inter alia, defines which objects of cultural value are covered by the state's care as cultural monuments (MK 2020).

The dam-type constructions, at which this article is directed, form part of industrial heritage which includes technical equipment, constructions, objects and phenomena of anthropogenic geomorphology developed in the context of the industrialization process (Matěj and Ryšková 2018).

Since the 1990s, systematic documentation of industrial cultural heritage in the Czech Republic has been carried out under the responsibility of the National Heritage Institute. Its initial research which focused on sectors affected by economic changes after 1989, was followed up in 2005–2011 by a territorial and sectoral research of industrial heritage and subsequently, in 2012–2015, by a NAKI programme project called Industrial Heritage of Moravia and Silesia, which focused on detailed research of major industrial locations and sectors in the territory of Moravia and Silesia. Its research and methodological works are under the umbrella of the Methodological Centre of Industrial Heritage in Ostrava which was established for this purpose under the National Heritage Institute.

Industrial heritage in the Czech Republic is further addressed by the Research Centre for Industrial Heritage, founded at the Czech Technical University in Prague in 2002. The decisive part of its approach towards industrial heritage is from an architectural perspective — it focuses on industrial architecture, its new uses and conversions. It also concentrates on projects in the field of industrial heritage topography and its revitalisation, and regularly organizes the Vestiges of Industry conference (more on http://vcpd.cvut.cz/bibliografie-vcpd-fa-cvut/).

Apart from the Research Centre for Industrial Heritage, at the Faculties of Architecture of the Czech Technical University in Prague and Brno University of Technology, attention is paid to studying industrial architecture and the conversion of industrial objects, e.g. (Zemánková 2003).

Several specific studies have already been carried out in the field of water management. Water management constructions were analysed in the context of the development and decline of certain industry sectors, e.g. the elimination of water areas in relation to the sugar industry (Havlíček, Svoboda, and Dostál 2013). Within the framework of landscape conservation, the importance and re-use of existing water management constructions, such as functional historical pond systems or dam relics, has been analysed. A database of historical ponds (Pavelková et al. 2014; Pavelková et al. 2016) has been established and is currently, in this time of climate change, being actively used as one of the sources for the proposals of measures to improve the retention of water in the landscape.

As regards the documentation and evaluation of the importance of industrial heritage sites, this field has its own specific features. In the long term, these objects and their assessment were treated only from the point of view of traditionally conceived artistic, architectural and urban criteria, taking into account the historical context. However, professionals dealing with these types of monuments realized that their value was hidden also in their technical and technological solutions, their degree of authenticity or functional continuity, their link with important historical milestones, e.g. (Pavelková et al. 2014) and historical management and their co-development of natural and landscape values, e.g. (Pavelková et al. 2016). In 2018, the aforementioned Methodological Centre of Industrial Heritage established a methodology for the assessment and protection of industrial heritage (Matěj and Ryšková 2018) on a general level which will gradually and in a planned manner be followed in future years by specialist methodologies dedicated to key sectors, such as transportation, energy, metallurgy, textile production, and the food industry. One of the first ones will be the water management sector which will also include a methodology for assessing dams, presented in this text.

The general methodology (Matěj and Ryšková 2018) recommends that the assessment of industrial constructions is based on a wider value spectrum and on specific assessment criteria (in particular a typological value, presence or even completeness of technical equipment or traces of operation), whereas traditional categories — architectural, urban, artistic-historical and age values — may acquire new meanings within the industrial heritage. A monument may be assessed as significant, even though the traditionally regarded values may not be represented in the total monument value, or participate only partially in it (Matěj and Ryšková 2018).

It should also be noted that the assessment of the importance of industrial structures from the perspective of heritage preservation requires a multi-sectoral approach. The need for a multi-sectoral approach to the assessment is noted by a number of authors, e.g. (Fragner 2013; Fragner 2010; Kučová 2013; Matěj 2008).

The starting point in assessing a construction as an industrial heritage site is the execution of the typology of the constructions and their analysis. For this purpose, the cluster analysis method was used to identify groups of similar constructions and also to find constructions that are exceptional. The use of cluster analysis procedures for the purpose of analysing dams has not been published so far.

3. Assessment methodologies

3.1. Cluster analysis

One of the key issues in assessing a work as a technical monument is to recognize its uniqueness, or to recognize whether such a construction falls within a group in which it forms a typical representative.

Cluster analysis is a useful tool for finding the similarity, or uniqueness of a work.

For the purposes of cluster analysis, each hydraulic structure is characterized by a vector of values used for its description. These include the height of the dam as a quantifier of significance, age as a quantifier of historical value, and a vector of descriptive characters as a quantifier of typological value.

The typological value is decisive in terms of the assessment of dams and their classification according to types and designs. When taking into account the amount of details, each dam is unique. But if attention is paid to more general characteristics, dams can be divided into groups that reflect a technological development of the construction. A distortion in the assessment may be caused by continuous maintenance and modernization of dams that take place in connection with efforts to maintain these constructions as functional and safe. Interventions into original constructions have various impacts. Nevertheless, the nature, use and functionality of the dams do not change significantly over time.

