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Author:
Kinga Korniejenko
UIA Expert

URBAN INNOVATIVE ACTIONS

The Urban Lab of Europe !

The Urban infra revolution project Journal N° 2

*Project led by the **City of Lappeenranta***

CIRCULAR ECONOMY

European Union
European Regional Development Fund

Région Hauts-de-France

The Urban infra revolution project

Urban infra revolution will test new solutions to reduce CO2-emissions in urban construction development. Sidestreams from industry (ashes, green liquor dregs, tailings, construction waste) will be utilized in urban construction by combining them into a high-value material to replace concrete. Novel material formulas will be created containing suitable side streams to be used as geopolymer binder (replacing cement) and as inorganic aggregates in geocomposites. An innovative bio-fibre reinforced geo-composites will be developed to achieve the high standards of construction industry. Automated, on-site, fast and versatile additive manufacturing construction system, without molds, will be tested in comprehensive urban scale. The material and the piloted technology will be multifunctional and enable aesthetic design with revolutionary shapes with very low CO2 emissions. Selected pilot structures will be manufactured within the urban infra and their properties are tested in real climate conditions. To implement and finally benefit locally the project results, a viable sustainable business ecosystem will be designed and environmental and socioeconomic impacts assessed.

Partnership

- City of Lappeenranta
- Apila Group
- UPM Kymmene
- Lappeenranta University of Technology
- Fimatec
- Outotec
- Imatra Region Development Company Ltd.
- Nordkalk
- Design Reform
- Metsä Group
- Saimaan ammattikorkeakoulu
- Total Design
- Stora Enso Oyj

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1. Executive summary

The second edition of Journal (third article presented the project) describes and analyses the progress of the Urban infra revolution project in the last six months, from March 2019 to end of September 2019. During this period, the progress of the main tasks for the project is in line with project schedule. The some small delays are caused by specific technical problems.

The second section is a short information about the current project state. Moreover, this section reminds the most important information about the project and their goals.

The next section provides an update about the project status, especially in the area of development technical solutions and challenging connected with joining material and technology. Three main innovative area: material, production process and products are presented and each of them is analysed. The difficulties, barriers and challenges linked to the innovative nature of the project are presented. This part also describe the feasibility for the project, including coherence planned products with regulations on local, national and EU level. The sustainability of the material and planned technology have been taken into consideration, because it is an important aspect for the product implementation.

The fourth part of the article describes different area of the project implementation. The project, started in November 2017, is now at its half-way through. During the first half of the project a significant progress has been achieved. This section presents the activities that have been implemented for ensuring the right conditions for the project implementation and lowering the barriers in the following areas: leadership for implementation, public procurement, integrated cross-departmental working, adopting a participative approach, monitoring and evaluation, communicating with target beneficiaries, upscaling and others.

The last section presents the steps that will be provided in the nearest future, including ensure the sustainability of the project after the UIA funding ends. It also presents information about additional value from the project activities.

2. Introduction

"Sustainable development of cities has become one of the most discussed topics nowadays. Since the ecological and environmental consequences of the world economies' development have raised worries, the ideas of how to reduce the environmental impact have been under active discussions. Cities have become locations accumulating industries, organizations, and citizens, where each player has a role, acting individually and mutually, simultaneously affecting other players"[1].

The Urban infra revolution is an high innovative urban development project in three major innovative aspects: materials, process and product. The expected result of the project is to design new materials for circular economy that could be manufactured by 3D printing and they will be composite with tailored properties that are in the same time environmentally friendly and cost effective. The long-term goal is in turn local economy in circular economy. This goal required development the new eco-friendly materials and technologies. This innovative solutions will be contribute in creating carbon free and waste free cities by reduced amount of unutilised waste from local industries and lower CO_2 emissions. The project will be some kind of case study for future holistic solutions for developing climate change adaptation and mitigation that enhance the storage of carbon in process of raw material sourcing, manufacturing, transportation, installation and assembly. The project allows to introduce the circle economy through closing the loop with 3D printable, recyclable geopolymer composites made of side-streams in the Lappeenranta city.

