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Smart City Resilience with Active Citizen Engagement in Helsinki

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Abstract **— New solutions sometimes face challenges in acceptance as improvements and active citizen engagement plays a key role of resilient smart city development. This paper describes a set of actions in Helsinki as part of mySMARTLife project that are aimed to engage citizens in interaction. The actions range from online services and mobile applications to hands-on equipment implementations. They are mainly described from the technological but also from an economic and a social point of view. All the activities are connected to the Helsinki action plan to render the city carbon neutral by 2035. Motivation through positive experience requires practical solutions and reachable goals for approval and impact in smart cities progress.**

Keywords—citizen engagement; user participation; smart city energy solutions; climate change mitigation

I. Introduction

Helsinki is one of the Lighthouse Cities in the mySMARTLife Horizon 2020 project. The main driver for Helsinki climate work originates from the Carbon Neutral Helsinki 2035 Action Plan. A part of the action plan is to create an energy scaling program, namely Energy Renaissance, which means the city's efforts to improve the energy efficiency of the existing building stock and increase the share of renewable energy. The objective to reduce CO_2 emissions provides the framework for mySMARTLife Helsinki. The practical work for buildings energy efficiency consists of Merihaka city district retrofit, Viikki Environmental House smart control and the deployment of the Energy Advisor. Additionally, implementations in the course of the project are made on the city energy infrastructure. The project also arranges co-creation sessions with the residents, solution providers from the private sector, public stakeholders and specialists in energy efficiency as well as the ICT sector on open data development.

II. Objectives and Actions: User Participation to Resilient Smart City Actions

The main instrument to achieve Helsinki City ambitious strategy includes perspective to the planned city interventions on the basis of a rigorous impact assessment, an active citizen engagement in the decision-making process and a structured business approach. The economic framework for big companies and local SMEs and Start-Ups are also considered as part of development work. The overall approach is to introduce new smart city services with consideration to what citizens find interesting and practical. Project work is carried out with set actions however the implementations are discussed with the citizens in order to match the possibilities with real interest to improve quality of life and climate resilience.

Climate smart activity is a system of technical solutions and user experiences. User participation is included equally in actions where new implementations are tangible in everyday life such as indoor heat comfort or commuting to work as well as in actions that use ICT tools to assist with information or to manage specific tasks. Each Lighthouse City currently employs these tools for engaging and raising awareness. Benchmarking of the use of these tools with the ones in follower cities and other European cities may show good practices, distinguishing among participation areas and communication channels. An overview of climate smart solutions and incentives presented in this paper are shown in Fig. 1.

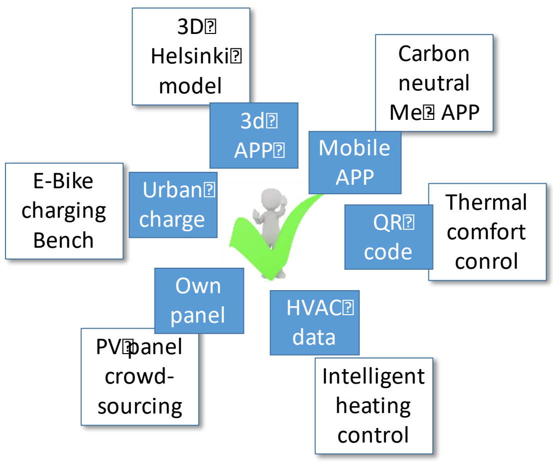

Fig. 1. Solutions and incentives for improving climate resilience.

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A. 3D Helsinki Model

City of Helsinki has an organized climate partner network for local business and it fosters cooperation to reduce emissions and to make companies smarter. The city strategy seeks to make Helsinki the world's most functional city to ensure sustainable growth and to provide good everyday life for all its residents. Smart, comfortable and carbon neutral city can be achieved in holistic collaboration and the 3D City Model with its energy data aims to help achieving these new goals.