In order to divide dams according to typological values, it is necessary to define the characteristics that differentiate dams. The following classification of the characteristics and symbols of dams was created for the needs of dam assessment and based on the results in the compiled database of dams in the Czech Republic:

Dam material

a. Concrete (concrete dams)
b. Stone (masonry dams)
c. Local material (embankment dams)

Dam type in terms of the statics

a. Gravity
b. Arch
c. Buttress
d. Embankment
e. Composite (embankment dam combined with concrete functional block)

Spillway type

a. Crest
b. Side
c. Shaft
d. None

Chute type

a. Smooth
b. Stepped
c. Gallery
d. None

Sealing type

a. Dam
b. Inner (inside dam body)
c. Upstream lining

Bottom outlets

a. In the dam
b. Diversion

c. None

A specific combination of these attributes then defines a dam from a typological point of view. A binary criterion was used for this purpose, where 100 was inserted into the vector of values when an attribute was present and 0 when it was not present.

Subsequently, similarities between each pair of hydraulic structures were assessed, and they were ranked according to the similarities. A cluster of similar works was thus created, allowing groups to be formed and unique representatives in the set of dams to be separated.

One minus cosine similarity (one minus cosine of the angle between the descriptive vectors — equation 1) was used as the similarity quantifier, i.e. (Romesburg 2004):

$$p = 1 - cos\theta = 1 - \frac{A \cdot B}{\parallel A \parallel \cdot \parallel B \parallel} \tag{1}$$

where A and B are the vectors of the attributes describing a hydraulic structure.

UPGMA (Unweighted Pair Group Method with an Arithmetic mean) (Romesburg 2004) was used to determine the length between the clusters and subsequently to construct a dendrogram showing the similarity of the individual works.

3.2. Description of scaling methodology in scoring assessment

In parallel, a set of dam constructions in the Czech Republic have been analysed using the so-called scaling method for the assessment of water management objects (and thus also for the assessment of dams) from the point of view of heritage preservation, in which a research consortium consisting of five professional institutions with different specializations have been involved: TGM Water Research Institute, p.r.i., National Heritage Institute, The Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Palacký University Olomouc and The Institute of History of the Czech Academy of Science.

According to an established general method of assessment (Matěj and Ryšková 2018), it was important to identify the key technical and technological milestones and approaches in the construction of dams and their associated infrastructure and to propose their typology. On this basis, an appropriate set of assessment criteria has been proposed which will effectively capture the specificities of the dams, also taking into account their significance and function often as part of a larger or smaller functional entity. Appropriately selected assessment criteria must enable the identification of the most important (iconic) and also characteristic (representative) examples of individual types of such constructions, as it is also mentioned in the TICCIH Charter (Douet 2012). This gap in heritage preservation is also touched on by the authors of the publication on the dams of the Czech Republic (Broža et al. 2005), who note that the list of heritage protected dams in the Czech Republic is unbalanced and lacks those with a special status in the development of the field. Here, Broža et al. (2005) point out that in the list of cultural monuments there are mostly masonry dams (10 dams from total 14 listed dams in the Czech Republic) built at the beginning of the 20th century (Památkový katalog 2020), and there are practically no dams of other types — 3 embankment dams (including the Bílá Desná dam as the only ruptured dam in the country), and 1 concrete dam (see also the Table 1). He also concludes that there are several dams representing a technological milestone in their construction, e.g., the Vrchlice dam as the only one arch-type dam in the Czech Republic, and the Štěchovice as the oldest pump-storage hydroelectric dam in the Czech Republic, which was unique in the whole of Europe at the time of construction (1937-- 1945). It can be finally stated, that the current cultural heritage monument assessment gives priority to the aesthetical and architectonical aspects of dams' constructions instead of the unique technological designs of dams with extraordinary parameters.0

Within these assessment criteria of heritage preservation, close cooperation among institutions, whose different views on the common water management issues call for clarification of the interpretation and understanding of heritage values, has proved desirable, and a range of points has therefore been chosen for their expression, combined with an explanatory verbal description.

The main objective of this method is to evaluate in a uniform manner, using an appropriately chosen set of criteria, the objects of industrial heritage (in this case, dams) not only from the point of view of heritage preservation, but also with respect to construction and technological exceptionality on which the main emphasis is placed.

The evaluation of individual water management constructions (and industrial constructions in general) must be carried out from a number of perspectives, and ideally in the assessment itself there should be described not only traditional heritage values, but their construction and technological values and their exceptionality or typicality in this respect should also be taken into account. For objective assessment, however, it is necessary to know the historical and typological development

Table 2. Score range for the current condition criterion .

Criterion	Score				
Construction condition	Undamaged **5**	Partially damaged **4**	Decaying **3**	Ruin **2**	Archaeological relic **1**
Technology-linked state	Preserved construction **5**	Construction with incomplete equipment **3**	Construction without technical equipment **0**		
Current operational level	Operational **5**	Partially operational **3**	Non-operational **0**		
Level of the technological functional unit	Technological entity — wider system **5**	Technological entity — entire technological flow **3**	Technological entity — complete phase of flow **2**	Individual construction — part of technological entity **1**	Stand-alone construction without any links **0**

Table 3. Score range for object authenticity criterion.

