Learning from Post-Blast Beirut

Humanitarian Data-driven Mapping and Co-planning Efforts

Piloting an agile data-visualization and co-planning tool

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Departing from a study of humanitarian data-driven mappings and responses in post-blast Beirut, this paper presents the concept and methodology behind the design of a digital co-planning tool piloted in a post-disaster context. The digital tool proposed enables cross-sector real-time data visualizations, to potentially inform agile collaborative response mechanisms. It aims to activate citizen engagement through e-participation, a concept that can be transferred to similar contexts, thus minimizing at-risk communities.

Keywords: humanitarian data-driven mappings, digital co-planning, post-disaster context, real-time data visualizations, collaborative response, e-participation.

1 INTRODUCTION: CONTEXT AND RESEARCH FRAMEWORK

On the 4th of August 2020, Beirut was devastated by one of the largest non-nuclear explosions ever recorded. Hundreds of tons of ammonium nitrate were detonated in the city's port, killing more than two hundred people, injuring thousands and displacing hundreds of thousands of citizens. This occurred in the midst of a lingering economic, political and health crisis that had left the country in lack of a proper governance system. At the wake of the blast, the level of urgency and scope of need for immediate humanitarian aid led to the participation of thousands of citizens, organizations, and grassroots initiatives in the recovery effort. The paper departs from a documentation of a selection of mapping methodologies that were deployed as case-studies of data-driven humanitarian mapping tools (2). It then expands to map the actor relational network of post-blast Beirut in view of identifying the systemic changes needed to enable a sustainable co-planning framework (3). The study then presents the design, development and testing of a pilot version of a web-app created by the authors and their collaborators at the wake of the blast (fig. 1 and 2 in appendix), to enable efficient data sharing, coordination and collaboration between the different actors of relief and planning (4). The research concludes with a summary of the findings and the elaboration of guidelines for further development of a cross-sector co-planning tool that engages citizens in the management of their city and the design of its future (5).

2 CASE STUDIES OF DATA-DRIVEN HUMANITARIAN MAPPING IN POST-BLAST BEIRUT

2.1 Bottom-up crowd-mapping

In the weeks that followed the blast, multiple crowd-mapping efforts took place in Beirut, putting to use a variety of platforms and methods to help cope with the intensity and scope of the immediate response rush. These collaborative bottom-up actions, also termed 'volunteered geographic information' by Goodchild and Glennon [1], present useful case studies to understand the role of citizen participation and cross-sector collaborations in data-driven humanitarian mapping, particularly in localities lacking digital data infrastructures such as Beirut.

In the context of immediate disaster relief responses, reliance on pre-existing softwares and **open-source applications** is key to enable the agile deployment of bottom-up data frameworks. For instance, the open-source software application Ushahidi, which utilizes **user-generated reports** to collate and map data, was adopted to Beirut's emergency response efforts in August 2020 to help connect people in need of humanitarian aid with those who were able to provide it (fig.9 in appendix). Similarly, the **street-level imagery** platform Mapillary was used to create a crowd-sourced geotagged photographic documentation of the extent of the damage to Beirut's built fabric following the blast (fig.10 in appendix). Open-source tools were also used to create **surveys** that feature **geolocation capabilities**, such as the Kobo Toolbox (fig.11). Volunteers visiting households in affected areas filled the form while providing basic needs to the inhabitants.

In parallel, the post-blast period was characterized by a speed of change of actors in charge of the responses. Relief initiatives emerged on the streets and online, and the need to document and structure the multitude of actors involved led to the emergence of organization driven collectives working on directories. Relief **directories were released** and were made available to the public in the form of editable content that would evolve progressively in parallel with the action. Open-source tools were utilized such as Airtable (fig.12), as well as more basic Google Drive Sheets or customized platforms such as the Beirut Recovery Resource Guide (fig.13).

The crowd-mapping efforts mentioned above were facilitated by the emergence of a **community of mappers**, who organized themselves through a collective, Open Map Lebanon, which conducted multiple initiatives to **promote open data** sharing, data governance and data-driven decision making in Lebanon. Similarly, emerging volunteer organizations and groups helped mobilize citizens and grassroot efforts to collaborate on post-blast surveying and data collection. In parallel, professional surveys of the built fabric and the impact of the blast were conducted by coalitions of students, practitioners, researchers and organizations (refer to paragraph A.3 in the appendix for more information). Moreover, the crowd-sourced data collection process is characterized by its rapidity and multiplicity, and thus requires a system of **consolidation** and **coordination**. Humanitarian organizations and governmental authorities have the potential to agree and disseminate a framework to follow (refer to section 3 for more information on the governance model and to section 4 for a description of the proposed alternative).

2.2 Specialized retrospective analysis

The bottom-up mappings detailed above were complemented by contributions from different specialized groups, organizations and companies within Lebanon and internationally.

