AUGMENTING COMPUTATIONAL DESIGN AGENCY IN EMERGING ECONOMIES

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Abstract. This /practice-based design research/ investigates the possibility of computational design to increase agency and impact in emerging economies through real-world projects. By cultivating a new kind of relationship to issues in development and local untapped resources, they inspire for more public engagement and resource-based conversations within a spatial framework. The topics that were addressed in this research are the democratization of data and affordability of construction. These two on-going early-stage initiatives have used computational design tools at specific areas in the project's development, therefore optimizing the parts where low-tech tools weren't sufficient. This demand driven design process explores ways in which different levels of technology can augment each other.

Keywords. Space; resource; housing; myanmar; optimization.

Although architectural design tools are advancing, their inclusivity is questionable. Digital fabrication often requires expensive machinery or advanced digital literacy in coding. It could therefore be seen as a luxury instead of a progressive initiative to expand the industry as a whole. Applications of such tools strive to push the boundaries of what is currently possible to build without necessarily questioning their purpose. Complexity isn't the end, but in a specific scenario, the means to an end. While the vast majority of architects in Myanmar still use Autocad and Sketchup to design; what can computational design bring to the table in a time of political, economic, health, and social instability? What kind of new disruptive processes can be created during a time where futures seem to be going back in time and repeating the past? This research does not pretend to bring a solution to an overly complex situation, but, internally, start addressing issues such as remote community development through architecture's multicultural and cross-disciplinary nature. This 'practice-based design research' investigates ways to expand computational design's agency and impact across the board, targeting different areas in society, at different scales and geographical locations in Myanmar. All of which are data-driven designs that respond directly to discrepancies between need and supply. These two on-going early-stage initiative projects have an aspiration for large scale rural development in Myanmar. Within the entire scope of these two projects, very specific steps have been optimized using computational design. The use of the tool is not holistic to the project, it is specific to a key area. In order to integrate real-world workflows, digital

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fabrication, implementation, and dissemination should be considered contextually using the appropriate tools. The methodology that was followed in both projects are replicable in other parts of the country, and perhaps in other parts of the world, however, the implementation is unique to a specific context. Both aspects have been developed in the following projects, defining a clear methodology of work and real-world applications in a target region. The topics that were addressed in this research are the democratization of data and affordability of construction.

1. Chin State mapping

Following up on the on-going military coup, many executive orders will be approved to enable targeted sanctions in Myanmar. Development-related budget spendings will need to be very carefully monitored to avoid leaks and achieve tangible results. This mapping pilot project is a prototype in exploring new data-driven approaches in site analysis and in computing projections for budget-allocation scenarios intended for development. This approach is bringing to the table a new perspective and insight, that formerly was either inexistent or done at a very basic level.

Today, data is being collected everywhere, there are many initiatives in creating dashboards for dynamic visualization. However, the impact is very questionable because accessibility is monitored with different levels of security allowances. Data visualisations are often oriented at a technocratic, policy-making class instead of being for the general public and more specifically for marginalized communities. This prototype investigates decentralized mapping, that qualitatively, allows for different kinds of engagement and non-government-complicit decision chains. Looking at Asia Foundation's Township Development Indicators (TDI) database that was published in 2019, some important measures were taken to prevent the data from being overly revealing. The precision of the data was intentionally reduced from the village track level to the township level. This decision also reflects on which level of decision-making the data is intended for, in this case, it seems to target a higher and macro-level. Explicit data visualizations, when publicly shared, can create public insecurity, ressource grabbing, commercial manipulation, and finger-pointing. This prototype was intentionally not designed to visualize the geographical location of ressources but to visualize where to tackle specific problems using colour gradients that highlight different levels of needed interventions throughout the target region. The data is therefore mobilized to start a conversation about on-going development-related issues, anomalies, discrepancies and inequalities within a spatial framework without jeopardizing and putting at risk ressources and communities. Therefore, the data harvesting process was carried out in order to obtain the highest accuracy and precision of information. A holistic approach is established, which considers all steps of the process from data acquisition, analysis, visualization, and dissemination.