Criterion	Score		
Degree of the construction preservation	Original without reconstruction **5**	More significant reconstruction **3**	Destroyed construction **0**
Degree of technical equipment preservation	Original equipment **5**	Original equipment with extensive repairs **3**	No technical equipment or new equipment **0**
Authenticity of construction material	Authentic material **5**	Partially unauthentic material **3**	Unauthentic material **0**
Authenticity of technology	Authentic including repairs and reconstructions **5**	Partially unauthentic repairs and reconstructions **3**	Unauthentic repairs and reconstructions **0**
Technology-linked state	Preserved construction **5**	Construction with incomplete equipment **3**	Construction without technical equipment **0**

Table 4. Score range for function authenticity criterion.

Criterion	Score				
Degree of function authenticity	It serves its original purpose **5**	Original purpose, or extended or slightly modified **4**	Operational condition, out of order **3**	Inoperative condition **2**	New usage **0**
Value of new usage	Exceptional use of the work **10**	Significant **5**	Not significant **0**		

Table 5. Score range for construction and technological exceptionality criterion.

	Score for different levels			
Criterion	Transnational	National	Regional	Local
The first of its kind	30	20	10	5
The oldest one of its kind	30	20	10	5
The only preserved of its kind	30	20	10	5
Exceptional use of the technology	30	20	10	5
Exceptional parameters	30	20	10	5

Table 6. Score range for the exceptionality criterion, based on the number of presence of the given type of constructions within the Czech Republic.

Criterion	SCORE		
Presence in the Czech Republic	1–2 **10**	3–5 **5**	6 or more **0**

of the construction type in question and to find as much preserved information as possible in national and transnational contexts.

The assessment criteria for water management constructions, based on mutual discussions among specialists from heritage and technical fields, are as follows:

General assessment criteria:

a. Time-based determination — the most accurate date of origin;
b. Current condition — the current integrity of the construction;
c. Authenticity (originality) of the object — the preservation of its condition corresponding to the time of creation;
d. Authenticity of the function of the object — assessment of functional continuity;
e. Historical value — verbal evaluation based on information retrieval;

Construction, technological and typological value:

a. Construction and technological value — assessment of the exceptionality and significant

Table 7. Score range for architectural value criterion.

Criterion	Score		
Significant author	Yes	No	
	10	**0**	
A style representative	Yes	No	
	5	**0**	
Architectural continuity	The construction corresponds to the time of construction	More quality construction phases	Original core only with extensions
	5	**3**	**0**

Table 8. Score range for artistic-industrial value criterion.

Criterion	Score	
Works of art and craft	Each type	None
	+1	**0**
Architectural and fine art details	Each type	None
	+1	**0**

Table 9. Score range for urban value criterion.

Criterion	Score	
Dominant landmark	Yes	No
	1	**0**
Part of a panorama	Yes	No
	1	**0**
Creates a site/town identity	Yes	No
	1	**0**

Table 10. Score range for age value criterion.

Criterion	Score	
Time traces	Yes	No
	1	**0**

characteristics of the construction or its technical equipment;

b. Typological value — selection of a typical representative;

Traditional assessment criteria

a. Architectural value — classification into a specific style, major architects, etc.;
b. Artistic-industrial value — assessment of significant artistic details;
c. Urban value — the impact of the construction on the surrounding landscape;
d. Age value — desired time traces.

It was also important to define terms such as functional entity, construction and object, and their possible links and connections because there might be a situation when an object or a construction on their own are not exceptional at all; nevertheless, when involved in a larger functional entity, they form a unique solution.

For assessment purposes, dam constructions were divided into four groups according to the typological value of the dam material — concrete, masonry, embankment and composite, and subsequently structures that need to be assessed comprehensively, in terms of technological functional entity (e.g. a pump-storage hydroelectric power station at Dlouhé stráně, consisting of two water reservoirs and a pump-storage power station, which form a unique construction unit at a European level), were selected.

The following tables (Tables 2–10) list-scoring criteria that emerged from the discussions mainly among workers of the TGM Water Research Institute, p.r.i. and the National Heritage Institute, i.e. of the synergy of two distinct perspectives — technology and humanities. The aim of the method was to place the main emphasis on construction and technological criteria so that the so-called traditional criteria, which often play a major part in the assessment of cultural monuments, were only complementary. Therefore, the construction and technological criteria have a much greater weight, or obtain a higher score. The score range (scale) was based on the experience of using multi-criteria analysis in previous projects, broad expert discussions, and field testing assessment.

By means of this method, all dam structures in the territory of the Czech Republic were assessed and thus these structures obtained scores which can be used as a basis for the subsequent assessment of their exceptionality for the needs of heritage preservation. This method will be used primarily by the National Institute of Heritage and is intended to complement and support classical verbal assessment of constructions and objects, which is based mainly on field research, information retrieval in scientific literature and expert judgement.

4. Results and discussion

4.1. Results of the cluster analysis

Similarity was evaluated within a sample of 119 dams in the Czech Republic. Many dams in the database are already protected as cultural or national cultural monuments. Especially with regard to masonry dams. The resulting dendrogram can be seen in Figure 2.