Helsinki climate experts recently produced an action plan to render the city carbon neutral by 2035 as part of the city strategy. Energy -related data on the city building stock has now been compiled in a 3D map application labelled Helsinki Energy and Climate Atlas [1]. Executed on the CityGML data model, the semantic 3D city model of Helsinki is part of a toolkit for climate action and adaptation to climate change and published entirely as open data, in accordance with the Helsinki principle of releasing public data for free use. The approach of the city to completely free open data is very noticeable comparing in global scale. The open data platform Helsinki Region Infoshare has also facilitated the change towards a vibrant start-up scene in Helsinki. Open data not only facilitates collaboration opportunities but also as an example showing city purchase data public has opened up a new view for citizens into city administration, and increased people's trust toward the city and its officials. [2] The Energy and Climate Atlas adds a considerable element into bringing practical data available for further utilisation and business potential.

Helsinki Energy and Climate Atlas contains both real and calculated data on buildings. The data includes for example completed energy-efficiency upgrades, energy performance classifications, and the energy sources used for heating and shows the estimated energy consumption of buildings as calculated by the Technical Research Centre of Finland VTT. The calculated scenarios of renovation packages propose several types of measures that concentrate on building envelope, heating, electricity and water consumption. Suggested actions are a practical tool for planning of energy retrofits.

With data on each building, the Energy and Climate Atlas can be used for advanced citywide energy analyses and simulations as well as assessments of specific buildings. Complementary to each other, the 3D atlas and the Kattohukka [3] data base on roof heat loss have been made visually easy for the citizens to access and can be used by property owners, residents, tenants and managers to assess the property's energy consumption. As a communication tool the services also work as reference for the residents to see how other similar buildings in the area perform to motivate energy efficiency measures, for the companies executing and financing renovations, for the real estate management sector to improve service and for the city planners and decision-makers to assess the potential and the available resources for energy efficiency improvements. Ultimately, the information is also practical for the housing market for the privately owned buildings.

The atlas also helps to inform both citizens and enterprises about the changing climate as well as to encourage them to act, for example, by harnessing renewable energy. Furthermore it helps enterprises to recognize clean technology business opportunities.

Plans for new datasets to be added to the atlas involve the renewable energy potential of buildings and data that can be used in climate change adaptation. For example, the atlas could be used to simulate flooding caused by heavy rainfall and to design flood control methods. The Energy and Climate Atlas not only helps Helsinki to achieve climate goals but supports Helsinki's strong IoT perspective in mySMARTLife project, as building energy data is released as open data and visualized on the semantic 3D city model.

B. Carbon Neutral Me application

The high-level strategy on meeting the climate goal focuses on three areas: lowering the consumption of primary energy, increase the role of renewable energy sources and reduce the greenhouse gas emissions. While some of the goals can be achieved at the systemic level, greenhouse gas emissions and especially the carbon footprint would require actions that target on changing the behaviour of the public. Public engagement with carbon and climate change has been an active topic and seen to fit well with the role the cities typically have in environmental awareness and education. According to recent research, while the awareness of climate change is widespread, the understanding and behavioural engagement are far lower. [4]

In order to provide tools for better understanding and engagement, digital tools are seen beneficial in increasing the awareness. While there are numerous apps that provide simple carbon footprint calculation, a service that could utilize data sources in larger extent still is missing. The service would require new data sources and application interfaces (API) in order to monitor daily activities in the background without the need of manual data entries. There are also new systems providing useful data: as an example, the vacuum waste collection system used in Kalasatama and Jätkäsaari districts can provide information on generated waste that could provide useful input on whether recycling or smarter consumption of resources had any potential benefits on daily life.

Mobile apps are somewhat challenging market. On average, smart phone users have 80 apps installed, of which 40 is used on monthly basis and only a few daily. The app –format however has some significant benefits: apps can run in the background of a mobile phone collecting activity information and they can also utilize better the existing functions like Apple Health API or Google Fit. The project has limited resources for marketing activities so to ease the deployment and increase the usage on early stages, it is recommended to combine the carbon neutral app service into some other smart city applications. In the case of Helsinki, there is a Helsinki App that currently is mostly used to collect feedback information on various issues. It is to be extended with library card function and it might be useful for the project to take benefit on the existing use base and introduce the carbon awareness app as a new service to the existing base.

mySMARTLife project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

C. Thermal Comfort control

Since there is solid new scientific evidence that citizens have individual expectations and preferences related to operative temperature levels in buildings, a new human centric thermal comfort concept has been implemented. Ultimate objectives are to improve both thermal satisfaction of occupants and energy efficiency of buildings with this smart control concept.

