The Urban Lab of Europe!

JOURNAL

PROJECT

Urban infra revolution - Circular economy materials and novel method development to produce recyclable and functional urban construction products

Lappeenranta, Finland

TOPIC

Circular economy

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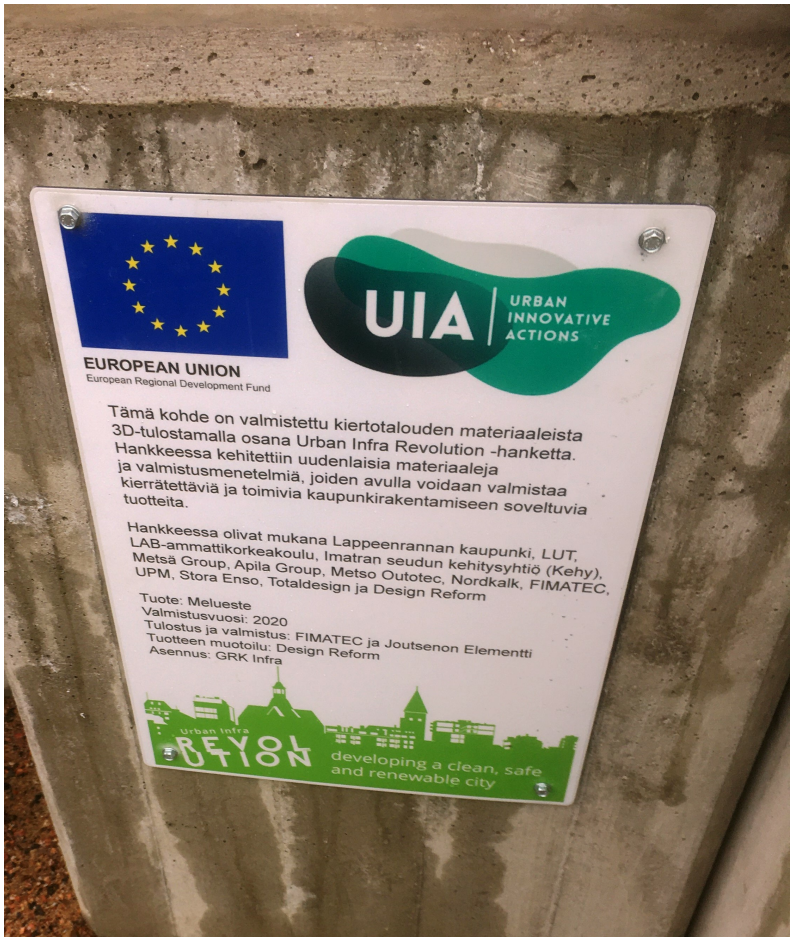
Journal n 06: Urban Infra Revolution: The Urban Infra Revolution project implementation

See on UIA website



The article summarizes the project implementation and comments the most important problems that occurred during the project. Despite the difficulties, the consortium achieved the main project goals by the end of 2020. Moreover, the consortium members finalised with own resources the implementation of the planned prototype solution – noise barrier in full scale.

Executive summary

The sixth Journal describes and analyses the Urban Infra Revolution (UIR) project implementation. The project was successfully finished in December 2020. The most obvious results are the new material created and the technology developed for circular economy. They have been applied in prototype products such as a skate park infrastructure and noise barriers in Lappeenranta city. Despite the crisis caused by the COVID-19 pandemic, the main goals of the project have been reached.

The journal provides a detailed analysis of the project implementation, not only in the last period from November 2020 to the end of December 2020, but also during the whole project duration. The main attention is focused on the main project results, especially the measurable ones, such as the prototypes for the skate park infrastructure and the noise barriers. Furthermore, the important outcomes of the project were the enhancement of the

