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INTERACTING NATURAL-TECHNICAL SYSTEMS IN THE CULTURAL LANDSCAPE

Our contemporary cultural landscape has developed under the influence of human society on the primary natural landscape complexes at the choric and topic levels (called geochoras and geotops in the German landscape school). In addition to primary natural geocomplexes, Man has created socioeconomic landscape systems, such as traffic systems, urban systems, factories etc. At the present stage of the scientific-technological revolution, Man is also modifying natural landscape complexes (natural geosystems) by introducing different substance (e. g. pesticides) unknown previously into the natural circulatory systems. The primary natural complexes change into secondary complexes of the cultural landscape, which is called „secondary Nature". The present human society forms an integrated part of the cultural landscape, which, at the same time, provides the immediate living environment for the society.

Man has been trying to separate socioeconomic systems from the natural components of the landscape (e. g. by closed circulation of fluids in factories, by re-cycling waste products etc.). But in fact the socioeconomic subsystems of the cultural landscape are intimately related to the natural and quasi-natural landscape subsystems. Relationships between the natural and socioeconomic subsystems of the cultural landscape are of different types and different strength. Two types of relationships are of special importance, i. e. locational relationships and relationships changing the environment of the socioeconomic subsystems (e. g. engineering works).

Locational relationships always point from nature to the engineering work to be constructed. It is well known that the present stage of technology allows water dams to be built almost at any place along a river valley, their construction being only a problem of capital costs. Nevertheless, the dam site is always chosen very carefully after a thorough consideration of all pertinent natural conditions, i. e. the valley width, slope stability, etc. Locational relationships are classified according to the state standards (e. g. Czechoslovak State Standards) which have to be respected by designers of the engineering work in question.

Relationships changing the environment, such as engineering works, are manifested by their influence on the neighbouring natural geosystems, on the whole landscape and the living environment of Man. Individual types of socioeconomic subsystems (factories, mines, traffic networks etc.) influence the natural base of the landscape in various ways.

Studies of the spatial aspects of engineering works in relation to the landscape revealed individual spheres and zones of their influence. The spheres of influence around every engineering work are approximately concentrical. We can map the sphere of influence of a reclamation system or an open mine on the underground water table etc. Within the sphere of influence the following subspheres may be distinguished:

1. A subsphere of direct influence in which the landscape structure is changed by air pollution, by falling water table etc.; the term „landscape structure" indicates a complex of landscape components and their mutual relationships. For example, the disturbance of the drainage system will first affect the underground water table, then the soil water content and the régime of soil humidity; secondarily these changes result in the changes of biota as well as of the soil type. Another example is the fall of the water table in the subsphere of direct influence due to an increased water consumption in open-cast coal mines, which results in the drying up of streams, in changed soil properties of even altered use of land, etc.
2. In the subsphere of indirect influence in which the course of natural landscape processes is changed the landscape structure remains stable.

The zones of influence of individual engineering works may be elongated in certain directions, e. g. in an area affected by gas dispersal from a chimney the zone may be shaped by the direction of prevailing winds. Another example is the zone of influence of liquid waste emptied into a river. Apart from zones of negative influence we can also find zones of positive influence in the vicinity of engineering works, e. g. zones of intensive agriculture along irrigation canals.

The influence of individual engineering works and their systems depends also on their location in the landscape. In dependence on their different spatial relationships the influence of engineering works on their surroundings will also vary, e. g. the influence of water reservoirs built in deep incised river valleys in contrast with other water reservoirs excavated in the lowland, such as the Danube Plain. The influence of some engineering works on the landscape and the living environment may become apparent in exceptional situations, for instance during meteorological inversions in intermontane basins or at times of minimum discharge in rivers.

The strenght of the relationship between natural and socioeconomic subsystems also varies in different places of the cultural landscape. An engineering work in direct contact with the natural or quasi-natural components of the landscape is a good example. A factory is built on clayey ground, its foundation being in a direct contact with the groundwater in the clay mass. Due to the properties of clay, the movement of groundwater is very slow and has no influence on the foundation of the factory. In this case the strenght of relationship is very low. Stronger relationship may be observed, for instance, when heat is released from a factory into the clay ground bellow its foundation. In the USSR temperatures of more than 100° centigrade were measured below blast furnaces built on clayey ground. Volumetric changes took place in the clayey ground and the foundation subsided by 0.2—0.3 m, in some places even more (Kotlov, 1978, p. 160). In this case the relationship was much stronger than in the first example. The strongest thermal relationship would show if a factory is built on permanently frozen clays with a high content of ground-ice. The release of anthropogenic heat can start a thermokarst process, and in extreme conditions may even endanger the whole construction.