According to the typology, dams can be divided into several groups. The basic classification is based on the

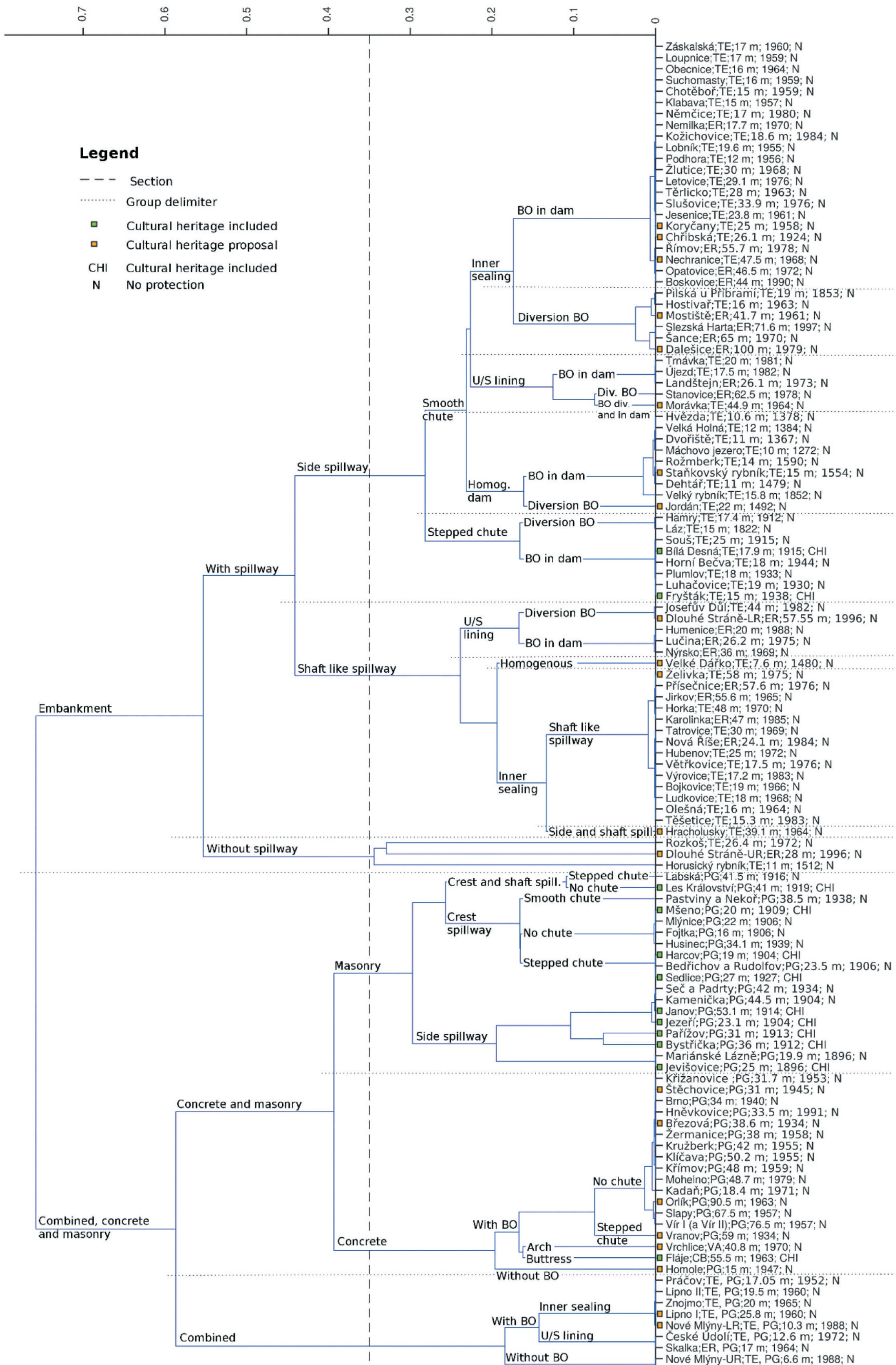

Figure 2. Dendrogram of dams.

material used according to which dams can be clearly divided into composite, concrete, masonry and embankment (using local materials) dams. Within these groups, other sub-groups of dams can be then differentiated according to other typological characteristics, such as statics action, spillway type, chute type, sealing type and bottom outlet type.

The following sub-groups can be designated as significant:

- embankment dams without a spillway,
- embankment dams with a shaft spillway and inner sealing or homogeneous dams,
- embankment dams with a shaft spillway and upstream lining,
- embankment dams with a side spillway and stepped chute,
- embankment dams with a side spillway and a smooth chute combined with a homogenous dam,
- embankment dams with a side spillway and a smooth chute combined with a dam with upstream lining,
- embankment dams with a side spillway and a smooth chute combined with a dam with inner sealing.

Individual groups and sub-groups differ in the number of representatives. In the dendrogram there are also dams which differ from the others in a typological way. Based on the individual groups and subgroups, it was proposed to further explore the possibility of protection of dams mentioned in Table 11.

