

TECHNOLOGICAL AND ENERGY CHALLENGES IN THE MOST VULNERABLE COMMUNITIES: A STUDY IN THE STATE OF CHIHUAHUA, MEXICO

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ABSTRACT

Based on the assumption that the technological system is assuming a leading role as a driver of socio-environmental development for contemporary societies, the ‘Design for Vulnerables – Technology Challenge’ research project aims to define strategies to facilitate the adaptation of technological devices in the most vulnerable communities, with the aim of overcoming the socio-environmental threats that contribute to creating situations of vulnerabilities. Defining the most appropriate methodologies to encourage technology adaptation to reduce vulnerabilities remains one of the main challenges for architecture and urban planning. The ‘Design for Vulnerables – Technology Challenge’ research project works with multidisciplinary approaches; there are seven disciplines involved in four communities of the state of Chihuahua, Mexico: Paso del Norte, Chihuahua (urban); Nuevas Delicias, Chihuahua (peri-urban); La Regina, Julimes (rural) and Basaseachic, Ocampo (forestry). With the goal to understand methodologies for technology adaptation and to reduce vulnerabilities, the research group is implementing (together with the residents) tech-based interventions, studying their adaption and evaluating their impact on the built environment. The aim of this article is to: (1) describe the analysis and planning processes conducted with vulnerable communities; (2) describe the projects defined by the communities during the participatory planning process and their relationship with the context; (3) analyse the characteristics of these projects; and (4) observe how these characteristics are related to the technological appropriation and energy limitations of the studied contexts. In the four communities, six ‘hub-oriented’ and ‘tech-based’ projects have been defined together with the residents. All of them had to face energy challenges, trying to demonstrate the possibility of independency and replicability of the projects.

Keywords: architectural design, urban design, vulnerable communities, design for vulnerables, Mexico, technology adaptation, technology and vulnerabilities.

1 INTRODUCTION

The particular conditions of contemporary changes require a profound reflection on the role of design, especially as we are living in a historical moment in which humanity finds itself with the enormous responsibility of being able to do all the possible good and all the possible damages to itself and to the planet [1]. ‘Responsibility’, ‘technological development’ and ‘vulnerabilities’ are three base concepts for this research.

1.1 Responsibility

This unprecedented situation of power gives us all an important responsibility which, without fear of protagonism, we can say is fundamental for the future of our species and the planet [2]. Undoubtedly, being aware of this enormous responsibility is the most important challenge to make an important turning point towards a sustainable and regenerative development of society. This ‘new’ responsibility, which Hans Jonas talked about well a century ago in his book *The Imperative of Responsibility* [3] and which invests contemporary humanity is particularly alive in the disciplines called to define the environment in which we



live. This responsibility takes on a new and burdensome call, forcing important considerations of an ethical and moral nature [4].

1.2 Technological development

However, the same ethics and morality are currently being challenged by an impressive technological development which undermines cultural certainties, imposes unprecedented questions (which we do not know how to answer ethically or morally) and transforms itself from being a means to the goal of our history [5], [6]. These upheavals regarding the very concept of technology impose an important reflection on how design practice must adapt to the new reality and benefit from it, especially when dealing with vulnerable communities [7]. The ‘technology’, which has already largely entered even the most marginalised and poorest communities, must be assimilated as an important resource aimed at reducing vulnerabilities and inequalities present in our contemporary territories. Technological development cannot be expected to create even greater gaps between more and less advantaged populations.

1.3 Vulnerabilities

Although many efforts are made to define indicators, methodologies and analyses of vulnerability, the concept of vulnerability remains very difficult to define and to shape [8]. In fact, vulnerability, unlike risk, is difficult to measure and can even relate to psychological or very personal aspects [9]. Furthermore, vulnerability encompasses various dimensions and facets within itself, thus requiring a multidisciplinary and context-holistic approach [10]. Lastly, the very concept of context is strongly related to the idea of vulnerability, since vulnerability is contextual: the conditions of the social and environmental context create the characteristics of a particular vulnerability [11].