2.2.1Analysis of post-blast satellite imagery

Analysis of **satellite imagery** can be instrumental in post-disaster situations as it allows to compute comparative spatiotemporal readings of changes on a territory. The level of precision and accuracy of these mappings vary, and these

methods remain prone to **algorithmic bias**, however, in contexts of post-disaster immediate response rush, they are needed to provide macro reading of the scope of the damage, as the following cases exemplify.

NASA's Advanced Rapid Imaging and Analysis (ARIA) team, in collaboration with the Earth Observatory of Singapore, used satellite-derived **synthetic aperture radar** data to estimate and map the **extent of the damage** caused by the Beirut blast (fig.14). This map was published a few hours after the blast and was used by ground relief teams to coordinate the first deployment efforts. The comparison of this mapping with the extent of damage surveyed by the relief teams confirms the inaccuracy due to image pixelation and obstruction of view by the explosion cloud.

More detailed satellite data analyses were conducted at a later stage: the European Space Imaging published before and after satellite images of the damaged area captured by WorldView-2. Comparative study of open access and freely distributed Sentinel mission data and imagery of the area before and after the blast allowed researchers to compose damage proxy maps of the Beirut blast of August 4th 2020 by using both optical and radar Copernicus Sentinel data in parallel. [2]

Satellite data was also used to retrospectively compute and analyze the level of **air pollution** in Beirut following the blast: publicly published data from the Sentinel-5P program enabled an analysis of the spatiotemporal distribution of nitrogen dioxide over Beirut in the days that followed the blast [3]. Since Beirut is not properly equipped with air pollution monitoring equipment, this satellite data analysis method is instrumental in such contexts.

2.2.2Computational blast simulation

Satellite data analysis provides patches and outlines of potential highly affected areas, however, to achieve an accurate heatmap of levels of impact without micro surveying, one needs to take into account the three-dimensional morphology of the city, as well as a variety of fluid dynamic conditions such as wind flows. In this context, a simulation of the impact of a 2750T ammonium nitrate explosion was conducted using the **computational fluid dynamic modeling software** Viper::Blast following a personal initiative by engineers at ARUP and explosive simulation company SSSL. (fig.15)

2.2.33D-Scanning and drone photogrammetry

Access to updated digital three-dimensional mapping of the built fabric is instrumental to ensure an efficient urban recovery. In the context of post-blast Beirut, the technique of **photogrammetry** was used to compose three-dimensional surveys of the area. Specialized **drones** by Geospatial Minds were deployed to gather images of the city. The collected data was later processed using Pix4D, a photogrammetry software that merges the imagery using machine learning to generate the point clouds which were modeled by Augment and made available under a Creative Commons License to inform the rehabilitation plans (fig.16). The project was realized in collaboration with Beirut FER, facilitated by LiveLove Beirut and Open Map Lebanon. Similarly, UNESCO and the Directorate General of Antiquities of Lebanon (DGA) commissioned the French startup Iconem to photogrammetrically create detailed 3D models of the damaged cultural sites to help in their reconstruction including iconic heritage buildings such as the Sursock Palace. Photogrammetry was the preferred choice as it is less costly than 3D-scanning, however, **3D laser scanners** were also used for specific structural assessment cases such as the analysis of the impact of the blast on the silos of the port. The silos surveyed using a 3D laser scan, then modeled using three-dimensional finite element techniques using Abaqus Explicit. [4] This approach was also explored in partnership with academic institutions: The Columbia GSAPP Collective for Beirut hosted a summer workshop with Beirut's Université Saint Joseph (USJ), where its students from both faculties of Architecture and Engineering assessed the damage of eight historic buildings in the city using 3D scanners.

2.2.4Investigative reports and macro analysis of crowd-sourced data

Crowd-sourced data was used retrospectively by specialized groups to generate assessments and reports. For instance, Forensic Architecture was invited to examine open-source information to provide a timeline and 3D model that would help investigate the cause of the 4th of August 2020 blast of Beirut. The team released an investigative report (fig.17) based on a detailed spatiotemporal analysis of videos, photographs, and documents with the support of an open-source 3D model of Beirut used to retrospectively estimate exact angles and locations of footage (fig.18). Similarly, the Beirut office of consultancy firm Strategy& compiled a needs assessment report and created a microsite making the data available to help inform relief efforts and reconstruction plans (fig.19). Moreover, The Zovighian Partnership organized round tables and the co-drafting and co-design of a "National social investment strategy to fund citizens' centered emergency response" presented as a working paper (fig.20). International academic institutions like the Architecture Association in London (AA) and Columbia University Graduate School of Planning and Preservation (GSAPP) organized symposiums connecting relief actors with academics specialized in urban planning and architecture to help co-analyze and discuss recovery strategies. These efforts emphasize the importance of collaboration between the different city actors to enable a shift from emergency response to long term planning as detailed in the next section.

