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Smart Green Bridge - Wildlife Crossing Bridges of New Generation

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Abstract. The research content of the paper is focused on landscape-vegetation and technical-economic optimization of vegetation elements of buildings. The length of the motorway in the Czech Republic has increased approximately three times since 1995. Road transport infrastructure is constantly growing. Ensuring the passage of important transport structures for fauna is an objective requirement. The function of migration corridors is ensured by wildlife crossing bridge. These constructions are currently based on concrete and steel, which is not only environmentally friendly but also presents several other problems. The paper presents the idea of a new smart solution for wildlife crossing bridge. Smart Green Bridge is based on principles and technologies following the sustainable development such as the use of load-bearing timber structures, extensive greenery of about 100 mm thickness, vertical greenery, self-guiding vertical and horizontal irrigation systems, photovoltaic panels, battery energy storage and next.

1. Introduction

Urban areas show significantly higher temperatures than other areas located in the undeveloped surrounding area in the context of climate assessment. This is due to the overlapping of large areas of the original vegetation with buildings and roads. Concrete and asphalt surfaces absorb a huge amount of heat from the Sun, which then radiates back into the environment. The overheating of cities causes the rise of warm air, which raises dust particles that people inhale. Due to the ever-expanding urban development, the intensity of the so-called thermal islands is increasing and life in some cities becomes even more difficult in the summer months. For example, the thermal islands in the center of Prague show a temperature of more than 2°C higher than the temperature in the outskirts of the city. Due to the absence of green areas in cities, natural run-off points disappear and water is very difficult to retain on concrete or asphalt surfaces and with its help to cool the surroundings. One possible solution to prevent this problem is to design more green spaces in cities. The green facades or green roofs can retain water and subsequently evaporate it. However, it must be emphasized that greenery on buildings also benefits the building itself. Adaptation measures in cities aim to adapt to climate change. This can be achieved by sustainable urban development while maintaining the necessary quality of life for the population. Water management also plays a very important role. It is necessary to focus on water retention and slowing down of water runoff from hard surfaces. It is also important to ensure the seepage or use of rainwater and to functionally connect the areas with the prevailing natural components. Water and vegetation areas with elements that significantly affect the microclimate will play an important role. Their basic mechanism is water evaporation, which has the effect of lowering the ambient temperature.

Construction, and in particular the operation of traffic linear constructions (roads, motorways, railways), means hard negative impacts on the landscape and related ecosystems. The effects of linear transport construction on wildlife populations have been the focus of many studies in the last years [1-5]. The violent fragmentation of the landscape environment, connected with migration retardations and ecosystem vegetation barriers, is essential. The usual compensatory measures are technical objects, so-called wildlife crossing bridges or ecoducts. These are under-ground passages and over-ground crossings for the zoo-component and synergistic transfer of vegetation. The relevant buildings are based on migration corridors. Heavy reinforced concrete constructions are typical, especially above traffic road constructions. These constructions reflect thousands of tons of concrete, other technical elements, and great construction, energy and financial demands.

2. Wildlife crossing bridges - ecoducts

Nowadays, with the ever-expanding road network, not only is there a reduction in intra-urban traffic, but many of negative environmental impacts arise. Wildlife crossing bridges are now widely used they are abundantly built in many countries around the world [6]. Road traffic systems were developed to allow relatively easy, fast and effective transport of people and goods. However, it is precisely the impact of densifying transport infrastructure and moving people to larger cities that results in environmental restrictions, especially for animals. The consequence of these factors is the disintegration of the landscape. Table 1 shows the development of the road transport infrastructure in the Czech Republic from 1995 to 2018.

Table 1. Road transport infrastructure in the Czech Republic from 1995 to 2018.