4.2. Results of the scaling method

Based on the scaling method assessment of all the 119 dam structures in the Czech Republic complying with the definition of a dam-type construction according to the parameters of ICOLD (ICOLD 2020), a scale of significance was proposed (Table 12). This scale was created only after the score evaluation of the comprehensive set of dams on the basis of the knowledge of the significance of individual structures.

The analysis of the results of the dams evaluated is illustrated in a graph (Figure 3) which shows the maximum, average, median and minimum points obtained from the entire set of constructions evaluated in terms of three groups of criteria. As expected, the highest score was achieved in the category "Constructional, technological, and typological value" because we wanted to highlight the exceptionality of the specific dam construction. These extraordinary constructions come from the specific and mostly difficult natural conditions of the particular place, which must have been overcome. This was the main aim of our methodology to emphasize the exceptionality of dams in four spatial levels (from local to European level), which was successfully done. It must be also noted that about a quarter of the dams did not obtain any points in this category of criteria. On the other hand, in some cases dam can acquire big portion of points in several criteria thanks to multiple construction uniqueness, e.g., Fláje or Dlouhé Stráně. According to Figure 3, the highest median value was achieved in general criteria. This is due to the fact that in general criteria, most dam constructions have achieved a high score since they are integral, functional constructions.

The following tables list dams (Table 13), or functional entities (Table 14) which have reached significance on a regional or higher level by the scaling method assessment, i.e. the total score was at least 101 points. The score of 101 points was chosen as a threshold to separate the unique dams with extraordinary constructions at regional or high level. The threshold mostly reflects the multiple combination of several unique technological parameters of particular dam, which means that one dam can gain big portion of points in several evaluated categories, and, due to this multiplicity, the dam receives higher final score and becomes more unique in the solved set of dams. These combined constructions should be considered as the national heritage in our point of view. The rest of dams with the total score lower than the threshold of 101 points are unique only in the particular location or are not unique at all.

During the application of the presented scaling method, it is important to approach the dams' constructions as a large group of different entities, and keep in mind that there may always be a situation where a dam may be excluded from the final significant list of dams. The excepted dam could be evaluated very significantly only in one category at national or higher level, but not reach the 101 points threshold. In such case, it is advisable to verify the results, and look up the significant individuals (if any), which would not achieve the required 101 points because the construction individuality can also be considered as valuable technological heritage.

4.3. Comparison of applied methods and discussion

The methods described above represent two different avenues of approach to a uniform assessment of constructions. The cluster analysis method makes it possible to create groups of constructions on the basis of the aforementioned selected characteristics, in the case of dams they include dam material, types of bottom outlets

Table 11. Selection of significant representatives of individual types of dams in the Czech Republic (concordance of the methods is highlighted in colour).

Type/Group (Sub-group)	Dam	Brief Explanation
Composite dams	Nové mlýny, lower reservoir (TE, PG, 10.3 m, 1988)	The longest dam; the largest water area in the Moravia basin
	Lipno I (TE, PG, 25.8 m, 1960)	The largest water area in the Czech Republic, equipped with a unique underground power station
Concrete dams	Vrchlice (VA, 40.8 m,1970)	The only arch dam in the Czech Republic
	Štěchovice (PG, 31.0 m, 1945) Homole (PG, 15.0 m, 1947)	System of power stations; the first pump-storage hydroelectric power station in the Czech Republic; the most important pre-war hydraulic structure in the Czech Republic
	Vranov (PG, 59.0 m, 1934)	The first dam made of cast concrete in the Czech Republic
	Orlík (PG, 90.5 m, 1963)	The tallest concrete dam in the Czech Republic
	Březová (PG, 38.6m, 1934)	The first concrete dam in the Czech Republic
Masonry dams	-	Already has a number of representatives protected as a cultural monument or a national cultural monument
Embankment dams without a spillway	Dlouhé stráně, upper reservoir (ER, 28.0 m, 1996)	The highest artificial PSH reservoir in the Czech Republic
Embankment dams with a shaft spillway and inner sealing or homogeneous dams	Hracholusky (TE, 39.1 m, 1964)	The only representative with both shaft and side spillway
	Želivka (TE, 58.0 m, 1975)	The largest waterworks reservoir in the Czech Republic
	Velké Dářko (TE, 7.6m, 1480)	The only representative with a homogeneous dam; a historical pond; a representative of structures with a spillway object of small size with a straight spillway edge, it is not a typical shaft spillway
Embankment dam with a shaft spillway and upstream lining	Dlouhé stráně, lower reservoir (ER, 57.6m, 1996)	Together with the upper reservoir, it forms the largest pump-storage power station with the highest head in the Czech Republic
Embankment dams with a side spillway and stepped chute	-	Already has representatives protected as cultural monuments
Embankment dams with a side spillway and a smooth chute combined with a homogenous dam	Jordán (TE, 22.0 m, 1492)	The oldest waterworks reservoir in the Czech Republic (the reservoir is protected as a cultural monument, the dam is not)
	Staňkovský rybník (TE, 15.0 m, 1554)	The first retention basin in the Czech Republic; the tallest dam from historical ponds
Embankment dams with a side spillway and a smooth chute combined with a dam with upstream lining	Morávka (TE, 44.9 m, 1964)	The oldest dam in the group of dams with coat sealing, originally asphalt-concrete, then changed to a geomembrane.
Embankment dams with a side spillway and a smooth chute combined with a dam with inner sealing	Dalešice (ER, 100.0 m, 1979)	The tallest embankment dam in the Czech Republic.
	Mostiště (ER, 41.7 m, 1961)	The only representative of a dam made from stone rockfill in the Czech Republic.
	Nechranice (TE, 47.5 m, 1968)	The longest straight dam in the Czech Republic. Given its volume, it is one of the largest European dams.
	Chřibská (TE, 26.1 m, 1924)	A typical representative of the group; a technical monument; the largest of the three dam reservoirs in the territory of the Lužic Mountains
	Koryčany (TE, 25.0 m, 1958)	The first zoned embankment dam in Moravia