Over the past months, the project received more reliable form – road / railway noise barrier. The consortium, after discussion, comes to an agreement that the final product of for the planned works will be sound-absorbing screen against the noise form railway. The place for realization has been chosen and the formal documents are under the progress. The activities on different level are undertaken. The works connected with material development are continued as well as the construction of 3D printing devices.

A lot of additional analysis has been conducted from different points of view. One of the most valuable is master thesis that have been prepared and defenced on Lappeenranta-Lahti University of Technology in School of Business and Management as a part of Master's Programme: Supply Management. The author Evgeniya Tsytsyna under the supervision of Professor Katrina Lintukangas and Professor Veli Matti Virolainen, presents on 83 pages the topic: "Risks and benefits of a circular economy within geopolymer ecosystem for South Karelia region". The research show great potential of the project for the developing circular economy, but also conclude that there are a lot of risks related to the project implementation, especially connected with legislative framework, economic and technological development. All of them are discussed in the next part of this article and presented in the project framework.

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[1] Tsytsyna E., 2019, *Risks and benefits of a circular economy within geopolymer ecosystem for South Karelia region,* https://lutpub.lut.fi/handle/10024/159374

3. Project update

3.1 Material development - acoustic isolation

The project approach is based on a highly innovative solution, which combines material innovation and modern manufacturing technologies – 3D printing. The production should be close to the building site, use local raw materials and close the material loop in order to diminish the CO_2 emissions of urban building and enhance zero waste arctic cities. The first half of the project was dedicated for creating the composites based on local raw materials such as: flotation sand, green liquor sludge, ashes and waste fibres (side-streams of the forest industry). The material composition has been created and tested for additive manufacturing technology (Figure 1), however there is still some work to do in this area.

Team members in laboratory – study visit during the project meeting

Meantime, the new challenges appeared. Some of them, as material durability and safety, were discussed in the previous article. The newest challenges are connected with planned application for sound-absorbing screens. The research shows that geopolymer composites are sound-absorbing, especially foamed one[2], but not only. The composites with sand[3] and demolition waste[4] give also positive effect as a noise barrier. This effect could be also increased

[2] Hung T-C., Huang J-S., Wang Y-W., Lin K-Y., 2014, Inorganic polymeric foam as a sound absorbing and insulating material, Construction and Building Materials, 50, 328-334.

[3] Perná I., Hanzlíček T., Straka P., Steinerová M., 2009, Acoustic Absorption Of Geopolymer/Sand Mixture, Ceramics – Silikáty, 53 (1), 48-51.

[4] Arenas C., Luna-Galiano Y., Leiva C., Vilches L.F., Arroyo F., Villegas, R., Fernández-Pereira C., 2017, *Development of a fly ash-based geo-polymeric concrete with construction and demolition wastes as aggregates in acoustic barriers*, Construction and Building Materials, 134, 433-442.

by proper admixtures, such as rubber[5], including waste coming from used tires. The additive waste rubber (2 - 6 wt%) for geopolymer concrete is able to satisfy both higher sound transmission loss and better sound absorption compared to conventional concrete samples. In the case of the project, this kind of additives could be by-products from the forest industry. The wood as a material has very good sound-absorbing properties. Additionally, the planned technology support this kind of solution. Despite the traditional casting technology, in the case of 3D printing, the surface of the product has a characteristic structure of layers with pattern. In a lot of cases, lack of smooth surface could be some barrier for application, but in case of sound-absorbing wall it increases isolation properties.

The future challenges are related with large scale implementation. The project emphasizes on new products by functionalized approach that will have strong societal and environmental impact, including energy efficiency, reduction of carbon foot-print, waste reduction and development of idea of circular economy. The works in the area of environmental impact are discussed in section 3.4, but also to find the constant place on the market the product should be also cost effective. This kind of optimization could decide at extension of the potential application.

3.2 Process development – workability

The second innovative element is connected with developing the additive manufacturing technology (AM) – 3D printing for geopolymer admixtures. The first step of works in this area were place in June 2019. On this stage, the main challenge is the combination of the new materials, including reinforcement by bio-fibres with advanced technology to receive effective process (Figure 2).