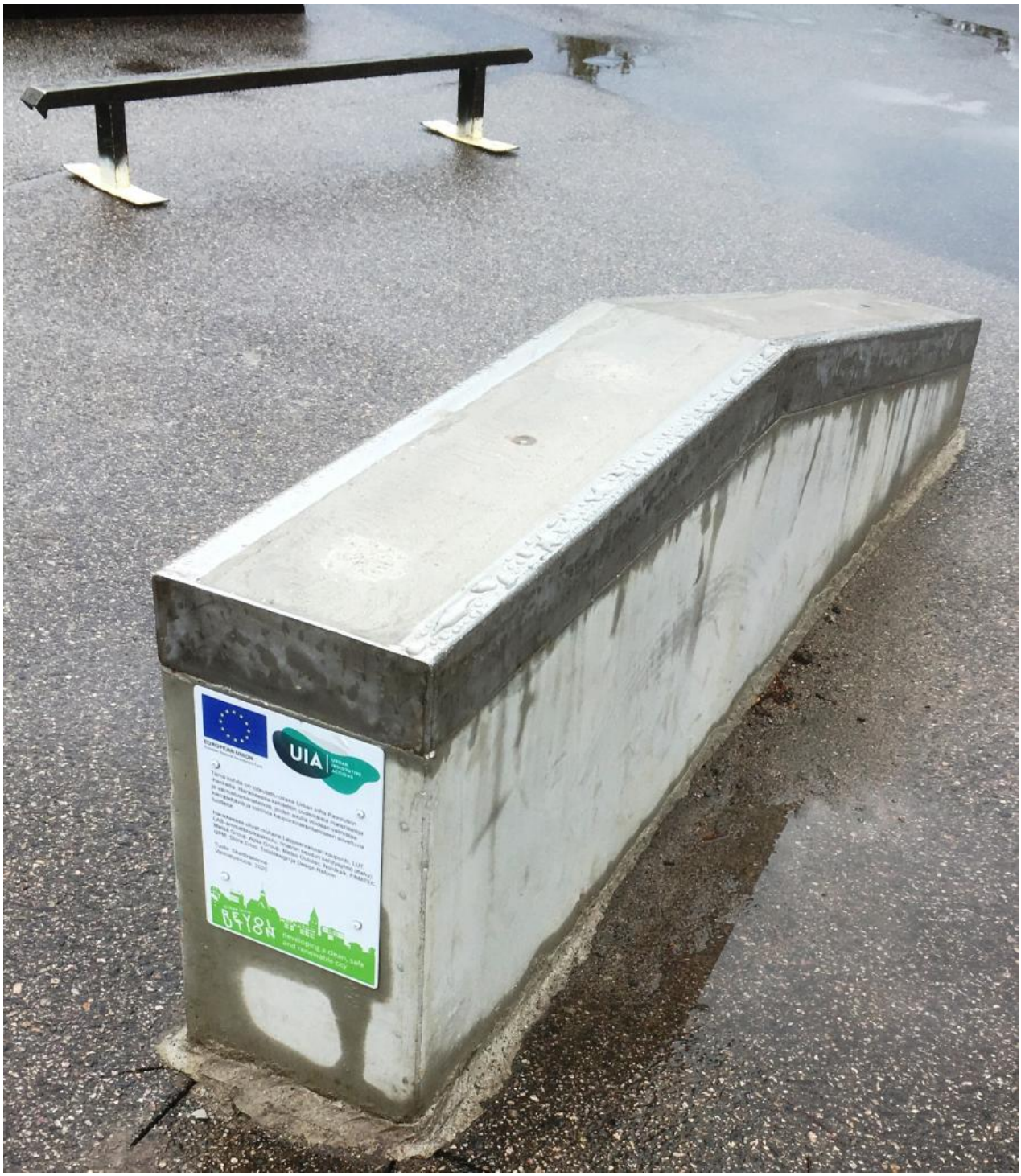
circular economy in the region and the network developed thanks to the cooperation between the business and public institutions involved in the project.
Other sections of the journal are: the presentation, the main lessons learned in the most important areas of the project - such as: leadership for implementation, public procurement, integrated cross-departmental working, adopting a participative approach, monitoring and evaluation, communicating with target beneficiaries, upscaling - and other relevant aspects of the project also related to the future.

The last section of the journal presents the summary of the project implementation and comments the most important problems that occurred during its implementation. Despite the difficulties, the consortium achieved the main project goals by the end of 2020. Moreover, the consortium members finalised with own resources the implementation of the planned prototype solution – noise barriers in full scale. The journal also summarizes some project outcomes and presents some recommendations to other urban authorities that wish to implement similar innovative projects.