From the point of view of relationship and their strength, a special place is occupied by landscape subsystems controlled by Man. Controlled geosystems consist of natural, technical and controlling components. As an example of this type of geosystem a water reservoir system is composed of technical components (i. g. dam etc.), of natural components (e. g. water in the reservoir) and of controlling components (e. g. manual or computer control of the water level in the reservoir). The weight of water in such an artificial lake can initiate crustal movements and anthropogenic (artificial) earthquakes. Anthropogenic earthquakes initiated by water filled to a reservoir have been described from Lake Mead on the Colorado River, U.S.A., Koyna Lake, India, and many others. The water reservoir system as a landscape subsystem is characterized by very close relationships between natural and technical components forming a single system termed natural-technical system. The formation of natural-technical systems and their functioning is enabled by numerous relationships — on the one hand among the components of natural-technical systems, on the other among natural-technical systems and other subsystems of the cultural landscape. I would especially like to stress some typical features of these systems, including the very close relationships among natural, technical and controlling subsystems. Consequently, natural-technical systems may be defined as a special type of system in the cultural landscape, occuring along the boundary-line between natural and socioeconomic geosystems.

I have already said that Man has been trying to separate socioeconomic subsystems from the influence of the surrounding natural and quasi-natural subsystems. A complete separation has been achieved only rarely due to high technological complexity and high costs. On the other hand, the complexity and strength of relationships between natural and socioeconomic components in the cultural landscape has been increasing. The unification of natural and socioeconomic landscape subsystems in natural-technical systems is therefore a very progressive process. Natural, technical and controlling subsystems united by relationships and feedbacks in natural-technical systems fulfil a social function in the system.

From the standpoint of the type and strength of relationships we can distinguish several types of natural-technical systems:

1. Productive systems, serving the purpose of exploitation of natural materials, energy and information; this group includes mines, quarries, fields and other agricultural complexes;

2. Enrichment systems, in which certain natural materials are concentrated under the assistance of Man, i. g. salinas where salt is obtained by evaporation from salt water;

3. Processing systems, which include factories changing natural materials into final products, e. g. food-processing factories;

4. Transport systems providing natural landscape components for the distribution and transport of materials, e. g. water in canals, etc.;

5. Storage systems providing storage of natural materials, e. g. underground gas reservoirs, etc.;

6. Regulating systems which control the required level of certain proper-

ties of the cultural landscape, such as dams, weirs, drainage systems, irrigation systems, regulated water courses, etc.

Natural-technical systems have the same properties as natural and socioeconomic geosystems, i. e.

1. a time limited existence comparable with the time of existence of other geosystems of the cultural landscape,
2. spatial dimensions comparable with those of other landscape geosystems,
3. occurence within the landscape sphere.

The spatial structure of natural-technical systems is formed by their components and their mutual relationship. It is represented by the use of two basic models,

a) the monosystem model,

b) the polysystem (territorial) model.

In the monosystem model three subsystems are usually distinguished, i. e. natural subsystem, engineering subsystem and control subsystem. Using water reservoir systems as an example, we can distinguish:

i) the natural subsystem, including
  — natural geocomplexes in the river basin above the reservoir, not influenced by the Man-made lake nevertheless influencing the quality of the water in the reservoir;
  — natural complexes influenced by the construction of a reservoir above the dam (flooded area) or below the dam;
  — water in the reservoir,

ii) the engineering subsystem including the dam and the hydroelectric power station,

iii) the control subsystem including the control room with regulating and control equipment and controlling staff. In the polysystem model we can distinguish:

i) the core of the natural-technical system, e. g. dam hydroelectric power station, control room and the artificial lake,

ii) areas influencing the natural-technical system (e. g. river basin above the reservoir),

iii) areas influenced by the natural-technical system, e. g. the leisure zone around the reservoir or in the river basin below the dam.

The spatial structure of the natural-technical system changes in the course of time. Apart from stable locational relationships and relationships influencing the background of the technical work, there are also relationships changing over space and time. This is especially true of relationships determined by movable landscape components (e. g. water, air, animals, Man, etc.).

We can distinguish primary and secondary relationships. Primary relationships point from technical components of the natural-technical systems to the surrounding natural geosystems. Secondary relationships either point from natural geosystems to other natural geosystems or from natural components to technical (engineering) components of the natural-technical system. For example, air pollution affects a forest; the resulting changes in the forest may speed up soil erosion or even mud flows. The products of soil erosion can influence the natural-technical systems e. g. an accelerated silting of the Man-made lake. The influence of changing relationships is usually not limited to one process only (even if it looks like it); in fact, the transformation of the geosystem starting from a primary source of disturbance usually takes the form of a chain reaction of several stages. A chain reaction in the geosystem will usually continue for a longer period of time. In some reactions, only natural components take part. Other transformations can include the influence of certain engineering measures resulting from processes which took place in the landscape some time earlier (e. g. engineering constructions on mountain rivers for the accumulation of gravels, weirs, etc.). The chain reaction is limited either by natural subsystems with a limited ability to change or by technical subsystems specially constructed to interrupt the reactions (e. g. measures to stop soil erosion).