Discussion between work team members

[5] Gandoman M., Kokabi M., 2015, *Sound barrier properties of sustainable waste rubber/geopolymer concretes*, Iranian Polymer Journal, 24 (2), 105–112.

Nowadays, the main challenge is connected with proper selection of material for 3D printing technology. The most important parameters that decide about material behaviour are: reactivity and stability. They decide about possibility to application material in additive technology. The further challenge is the selection of proper fibre technology. For this purpose it is required further improvement material and technology - the optimization of a lot of elements, especially the development of time and parameters for reactivity composites, optimization of the construction of devices, including nozzle construction (materials of nozzle, dimensions, potential effectiveness and critical work parameters), an optimization of construction according the thickness of the layers (coherency between materials properties and technical solutions) and modifications according to filling percentage, filling geometry (parameters of the work such as effectiveness of 3D printing).

The reactivity is a quite complex problem, especially if the material have limited time to achieve required properties. The 3D printing process is involved applying by layers. The particular layer must have a proper strength to be possible applied to another one in short time. At the same time it has to be also enough 'elastic' to be bonded with previous layer. Taking under consideration the numbers of factors that influence this process, such as[6] type of raw materials containing aluminosilicate, chemical and psychical composition of raw material, especially surface area, size of particles and amount of aluminium and reactive silicon, glassy phase content in the raw material, type and concentration of alkalis, alkaline liquid-to-raw material ratio, water ratio, pre-curing conditions, curing temperature, pressure and temperature and other, this task seems to be almost impossible. Additionally, there are new factors that are connected with limitation caused by 3D printing technology such as necessity providing curing process in relatively low temperature. It happens that the process required many trials before receiving the final products.

The fiber technology is also potential technical challenge. On the one side, the long fibers are more effective as a reinforcement, but their application could be limited by the technology. On the other side, the short fibers are easier to applied, but they just reinforced the whole structure and not a particular part because of random arrangement.

The next challenge will be process stabilization, including insurance that will be performing and replicable, especially in low temperature and using changeable materials during the 3D printing process. In the future, it will be also necessary to ensure process control for increasing the quality of final products. Low temperatures significantly reduce the curing process for geopolymers and in case of temperature below zero, it could be impossible to initiate. This kind of conditions are typical for Finland's climate - arctic weather.

3.3 Product development – feasibility analysis

The project's main implementation will be sound-absorbing screens produced by 3D printing technology with using secondary raw materials. The solution will be exemplary of circular economy application. The first steps to design planned product have been undertaken. The final

[6] Singh N.B., 2018., *Fly Ash-Based Geopolymer Binder: A Future Construction Material*, Minerals 8 (7), 299-320.

product has been defined and the place has been chosen - it will be located behind a kinder garden and a school blocking the noise from the railway (Figure 3A & 3B).

Planned application for the project results – noise wall (inspection for the future location)
Source: Received from the city of Lappeenranta

The project and visualisation of new element will be performed using the 3D modelling. Because of the weather limitation the first construction works should start in spring 2020.

Meanwhile, the project is focusing on the legislative works. Because of using a new material and technology where a raw materials came from wastes and by-products. The introduction of new product on the market required fulfilling a lot of regulations, especially if it is a construction area. Additionally, the separate risk is related with applying side-streams as a material for production. The legislation in this area required confirmation environmental safety, including lack of hazardous and toxic elements (Figure 3C). In this case the additional risk is connected with investment in new technology and achieving reliable economic profits.

Presentation of main legislative challenges

Other potential problems could be society awareness and acceptance of the 'waste products'. The using side streams in city constructions may awake concerns about health and safety. The technological solutions required not only a positive result in additional quality procedures and leaching tests, but also need to be presented for a local society, as these materials require a lot of time and efforts.