Table 12. Proposal for the scale of significance of hydraulic structures.

Significance class	Score range	Number of dams within class
GLOBAL SIGNIFICANCE	> 300 points	0
EUROPEAN SIGNIFICANCE	201–300 points	1
NATIONAL SIGNIFICANCE	151–200 points	8
REGIONAL SIGNIFICANCE	101–150 points	23
LOCAL SIGNIFICANCE	51–100 points	72
LESS SIGNIFICANT	0–50 points	15

and safety spillways, etc. Subsequently, based on the knowledge of the evaluated sample of constructions, both a significant representative of the group, which is exceptional within its group, and a typical representative, which is the most typologically characteristic for the given group of constructions, can be identified within each group. A unique dam is such a dam that is dissimilar enough to others. These can be

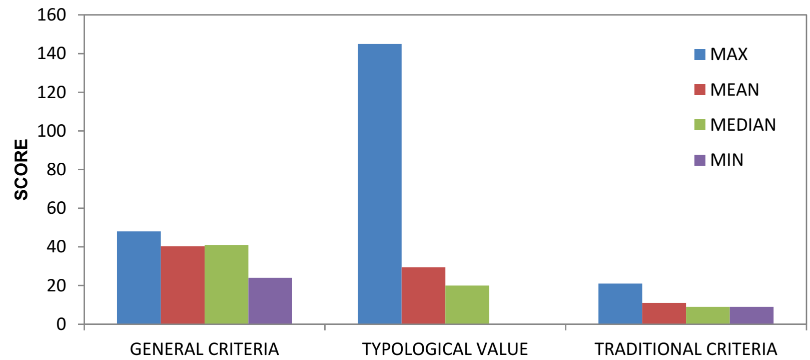

Figure 3. Graph of the analysis of the results of scoring evaluation of dams.

found in some groups, such as dams that show significantly higher heights or ages or that are equipped with more types of safety spillways, e.g. the Hracholusky dam. In other cases, virtually homogeneous groups of dams are formed, from which a typical representative should then be selected on the basis of other criteria.

On the other hand, the scaling method makes it very easy to identify exceptional constructions, whether from a construction or other points of view. The selection of a typical representative for a narrower group is not apparent from the scoring and must therefore be done only through a professional selection, which is conditioned by good knowledge of the constructions in question. This is one of the reasons these methods should be connected and used simultaneously in the future.

Although the assessment by means of both methods was carried out independently of each other — the cluster analysis was carried out at Brno University of Technology and the scaling method at TGM Water Research Institute — the consensus on the selection of significant dams that could be heritage-protected in the future was 80%, which can be considered a positive result. This comparison of significant dams included all those that achieved a score of at least 101 points, i.e. they show significance at least at a regional level. It should be mentioned that in the selection of significant dams by a cluster analysis, only a limited number of earth dams was included as the vast majority of them had already been heritage-protected. If this was not taken into account, the consensus would have been even greater. The identical results of both methods indicate the correct trend of these methods in the assessment of water management constructions for the needs of (not only) heritage preservation.

There were several cases of dam constructions which have not been evaluated as significant although they had already been protected by heritage preservation measures. Nevertheless, in the group of pre-existing heritage-protected dams, masonry dam constructions prevail, mainly owing to their architectural and aesthetic value. However, with regard to their exceptionality in terms of construction and technology, to which the main priority was given when these assessment methods were created, a significant proportion of cultural monuments have not been assessed as exceptional. 15 structures in total have been found in this category, examples being the masonry dams of Mšeno, Harcov, Jezeří and Pařížov (Figure 4). These dams were evaluated according to theirs architectural, aesthetical and landscape values during the cultural heritage monument assessment, and, unfortunately, the construction and technological parameters were omitted. In conclusion, this not entirely appropriate procedure leaded to formulate justification of monument protection like “This is the architectonic significant technological monument built in a style of Modern with romanticism elements” or “Valuable technologic building sensitively set in the landscape” (Památkový katalog 2020). On the contrary, the assessment methods have shown that some dams, which had already been declared as cultural monuments, have proved to be significant in terms of construction or technology, i.e. their score was above 100 points. In this way, the exceptionality has been confirmed in the case of these five dam constructions: Les Království (Figure 5), Bystřička, Janov, Fláje and Bílá Desná (which is the only non-operational dam in our country and it is only the body that remained after the dam breach in 1916. Its value can be therefore considered merely as a historical memento).

