HOPE IN PERTURBANISM

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Abstract. A fundamental assumption in this conference is that human actions in creating and modifying our constructed environments can be rethought and made better for the environment. There are few laboratories in which to conduct research; an isolated island system offers one such opportunity. This paper reflects on work that carried out in the past five years in the Galapagos Islands by a collaborative of researchers from five institutions. The research examines potential positive changes in urban settlements and their impact on a fragile ecology of the islands. In this work, we illustrate how small perturbations (disturbances) within urban systems can lead to changes not only within urban form but also in the citizen's environmental awareness and how these, in turn, can lead to positive changes in the environment. The paper discusses applications of models we developed using Python scripting, GIS, and agent-based modelling, as we applied them to design strategies, built outcomes and community awareness.

Keywords. Complex adaptive systems; urban design; CAS; panarchy.

1. Coupled urban and natural systems

By articulating an Anthropocene era, we are increasing awareness of the impact of human activity on the environment. Some suggest that the impact of human action on the environment can be best understood through the concept of coupled human-natural systems (CHANs) (Liu et al. 2007). While there is a growing awareness of the mechanisms by which we harm the natural environment, such as through pollutants and waste, the greater impact of human settlements is less examined and understood. Increasingly, insights call upon us to recognise that urban and natural ecosystems must be considered as coupled continuities (Batty et al 2019). Of particular relevance in this context, others have suggested that the environmental crisis is a design crisis (Van der Ryn and Cowan 1996). In the work discussed in this paper, we consider how design can engage with coupled urban-natural systems.

The term 'sustainability' is now over-used, devoid of meaning and has ceased to illuminate the path to secure a better future. There is no point in 'sustaining'

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what we have at the moment, we recognise that a dramatic change is needed to reset the framework (Karakiewicz 2016). But how do we introduce appropriate change without causing greater damage? Blastland (2019) tell us how we are still unable to admit to the fact that our knowledge is much weaker and less reliable that we think it may be. He also talks about our fear of uncertainty and gives us some advice how to deal with unavoidable uncertainty and still gain some credibility. One of his suggestions is: don’t jump to conclusions. The other suggests that there are no “policy levers”. And what we should do is to experiment and adapt if something will change. If we accept the believe that our future is full of uncertainties, and prediction are useless, and whatever we decide to do will be at least to some extend wrong, then we can assume that sometimes small disturbances or what we call small perturbation to the system might achieve better results than zoning, master planning and policy levers.

In our work we have been heavily relying on Complex Adaptive Systems (CAS) theories. CAS theory dominates many disciplines at the moment. And although CAS theory has originated in physical and natural sciences, there is now growing interest in the dynamic processes and global patterns that in many ways defy our believes and assumption about the world we live in (Eidelson 1997). In CAS, healthy systems require periodic perturbations that, in turn, allow systems to enrich themselves or reach the state of new complexity. This allows the system to be more resilient and more adaptable. Perturbations, or disturbances, can enable as disruptive innovations. We have supplemented our models in CAS with Cycles of Adaptive Change (Holling & Gunderson 2002) to illustrate the positive potential of perturbations that could lead to more resilient urban futures and positive changes in the environment.

2. Case study of Puerto Baquerizo Moreno

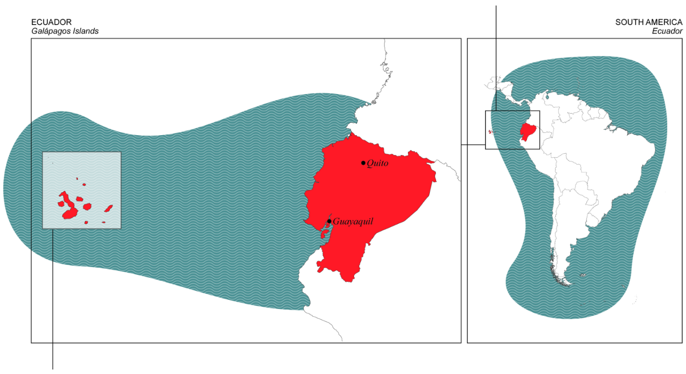

Figure 1. Location of the Galapagos Islands.