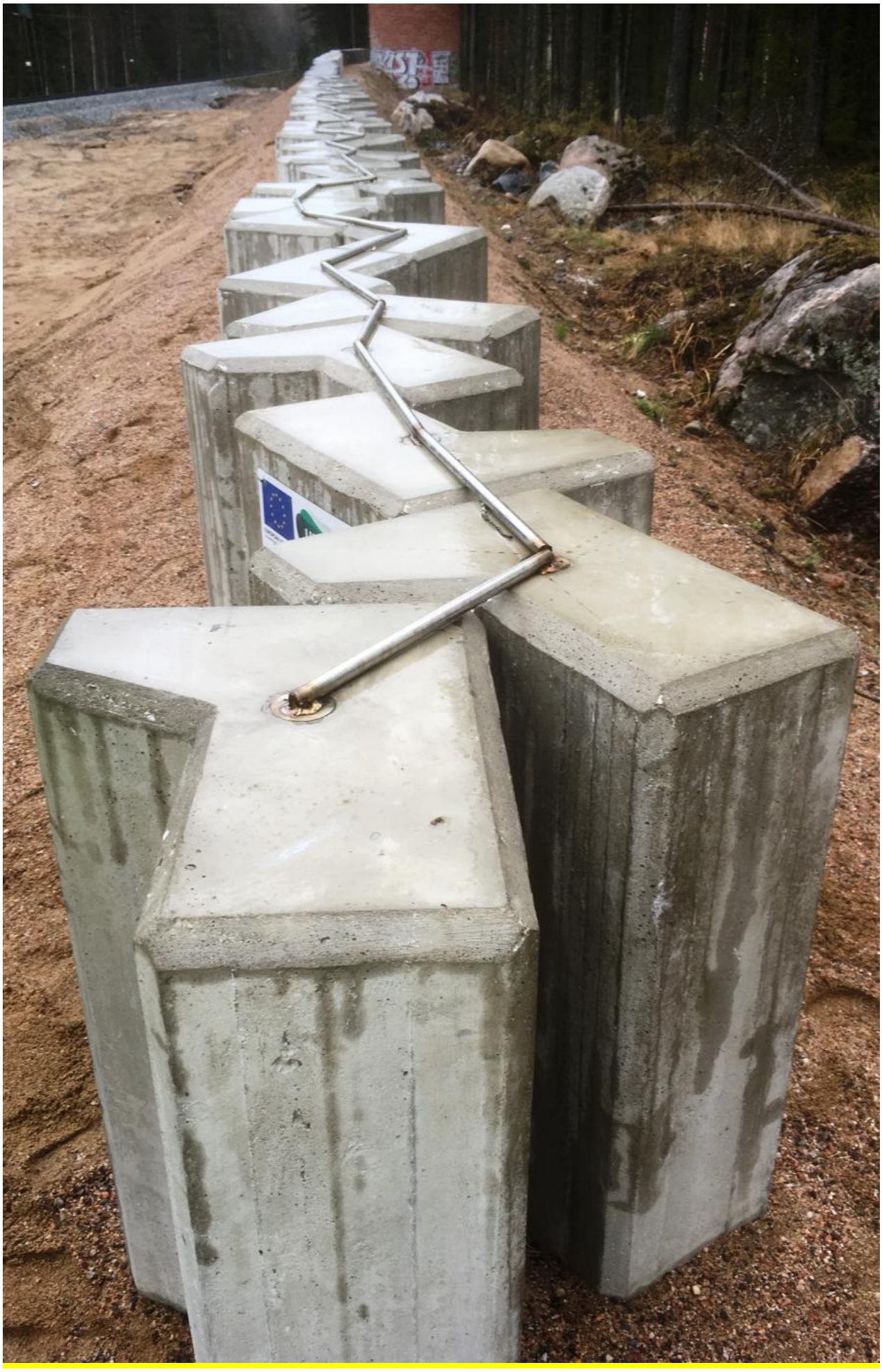
Project's progress

What has happened with the project since its end date

Urban infra revolution project was finished in the end of year 2020. The last 2 months was the period of intensive work on prototypes. The basic works were finished in this time. The element of the skate park was accomplished (Fig. 1). Performance of this element was important in the point of view of collaboration with the local community. The project of skate park element was the winner organized competition in the framework of the project. The organization during this event allowed to involve the local society in the project activities.