People-led data collection processes can lead to some degrees of inaccuracy, incompleteness, and scarcity within the set. In physics, for example, significant figures are ways to remediate to the difference in precision between different numbers in an equation. However, this logic conforms the output to the smallest level of precision amongst all the inputs. In order to get a higher level of precision, the least precise inputs need to find more digits after the decimal point. This research explores ways to fully utilize every data set to its full potential without culling out levels of precision. Instead of digits after the decimal point, the data is previewed as geographic points or pixels within the spatial framework.

Myanmar Information Management Unit (MIMU) released in 2017 *P-Codes*. This new system created a distinct and ordered classification of all Districts, Townships, Towns, Wards, Village Tracts, and Villages throughout the country, allocating to each geographical data point a specific code of reference. This initiative revealed itself as a major improvement for data collection and in facilitating mapping projects. Referencing villages by name is extremely difficult, as translations can be slightly different from one person to the other and some of the villages have the same name as other villages or townships. However, P-Codes cannot be assumed to be 100 percent reliable either; in Chin State, for example, villages very regularly move from one place to another, their documented geographical location is seldom updated on the Open Access Database. Furthermore, many remote villages have not been documented yet as they are difficult to access. Even though this documentation could be considered one the most reliable in Myanmar, not everyone uses this system in their own datasets, collaboration is not always perceived as positive, many companies would rather ignore this tool rather than use it. Therefore, some sets of data were not used to their full potential during this research, all translated village names that were not corresponding to the MIMU translations or had the same spelling as other villages were therefore culled out from the set before being operated on. A portion of data was therefore lost during the formatting process.

During the course of this pilot project, we collected data from a wide variety of sources, some of which were simply downloaded from existing Open Access Database, others were collected through more unconventional methods. In order to collect data from local Myanmar tourism agencies that record roads and tracks during their guided tours in the country using GPS tracking devices, we had to sign a Non-disclosure Agreement (NDA) that specifically mentioned the fact that the final map would not preview the data but use it exclusively for analysis. Similar processes of data acquisition were used to get government data from the Ministry of Construction (MOC) and the Ministry of Hotel and Tourism (MOHT) in Chin State. Other processes in data collection we went through required the use of a motorcycle and a USD stick in Hakha, the capital of Chin State.

Prior to data analysis, the acquired data sets were graded in terms of accuracy, this grading can be seen as a benchmark to build a trustworthiness indicator for each individual set. In this way, all data is usable, their aptitude in influencing the output map is relative to the perception of their accuracy. This perception is based on the format of the data, the uniform spread of the data throughout the target region, and a personal judgment. For example, if it is a GPS route recently collected by a trained guide on a motorcycle, the accuracy of these geo-localized recordings is high and should therefore be able to influence the analysis in a more thorough way compared to a hand-drawn road on a printed map for example.

The wide range of add-ons for Grasshopper allows us to import many different data formats into the same file, should they be excel spreadsheets using GHExcel; SRTM HGT, OSM, and GeoTiff files using Elk; SHP files exported GPS coordinates through Google Earth using Heron; JPEG images through Rhino. Each format has different types of output, some are points with attributes, others are polylines, meshes, pixels; furthermore, each data set has a unique level of precision. In order to start analyzing the imported data, we changed them to the same format. During this research, topography meshes were chosen as a common format because they are light to compute and are easy to work with. This technique allowed us to layer on top of each other many different imported data sets from various sources. By calculating the height difference between different topographies, we created indicators based on the distance ratio. These indicators do not have units, they indicate densities that can later be used to create new topographies that can visually represent them.