From the results shown in Tables 11 and 13, a good agreement between both methods can be observed. Differences comes from individual methods, where in cluster analysis dams are grouped according to similarity and in scaling method they are individually awarded by scoring. It should be noted here that Table 11 does not list dams that are already on the list of monuments, while Table 13 also includes already protected works (e.g. Fláje, Bílá Desná and masonry dams). The results

Table 13. Selection of the most important dams in terms of construction and technology according to the scaling methodology (conformity of the methods is highlighted in colour).

Dam	Type	Score (points)	Brief explanation
Fláje	concrete	191	The only buttress dam in the Czech Republic; the tallest and longest dam in the river basin; four bottom outlets. There are only two of this kind in Europe. A pre-existing cultural monument.
Dlouhé stráně (upper reservoir)	embankment	167	A reservoir with asphalt-concrete sealing without a tributary, the only one of this type in Moravia; the PSH power station has the largest reversing water turbine in Europe.
Štěchovice	concrete	164	The oldest PSH power station in the Czech Republic; the oldest concrete dam in the river basin; the most important pre-war hydraulic structure.
Janov (Hamerská)	masonry	160	The tallest and longest masonry dam in the Czech Republic, the most modern at the time. A pre-existing cultural monument.
Vrchlice	concrete	157	The only arch dam in the Czech Republic; the tallest and longest concrete dam in the river basin.
Bílá Desná	embankment	155	The only preserved burst dam, including functional objects, in Central Europe; a memorial site. A pre-existing cultural monument.
Slapy	concrete	158	The oldest overtopped hydroelectric power station(1) in the Czech Republic with steel segments; a milestone of Czechoslovakian dam construction.
Orlík	concrete	154	The tallest concrete dam in the Czech Republic; the longest concrete dam in the river basin; the parameters of the hydroelectric power station are a global rarity.
Staňkovský rybník	embankment	133	The first and oldest retention basin in the Czech Republic; the tallest (deepest) dam from historical ponds.
Vranov	concrete	129	The oldest concrete dam in the Czech Republic (together with the dam of Březová); it has four bottom outlets, the only only one of this type in the Moravia basin.
Nové mlýny (lower reservoir)	embankment	129	Part of a system of three interconnected reservoirs; the longest dam and the largest water area in the Moravia basin.
Dalešice	embankment	124	The oldest PSH power station in the river basin; the tallest embankment dam in the Czech Republic.
Rozkoš	embankment	120	It does not have a safety spillway, the only dam without one in the Czech Republic; the largest reservoir in the Elbe basin; the longest embankment dam in the Elbe basin.
Mariánské Lázně	masonry	119	The oldest masonry dam in the Czech Republic (together with the dam of Jevišovice); it has only one bottom outlet, the only one of this type in the Ohře basin.
Kružberk	concrete	118	The oldest concrete dam; the tallest and the first valley reservoir in the Odra basin.
Želivka (Švihov)	embankment	118	The tallest embankment dam in the Vltava river basin; one of the most important waterworks reservoirs in Central Europe.
Nechranice	embankment	116	The longest straight embankment dam in Europe and the largest dam in terms of volume.
Les Království	masonry	114	It has five bottom outlets and three safety spillways, the only one of this type in the Czech Republic, a structure of significant architectural value.
Jevišovice	masonry	112	The oldest masonry dam in the Czech Republic (together with the dam of Mariánské Lázně). A pre-existing cultural monument.
Bystřička	masonry	108	The tallest and longest masonry dam in the river basin; the Intze-type, the only one of this type in the Moravia basin. A pre-existing cultural monument.
Morávka	embankment	108	The oldest dam in the group with a coat sealing in the Czech Republic.
Jirkov	embankment	107	The technology of spreading material in high layers was used here for the first time in the Czech Republic; inflow via a gravity pipe system from the other basin.
Dvořiště	embankment	105	The oldest embankment dam in the Vltava river basin with two safety spillways.
Lipno I	composite	105	Composite dam — the only one in the Vltava basin; Swedish-type hydroelectric power station (unique in the Czech Republic); the largest water surface in the Czech Republic.
Mostiště	embankment	105	The only representative of a dam made from stone rockfill in the Czech Republic.
Březová	concrete	104	The oldest concrete dam in the Czech Republic (together with the dam of Vranov); it has three bottom outlets, he only one of this type in the Ohře basin.
Nové mlýny (upper reservoir)	embankment	104	Part of a unique system of three interconnected reservoirs.
Nové mlýny (middle reservoir)	embankment	104	Part of a unique system of three interconnected reservoirs.
Koryčany	embankment	102	The earthfill dam consists of several zones of different materials — the only one of this type in the Moravia basin.
Seč I	masonry	101	The tallest earth dam in the Elbe basin; the headrace of the power station is partially wooden, which is unique both in the Czech Republic and in the world.