Thermal satisfaction of occupants can be executed by implementing a new thermal comfort concept controlling thermal environment autonomously. This concept pays attention to both space-related and occupant-related parameters (Fig. 2). On-line monitoring of these key-parameters (Fig. 3) has been delivered to a calculation tool (Human Thermal Model, HTM), which estimates thermal comfort and thermal sensation index values - and adjusts temperature set-point values of an existing control system if necessary.

Energy efficiency of individual buildings can be improved simply by avoiding unnecessary heating and cooling when these buildings are unoccupied. On community level, this new control concept can be utilized for peak shifting. In individual apartments and buildings, heating and cooling power supply can be reduced in such a well-argued and controlled way that certain agreed minimum criteria for thermal satisfaction will be obtained even during peak shifting.

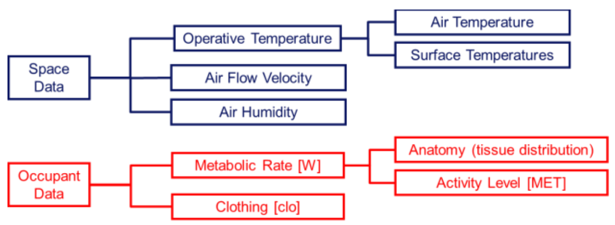

Fig. 2: Key parameters of thermal satisfaction.

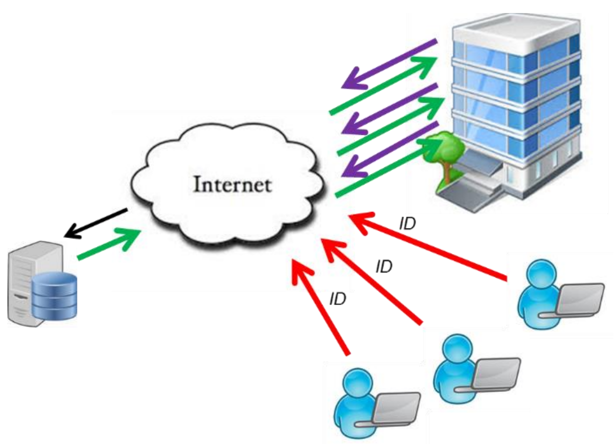

Fig. 3. Monitoring both relevant space-related and occupant related boundary conditions, estimating individual thermal sensation and autonomous adjustment of temperature set-point temperature values.

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D. Intelligent heating control

At Viikki Environmental House smart heating control is applied with digital radiator thermostats provided by Fourdeg Ltd. Viikki Environmental House is an energy efficient office building with a measured energy index of 90 kWh/m^2 [5]. The energy demand can be divided into 60% of heat and 40% of electricity. The thermostats are connected through the Wi-Fi network to a cloud server. The cloud receives through API's weather forecasts from the Finnish Meteorological Institute and demand response signals from the local district heating provider Helen Ltd. The ecosystem is presented in Fig. 4.

The cloud algorithm started to control the heating on room-level accuracy from December 2017. The heating program includes night and weekend drops and it is synchronized with the ventilation. Together with the local weather forecast and the room's individual heating resistance, the program learns the heating schedule of each room. In addition, the rooms' target temperature is shifted according to the requirements of the district heating system. The objective is to shift heating load from expensive hours without scarifying thermal comfort. During the project, indoor air temperature data is collected from every room. The users' thermal perception is inquired through questionnaires via a QR-code feedback system as previously described.

E. PV Panels crowdsourcing

There are several solar energy business models for customers to support renewable energy production. In order to meet the carbon neutrality targets also customers are engaged to participate to city's energy system. Helen has been the forerunner with innovative designated panel concept, which was first created to allow customers to be easily part of renewable energy revolution. Many customers of Helen live in residential buildings in small apartments where they do not have the ability to make a difference with their actions by e.g. installing PV panels on their roof. Designated panel is a product where Helen's customer rents a panel from larger solar power plant owned by Helen. The monthly rent is 4.4 €/month and the solar production is compensated in customer's electricity bill. One panel produces electricity approximately 11 % of a two-room apartment's yearly consumption.