3.4 Product development – LCA analysis

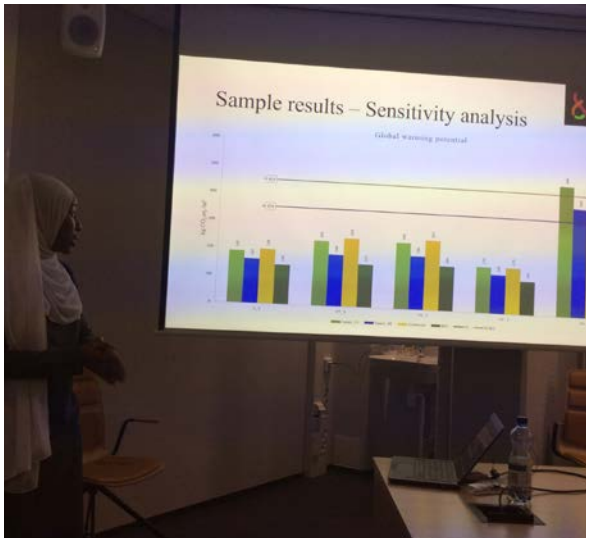
A new challenge is the Life Cycle Analysis (LCA) conducted for materials, technologies and products. The full environmental analysis contain following areas:

- Basic LCA analysis - potential environmental impacts from resource recovery of waste materials that are useful as an input for the manufacturing. This will help to do life cycle

design right at the beginning of the new product development process.

- End of Life (EoL) environmental benefits and burdens will be identified for each potential waste stream. The new product should be modelled using LCA including all the inventory such as raw materials, energy, water etc.
- Life cycle impact assessment (LCIA),
- Life cycle energy analysis (LCEA),
- Life-cycle cost analysis (LCCA).

The environmental impacts should be analyzed in different categories of damage at resources, human health & ecosystems, including various sub-categories such as climate change. The first attempt to environmental analysis shows that the largest environmental impact is connected with using activator for geopolymerization process (Figure 4).



Presentation first results of LCA for the project results

The future challenge connected with first attempt to environmental analysis is to find the alternative ways for silica sources for the process trying to make it more environmental friendly.

4. Implementation status

4.1 Leadership for implementation

The management is provided by the project leader - the city of Lappeenranta supported by proper bodies such as the Steering Committee. The leadership of the project is strong, on the level of the project as well as on work package level, including operational management. The communication between the partners goes smoothly and it is supported by regular meetings where the knowledge is shared. All partners are actively involved in the decision making process. The frequent contacts and briefings makes sure that the leaders are well informed about the progress in each domain.

4.2 Public procurement

The public procurement is fully in line with procedures presented in grant. All the procedures implemented in first stage of the project (first half year) in this area. It was realized by traditional way without any problems. The public procurement procedures predicted for the project have been successfully finished.

4.3 Integrated cross-departmental working

The cooperation between the departments goes smootly and common activities are successfully implemented, including those undertaken in the last period. The first is the decision about prototype solution - sound-absorbing screen,that required cross-departmental decision process and next working together to find optimal location for the sound barrier. These decision has been made after analysing all data and inter-department consultation. The overall situation and needs of the citizens has been taken into consideration. The process was time-consuming, but the final effect is satisfying for all involved departments. The most involved in this process were the Design Reform and Total Design. They are together creating an outlook and form design of prototype solution - the noise barrier.

The second one is organizing common event for the citizens, connected with the design and modelling of Lappeenranta future visions for 2030 and 2050. In this event, not only the different departments have been involved, but also involvement of other partners such as the Saimaa University of Applied Sciences and Design Reform.

4.4 Adopting a participative approach

The project has a large number of the participating organizations form different sectors, which play different roles in the project. There are engagement in different project activities (Table 1)[7].

[7] Tsytsyna E., 2019, *Risks and benefits of a circular economy within geopolymer ecosystem for South Karelia region,* https://lutpub.lut.fi/handle/10024/159374