We chose to focus our work on the settlement of Puerto Baquerizo Moreno, the capital city of Galapagos Island, located on San Cristobal Island. The Galapagos Islands are located 1000 km from the South American mainland; therefore, it is relatively easy to consider the systems which operate in this extremely fragile and isolated environment (Fig.1). San Cristobal Island is relatively small, only 55,697ha, with a population of 7,330 people. Originally, Puerto Baquerizo Moreno was colonised for sugar cane and coffee plantations as well as cattle farming (Latorre 2001). While it depended heavily on farming, the fishing industry took over and by the 1970s fishing and tourism became to be leading industries. This resulted in many people moving from the farms, located in the island's hills, to the coast.

Today tourism is the main economic driver, with a few working the public sector, and very few people remain in the agriculture areas, consequently a majority of their food is import from the mainland. There has also been an increasing problem with invasive species since unattended fields provide a perfect place for invasive species to flourish, threatening this fragile environment. Another source of employment is in The Galapagos Science Centre (GSC), which was established in 2010 and now is an important centre for academic activities (Quiroga 2019).

The majority of the island is a protected national park. Human habitation is largely limited to the south west tip of the island. Here, the town of Puerto Baquerizo Moreno has 86.9 ha of surface area in all private and public ownership with a built footprint of 24.87 ha, which gives a ground coverage ratio of 29% (Lopez and Quiroga 2019). With such a low ratio and the challenge of an increasing population, there are many opportunities for densification instead of horizontal expansion. The urban area is defined by three main street running parallel to the waterfront, and one perpendicular road connecting the sea to the rural area. Most of the tourist activities are concentrated along the first two streets running parallel to the waterfront. The town is therefore compact with most parts, including the airport, readily accessed by foot or bicycle (Fig.2).

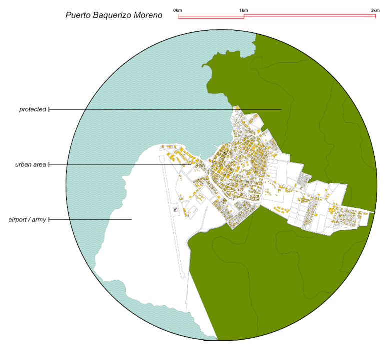

Figure 2. Puerto Baquerizo Moreno.

2.1. SETTING UP THE FRAMEWORK

We established the framework for our research and investigation, working with students and academics from the University of Melbourne, University of San Francisco de Quito, University of Chicago, University College London and the

Galapagos Science Centre (GSC), and aligning our work with that of the GSC by using CAS theory to examine urban change (Karakiewicz 2015, 2016).

In earlier work at the GSC had mapped the history of the islands onto Holling's cycle of adaptive change in order to show how major events through the history of the Galapagos Islands have led to regime shifts and allowed the islands to reconfigure to a new system (Gonzales at al. 2008). This depiction suggests that the islands are today in a unique position where there is no evident structure that emerges, despite several attempts from the Government, National Park, or National Special Laws, which were passed in 1998. Furthermore, there is clear evidence that the system may shift into undesirable stage if a favorable intervention is not made. This framed our design opportunity.

We used a framework based on panarchy model by Holling and Gunderson (2002) with three cycles of adaptive change operating at different speeds and scales (Fig.3). The functioning of, and signaling between, these cycles determines the survival of the overall system. In our model, the three cycles are: the environment (the biggest and the slowest acting), urban structure (the middle scale and the middle speed) and noosphere (the smallest and the fastest of all three cycles) (Karakiewicz 2019). The term *noosphere* is borrowed from Vernadsky (1945) and represents environmental awareness and the role of knowledge in society that informs and influence our actions. In this, we are particularly interested in the knowledge that is developed through our disturbances, or what we call perturbations within urban structure. What we want to find out is, how the conditions for a perturbation in the form of innovation are created and how knowledge emerges from this perturbation. If a proposed perturbation results in attitude change and the creation of new knowledge, the chances for another perturbation become greater and this, in turn, might lead to a transition towards a more resilient future.

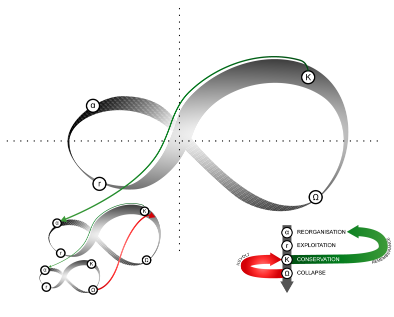

Figure 3. Reinterpretation of Panarchy model by Holling and Gunderson 2002.