In addition, the fundaments of the noise barrier were installed (Figs. 2 and 3). At the same time, the 3D printed elements for noise barrier were produced, unfortunately, because of the weather, all construction works were not accomplished on time. The leader of the consortium finished this work in the first part of 2021 at their own cost. The noise barrier was installed near Pontus School in Lappeenranta. The sound-absorbing screen in this place will block the noise from railway trains. The noise barrier is a large-scale prototype solution. It has over 100 m length and made in major part in 3D printing technology. It was designed to look organic and multidimensional compared to solutions based on conventional casting technology.



In the meantime, some barriers to local regulations have been solved. The proper standards for the product were defined. The main requirements for noise barriers are the common European product standards set in the EN 14388:2015 and the Finnish Transport Infrastructure Agency regulations. Such kind of product requires characteristics connected with i.e. sound absorption performance as well as resistance to loads and forest fire. Geopolymer composites are a new material not yet covered by EU construction product standards. Fortunately, the law allows to install prototype solutions for research purposes without confirmation of all requirements and investigate this property during the life cycle of the products.

That period was also an intensive work on closing all research and analyses provided by the project. The most important results were summarized. They included:

- Design of closed-loop geopolymer composite material that could replace the concrete. The new material includes 99,6 %

of circulative materials and it is 100 % recyclable and printable. It consist only 0,4 % of virgin natural materials, so it is a solution in line with circular economy goals. The most important circulative materials were biomass boilers, chemical recovery cycles of pulp mills, and a local mine that produces large amounts of tailings.

- The environmental analysis by using life cycle assessment (LCA) showed that the environmental impact of geopolymer composites is highly dependent on the recipe. It was varied between +40% and -98% depending on the quality and quantity of the raw materials used in the geopolymer composites compared to conventional concrete.
- Design materials based on local sources (not more than 100 km). Almost all industrial side streams were local. The only exception was coal ash, which was obtained from the commercial production factory in Hausjärvi, 200 km away from Lappeenranta. The availability, quantity, and quality of side streams were varied during the project and used for an adjustment of recipes. One of the most important findings of the UIR project was the identification of commercial opportunities related to tailings, which can be enriched in this context by means of geopolymer chemistry. This waste material has a potential to replace natural sand as the fine aggregate used in construction-grade geopolymer materials.
- Improvement of new materials for arctic conditions of the north taking into consideration physical and chemical standards, including exposition to different kinds of industrial or weather conditions (such as water and frost). The materials were tested against standard tests of the construction industry, including durability.
- Design and performance of revolutionary, aesthetic and safe multifunctional structures for urban architecture, for example, a better shape that attenuates noise compared to other analogous products. The prototype solution was positively evaluated by more than 75 % of the interviewees because of aesthetic values, especially a new kind of shape, increased well-being, and attractiveness of the city.
- Creation of an advanced business model of closed-loop circular economy. It is predicted that it would generate 50-200 new jobs directly or indirectly to local industrial organizations during the next 5-8 years.
- Design ways for upscaling technology. According to the estimation, about 25 % of the delivery amount of noise barriers of Finnish railway transportation is possible to build with 3-4 printers. It is possible to spread the solutions with low carbon footprint, where low emission raw materials and manufacturing technologies were utilized in different stages of the production chain and thanks to it spread environmental effect.

What is the project's plan for long-term sustainability

One of the most important elements of the project is a long-term sustainability of predicted project's outcomes. The plan for a long-term sustainability was created and the city modified its strategy of development to be coherent with the goals of the circular economy.
Firstly, the prestigious prize of the European Green Leaf Award 2021 title given in a competition organised by the European Commission was assigned to the city of Lappeenranta for the visible commitment to developing climate work. One of the commitments is related to the activities undertaken in the project framework. Their realization brings the city closer to the main goal - becoming carbon neutral by 2030.
Secondly, in the project's framework, the complex model of future development was created. It estimates that the local business will be reinforced by the project activities and thanks to the project's ideas, between 50 and 200 new jobs will be generated in a local industrial organization during the next 5-8 years. Finally, the some new collaborations were created thanks to the project activities connected i.a. with supporting other Finnish cities in application for innovative grants and the transfer of know-how between them.
Nevertheless, the full assessment of project effects will be possible in the perspective of over a dozen years. In the future it will be showed if the perspectives for local business development presented in the created models become true. In a long perspective, the local business is the main target group for the long-term benefits from the project outputs.