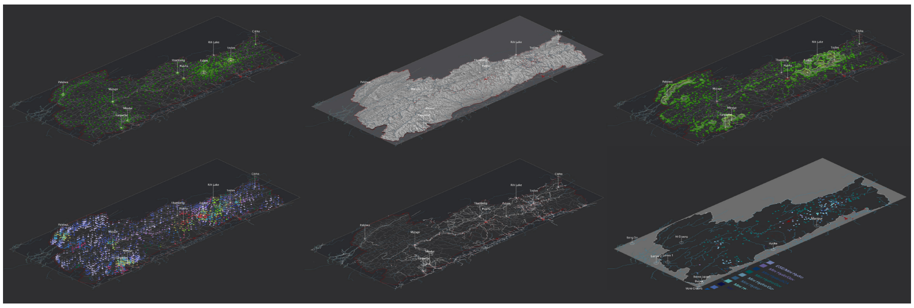

Figure 1. Development related data visualizations from Chin State (NGO activities per sector, energy harvesting, topography, population density, road networks, water resources) by Blue Temple Co., Ltd.

Through the use of the HERON add-on for Grasshopper we were able to import the geolocalized target region we wish to base the analysis on in Rhino. This frame was then used as an input in the Elk topography component that contains *Geospatial Data Abstraction Library* to better read GeoTiff format images. The high-res GeoTiff image was downloaded from the Earthobservatory NASA website. The output is a 3D topography mesh of the target region that visualizes the observable nightlight in the region from the Suomi NPP satellite. The highest point of the mesh shows the brightest area of the region.

The created maps collect a large amount of information in a small format. In just a look, we can understand thoroughly an incredibly dense amount of data. Where the spreadsheet is scattered, the map is condensed, this allows the viewer to understand data in a relative way, comparatively speaking. Data is no longer an individual, isolated piece of information, it is a point within a cloud. Observing the cloud itself instead of the individual data releases the visualization from possibilities of inaccuracy. The viewer is no longer reading information but trying to read between the lines, to find patterns within the database. The ability to reveal patterns was therefore a priority. The jpeg image conceals all data sets in an unhackable format, a JPEG image. This also guarantees compliance with NDAs.

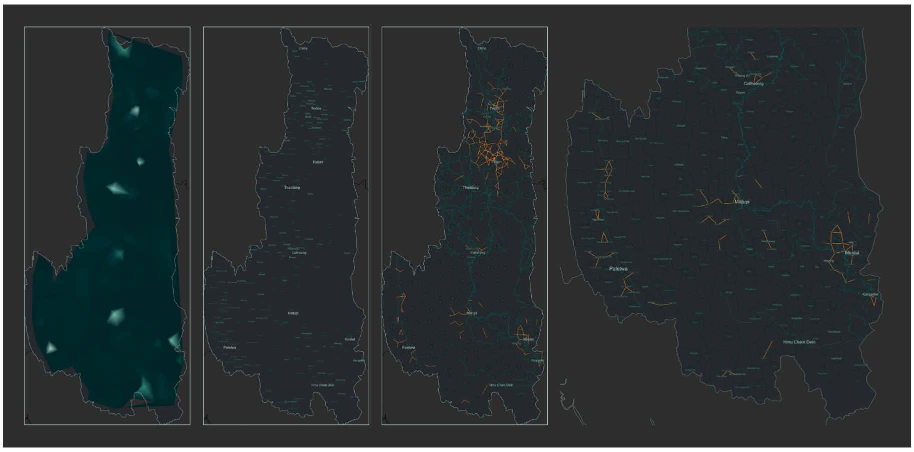

Figure 2. Map of Chin State emphasizing on towns with the greater population with the least access to energy supply as well as possibilities of mini-grid implementation by Blue Temple Co., Ltd.

The high-speed mobile internet coverage in Myanmar has recently improved dramatically, mobile service providers have built towers across the entire country that serve 80 percent of the national population. Furthermore, 70 percent of the connections are made through smartphones. The dissemination of our maps was presented through an app for smartphones, accessible to everyone without any levels of security allowances. Making raw data accessible to a wide audience through open data platforms does not necessarily entail the democratization of data because a large portion of the population does not have enough digital literacy or the tools to read them. By using color gradients instead of text, the data becomes apparent and readable.