In order to examine what perturbation might make a shift towards a more resilient future, we worked with the Batty model of coupled urban and natural systems. We were also aware that any perturbation we proposed should be recognized as positive. Changes are never easy and unless the population can perceive something of the value to them, they often fail. Therefore, we decided to add another element to the coupled system, that is, the noosphere of environmental awareness.

Through our models we are trying to find out how small perturbation could not only provide residents with possibility to reliable income, create employment for themselves and community, and in turn create economic benefit for many, but also how this perturbation could affect environmental awareness within community, create new knowledge, and new niches for more innovations and more perturbation to take place. We based our assumptions on theories derived from Bandura (1986), Kelling and Wilson (1982) and Bickhard (1992) who propose that the context can change human behavior. Amel et al (2017) and Klinenberg (2018) suggest that individuals have great potential in transition towards more sustainable futures through collective and collaborative actions through their connections, by forming networks, and find ways to support one another.

Identifying the most appropriate location for each perturbation within urban structure was therefore a priority. We wanted to make sure that our perturbation could benefit the largest number of residents by providing visible positive change towards a better quality of life, bringing new knowledge and expertise, key steps towards future development. We also wanted to make sure that our perturbations will become facilitators for building new networks for common benefit and mutual support.

The model was written in Python 3.x with an Object Oriented Programming structure in which the generic city parcel was the base unit (the Agent) to which parameters and attributes were associated, including the spatial location within an urban network model. Using a cellular automata approach, models were run iteratively and results visualised using a Grasshopper plugin for Rhinoceros 3d.

2.2. CHOOSING THE RIGHT LOCATION

As noted earlier, each of the cycles in the panarchy model works at a different speed and scale. Although the noosphere works at the smallest scale and the fastest speed, it is still very much dependent on the urban environment. Changing our context maybe more powerful way of shaping our behavior than trying to change our minds. So, if changing our context can influence our behavior the next question is what will be the best and most effective way to change this context, with limited or no resources? Furthermore, how to make sure that this process is not limited to just one event but instead creates a domino effect, which will continue for very long time, without final goal and ideal final condition.

In order to find the best location for our disturbances we started our work by mapping all the empty sites and sites with half-finished buildings (Fig.4). We mapped the location of all services, restaurants, hotels and other tourist accommodation. We collected data on pedestrian and vehicle movements in order to establish the most suitable sites for our perturbations. We established possible connections between variety of different functions, for example, how recycling water from the laundry can be used in hydroponic and aquaponic gardens, and how hydroponic and aquaponic gardens can support restaurant, etc. These connections helped students to define rules for their models.

3. Designing Perturbations

Our students focus was on understanding and applying a CAS approach and to design perturbations in the form of innovation that would redirect the urban landscape to a more desirable outcome. The computational model was designed as an agent-based model in which individual parcels of the city became the "agents". A network graph of the city was built in order to create relationships between all parcels such as connectivity and distance to each other. Each parcel would have its own set of attributes which came from the data that was gathered by the students through their in-person surveys of the city and provided digital information (public/private use, occupation of public space, interior public space, use, number of floors, etc.). The model was then programmed to work as a cellular automata model in which agents change their attributes based on the relationship to their closest neighbors and previous states. In this way, students could create their own logic and rulesets to define what would happen to a parcel if conditions around it changed. By having this framework in place, iterations of urban change could be introduced that would allow for a bottom-up gradual change over time to happen in the city.

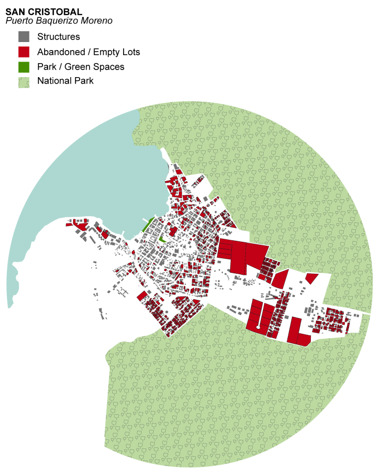

Figure 4. Location of empty lots within Puerto Baquerizo Moreno.