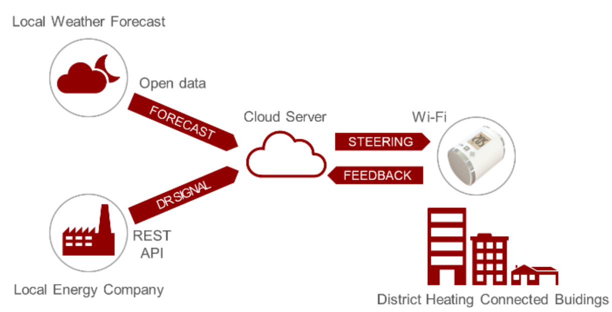

Fig. 4: Ecosystem of the smart control at Viikki Environmental House.

Helen's first designated solar power plant with 1194 panels was built in 2015 in Suvilahti and it was the largest solar power plant at its time with 340 kWp nominal power. The panels shown in Fig. 5 were sold out, and as promised Helen began to plan new solar power plant with the same concept to fill in the demand. Second power plant was built in 2016 in Kivikko with 2992 panels outperforming Suvilahti plant with 850 kWp capacity being again largest at its time in Finland. Kivikko power plant has also been sold out and at the moment Helen is planning third solar power plant with the same concept to be built in 2019.

Designated panel is a concept that makes solar energy available for everyone and many utility companies copied the original concept. Helen sees that there would also be need for a concept making solar energy available for customers by serving them the possibility to invest in real solar system at third party's premises. This would mean that instead of renting a panel, one could buy a share of larger power plant with compensation of produced electricity in their electricity bill. In addition to consumers also companies are interested in solar energy and new service models could be introduced to them also. Helen is continuously developing new service models in addition to the three-year old designated panel concept, one being the solar share. Helen has committed to the City of Helsinki Climate Action Plan to reduce carbon emissions and to bring new models to support the growth in solar energy business as part of smart energy transition and change from the conventional electricity production.

F. E-bike charging stations

Helen introduced five solar benches to Helsinki citizens that enable carbon neutral charging for mobile devices and electric bikes. Solar bench is powered entirely with solar electricity from the panel installed on top of the bench as can be seen in Fig. 6. The produced electricity is stored in the battery system underneath which means that the energy can be used any time and even when the sun is not shining. The solar benches make living and mobility comfortable and non-polluting. The benches support mySMARTLife project goals towards increased share of renewables and reducing carbon emissions in terms of mobility.

Fig. 5. Suvilahti solar power plant, built in 2015.

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Fig. 6. Solar benches at Teurastamo in June 2018.

The bench is multifunctional and strong: the concrete bench is 2.4 meters long and 1 meter wide, so it has room for bigger groups or two separate groups at both ends of the bench. Simultaneously people can charge up 6 different devices. The solar panel is approximately 250 Wp and the battery system has the capacity of approximately 230 Ah. Depending on the required power of charged device the power is enough for charging throughout the day.

The solar benches are one of their kind in Finland. The locations for the five benches were selected in cooperation with Helsinki city. Kalasatama was chosen as one site being the smart district and platform for agile pilots of smart and green solutions for citizens. Two other locations, Teurastamo and Helsinki market square, were chosen by the visitor count. The locations are the heart of summer events and the benches are assumed to encounter continuous usage. The Central Market Square was introduced also with solar shelter for e-bike parking and charging. The wood-framed shelter has four solar panels supported by battery system. The bikers can easily park their bike and store carry-ons in lockers. Several summer attractions are located nearby the solar shelter making it possible for citizens to travel carbon free to the city centre.

III. Results

A. 3D Helsinki Model

Information such as specific step-by-step instructions for installation of solar panels in old city centre protected buildings have been received well by the citizens and the city building control and permitting sector for easy to use and illustrated detail. Best case scenarios have been noticed to have a snowball effect when people share their experiences and get interested once they hear good comments from their neighbours of a particular implemented measure. The 3D model combines a lot of this type of information. Background information complemented with IT solutions show visible development and at the same time motivates people when the information is easily available and precise enough for turn-key solutions. Further use for the atlas has been noticed as an example of the 10 Days 100 Challenges open Innovation contest in June 2018 for added value services and software development on top of the existing open data in the 3D model.