1.4 ‘Design for Vulnerables’: the responsibility of designers to promote technology adaptation in vulnerable communities

For those who, like architects and engineers, are called upon to conceive and create living spaces, these intellectual concerns must undoubtedly be brought to the fore in the contemporary design debate [12], [13]. What responsibility do we have in designing environments and territories in which technology unleashes its full potential as a tool to improve the wellbeing of our communities and the environment, allowing populations to reduce their vulnerabilities? This question generates the research project ‘Design for Vulnerables – Technology Challenge’ which is currently funded by the ‘Challenge Based Research Funding Program’ of Tecnológico de Monterrey (Mexico) with USD 200,000, for the period November 2022–June 2024. This project arises from two seed grants that the research group had previously obtained: ‘Design for Vulnerables’ (2021) and ‘Vulnerable Socio-Ecotones’ (2022), both with the aim of understanding how urban-architectural and service design must evolve in the coming decades, in the most vulnerable communities [14].

1.5 The role of technology and energy in the most vulnerable communities: The research question

The general objective of the entire ‘Design for Vulnerables – Technology Challenge’ project is to define one or more citizen participation methodologies that facilitate technological appropriation in vulnerable communities. To achieve this goal, the project consists of various phases and sub-objectives which will be described later.



Specifically, the contribution of this article is: (1) to describe the analysis and design processes conducted with vulnerable communities; (2) describe the projects defined by the communities during the participatory planning process and their relationship with the context; (3) analyse the characteristics of these projects; and (4) observe how these characteristics are related to the technological appropriation and energy limitations of the studied contexts.

2 THE STRUCTURE OF THE RESEARCH PROJECT

As has just been anticipated, the entire research project is made up of various phases and various secondary objectives, which come together with the aim of giving an answer to the initial research question: which citizen participation methodologies facilitate the technological appropriation in the vulnerable communities. With this objective, the entire project is structured in the following phases: (1) Multidisciplinary diagnosis of vulnerabilities in the four contexts, to understand which dimensions should be considered priorities for each community; (2) Definition of socio-environmental barriers to technological accessibility in these communities; (3) Definition of the appropriate technological resources (a) to deal with the contextual dimensions of vulnerability; and (b) to overcome the socio-environmental barriers existing in the communities; (4) Evaluation of the processes of 'technological understanding' and of 'community appropriation' in the communities; (5) Understand how architectural design and the built environment, together with spatial changes, can contribute to accelerating and facilitating technological assimilation to reduce vulnerabilities; (6) Development of a startup, which aims to: (a) disseminate easy and convenient technological solutions in vulnerable communities; and (b) promote changes in urban-architectural dimensions in order to integrate technology in vulnerable communities.

2.1 The four communities

This research project is currently taking place in four communities in the state of Chihuahua, Mexico (Fig. 1) that have been chosen for the fact that: (1) the residents are in situations of vulnerability, generated either by human or natural factors; (2) communities offer interesting unexplored potential for sustainable and regenerative community development; (3) they are experiencing major consequences of climatic and environmental transformations in a semi-arid region such as the state of Chihuahua; and (4) each representing a different context (urban, peri-urban, rural and forest), they can be considered a reference for other regions in which these contexts coexist.

2.1.1 Paso del Norte (Chihuahua, Chihuahua): Urban community

Paso del Norte (28°67'41.77" N, 106°06'90.05" W – Accionética) is an urban community located in the municipality of Chihuahua, capital of the homonymous Mexican state (Fig. 2). It is a semi-formal community, which originated around the 1960s of the last century, mainly to provide housing solutions for families who migrated to the city from the neighbouring rural areas. The main feature of Paso del Norte is its geographical location: it is located on the slopes of a mountain range that limits the development of the city and is separated from the formal urban area by an urban highway and the Sacramento River. These elements undoubtedly make difficult the connections between the community and the city itself, creating a sense of identity exclusion and lack of services. Accionética is the contact association, which has been working for 6 years in the community, mainly carrying out recreational and educational activities with the youngest. From the analysis and mapping of