TABLE 1: CONSORTIUM MAPPING – THE URBAN INFRA REVOLUTION PROJECT

Partner	Sector	Role in the project
The city of Lappeenranta	City	Leader, grant holder, coordination activities.
Apila Group Ltd.	SME	Knowledge creation and sharing Technology, design, and production
FIMATEC Finnish Intelligent Module Apartments Oy	SME	Technology, design, and production
Design Reform Ltd.	SME	Technology, design, and production
Totaldesign Ltd.	SME	Technology, design, and production
UPM-Kymmene Oyj	Private enterprise (outside SME sector)	Materials supply
Outotec Ltd.	Private enterprise (outside SME sector)	Materials supply Technology, design, and production
Nordkalk Corporation	Private enterprise (outside SME sector)	Materials supply
Metsäliitto Cooperative	Private enterprise (outside SME sector)	Materials supply
Stora Enso International Oy	Private enterprise (outside SME sector)	Materials supply
Lappeenranta University of Technology	Higher education and research institutes	Knowledge creation and sharing Technology, design, and production
Saimaa University of Applied Sciences	Higher education and research institutes	Technology, design, and production
Imatra	Region Development Company	Knowledge creation and sharing

The participative approach is a strong side of the consortium. Cooperation between the private sector and higher education/knowledge institutes is well developed. The key players are partners in the project and they are strongly involve in the project tasks (Figure 5).

The project partners fully understand their role in the project and cooperate each other. Neverthless, a constant work in this area is required. The most important factor that creates participating approach are regular meetings between the partners. The city well organized this activity, including formal meeting of all consortium as well as informal meetings between the partners where particular challenges are discussed.

Discussion between work team members – representative person form different sectors

4.5 Monitoring and evaluation

The Urban infra revolution project is implemented by large consortium. Because of that, monitoring, evaluation and risk management play really important role. The city of Lappeenranta has implement an indicators-based system to monitor and measure project progress and task compliance. The implemented system based on the indicators from the grant application. Their project status is monitoring periodically and the necessary data are up-dated. Additionally, indicators are consolidated and benchmarked against best practice standards. The common database is very helpful in this area. The partners have on-line access to the up-to-date data.

4.6 Communicating with target beneficiaries

The planned goals for communicating with target beneficiaries are achieved. The communication campaign is well coordinated and it is provided successfully. In the second half of the project, it is essential to communicate effective messages about the results and outcomes of the project, including potential added value. The challenges are relates to the proper target area and groups as well as clear statements. The consortium members decided to develop the traditional communication ways as well as modern one using visualisation techniques. Based on experience of the consortium members, the future visions of Lappeenranta in 2030 and 2050 has been developed and is going to be implemented into virtual reality. This kind of activity gives the valuable tool to communication with young generation.

It is a key challenge to highlight and showcase good practices, to show that collaboration gives real returns in the area of innovation. This is a matter of visualising successes and present the prototype solution could play an important role.

4.7 Upscaling

Upscaling remains a future challenge at the local and regional level as well as in the area of transfer the knowledge to a wider scale – country or EU. During the last period, the consortium identified the main legislative barriers in this area and identify the steps that are necessary to implement new solution, not only as a prototype, but also as a technology of the future. The solution represents new construction materials which existing product standardization and regulations cannot be directly applied. Taking it into consideration the main barrier has been identified in with the regulations and standards framework in Finland

The separate problem is scaling up the solution to the national or international level. The applications required additional research especially connected with using local raw materials - local waste / by-products resources. The technology will required some changes in case of use it for others raw materials. The important issue is providing some changes in material composition depending on the local streams of waste and by-products.

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

Challenge	Level	Observations
1.Leadership for implementation	**Low**	The leadership and coordination are well provided. The project leader is the city of Lappeenranta. It does excellent works in this area - the leadership is clear and consistent. The leader is accepted by all partners. The city takes into consideration communication with all partners and regularly organized meetings where the progress is reported. The communication base on both traditional and modern ways of communication (via the Internet and files on common server). All project partners participate in decision making process. The management of the project is performed in a way to ensure active role of each of the partner.
2.Public procurement	**Low**	The public procurement procedures predicted for the project have been successfully finished. The procurement procedure was traditional way; no specifically innovative types of procurement are applied in this case.
3.Integrated cross-departmental working	**Low**	The project on current stage required cross-departmental communication in the city. The project of noise barrier required many actions undertaken by a few departments together. The city of Lappeenranta has established good working relationships with a number of other departments in the framework of the project. The necessary results are delivered by departments on time. The collaboration is smooth and effective. All departments understand timeframes, risks and implications for the stakeholders the project activities.
4.Adopting a participative approach	**Low**	The consortium is characterized by effective coordination mechanisms. The participative approach is done in parallel with effective management and as thoroughly as the engagement and communication planning. The consortium members have coherent roles and cooperate each other. The consortium tries also different practiced for engaging the local society into the project.
5. Monitoring and evaluation	**Medium**	According the previously planned schedule there are some slight delayed in the project, but they are the consequences of previous periods and late project start. Currently, the works planned in this period are continued and there are logically consequence of achieved results. More time is needed in order to be successfully finished, however the progress is significant. The city of Lappeenranta has succeeded in delivering a robust (qualitative and quantitative) indicators-based monitoring and evaluation methodology as well as a risk management plan.