Year	Motorways [km]	Expressways [km]	Roads [km]	Total [km]
1995	414		55 086	55 500
1996	423		55 088	55 511
1997	486		54 908	55 394
1998	499		54 895	55 394
1999	499		54 933	55 432
2000	499	299	54 909	55 408
2001	517	300	54 910	55 427
2002	518	305	54 904	55 422
2003	518	320	54 929	55 447
2004	546	336	54 953	55 500
2005	564	322	54 945	55 510
2006	633	331	54 952	55 585
2007	657	354	54 927	55 584
2008	691	360	54 963	55 654
2009	729	370	54 990	55 719
2011	734	422	55 018	55 752
2012	745	427	54 997	55 742
2013	751	442	54 965	55 716
2014	776	458	54 985	55 761
2015	776	459	54 972	55 748
2016	776	459	54 962	55 738
2017	1 223	0	54 535	55 757
2018	1 240	0	54 517	55 756

Transport infrastructure in the form of motorways and expressways is a big and insurmountable barrier for animals. This phenomenon is negative and undesirable because the landscape that is still working is then divided into smaller and even smaller parts. The result of this phenomenon would be the construction of migratory objects in the form of ecoducts. Wildlife crossing bridges would be placed in problem areas. Wildlife crossing could be divided into two basic group - overpasses and underpasses [7].

Figure 1. Wildlife crossing bridge, Czech Republic, Dolní Újezd, Motorway D35, realization 1999.

Currently, there are the following possible construction solutions for wildlife crossing bridges:

- Monolithic beam construction with the top plate. The basis is a load-bearing structure consisting of a combination of a monolithic beam (one or more) and a monolithic slab. Depending on the span length, the structure is designed as reinforced concrete or prestressed.
- Beam structures are based on prefabricated prestressed beams coupled with a monolithic reinforced concrete slab.
- The second type of beam structures consists of steel beams coupled with a monolithic reinforced concrete slab. It differs from the previous construction in that steel beams are used instead of prefabricated prestressed beams.
- Reinforced concrete monolithic structure in the form of a vault.
- Monolithic arch construction. In order to ensure the transfer of the arc force from the horizontal component, a prestressed plate in the form of a tie rod is designed for the structure (the prestressed plate is placed above the arcs). In order to ensure the transfer of forces to the drawbar, the structure is supplemented by struts in the area at the edge supports of the arches. The whole solution of the migration object involves a relatively complicated structural arrangement, the overall static functioning depends on the exact functioning of all the partial components forming the overall structure.
- Prefabricated reinforced concrete arch construction. The wildlife crossing bridges is based on a supporting structure consisting of a precast reinforced concrete structure in the shape of a vault. This construction is made up of the prefabricated wall and arched parts which are supported by an articulated joint. In order to ensure the interconnection of all components, a monolithic casting of the realized joints is made.
- Construction of the composite arch. The structure consists of arched beams, which are made of glued wood.
- Steel flexible construction. The overall supporting structure of the building is made of a flexible steel structure made of corrugated sheet metal, together with a vault made of compacted gravel sand [8].

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Disadvantages and weaknesses of current structural and construction solutions of wildlife crossing bridges include:

- The major parameter of the negative biotic effect of the motorway under the wildlife crossing bridge is the wide width of current crossing structures.
- It is not possible to use standardized construction systems for the construction of current wildlife crossing bridges because these are individual projects.
- In order to ensure the growth of vegetation located on the surface of the wildlife crossing bridge, it is essential that the layer of soil is formed in a high thickness (mainly if it is a vaulted structure).
- Heavy and massive structures are the result of high loads.
- The retrofitting of existing wildlife crossing bridge constructions cannot be achieved without the necessary restrictions on the traffic on the crossing road [8].

3. Smart Green Bridge

The basic strategy of access and innovation of the above-ground ecological transition, the wildlife crossing bridges, is a light bridge structure with marginal walls created by vertically cultivated vegetation, separating transferring individuals and communities from the operation of the crossed barrier road. For the previously applied solutions of aboveground concrete crossings, their vegetation effect required at least 1 meter of the soil layer, which allowed cultivation, but only lower forms of vegetation (shrub layer). Recent soil layers, due to directional runoff conditions, are not aqueous, vegetation suffers from drought and gradually disappears. The construction is a completely foreign element for the landscape.