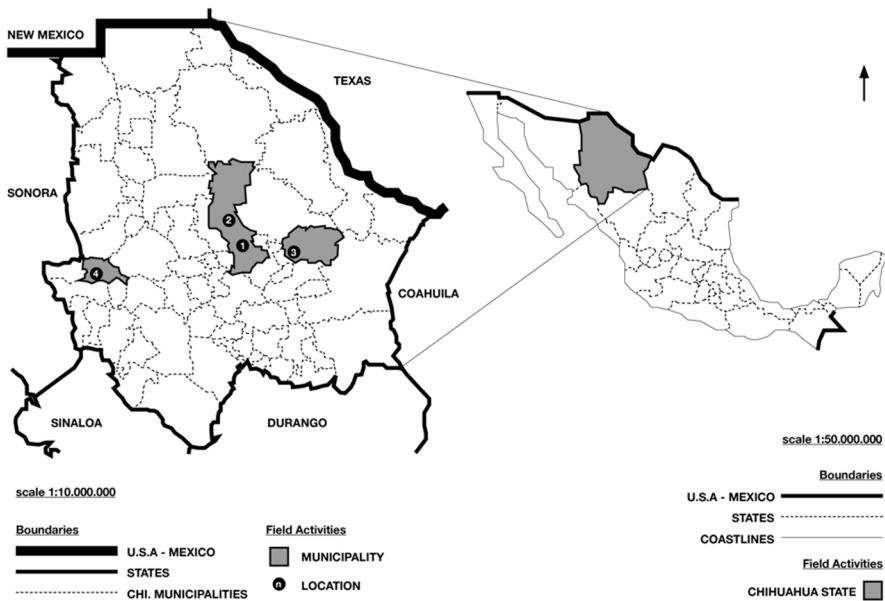


Figure 1: Maps showing the field activities in the state of Chihuahua (Mexico) of the ‘Design for Vulnerables – Technology Challenge’ research project.



Figure 2: Satellite view of the community of Paso del Norte, showing the separation from the rest of the formal city (highway and river).

the problems and potentials, it emerged that there are two problems that the residents want to solve: (1) accessibility to the community; and (2) accessibility to technological resources for knowledge.



2.1.2 Nuevas Delicias (Chihuahua, Chihuahua): Peri-urban community

Nuevas Delicias (29°07'19.96" N, 106°25'16.02" W) is a town in the municipality of Chihuahua, founded after the Mexican Revolution (c. 1910–1920) to divide the lands of the latifundium to the less wealthy population (Fig. 3). In this view, the agricultural and grazing land was divided among the residents of the community, providing each family with an equal portion of land for agriculture and the right to graze livestock in a large grazing area still shared among all community members. The management of the community and of these productive spaces is mainly in the hands of the Union Agrícola y Ganadera of Nuevas Delicias. This community hosts an important educational centre that attracts young people from all the neighbouring agricultural areas, and which is made up of an elementary school (300 students), a secondary school (250 students) and a high school (100 students). Community and associative life is so well structured, that the 'Club del Abuelo' is one of the main partners in the project. Today, the effects of climate change and the misuse of water resources, especially for the irrigation of non-native plantations such as walnut, threaten the survival of the agricultural system of Nuevas Delicias. During the workshops, this condition emerged as the situation to work on.



Figure 3: Satellite view of Nuevas Delicias, showing the village (left/west), the private agricultural fields, originally shared between the families of the community (centre) and an area for wild grazing in a territory still shared between the families (right/east).

2.1.3 La Regina (Julimes, Chihuahua): Rural community

La Regina (28°24'45.1" N 105°27'05.3" W) is a community in the small municipality of Julimes and has a mainly agricultural vocation due to the relative abundance of water brought by the Conchos River (Fig. 4). Despite the presence of water, this appears to have extremely high levels of contamination (particularly of arsenic and fluorine) which seriously endanger the health of the residents. Much has been done by state and municipal authorities, as well as by the private sector, obtaining results that limit the problems regarding the use of water for hydration and nutrition. The reverse osmosis systems that have been used up to now to limit

health problems are no longer considered compliant as, although they produce drinking water, they contribute to further contaminating the aquifer with waste heavy metals. Although there are also numerous emergencies of a social nature, mainly associated with situations of extreme poverty, the population has indicated that the issue of water is the main problem, which needs to be tackled with greater urgency.