Key aspect is to align the interests and provide easy information access to all essential stakeholders, building owners, renovators and external financiers (ESCOs), to advance with the renovations. Challenge and the role of the city is to facilitate the interaction of the stakeholders in finding best solutions. In the construction sector the private companies have similar models to study individual buildings and this can provide a practical continuation for more detailed planning and subsequently executing the energy efficiency actions.

Furthermore to help in planning and decision making additional support in mySMARTLife Helsinki is provided by a dedicated energy advisor and direct contact person in the project area. Actions include series of info evenings and co-creation workshops to find out the specific needs of the residents and possible ways to utilise the 3D model. Progressively the model has been presented and introduced in the first info evenings followed by workshops to develop the services and use cases further with the residents.

Feedback of the 3D model and its use has been collected also via a survey at a local Lähiöfest (suburban living festival) amongst the festival visitors. The results showed that most likely the respondents would use the model to visualise energy savings or to compare building performances. The private and public sector actors as well as the start-up scene in the city have also shown interest to the work to utilise, encourage and co-develop the data.

As part of the co-creation efforts, a living lab space was set up in the Kalasatama district in 2015 in the Smart Kalasatama –project. The space is located within the district and has attracted people living in the neighbourhood participating in planning events. From 2015 to 2017, a total of 76 events and larger workshops have been organized with over 2300 people participating. The space and approach has also interested visitors, the Kalasatama activities have been demonstrated to over 1300 visitors during that time. The space is also utilised to share information of the mySMARTLife project aspects and developments.

B. *Carbon Neutral Me application*

The development of Carbon Neutral Me –app has started by carefully evaluating the existing services and demos, such as the Kotihiili App concept introduced as part of the Smart Kalasatama Agile Pilots programme. The experiences of earlier demos has been collected and this has provided a better understanding on what are the areas where further development is needed. The key message from earlier experiences is that the development of a new app is not a technical challenge or even major effort. The availability and quality of data sources however is. The benefit of a project like mySMARTLife is that since there are various kinds of interventions, they also provide an opportunity to open useful data sources and make them available for other purposes as well.

Currently the main goal of the app has been set to target on data-driven behaviour changing. In order to accomplish that, an extensive service design and user experience planning project has been commissioned and it is expected to provide detailed specification of the features and functions that would best support the goal. It is expected that the actual service and app can be produced by the end of year 2018.

C. *Thermal Comfort control*

Thermal comfort control concept has been implemented in Viikki (an energy efficient office building) and Merihaka (apartment house) test cases. In both field test cases, body compositions of volunteer test persons are measured. In addition, all test persons are guided to give feed-back of subjective experiences of experienced Indoor Environment Quality by individual QR codes as shown in Fig. 7.

D. *Intelligent heating control*

During the first test period of January 2018 to April 2018, the heating energy consumption of the building has dropped by an average of 10% compared to 2017. The reduced heat amount equals 5-7 MWh per month. Furthermore, demand response is expected to reduce energy efficiency as the temperature set-point frequently increases.

Demand response is performed on a room-level accuracy by increasing or decreasing the set-point temperature of each room. The thermostat adjusts the radiator valve to keep the room temperature within moderate temperature thresholds according to EU standard EN 15251:2007. As seen in Fig. 8, room temperatures can be kept steady during demand response. The temperature does not change at the radiator more than 1 °C, and even smaller changes in indoor air temperature can be measured in the middle of the room. The QR questionnaire revealed that users have not noticed the temperature set-point shifts, as the satisfaction in indoor air temperature has not differed during the test period.

Further development in energy services and business models are required to scale demand response district heating connected buildings. As Viikki Environmental House's minor energy index presents a niche in the existing building stock, the potential of smart control is challenging to prove. After proof-of concept, smart heat control can be scaled to the whole building stock.

Fig. 7. QR code technology for giving personal feedback of experienced Indoor Environment Quality.

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E. PV Panels crowdsourcing

The designated panels from Suvilahti and Kivikko have been sold out by spring 2018, resulting total amount of 4180 rented panels. The yearly production from these panels is 1 GWh which corresponds approximately to 50 detached households' yearly electricity consumption reducing carbon emissions by 198 tons in total.