After determining the best sites for perturbation to take place, the next step was to design the best possible perturbations to happen on the particular site. As always, we relied on data and work which has been done by us and students previously. Students were able to work in groups with each group addressing one of issues that were considered as top priority by the government. These included: water, invasive species, food securities, waste, diversity of employment and dependencies on the mainland.

One of the perturbations proposed was the introduction of hydroponic and aquaponic growth kits on certain parcels of the city which, over time, would increase their income attribute and its demand of water (Fig. 5). A higher the demand of water in a neighborhood would incentivize the creation of decentralized greywater treatment facilities that would supply this demand. It will also allow the local population different forms of employment and create opportunities for innovation and experimentation to take place.

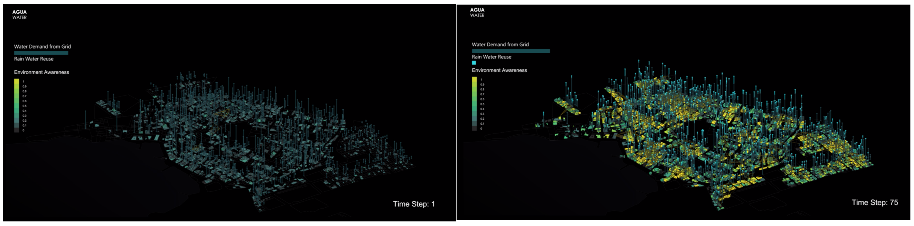

Figure 5. Effect of perturbation on water consumption and growth in environmental awareness

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Another example was a project in which decentralized tourist accommodations. Seeding certain parcels, this would create a gradual change over time and neighborhoods would start to develop as a network of tourist services that worked as a whole. This project also proposed to use guava trees as a building material. Guava trees are invasive spices and create huge damage to the environment. Eradication is very difficult, extremely expensive and so far, has not produce good results. In the same time guava trees could provide us with hard wood for construction via laminated cross-panels. Using guava trees as a building material will not only help in controlling guava trees grows and spread, but will also dramatically reduced import of building materials from the mainland and provide local population with new types of employment, which in turn could lead to more innovation and more job opportunities related to craft, furniture making etc. All these initiatives will contribute towards reducing imports and therefore possibilities of importing other invasive species into the islands.

A third project dealt with plastic recycling. Although the Galapagos Governing Council announced the plastic ban in April 2018, with different types of single-use plastic (straws, bags, takeout containers and bottles) being banned progressively over four months, there is still a lot of plastic being deposited on the beaches each day. Some of the plastics arrives from South and North America, but some drift in from Asia. Even if the Galapagos government stops all imports of plastic, it will still be deposited on the beaches each day. If this plastic is removed from the beach through community action, it ends up being transported by boats to the mainland. This not only costs money, it pollutes the atmosphere and water, and some is accidently lost and ends up back in the sea (Fig.6).

One of the ways to deal with this problem is add value to the waste, transforming the plastic deposited on beaches into a desirable material. This could be achieved through the provision of pulverisers and 3D printers in strategic positions within urban areas and providing residents with basic knowledge. A project suggested that first perturbation should start in schools, where young children could learn how to segregate different types of plastic, how to use pulverisers and additive printers, and to design useful objects from this material. If this idea works, it could then be moved into the more central location which will allow anyone to experiment and innovate, or even start their own business. One idea was to produced souvenirs, (which currently are imported from China) and sell them to tourists. In this way tourists will be paying for waste and taking it home with them.

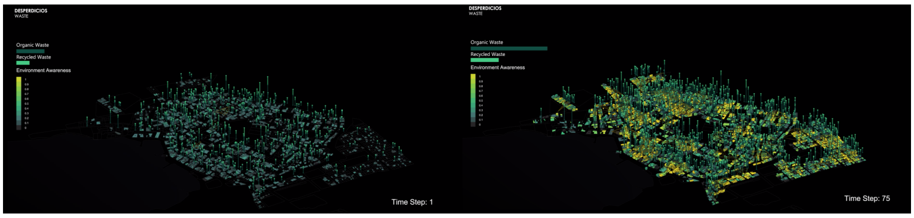

Figure 6. Effect of perturbation on recycling of plastic .