The app was inspired by 'Draw Something', it is an intuitive interface where users can sketch on top of a base map. This social media connects through the use of *Discussion Rooms* the users together. All the way until this third national lockdown in Myanmar, traveling has been banned throughout the country. Online communication has become a real challenge to organize the decision-making process, Zoom has revealed itself not to be the best performing tool. More specialized and practical tools are needed to quickly and efficiently connect people. This app also allows for more transparency to happen and get stronger citizen participation. It is a conversation starter instead of a decision-making tool. People can vote for each conversation to go up or down, the more popular topics therefore appearing the most visible at the top of the list.

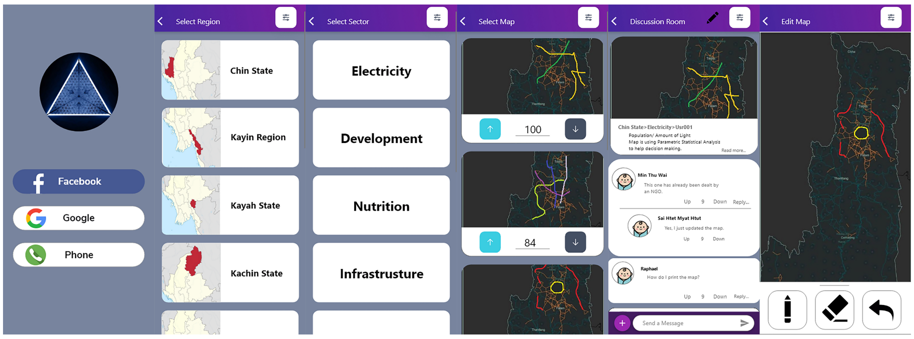

Figure 3. Phone application prototype, developed within the Blue Temple proposal with Min T. Wai and Sai Htet Myat Htut during the 2019 Data4Change Hackathon organized by Asia Foundation at Phandeeyar (Phandeeyar is a community tech hub that is fostering Myanmar's technology & innovation ecosystem) in Yangon.

Mapping is just one element of representation, decision-making processes shouldn't exclusively rely on maps, there are many more factors, non-measurable and intangible variables that can influence decision-making in much more practical and often greater ways. Such kinds of data are essential to render a much more accurate representation of a site, such as political instability, historical events, internal conflicts, religious beliefs, land ownership, language, local culture. In this manner, mapping is not enough, it is just one part of a complex puzzle. The combination of both mapping and public engagement can increase community empowerment.

2. Optimized Bamboo Frames

There is a major discrepancy in the affordable housing market in Myanmar between very high demand and very low supply. A big percentage of the total national population does not have access to decent housing and does not have access to safe microfinancing options to afford it. The demand for affordable housing in Yangon is 100,000 housing units per year, the public sector was able to supply 9,200 units in 2016, while the private sector supplies between 7,000-9,000 units, although none of them were targeted for *low to lower-middle-income households*, they were exclusively targeted to the high-end markets. While the demand for affordable housing continues to rise due to the effects of rapid urbanization; internal migrations because of climate change, poverty, and violence; the need for house replacement because of damages; the supply is heavily lacking. The effects of this lack of supply generate an increase in households having to resort to informal settlements as a solution.

One of the main perpetuating factors of poverty, ironically, is housing in Myanmar. According to the 2014 Myanmar Population and Housing Census, up to 42.7 percent of housing units in rural areas are constructed from bamboo, and 23.6 percent in urban areas. Bamboo is the cheapest building material in Myanmar, therefore the most common because of widespread poverty. Low-income households cannot afford long-term solutions, therefore, the house gets damaged due to lack of proper maintenance, the lack of proper treatment of the bamboo, the lack of proper footings to protect the bamboo against exposure to water during the rainy season, flooding, high winds, and more. Every year, they need to rebuild the house but don't have enough money to do so, therefore they borrow money from non-regulated shark loaners around the village, they become unfairly indebted but still don't have access to decent housing. If the payments are not done in time, some households can find themselves in dangerous situations. This vicious circle keeps them in a state of poverty, perpetually owing money to others, and not having decent living conditions.