Figure 4: Satellite view of Juimes municipality, showing the agricultural fields cultivated along the Conchos river, with the La Regina village (on the left/west) which develops along a main road and the town of Julimes (on the right/east).

2.1.4 Basaseachic (Ocampo, Chihuahua): Forestall community

The community of Basaseachic ($28^{\circ}12'14.1''$ N $108^{\circ}12'34.5''$ W) is located in the municipality of Ocampo, in the western Sierra Madre, which is called Sierra Tarahumara, from the Spanish name of the indigenous population that lives in this mountainous territory (Tarahumara in Spanish – Raramuri or Ralamuri in the indigenous language) (Fig. 5). The natural resources and landscape importance of these valleys make the Sierra Trahumara one of the most important tourist attractions in Mexico and certainly in the state of Chihuahua. In particular, Basaseachic is internationally famous for the highest continuous (non-seasonal) waterfall in the Americas. Despite this, tourism in Basaseachic suffers considerably from lack of retention (it is daily tourism of tourists staying overnight in Creel or Chihuahua). Furthermore, the natural and landscape resources, as well as the social and economic structure of the municipality, are put at serious risk by the mining activity which sees 4 mines active in the municipality of Ocampo alone. This mining activity, together with the effects of climate change, as well as the lack of sensitivity towards environmental issues creates a difficult situation for sustainable and regenerative development. For this reason, during the workshops, two themes emerged on which the population wants to work: (1) raising awareness of the population regarding environmental issues and (2) thinking about a new form of tourist offer in the municipality.



Figure 5: Satellite view of Basaseachic (in Ocampo municipality), showing the main town (centre), the villages for the mining activities (top-left/north west) and the Rio Mayo (bottom/south) where the waterfall of Basaseachic drops.

2.2 Approaching the communities

The four contexts have been studied with experts who come from the six faculties of the Tecnológico de Monterrey and by international experts in themes of socio-environmental vulnerability. This with the aim of being able to analyse contexts from different points of view, limiting the partiality of the analysis and allowing the connection of the causes or implications of vulnerabilities between different disciplinary fields.

In each of the four communities, the research group had previously close relations such as to know in depth both the main problems and the potential of each locality. Furthermore, a fundamental aspect in the community definition process has been that in each of the four communities there were already structured relationships of trust with the main actors. This last aspect ensured that the research group could count on actors who (1) organised the activities and logistics in the four contexts, (2) had an important summoning power for the other actors, (3) facilitated the access to information, and (4) facilitated residents' acceptance of the research team and participation in community activities. Although the previous contacts with the community existed, the need to operate in each context with the vision of 12 interdisciplinary experts and the fact of bringing new actors in the communities together made it necessary to work for several months with the aim of establishing a solid interpersonal relationship. This has been achieved at different points in the four localities.

2.3 The workshops done with the communities

During the January–June period of 2023, a series of activities were carried out throughout the entire first period of the project. In fact, these activities are what allowed us to define an intervention strategy and, consequently, to decide which type of technology to adopt in the four communities: 25 workshops have been carried out over 28 days of field work. These 25

workshops have been organised by the field manager, together with the main contact person in the community. The call to participate to these workshops has always been open to all the community and there has not been any restriction to the participants, others than to be adult.

To carry on the workshops, different methodologies have been implemented during this first stage: not structured, semi structured and structured interviews, together with mapping exercises and field visits lead by the residents have been implemented according to the different stages of the projects. To have better discussion with the community and better involvement within the environment, all these workshops have been developed within the communities and no meeting has been organised in the facilities of the university.