6. Communicating with target beneficiaries	**Medium**	The communication with target beneficiaries is a very important element for the successful introduction of the outcomes for the Urban infra revolution project. It is because the character of the society that has high level of awareness and want to participate in local government. The communication with target beneficiaries is a great challenge, because each urban investment must be accepted by all inhabitants (local legislation). Nowadays, the implementation of the planned solution – sound-absorbing screen is just only one of the exemplary solution. The city makes the activities that caused that the new material start to exist as eco-friendly solution with the habitants awareness. Contemporary the project members are working on the visualisation the city of the future. In April 2019, there where a place common activity the City of Lappeenranta and the Saimaa University of Applied Sciences and Design Reform. During this meeting the institution development the plan of new ways of communication with citizens with using the virtual modelling of the city. Some areas in the city centre has been modelled and the future visions of 2030 and 2050 are created describing the anticipated city views. This kind of activities has a great potential and could be successful example of effective spread the information between the local community and the project with using new technologies. The communicating with the target users will be still on of the most important challenges in the next period of the project implementation. The further informative activities are required on different levels.
7. Upscaling	**Medium**	The most important challenges are connected with upscaling the technology. The solution represents new construction materials and new technology for manufacturing the final product to which existing product standardization and regulations cannot be directly applied. In the last period, the works connected with law analysis and clarifying the relevant standards and regulations has been conducted. The ways necessary for legalization the material and technology has been identified. The required test for the material and product will be carried out in the next periods. It will be the background for the product acceptance procedure. The other activities that could help with future upscaling the similar products are also performed, such as creating the future visions of Lappeenranta city in 2030 and 2050 with introducing in the city area some elements manufactured by using the new technology.

5. Conclusions and next steps

The article summarizes the key activities that took place in the last months in the Urban infra revolution project. Currently the significant progress in the Urban infra revolution project since March 2019 has been achieved. The Project team is progressing in all open fronts, and the most important milestone has been accomplished in the past months. There are still some delays in the implementation of the project goes, but the problems that appeared have been solved as fast as possible. The most important in the last period was the decision about prototype solution (noise barrier) and their location. The important aspects are also starting the works connected with law analysis and environmental assessment. Currently, the project faced new challenges connected with technology development as well as effective managment to implement its most innovative components.

The article stress overall positive consensus for all project activities, despite some delays. The important aspect is also fact that the projects starts to develop additional values such as the master thesis conducted as a part of Urban Infra Revolution (UIR) project. Such kind of activity helps to promote the project into academic world as well as brings academy closer to practice application and helps turn the ideas into business.

Urban Innovative Actions (UIA) is an Initiative of the European Union that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges. Based on article 8 of ERDF, the Initiative has a total ERDF budget of EUR 372 million for 2014-2020.

UIA projects will produce a wealth of knowledge stemming from the implementation of the innovative solutions for sustainable urban development that are of interest for city practitioners and stakeholders across the EU. This journal is a paper written by a UIA Expert that captures and disseminates the lessons learnt from the project implementation and the good practices identified. The journals will be structured around the main challenges of implementation identified and faced at local level by UIA projects. They will be published on a regular basis on the UIA website.

Urban Innovative Actions

Les Arcuriales
45D rue de Tournai
F- 59000 Lille

+33 (0)3 61 76 59 34
info@uia-initiative.eu
www.uia-initiative.eu

Follow us on **twitter**
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and on **Facebook**.