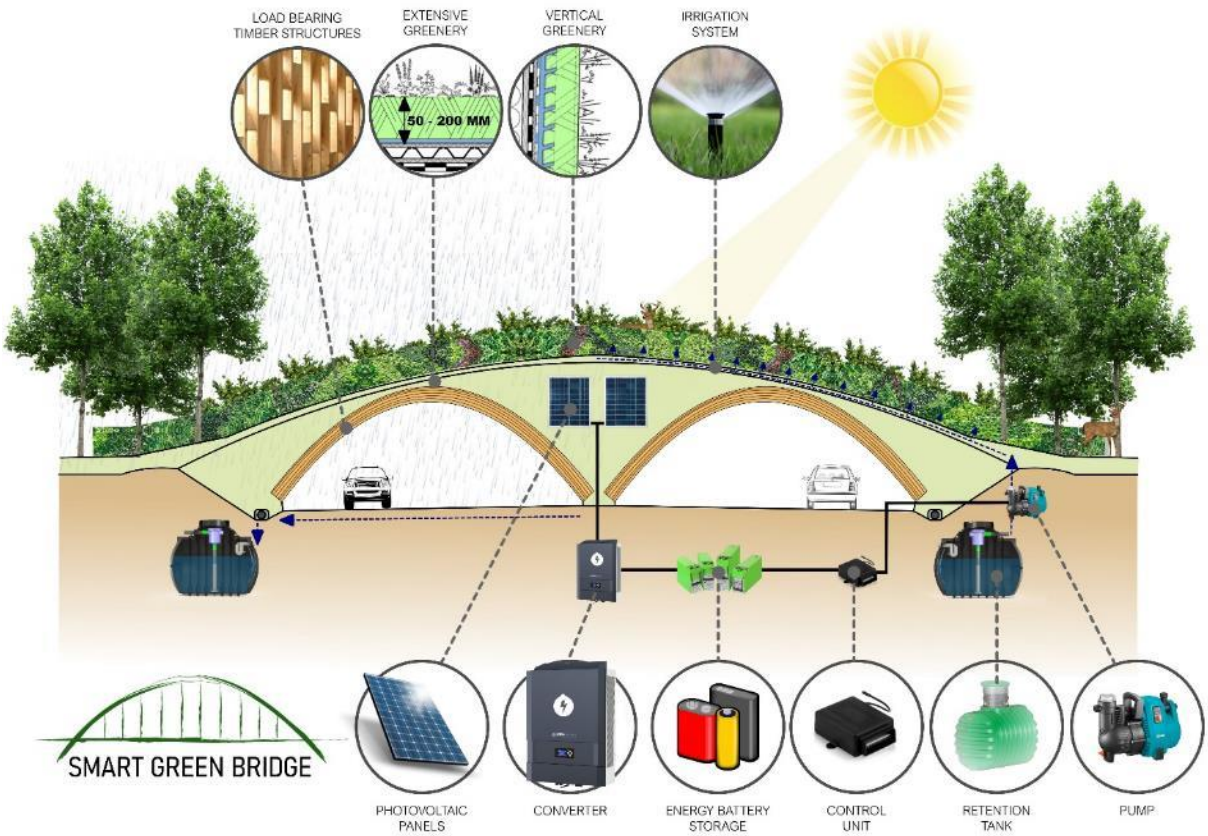

Figure 2. A pilot scheme of Smart Green Bridge.