Many relationships within the framework of natural-technical systems as well as the mutual relationships of these systems and their environment change according to the landscape dynamics. In Central Europe the changing relationships can be controlled by seasonal aspects. The term landscape dynamics is used to determine changes occuring within the framework of a stable landscape structure (called invariant structure). For example, there are specific relationships between the water surface in a reservoir and its banks in summer but they differ a great deal in winter when the surface is covered by ice.

Relationships changing over space and time play an important role in the interaction between natural-technical systems and other landscape geocomplexes. Forest clearance changing the properties of the soil cover and the régime of the surface water flows has a direct influence on the régime of water courses, especially on the discharge and the amount of sediment transported by water. This, in turn, affect the hydrotechnical work. On the other hand, barrages constructed to regulate river discharge may influence the growth of floodplain forests. These examples have shown that the relationships between natural-technical systems and other landscape geosystems have a double character — from the system to the environment and from the environment to the system. In the landscape, however, relationships acting in only one direction are prevalent. In the case of two neighbouring systems, one system will influence the other (e. g. a reservoir will affect the river below the dam).

I have already said that the influence of natural-technical systems on an area can be divided into the primary influences conditioned by the fulfilling of a planned operation within the frame of the engineering work, and the secondary influences accompanying the primary influences.

Primary influences are due to the fact that at the time of the construction of the natural-technical system other solution to the respective problems was impossible. The disturbance of natural geosystems caused by the primary influence can be regarded as a form of compensation, as a „sacrifice" associated with the use of natural resources by human society. These disturbances, however, must not exceed specific limits, because in this case they could endanger the function of the natural-technical system.

Since the secondary changes caused by engineering subsystems in the landscape can be avoided the aim of designers of an engineering work is to minimize these changes or to eliminate them completely. The limitation of these secondary changes is the main function of the control subsystems in a natural-technical system.

The minimization of changes caused by a natural-technical system in its vicinity can be achieved in two ways, as follows:
i) by a careful study of the relationships between technical and natural components within the framework of the natural-technical system,
ii) by the maximization of the strength of relationships between the natural-technical system and the surrounding natural and socioeconomic geosystems of the landscape.

At the stage of designing engineering works we usually are not able to identify all the relationships in the landscape, especially in areas with a disturbed environment (with air and water pollution, accelerated soil erosion, etc.). Therefore we have to concentrate on the main controlling relationships, especially on feedbacks. By the identification and use of feedbacks we can direct the structure and function of natural-technical systems. Attention should be paid to the auto-regulation of individual components. In the contemporary cultural landscape of Central Europe such controlling relationships are bound to the living components (biota) of the landscape. Only the biomass combines the abiotic base with the biota in one landscape unit, or with the technical subsystem (for example in the case of food industry). Biotic components are also very sensitive to changes in the natural-technical and socioeconomic systems. Biotic components therefore can be used as indicators of movable components of the landscape evoked in it by natural-technical and socioeconomic systems.

We also must remember the cumulative character of the activity of natural-technical systems. It is well known that long-lasting pollution within the limits of the State Standards can result — due to their cumulative character — in the crossing of certain thresholds, resulting in catastrophes, such as floods, whirlwinds, and so on. Forest in mountains have been gradually damage by emissions from power stations. Their catastrophical state shows by a lowered resistance of trees to storms and pests, e. g. *Zeiraphera diniana.*

Our cultural landscape forming the immediate environment of our society is a complex spatial system (geographical system, geosystem), composed of natural (quasi-natural), natural-technical and socioeconomic systems. In this cultural landscape, natural-technical systems represent a stabilizing factor, due to their hybrid nature, approaching the boundary-line between Nature („secondary Nature") and the technical works of human society. There are still some problems of natural technical systems to be solved in the field of the theory. Geography as a science interested in the relationships between Nature and Human Society will have to deal with them in future.

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Shrnutí

PŘÍRODNĚ TECHNICKÉ SYSTÉMY V KULTURNÍ KRAJINĚ

V naší kulturní krajině se nacházejí ve vzájemných vztazích přírodní a socioekonomické územní (teritoriální) komplexy. I v komplexech, které tradičně označujeme jako přírodní, obíhají látky, které se v původní přírodě nevyskytovaly (např. biocidy). Současná geografie chápe kulturní krajinu jako systém (geosystém), v kterém existují mezi přírodními (kvazipřírodními) a socioekonomickými subsystémy vazby různého typu (hmotné, energetické, informační) a různé síly. Z geografického hlediska mají v kulturní krajině zvláštní význam lokalizační vazby a vazby měnící okolí socioekonomického subsystému (např. technického díla).