Generated Knowledge

Lessons learned

1. Leadership for implementation

In the last period, the management was very effective. It was an effect of changing the management strategy during the project. Firstly, the management was quite participative with great freedom of action left to each consortium partner. It evolved more towards the authoritative one, but remained in the participatory area all time. From the end of the project perspective, it was a quite successful aspect of the project, but also one of the most interesting, where some lessons have been learnt.

The management structure described in the project application was implemented in practice. The main responsible institution for the whole activities was the leader – the city of Lappeenranta. The leader was supported by a Steering Committee, in which the representatives of the key partners were involved. The main role of the leader was supervising and coordinating all activities and tasks according to the project schedule and in the planned budget framework. The leadership was quite challenging because of the large size of the consortium, and in the last phase also the COVID-19 pandemic. The COVID-19 pandemic forced the changing the style of work - many tasks were performed using online tools. Fortunately, the basic IT supporting systems were implemented at the beginning of the project and partners used it. The main change was connected with meeting organizations. Instead, in a traditional way, during the COVID-19 pandemic, they were conducted using web

meeting platforms - MS Teams.

Furthermore, the important issue was a financial participation of the project partners (required by call rules). The partners' contribution was 20 % of the total budget. The required contribution made the consortium partners feel more responsible for the undertaken activities.

2. Public procurement

In the area of public procurement, there were no problematic issues. There were performed in a traditional way and supported by the experience of the Lappeenranta city hall team. They were fully in line with the procedures presented in the grant application and completed in the first stage of the project.

3. Integrated cross-departmental working

In the last period of the project, the effective collaboration between different departments of the city of Lappeenranta was continued. During the whole project, the cross-departmental cooperation was supported by meetings, firstly the traditional one, and next by using virtual tools, for example, MS Teams. The common activities during the project include the decision-making process as well as activities related to project implementation and promotion. It was especially important during the last phase – prototype implementation. It requires interdepartmental collaboration and some consensus in the final stage of the project.

4. Adopting a participative approach

The participative approach was strongly implemented into the project management procedures. The communication between the consortium members was excellent, and they actively participated in the decisions taken by the consortium in different areas of the project. The decision-making process requires the opinion of key partners, additionally each partner could influence on the consortium's decisions in particular are connected with their activities. The regular meetings enforcement the participative approach. It also helped to create better and more effective solutions for the project. The open dialogue was supported by the leader.

5. Monitoring and evaluation

The main problem in the area of monitoring and evaluation was the large size of the consortium. The city of Lappeenranta as a consortium leader was responsible for monitoring and evaluation of the project activities. These tasks are supported by an indicator-based system. The indicators were strictly connected with this described in in the grant application. The system occurred quite effective. The consortium members had updated data in the system and they could also check the project progress. The monitoring system was also helpful in the last period of the project. It allowed to re-analyse all project documentation and achieved progress, especially objectives, milestones, and outcomes.

6. Communicating with target beneficiaries

Communicating with target beneficiaries was a strong point of the UIR project. The communication campaign was quite spread and addressed to different target groups. The communication activities were well coordinated. In the last period of the project, digital communication tools have been used widely in the project. The communication activities were dedicated to different target groups. During the last two months, the communication was based on web pages and virtual content.

The useful promotion tool was the wined award of European Green Leaf Award 2021 for the city of Lappeenranta (Finland) as the greenest city in Europe (Fig. 4). This website were also used for presentation the final results of the project as a bilingual publication in English and in Finnish.

The virtual tools interest is also growing all time. The two city models were created: a browser-based, and based on a video game engine. Both are efficient interactive tools. Additionally, a separate Virtual Reality Expo was built in the Venla meeting room of Lappeenranta City Hall, where the public can explore a virtual city on a grander scale. The possibility of visit depends on Covid-19 pandemic restrictions.

7. Upscaling

The upscaling in the project had two dimensions. One is strictly connected with the project goals – it is a performance large-scale prototype and this part was successfully accomplished. The final developed version of the 3D printer was capable of producing new kinds of urban products. Some prototype solutions were performed, including noise barrier elements, benches, planters, and skate park structures (Fig. 5). They were placed around Lappeenranta and Imatra.