There are more than 350 species of bamboo in Myanmar, only 7 of which are used in construction because of their load-bearing capacity. They grow in particular areas in Myanmar and are in high demand; therefore the cost per pole is relatively high. The supply of bamboo is inconsistent, even though bamboo grows everywhere in the country, the species used for construction are in reality not abundant. The price of this kind of bamboo fluctuates, it, therefore, adds another risk for businesses that strongly depend on their exploitation. Finding a way to use the abundant and cheapest species of bamboo on the local market would radically lower the cost of construction. Smaller bamboo has a high bending capacity that allows for more complex designs. Bundling together sets of bamboo subsequently makes the structure more resilient to damage compared to a structure made from single large diameter bamboo poles. The structure's integrity is therefore no longer subjected to its weakest link, it is a composite material within a monolithic structure. Computational design tools can therefore be used to reassess materials that are commonly non-commodifiable, create a new utility, and mobilize abundant and untapped resources that are often beyond the realm of marketization. Using locally found materials and low-cost simple construction techniques inspired by vernacular architecture integrates digital fabrication into ordinary real-world workflows. This proposal explores a different form of application, resolving the conflict between the complexity of design and affordability of construction.

The designed structural frame is made out of cheap small diameter bamboo combined with locally found recycled and everyday materials. The bundling makes it possible to use commonly non-structurally performing materials in a structurally performing way. Its modularity allows for prefabrication where quality control of the whole assembly chain is more easily monitored. The combination of both, a large scale production, and an optimized building process over time will reduce the price of the structural frame units every year. Once the structural frames are put into place; the walls, floor, and roof are built locally by workers from the village using the construction materials of their choosing. Additionally, in case of damage, the frames are easily replaced with new ones without the need to dismantle the entire house. Therefore specializing the production specifically on the structural elements of the house, which is the most complex and costly, will reduce the price of the entire house, while still ensuring its durability.

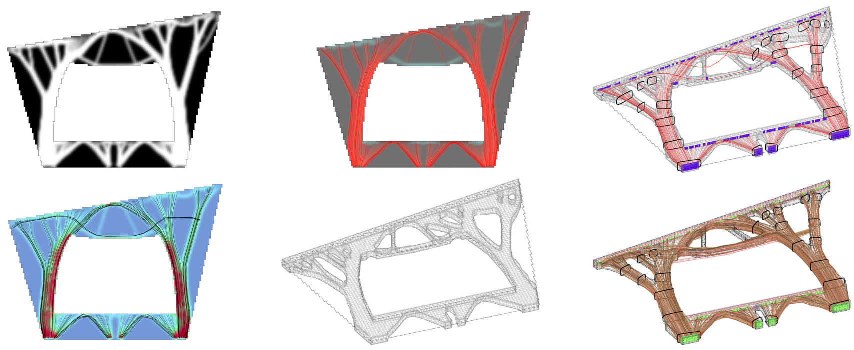

Figure 4. 2D topology optimization by Blue Temple Co., Ltd.

Calculating the structural integrity of the frame is incredibly difficult because it is a complex composite material made of many small non-isomorphic parts. Instead of working with real loads using Fusion 360 by Autodesk for example, we choose to use Millipede on Grasshopper. Its ability to compute 2D topology optimization was also a plus. The overall shape where we allowed the software to work was defined according to local regulation such as the overhang distance of the roof, local context such as the raised floor as a form of protection during the rainy season, the overall dimensions of the interior space. The 2D mesh result based on a stiffness factor shows an optimized overall shape that responds to the sets of loads we predetermined, such as live load, dead load, and three footings for support.