(1)Overtopped hydroelectric power plant is a special type of power plant; the power house is located under the spillway of the weir or dam, and water overflows the power house; this is an unusual technical construction.

of the cluster analysis do not include some types of evaluation (e.g. the authenticity of the materials used). When deciding which dam to put on the list of cultural monuments, the results of the scaling method should be taken into account.

The first aim of proposed methodological approach was to identify a package of objective evaluation criteria, which should bring a more uniform and objective perspective into the cultural heritage assessment. It is supposed to reduce an inappropriate subjective meanings of particular evaluator, and, finally, to get more valuable and sufficient results of significant cultural monuments in all region in the Czech Republic. The proposed method, and the criteria, highlights the construction and technological parameters, which was reflected in the methodology by assigning high weights to these criteria.

Table 14. Selection of the most significant functional entities in terms of construction and technology according to the scaling methodology.

Functional entity	Type	Score (points)	Brief explanation
PSH power station Dlouhé Stráně	PSH power station	244	Newly developed type of the FR100 turbine with a pump function; in the Czech Republic there are only three PSH power stations; PSH power station has the largest reversing water turbine in Europe, 325 MW; it has the largest head of all power stations in the Czech Republic, 510.7 m; and it has the largest installed capacity in the Czech Republic, 2 × 325 MW.
PSH power station Štěchovice	PSH power station	175	The oldest PSH power station in the Czech Republic The lock chamber has the size of a sliding gate as one of the most unique in hydraulic engineering in Europe. The slope of the chamber is 19.70 m and the passage of the ship takes 12 minutes.
Nové Mlýny	reservoir system	129	Unique system of three closely interconnected reservoirs.
PSH Dalešice + Mohelno	PSH power station	124	The oldest PSH power station in the Moravia basin, there are only three PSH power stations in the Czech Republic.
Lipno I	reservoir system	115	The largest water area in the Czech Republic; Swedish-type power station situated underground at a unique depth of 160 m.
Seč I + II	reservoir system	101	The tallest earth dam in the Elbe basin, the headrace of the power station is partially wooden, which is unique both in the Czech Republic and throughout the world.

Figure 4. Pařížov dam (Source: Author of the article).

The proposed method for Czech Republic can be applied to evaluate dams in other countries and regions, nevertheless, it is recommended to use the method on comprehensive list of dams in particular area. Also, it is advisable to modify the setting of criteria values according to the specific natural conditions, and historical and social economic consequences of the specific area.

The great question in the context of the cultural heritage assessment is an influence of the heritage preservation on the dam conditions, respectively, the conflict between the preservation practices and the owner or operator of a dam. The safety of a functional dam must play a main role during the maintenance and reconstruction of a dam. The long practical experience in the Czech Republic points out that there is a need of the communication between a conservationist and manager of a dam to find out the good solution for both sides. This applies in particular to the use of authentic or similar materials in the reconstruction, as far as possible, in the case of extensions, the choice of architectural style without disturbing the original character of the building, if possible. When exchanging historical technologies, there is often an effort to place them directly in the area for raising awareness and tourism or to store them in the depositories of technical museums. However, it should also be noted that with regard to the required safety of the work and economy during reconstructions, new materials and new technological procedures are often used.

5. Conclusion

This article describes two methods for assessing whether a dam is to be included in the list of cultural or national cultural monuments. They are cluster analysis and scaling methods. Cluster analysis can be used for classifying dams in groups according to their similarities and makes it possible to evaluate the uniqueness of a structure. At the same time, it also enables the structures to be divided into groups in which a typical representative is to be

Figure 5. Les Království dam (Source: Author of the article).

sought. This must be selected on the basis of other criteria. The scaling method evaluates dams according to several characteristics and assigns scores to them. Both methods are comparable in terms of their results and mutually complementary since the structures are first sorted out according to their similarity by means of cluster analysis and then appropriate representatives for heritage preservation are identified using the scaling method. The advantage of both methods is, contrary to past practice, that the whole selection process of suitable candidates for heritage preservation is objective. This provides solid arguments for deciding about the inclusion of a dam in the list of cultural heritage, which is not always perceived positively by the dam operator. The principles of both methods can also be applied to other types of objects, especially for larger, comprehensive databases of constructions.

In assessing whether or not to protect a dam and to what extent, its safety and functionality must firstly be taken into account. Here it is necessary to draw attention to the need to meet the current requirements for structural stability and hydraulic capacity. Heritage protection may cover either the structure as a whole or only its constituent parts. The protection of a hydraulic structure should not restrict the functionality of the structure (for example, some types of valves are no longer produced). Long-standing experience has shown that it is beneficial to have two independent bottom outlets available although many older hydraulic structures are equipped with only one. Where possible, bottom outlets are added. An attempt is often made to increase the diameter of the bottom outlet in order to improve the conditions for handling the water level in the reservoir (e.g. faster emptying of the reservoir during floods). During the reconstruction of dams, it is usually necessary to propose such a solution that respects the current regulations (e.g. the requirement for the width of the communication on the crest of the dam may lead to an extension of the crest of the dam). Very often, it is not possible to apply the same materials or construction techniques as in the past since these are no longer available on the market. On the other hand, it is possible to use gentle (although often more expensive) technologies, such as stone linings of concrete structures, etc.

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