The objectives of these workshops have been several: (1) develop a shared definition of the meaning of vulnerability among the research group and with the communities; (2) define the instruments to measure the vulnerabilities themselves, through a participatory process; (3) define which strategies are the most opportune to develop in the communities; (4) define which technological resources to experiment in the different communities. It should be noted that the project wants to define methodologies so that the technological adaptation of accessible technological resources is effective in vulnerable communities. For this, the process of understanding and trust building were very important. In addition, the fact of wanting to reach a deep level of discussion with the community, about what type of technology to experiment with, has the objective of not only creating knowledge about technological adaptation, but also the objective of creating a significant impact in the communities. Another aspect to highlight is that the possibility of being able to have several moments of approach to the communities allowed almost all the members of the research group to participate in the discussions with the communities, thus being able to contribute with their own disciplinary vision. This vision made it possible to develop, together with the communities, intervention strategies. The methodology of these workshops is not a 'traditional' research methodology: the workshops and surveys of vulnerabilities were made based on an open call to residents and the main actors. The lack of a budget to pay the participants meant that the participants in the participatory workshops could vary throughout the process of defining the process. It was clearly intended that the participants were always the same (the invitations were the same, which with the passing of time and the growth of trust were made individually and directly to avoid delays). The interesting thing about this methodology, whose results will be evaluated in August with an appraisal questionnaire, is that it could be replicated on all occasions in which lack of resources complicates the constant participation of the same population.

3 THE SIX PROJECTS (HUBS) DEFINED WITH THE COMMUNITIES

As has already been mentioned, the main purpose of these workshops was to be able to define projects which, based on the introduction of technological resources, would contribute to solving the problems highlighted and strengthening the observed potential. For each community, one or two projects have been defined with the residents, which will be implemented starting from August 2023 (Fig. 6). The total cost of the technological resources was 1.5 million pesos (about 90,000 USD). With the aim that these projects can generate an effective change in the communities and that the residents can actually take over the management of the projects, they have assumed the concept of 'hub', or (stealing the term from information technology) an element capable of grouping actors united by the same objective and to stimulate change in the communities. The financial support of this first step comes from the research funding 'Challenge-based research funding programme', with the technical support of those private companies involved in the development of technologies (greenhouses, biodigester, solar panels, etc.). The Health Secretary and the Protected Natural



Area of Basaseachic (CONANP) are directly involved in the project, while those public institutions in charge of specific issues related to the interventions have been contacted to participate in supervising activities.



Figure 6: Some of the workshops developed during the period January–June 2023, in order to define with the populations, the main potentialities, vulnerabilities and projects for each community.

3.1 Paso del Norte: Mobility hub

To facilitate the connection between the community and the formal city, it was proposed to generate an electric bicycle system that facilitates access to the community and urban services. The initial phase of the project involves the installation of four electric bikes that connect the main square of the community to the Tecnológico de Monterrey campus, through which the main transport lines of the city pass. The second phase involves a community taller, with the aim of teaching residents how to convert regular bicycles into electric ones. The last (hopefully) phase is to support the community enterprise initiative for the generation of an electric bike service in other vulnerable communities.

3.2 Paso del Norte: Technology hub

To facilitate the association's activities and limit school dropouts, an existing kiosk will be transformed into a high-tech public element: (1) a wi-fi router will bring internet into the community; (2) a projector, screen and speakers will allow residents to organise shared cinema activities; (3) tablets and 3D viewers will allow Accionética to organise educational activities for the children of the communities.

3.3 Nuevas Delicias: Agricultural hub

To raise awareness of the importance of sustainability in agriculture and to promote new forms of agricultural production, as well as to bring the young generations closer to work in the fields, the following projects will be generated: (1) two greenhouses for vegetable production (high school) and flowers for sale (club del abuelo); (2) cactus cultivation for new cattle forage techniques (secondary – a cactus garden has already been planted); (3) drip irrigation systems, with solar panels; (4) composting system for the recycling of (elementary) food waste; (5) drone system to supervise water resources maintenance and livestock surveillance. The five systems work in a circuit, so that the compost products are used for the greenhouses and vegetable gardens that feed the school canteens.

3.4 La Regina: Water hub

To allow residents to access the water supply without the need to resort to contaminating reverse osmosis systems, and to avoid high energy consumption, five slow filtration filters, capable of remove significant amounts of arsenic and fluoride will be installed in public spaces (municipality council and schools). In addition, rainwater collection systems and drip irrigation systems with solar panels will be installed to limit the consumption of this filtered water.