After Kivikko was built it seemed that the demand for designated panels saturated and there were free panels for rent for a long time. With marketing at the beginning of 2018 Helen found new wave of interested customers who wanted to rent a panel. Within few months the free panels were sold out. At the moment it seems that the market for such product is attractive again. Solar energy has high interest within customers, they invest in own solar systems but also support renewable energy production by renting the designated panel. The assumption is that the solar share is attractive track to follow to engage new customer segments.

Renting or owning a panel is partly a social activity because you can show for example in social media that you are a small producer. At Helen's website one can link their Facebook account to the rented designated panel and join the community [6]. The fundamental ideology of designated panel is to be part of community that considers environmental issues important.

One barrier for the concept is that the crowd of environmentally aware people is limited. There is difference whether you are a supporter or you are a producer: some people want to actually have and feel the panels at their own roof. With the designated panels people also need the same confirmation that the panels actually exist. For this reason Helen has live-video from solar power plants showing the panels and current production situation. Similar confirmation is available from customer's own solar panels via data visualization.

F. E-bike charging stations

The solar benches have raised a lot of awareness in public media and among politicians. The current trend among young adults is the hectic lifestyle with all the information being available. This means that the mobile devices have to be charged up and the internet needs to be available around the clock. To be up to date on news and media, lot of people search for public sockets to charge their batteries. The solar bench provides free charging in public places where large crowds tend to spend their free time.

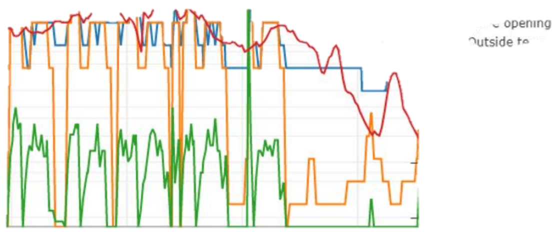

Fig. 8: Heating control during one work week in one room at Viikki Environmental House.

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The bench is a landmark providing an environment for outdoor activities around the bench. An important indicator to measure the desirability and utilization is the number of charges that the benches have performed. The utilization will be considered after user experiences of the first summer season. The bench is assumed to attract young and mobile people but not electric bikers in such large extent. One recognized barrier for electric bikers is that they do not necessarily need public charging places during their trips: they usually charge the batteries at office and at home. For the bikers it is also important that safe place to park the bike is provided. The experience shows that people do not want to leave the expensive bike unattended hence the utilization is assumed to come from mobile devices rather than electric bikes.

The solar shelter for e-bike charging will provide user experience to justify the assumption if bikers are using the parking and charging possibility. The pilot will show the barriers and enablers before the solution can spread commercially. The pilot provides testing platform for product development in order to serve the e-bikers needs.

IV. CONCLUSION

MySMARTLife project sums up a diverse number of projects in Helsinki, Finland. The roll-out of smart devices and the target to decarbonize the heating system are drivers which require both technological and business model innovation.

The designated panel concept has led to new service models being developed to follow the market need and to drive the solar business. New methods to produce solar energy and affect citizens' way of living are the solar bench and solar shelter that will validate the customer need for mobile charging of their devices and electric scooters or bikes.

Technical functionality of Thermal comfort control concept has been confirmed in full-scale research environment. However, implementation of this concept is still under development due to practical challenges (e.g., unclear data transfer platform definitions). The smart control algorithms in the Viikki Environmental House have led to a decrease in heating energy, improving further the energy performance of the building. Opening APIs between the heating control operator, the thermal comfort operator and the local energy company, perceived indoor air comfort can be obtained while implementing energy efficiency and demand response measures.

Open data services with practical ICT solutions can ease the transition towards the objectives how smart cities are organised and what they are capable of. Companies financing and executing smart renovations as well as start-ups are interested to utilise the energy data from Helsinki in seeking new business and collaboration in parallel when the Carbon Neutral Helsinki 2035 Action Plan is proceeding to its implementation phase.

The key to successful delivery of cross-disciplinary projects is to make sure the proposed developments match genuine needs and provide more useful or comfortable solution to the existing situation. Active engagement and participation work play essential roles in ensuring that the citizens and stakeholders are committed to pursue and share the objectives towards aligned common goals.

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