In order to start 3D modeling the frame for visualization purposes and quotation preparation for prototyping, we needed to interpret the results of the program. This interpretation resulted in simplifying the overall shape, and according to the color gradient extracted from the principal stress 2D result mesh, create different densities of polylines. To do so, we extracted the iso-curves from the stress pattern by creating different densities of seeds according to the color gradient.

We created a virtual 3D mold and used Kangaroo 2 collider component to evenly spread out the contained polylines in order to mimic the bundling of the bamboo. The entire frame is made out of 350 small diameter bamboo poles. In order to create the smallest file size, we used the MeshPipe component of Ameba instead of the usual nurb piping component. The metal strapping was placed at the start and end of each branch segment.

According to the exchanges we had with Sebastian Kaminski, an Associate Structural Engineer at ARUP specialized in bamboo shelter construction processes, engineering, and materials in refugee camps, specifically for the Kutupalong refugee camp in Cox's Bazar, Bangladesh; he advised us to test the structural performance of the frames until demolition at least ten times per variation (choice of bamboo specie and slight variations in design) in order to get the most accurate data and assessment. Prototyping, testing until demolition, and assessment is another essential part of the design process. While computational design is essential in obtaining a preliminary blueprint of the frame, it is not enough to successfully carry out a final product onto the local market. The combination of both processes expands the agency of the architecture by making it more affordable and structurally performing.

A mockup prototype was tested for a structural column in a shelter in Yankin Township. The freshly cut green color bamboo called ‘Theik wa’ (Bambusa tulda Roxbo) was bought in Rhakine Yoma (Rhakine State mountain). These were the top part of the plant, the most bendable and cheapest part that is not in high demand because of their lack of load-bearing capacity. One hundred bamboo poles cost 4,000 Myanmar Kyat (3.06 USD). Moreover, this bamboo species has low sugar content, insects are not naturally attracted to it, which makes it more durable; also simpler, and less costly to treat. We tested different types of strapping for the bundling (coconut rope, post mounting straps, galvanized steel strap, and galvanized tie wires), the steel strap revealed itself to be the most suitable candidate. The prefabricated component of the footing, using a recycled 20L water bottle filled with concrete for a stronger and solid base, was very promising and cheap. A much more detailed assessment would need to be made in order to optimize and plan each step of the bundling and assembly process.

Figure 5. Mockup prototype as a structural column for a shelter in Yankin Township by Blue Temple Co., Ltd.

Inspired by the *The Grameen Bank Housing Programme* in Bangladesh, the structural frame would be brought to the local market together with a micro-loan. Today, we are currently working with brokers specialized in microfinance in Myanmar to conduct inverse auctions with official and regulated financial institutions in order to get the most affordable financial package that will be coupled with the sales of the structural frame. Our target end-users are low-income households in remote urban and rural areas in the lower 3 deciles of revenues. This strategy will allow the end-user to own at an affordable price, a quality, and long-lasting housing option.

3. Conclusion

During this period of great change in Myanmar, resources have become a major topic of conversation. Looking at The Belt and Road Initiative (BRI), most of the proposed infrastructure projects are resource-oriented whether is it in regards to rivers, jade, natural gas, and wood. Computational design can provide additional tools for designers to address this issue in creative ways, and explore the possibility of utilizing resources that are commonly outside the realm of marketization. This reassessment of resource utility can provide new design solution space in the housing sector, in specific regards to affordable housing, making accessible to marginalized communities new construction techniques that can take advantage of local abundant and cheap materials. Similarly, looking at a more macro level of intervention, computational design also addresses remote community empowerment through mapping. By re-orienting the typical target end-user from the technocratic policy-making class to remote communities, the maps allow for better public engagement. By revealing patterns of development, they can better understand their location within the spatial framework, and access a tool of communication that is a conversation starter. The combination of different levels of technology within the same project augments the agency and impact of the design. Each step is optimized using tools that best respond to the need. It is a demand-driven design process.

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