Over time the city would adapt, and school students would be able to see this change and fine tune the model and the initial parameters to test different outcomes. Figure 7 illustrates changes within urban structure and their effect on environmental awareness.

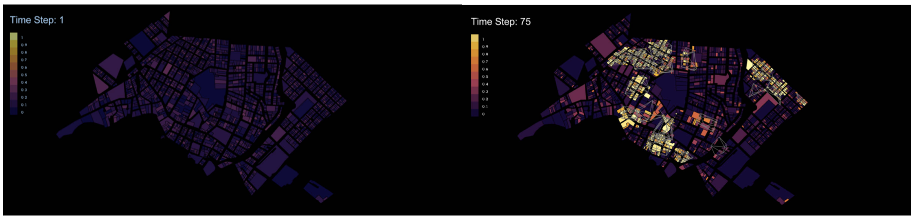

Figure 7. Changes in environmental awareness due to introduction of perturbations within urban system.

Unfortunately changes within the environment will not be visible for a long time. The only visible and measurable things within relatively short period of time could be extend of sprawl of invasive species, the demand for water, an increase in employment and economic benefits. All of these could be model with some degree of accuracy. However, what we are unable to model are things like the unexpected importation of new invasive species or the growth in volume of rubbish deposited on beaches, or any unexpected external innovation or disruption.

4. Conclusion

As mentioned above, in our work in the Galapagos Islands we have been using Holling's (2001) cycle of adaptive change. The model is useful to describe a process of change for one ecosystem function operating over a time period. Holling's model clearly illustrates that during periods of greatest uncertainty in nature, innovation and resilience are strongest, and in periods that are characterized by the strongest certainty, resilience and innovation are at the lowest ebb.

Therefore, if we are looking for innovation and want to create more resilient future, we should be investing in uncertainty instead of creating stability and certainty. This is counter to widely held assumptions that stability and certainty are the best foundation for resilience. Strategically, for this reason it is probably wiser to invest in small perturbations first if we want to change existing status quo.

Furthermore, we are very much aware that disturbed urban systems can recover and adapt much faster than disturbed natural systems. The impact of human intervention on a natural system is usually difficult to observed, it may take years to be noticed. At the same time, disruptions to urban systems might be difficult to accept for the general population. Humans do not respond very well to change, unless it is clear that this change brings some clear and fast benefits to them. If our actions benefit us but cause a negative impact on the environment, we choose to overlook this consequence.

In summary, we are always dealing with three interrelated systems: human, urban, and natural. They all respond to feedback loops and have reciprocal casual relations, they are all nonlinear, and have thresholds and therefore experience regime shifts, have historical path, are resilient (at least to some extend) and are heterogenous (Liu et al. 2007). Batty et al (2019) write:

...it is important to recognize that in most cases urbanization endows human dynamics with the ability for much "faster" dynamics and greater energy intensity (power) than is typical of natural selection. In this sense, human dynamics connected to urbanization are the fastest, driving influence on ecosystems, driving them into disturbed regimes that may indeed be unstable or prone to collapse as their ability to respond lag.

But there is also a small possibility that disturbance within urban structure can have positive impact on people's lives and that this impact could be visible within relatively short time. Batty et al. describe the need to for a close, consistent, and continuing analysis of coupled urban-natural system in order to tell us about mutual interactions and adaptation over extended periods of time and that incorporates expectations for good and bad trajectories. Humans will always try to control natural systems but we might change the way we make decisions by understanding the dynamics and the impact of our action on the environment. There is a clear need for innovation within urban systems which are more synergistic and geared to improve resource flows and biodiversity in natural systems.

We postulate that if we can influence environmental awareness within tourists and local population, we will be able to have some positive effect of the environment as well. In the context of the Galapagos Islands, we will be able to reduce import from the mainland of construction materials, food, and other products and therefore, reduce possibility of other invasive species arriving onto the islands. will be able to control the spread of invasive species. We will be able to reduce water consumption, to create different jobs and diversify possibility of local employment, thus improving economic situation for majority of the population. Furthermore, will be able to promote innovation and create specific local knowledge. This knowledge could become another form of export. Maybe in the near future, the Galapagos Islands will focus on exports, not on tourism and imports. This maybe the way to more sustainable future of this amazing but extremely fragile environment.

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