The second one is upscaling the technology and materials for future applications, including other regions. For this second dimension, some challenges have been defined. The most important is 3D printer technology due to issues with the performance and uniformity of the geopolymer material. It still needs to be developed before it can be used for industrial-scale production. The repetitiveness of the element and dimensional stability must be improved. The estimations provided in the project show that 3D printing will be deployed on a large scale in the construction industry within 5 to 10 years. The other challenge is the material itself. A computer-based scaling exercise, provided in the project framework, suggested that the original material costs of geopolymer composites were approximately 32% higher than those of conventional concrete of the same grade (M45). The high price of the material could be a crucial factor that decides about their widespread. With the benefits from the environmental point of view and very good material properties, including durability, the price still is a key factor about commercial applications.

Table 1 presents the implementation challenges for the UIR project. The main areas are grouped in seven thematic areas. According to the risk level, the challenging areas are marked as follows: red: high risk and important for the project, yellow: medium risk and important, and green: low risk and important or the tasks in the area were successfully completed.

TABLE 1: MAPPING THE URBAN INFRA REVOLUTION PROJECT AGAINST THE ESTABLISHED UIA CHALLENGES

Challenge	Level	Observations
1. Leadership for implementation	Low	The city of Lappeenranta was the organization responsible for the leadership and coordination of the project. The leadership had a participative style of taking into consideration the opinions of all partners. The main advantage of this solution was the common work with the solution. The main disadvantage – delays in the project. The leadership was, without doubt, consistent and accepted by all partners. The city organised regular meetings where all problems were discussed and solved. The management was supported by IT technologies, especially in the last period of the project.
2. Public procurement	Low	The public procurement procedures planned for the project were successfully completed in the first stage of the project. The procedures were made in the traditional way. The consortium leader was responsible for the public procurement of the project.
3. Integrated cross-departmental working	Low	The cross-departmental communication was connected mainly with the consortium leader - Lappeenranta city. In the case of other partners, the whole organization participated in the project activities or only one department was involved. The cooperation between the departments of the city hall was efficient and a good working relationship was established between the involved divisions. It was beneficial for the activities organized as promotional events. This collaboration did not cause any complications, and the results were timely delivered to particular units.
4. Adopting a participative approach	Low	The participative approach was a strong point of the project. All partners were involved in the decision making process. The very effective collaboration mechanism was built in the project. The consortium members know their role and support each other.

5. Monitoring and evaluation	Low	The monitoring and evaluation procedures were correctly designed. The most challenging aspect in this area was a consortium size. The monitoring procedures warmed to the delays in the schedule of the project, but because of COVID-19 pandemic it was impossible to do some activities to correct it. The main reason of delays in the project was the changeable law connected with restrictions on the COVID-19 pandemic.
6. Communicating with target beneficiaries	Low	Communication with target beneficiaries was a crucial aspect for successful outcomes of the UIR project. During the project , the approach to the communication activities has a little change. The traditional communication way was changed into virtual activities. The project implemented a lot of communicating activities. The most interesting seems to be the virtual support developed by the joined forces, the City of Lappeenranta and LAB University of Applied Sciences and Design Reform. They built two city models: a browser-based one and one based on a video game engine to promote project activities. These tools by using augmented reality show in an attractive and interactive way the project results overview. Moreover, they are tools that professionals can use in urban planning and residents can access to get involved in designing their living environment. More information about these tools were presented in zoom-in 3 (https://www.uia-initiative.eu/en/news/virtual-and-augmented-reality-innovative-tools-supporting-project-implementation-zoomin-3).
7. Upscaling	Medium	Despite the project being successfully accomplished, the upscaling of a technology is still the future task. During the project, some business models had been prepared and they show that the product had a great potential to be implemented in large scale, but the time is needed. However, the prototype solution had been finished some months after the deadline preparation confirmed the technology readiness for implementation. Currently, the most important challenges are: current material standards that hinder the acceptance of geopolymer technology, the availability of industrial side streams varies by location, and the cost of geopolymer production that is higher than for ordinary Portland cement (OPC) .

Recommendations to other urban authorities that wish to implement similar innovative projects

Despite of Covid-19 pandemic, project objectives have been reached. However, from October 2020 to the end of December 2020, the significant progress in Urban Infra Revolution (UIR) project was made, but not the whole activity was accomplished. Because of that, the City of Lappeenranta accomplished some works with own resources. The main barrier to end the whole project activities were issues and regulations connected with the Covid-19 pandemic as well as in the last period the weather that made the construction work impossible.