The new solution is illustrated in Figure 2. The new solution of the so-called light bridge construction is sufficient with a surface thickness of approx. 100 mm with a purposefully created water regime based on renewable energy sources. This solution means great relieving of the wildlife crossing bridges, drastically reduced material and energy demands, greater flexibility and economic efficiency. The secondary effect is the use of vertical - high greenery in the immediate vicinity of the wildlife crossing bridges, creating quiet places utilizing the use of the construction and thus its landscape and social meaningfulness. Efficient use of rainwater from the bridged road to ensure irrigation of vegetation is essential. Collecting water from the line structure (road or highway) will be collected into the retention tank and distributed to the horizontal and vertical vegetation using the soil moisture sensors and by own energy source (solar photovoltaic panels).

The design of a new smart green crossing bridge solution means low demands on the technical solution, higher financial efficiency of the construction and minimal intervention in the construction and construction of the bridged road. From the landscape point of view, it is also possible to minimize the risks of anthropic impacts in the perimeter of the crossing bridge, and, for example, to increase the frequency of realized crossings on line constructions for economical sums.

The proposed structures, in terms of civil engineering, will be considerably lighter and simpler, standardized prefabricated structural elements and routine proven construction methods can be used. Technically and technologically, the procedure of their additive placement on already realized line constructions will be elaborated without any significant limitation of the existing operation. High material, energy and financial efficiency, the variability of utilization and positive ecosystem and landscape-creative impacts are predicted and documented. Figure 3 illustrates the visualisation of Smart Green Bridge.

Figure 3. Visualisation of Smart Green Bridge.

4. Conclusions
Concerning the financial and technological demands of existing wildlife crossing bridge, it is necessary to demonstrate objectively the necessity of a wildlife crossing bridge under the given conditions, but also to examine all variants of the technical solution with an emphasis on the cost-optimal level and principles of sustainable development. The existing construction methods are very inefficient. Criticism of their construction is often justified. This contribution presents the new generation of wildlife crossing bridge, the so-called Smart Green Bridge. Smart Green Bridge is based on principles and technologies following the sustainable development such as the use of load-bearing timber structures, extensive greenery of about 100 mm thickness, vertical greenery, self-guiding vertical and horizontal irrigation systems, photovoltaic panels, battery energy storage and next.

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References

[1] S. Pell, and D. Jones, "Are wildlife overpasses of conservation value for birds? A study in Australian sub-tropical forest, with wider implications," *Biological Conversation*, vol. 184, pp. 300-309, 2015.
[2] M.P.O. Olsson, P. Widén, and J.L. Larkin, "Effectiveness of a highway overpass to promote landscape connectivity and movement of moose and roe deer in Sweden," *Landscape and Urban Planning*, vol. 85, issue 2, pp. 133-139, 2008.
[3] A. Benten, T. Hothorm, T. Vor, and Ch. Ammer, "Wildlife warning reflectors do not mitigate wildlife–vehicle collisions on roads," *Accident Analysis & Prevention*, vol. 120, pp. 64-73. 2018.
[4] M.P. Juijser, E.R. Fairbank, W. Camel-Means, J. Graham, V. Watson, P. Basting, D. Besker, "Effectiveness of short sections of wildlife fencing and crossing structures along highways in reducing wildlife–vehicle collisions and providing safe crossing opportunities for large mammals," *Biological Conservation*, vol. 197, pp. 61-68, 2016.
[5] D. Beben, "Crossings Construction as a Method of Animal Conservation," *Transportation Research Procedia*, vol. 14, pp. 474-483.
[6] L. Corlatti, K. Hacklānder, and F. Frey-Roos, "Ability of wildlife overpasses to provide connectivity and prevent genetic isolation," *Conserv. Biol*, vol. 23, pp. 548-556, 2009.
[7] P.A. White, "*Getting up to speed: a conservationist's guide to wildlife and highways,*" *Defenders of Wildlife*, 2007.
[8] R. Bocek, H. Kurth, and V. Křístek, The new construction system of ecological bridge (In Czech. *Nový konstrukční systém ekologických mostů*).