Lokalizační vazby jsou vždy zaměřeny od přírodních subsystémů krajiny k technickému dílu. Je všeobecně známé, že přehradu můžeme za dnešního stavu techniky postavit prakticky na libovolném místě řeky. Přesto se však při výběru stavebního místa většinou řídíme přírodními podmínkami a vyhledáváme místa zúžení příčného profilu údolí, místa se stabilními svahy ap. Na hodnocení lokalizačních vazeb většinou existují normy (např. ČSN), které projektant musí při projektování technického díla v krajině dodržovat.

Vazby měnící okolí technického díla se projevují jeho působením na okolní přírodní subsystémy krajiny, na celou krajinu a na životní prostředí společnosti. Jednotlivé typy socioekonomických subsystémů působí na přírodní subsystémy a na životní prostředí společnosti různým způsobem. Při studiu prostorového vlivu technického díla na krajinu můžeme rozlišit sféry a pásy působení. Sféra působení se rozkládá zhruba koncentricky kolem technického díla a lze v ní rozlišit:

a) subsféru přímého působení, v níž dochází ke strukturním změnám krajiny;
b) subsféru nepřímého působení, v níž se mění průběh přírodních (kvazi-přírodních) krajinotvorných pochodů, ale struktura krajiny zůstává zachována. Strukturou krajiny rozumíme prostorové rozmístění složek krajiny a vazeb mezi nimi.

Pásy působení technického díla se pak projevují v určitých směrech (např. převládajících větrů, podél dálnice ap.). Působení jednotlivých technických děl i jejich souborů závisí rovněž na jejich umístění v krajině.

Rovněž síla vazeb mezi přírodními a socioekonomickými subsystémy v kulturní krajině je různá. Zvláštní místo z hlediska vazeb a jejich síly pak mají člověkem řízené subsystémy krajiny, které jsou složeny z části přírodní, technické a řídící. Příkladem je např. přehradní geosystém, složený z technického díla (přehradní hráze), které však nadržuje přírodní složku, tj. vodu v přehradním jezeře, jejíž úroveň je určována řídícím prvkem (člověkem a jeho potřebami). Zatížení zemské kůry vodou nadrženou v přehradním jezeře může vyvolat pohyby ker zemské kůry a antropogenní zemětřesení. Uvedený subsystém kulturní krajiny se tak vyznačuje velmi úzkými vztahy mezi přírodními a socioekonomickými (technickými) složkami, které dohromady vytvářejí jeden prostorový systém (tzv. přírodně technický systém). Vznik přírodně technických systémů v kulturní krajině a jejich fungování je možné v důsledku početných vazeb jak mezi subsystémy přírodně technického systému, tak i mezi přírodně technickými a dalšími subsystémy kulturní krajiny. Především je však třeba zdůraznit příznačný rys těchto systémů, a to velmi silné vazby mezi přírodními, technickými a řídícími subsystémy, které umožňují vydělit přírodně technické systémy jako samostatný typ systémů kulturní krajiny.

Lidská společnost se snaží oddělit socioekonomické subsystémy kulturní krajiny od působení okolních přírodních nebo kvazipřírodních subsystémů. Úplné oddělení je však zatím řídké, protože je materiálově a energeticky velmi složité a náročné (např. závody s tzv. uzavřeným bezodpadovým oběhem). Naopak složitost a síla vzájemných vazeb mezi přírodními a socioekonomickými složkami v kulturní krajině se neustále zvyšuje, a proto vhodné spojování obou typů složek v přírodně technických systémech je zejména z hlediska životního prostředí velmi žádoucí a perspektivní. Přírodní, tech-

nické a řídící složky v přírodně technickém systému navzájem spjaté bezprostředními i zpětnými vazbami se totiž projevují jednotou při plnění společenské funkce systému v kulturní krajině.

Pro přírodně technické systémy kulturní krajiny je příznačná určitá doba trvání, prostorové rozměry a výskyt v rámci krajinné sféry. Struktura přírodně technických systémů není stálá, nýbrž se mění v čase. Je to důsledek toho, že vedle stálých lokalizačních vazeb i vazeb měnících okolí se vyskytují i vazby měnící se v prostoru a čase. Můžeme rozlišit měnící se vazby prvotní a následné. Prvotní vazby nejčastěji směřují od technických prvků přírodně technického systému k okolním přírodním geosystémům. Následné vazby pak směřují od jedněch přírodních geosystémů k druhým nebo od přírodních geosystémů k technickým prvkům přírodně technického systému.

Autor v článku dělí přírodně technické systémy kulturní krajiny na těžební, obohacující, zpracovávající, transportní, skladovací a regulační.

Podle autorova názoru právě využívání přírodně technických systémů založených na těsných (silných) vazbách může pomoci řešit problémy životního prostředí, s kterými se setkáváme v ČSSR.

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