It should be emphasized, however, that regardless of the difficulties occurring in the project, members of the consortium still decided to implement it with slight changes. Firstly, without the implementation of 3D printing technology. This idea was very innovative and promising, but in practice it was very challenging, especially as it was not able to meet the needs of Finland's construction industry and the harsh climate. Instead of that, the traditional casting technology was used. Secondly, with some limitation of the consortium size and changes of some partners to subcontractors.
The management of such a large consortium was really demanding and time-consuming. Finally, with some limitations of ambition about the final product certification. In the beginning of the project aim was product acceptance procedures and the criteria needed for CE marking were approved by the authorities. In practice, this task was very hard to achieve, because of the short time of the project, especially because the standardization for the geopolymer material itself doesn't exist yet. Instead of that, the consortium decided to choose some products that do not require fulfilling such restrictive regulations as construction materials, for example, noise barriers and skateboard structures. Because of that, this elements were finally selected as piloting products.

The lessons learned in the project show to other urban authorities that wish to implement similar innovative projects that this could be beneficial for the whole region, but it requires a large amount of work and carefully preparation. The basic element is the collaboration with local organizations such as universities, industries, and other stakeholders. Moreover, planning is a crucial element for a the implementation, especially the planning of

the timeline of the project key elements is essential. Eventually, the implementation should be monitored strictly. All the factors are the recipe for a successful project, but what is really crucial are people. Only a strong team with a common vision of the future can guarantee the implementation of the project and its significant potential in the future.

Conclusions

The background for the project was to mitigate the various risks posed by climate change, the Urban Infra Revolution (UIR) project was looking for possibilities to significantly reduce CO2 emissions. 80% reduction of CO2 emissions from 2007 level is the target for 2030 and eliminating waste is the target for 2050. The UIR project designed and tested new solutions to reduce CO2 emissions in urban construction development. It was implemented between November 2017 and December 2020.

The consortium was led by Municipality of Lappeenranta and involved 12 partners, with strictly defined roles: 4 SMEs (Apila Group Ltd., FIMATEC Finnish Intelligent Module Apartments Oy, Design Reform Ltd. And Totaldesign Ltd.), 5 private enterprises (UPM-Kymmene Oyj, Outotec Ltd., Nordkalk Corporation, Metsäliitto Cooperative, and Stora Enso International Oy), 2 higher education and research institutes (Lappeenranta University of Technology and Saimaa University of Applied Sciences) and 1 region development company (Imatra). The role of the Lappeenranta University of Technology was both material and manufacturing technology development and business models. The university also supported sustainable analyses. Apila Group and Outotec were designing the material recipes and tested it in the laboratory scale. This activity was supported by FIMAtec. The forest industry companies were provided side stream materials as well as Nordkalk provided tailings to be used as raw material for the new material. FIMAtec was also implemented 3D printing of the pilot structures. The main role of the Saimaa University of Applied Sciences was the development of information models of the built environment. There was multidimensional data in the information models. Utilizing the modeling project the results were made visible and the design and city planning know-how of the design companies partnering the project were provided for the use of planners and citizens. The other partners supported particular activities during the whole project duration.

Despite the COVID-19 pandemic, and thanks to effective collaboration, the project was successfully accomplished. Consecutive milestones had been achieved, and the main four goals were reached, including:

- Enhanced sustainable construction in cities through promoting sustainable urban construction.
- Developed a revolutionary urban design.
- Enhanced and circular economy in local urban construction businesses by creating a local urban construction business connected with this idea).
- Developed climate change adaptation and mitigation by helping society to adapt to and mitigate climate change.

The last period of the project was connected with the scaling up of the technology, including the preparation of prototype solutions. Two prototypes were prepared. One of them is element for the skate park and the second one – noise barrier. Both are localized in Lappeenranta, Finland. These elements are made from geopolymer materials and are eco-friendly solutions. Materials for the prototypes are based on local waste and by-products from the local industry. Additionally, the noise barrier is made by using 3D printing technology. The main aims of the project have been successfully achieved. The most important results were described in the final publication accessible in English and Finnish.

Circular economy

See on UIA website