3.5 Basaseachic: Environmental hub

To raise awareness of the importance of attention to the environment and the social opportunities related to environmental activities, we will work with the secondary school of Basaseachic and with the CONANP (National Council of Protected Areas) with (1) biodigester to recycle food waste from the canteen and heat the classrooms with gas instead of firewood; (2) greenhouse production of mushrooms and vegetables; (3) an air and water quality science laboratory.

3.6 Basaseachic: Tourism hub

To reflect on new possibilities of tourist offer and to digitally promote the image of Basaseachic (as a natural area with many tourist opportunities), we will work with the high school and the hoteliers. In particular, cameras will be provided for aerial and stellar filming, as well as 3D viewers for immersion in different tourist realities and to raise awareness of new forms of tourism.

4 ENERGY (AND WATER) COMMON DENOMINATORS

All these six projects, relying on technological resources, need a considerable energy input and, not being able to guarantee an adequate energy supply (continuous, safe, compliant and legally connected) with the existing distribution systems, it was decided to adopt strategies that would allow (1) to reduce energy consumption (for reasons of sustainability and necessity) and (2) to produce electricity locally. Table 1 summarises the energy needs of each community and project.

Furthermore, during the workshops it emerged that, although the effects of climate change are evident, the residents are not familiar with the concept of climate change itself, nor aware of its effects. Therefore, to raise awareness of the effects of climate change, a total of eight weather stations will be installed in all four communities, which will allow schools, in



Table 1: Summary of the energy needs of each community and project. Recap of the HUBs defined with the communities and their dependency from energy and water resources.

Hub	Tech. resources	Energy dependency	Water dependency
Mobility	• Electric bikes	• Solar panels for recharging the batteries	X
Technology	• Wifi • Public cinema • Tablets	• Solar panels for the operation of the public facility	X
Agricultural	• Greenhouses • Drones • Drip irrigation	• Solar panels for operating greenhouse instruments and for recharging drones	• Rainwater collection systems for greenhouses and vegetable gardens
Water	• New filters • Drip irrigation	• Filters without the need for electricity • Solar panels for irrigation	• Rainwater collection systems • Water quality analysis systems
Environmental	• Biodigester • Greenhouses • Drip irrigation	• Panels for the operation of greenhouse tools and for irrigation • Biodigester to reduce internal contamination for wood heating	• Rainwater collection systems for greenhouses and vegetable gardens • Water quality analysis systems
Tourism	• Cameras • 3D viewers	• Solar panels for recharging drones	X

particular, to develop exercises to bring residents closer to measuring climatic elements. Also these stations, to avoid impacts on existing energy resources, will be 100% exclusively dependent on solar panels.

5 CONCLUSIONS

From this first phase of the project presented in this paper, it emerges that: (1) people living in vulnerable communities are extremely willing to participate in workshops and activities to explain their point of view on the direction that their community should take, even if the process of creating confidence with the research team can take months due, in particular to its dimension (12 researchers); (2) on average, the projects defined with these communities aim to deal with one of the several vulnerabilities people are observing, while technological resources, whose definition have generally been avoided by the community, are several for each project; (3) the lack of continuous, safe, compliant and legally connected energy supply made it necessary to install several generators of energy such solar panels and biodigester. The next steps for the progress of the project consist in the implementation of these projects starting from the end of August 2023 and the evaluation of the impact in terms of technological adaptation by the communities. The base line also will help to define the reasons why people generally avoided the discussions on the kind of technology to be implemented. Undoubtedly, this type of interventions in the communities leave many areas of development regarding the implementation of technological resources and possibilities of social entrepreneurship based in technology and energy resources that deserve to be analysed in greater depth with the aim of allowing economic inputs to communities and facilitate the introduction of technological and energy resources capable of reducing conditions of vulnerabilities. If this were not to happen, the gap between different segments of the

population would be seriously increasing. Moreover, as next steps, the projects aim to develop a start-up offering a service for technological adaptation, based on this methodology. The final goal of this start-up would be to give financial sustainability to this project, so to enhance the existing interventions or to replace the methodology in other vulnerable contexts. Finally, it would be interesting to be able to evaluate whether these methodological processes can easily be applied to different contexts.

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