3 MAPPING AND SYSTEMIZING A DECENTRALIZED ACTOR RELATIONAL NETWORK

As portrayed in figure 22, Beirut's post-blast actor relational network gave rise to an increasing number of influential actors outside the mandated state governance, which created parallel dis-coordinated networks of coalitions. Figure 23 calls for a need to connect the scattered efforts and actors through a communicating entity. An example of that entity exists: BeirutFER, a GIS-based platform created by the army, responsible for coordinating the rehabilitation efforts and ensuring that all areas are covered (fig. 21). The platform provides access to the different relief actors to enable data sharing and coordination. Yet, as a restricted-access platform with a top-down coordination model, it could not include all the relief actors, and was designed for temporary utility that would end once the rehabilitation was complete; no transition to long term sustainable planning and city management was envisioned or intended. Moreover, its data structure catered for rehabilitation tracking only and did not allow for cross-sector analysis. Due to these limitations, a systemizing link that would ideally bring together all the actors for co-planning and bridging the gap between a bottom-up and top-down approach is needed. As an alternative, a proposed governance model with a digital platform at its core is presented by the authors in figure 24 connecting the different actors (bottom-up and top-down). Figure 24 illustrates an envisioned concentric model with the active citizen at its outer edge who is connected to the core: a platform functioning as a digital round table enabling e-participation and co-planning. The concept of a platform society is addressed by Ampatizidou et al. in 2015 by stating that digital platforms make it easier to hack our existing fabric therefore catalyzing existing responses and creating a hybrid online/offline community where events are organized and real issues are addressed [5]. The following section presents the pilot version of this platform as a web-app that systematizes this proposed governance model.

4 EMERGE BEIRUT WEB-APP: DESIGN, METHODOLOGY AND FUNCTIONALITY

As demonstrated in the previous sections, the decentralized actor relational network of Beirut was growing further at the wake of the blast, and despite the multiplicity of the data-driven mapping efforts conducted, it lacked proper collaborative tools to enable efficient cross-sector data sharing to avoid redundancy, identify gaps and opportunities, and better link bottom-up and top-down efforts. In this context, 'Emerge Beirut' was developed to offer an agile digital system of collaboration and coordination. Featuring user-generated real-time cross-sector data sharing and visualization, the web-app aimed at enabling citizen e-participation and was conceptualized with the long-term objective of supporting a transition

from reactive disaster relief to proactive sustainable planning. The first version of the app, which was piloted in August 2020, supported the digitization of the evolving actor relational network of Beirut through customizable dashboards and dynamic data structures. The following paragraphs detail the design and development of the beta version webapp and extract findings from its pilot testing.

4.1 **Functionalities and components of the web-app: building blocks of an agile co-planning tool**

The main feature of the webapp consists of an **interactive map** of the city's actors and actions presented **across sectors**, **space and time**. A dynamic filter and zoom features allow a macro to micro reading of the cross-sector information (fig. 3 in appendix). Pins are color-coded based on the layers and are scaled based on quantifiable data to offer a comparative reading. By clicking on a pin, users can access a detailed description, data source and contact information. Made publicly accessible to authenticated and non-authenticated users, this layer-based mapping tool facilitates the identification of gaps, challenges and opportunities to enable data-driven co-planning within a context of high-stake issues and rapid change.

To share data and keep track of their individual actions, users could create an **account**, which generates a **personal dashboard** that they can customize (fig.2 in appendix). **User types** include individual and organization. The users can take on **different roles**: (1) basic role, (2) coordinator role, (3) administrator role. Each user role gives them access to specific features of the platform and specific database rights. The assignment of these roles mirrored the actual distribution of responsibilities on the ground, and were systematized in an agile manner to allow for a horizontal model of decentralized consensus-based governance.

The web-app allows authenticated users to **share data** in the form of a pin on the map, a dataset, a GIS mapping, or an API integration. The 'add pin' form follows a similar layer structure and graphical representation as the interactive map, and offers the possibility for users to propose new categories and subcategories (fig. 4 and 5 in appendix). Depending on the tags selected, questions about **qualitative and quantitative information** appear in the form, allowing to deepen the documentation in a structured manner. Users are able to edit and update the information later on through their dashboard. Data source and timestamps are recorded for traceability. Users can share information or pins about an event that they actioned, or simply witnessed, thus offering **two distinct modalities of crowd-sourcing**: users as mappers and users as actors. In the case where a pin was shared through the 'user as mapper' modality, if the actual actors of the action have an account on the platform, the pin would appear on the actors' dashboards and be open for editing, vetting and updating by the actors. Authenticated users with coordinator roles are also allowed to **edit and vet data** submitted by other users in their respective categories. Authenticated users with administrator roles have the responsibility to coordinate the vetting and updating of the data. New pins do not appear on the public map before their vetting process is completed. Furthermore, the web-app enabled the **inclusion of pre-existing datasets** which were structured, cleaned and vetted by citizen scientists. Such datasets included publicly available maps such as NASA's ARIA Damage Map: Beirut Explosion Aftermath, Liveuamap and BeirutFER, as well as files directly provided by actors such as NGOs involved in reconstruction. In future versions of the app, API integration of different actors' own platforms as well as collection of social media data through Twitter and Facebook APIs would allow for a more efficient data aggregation process.

4.2 Dynamic cross-sector data structure and visualization

To enable a proper data collection and aggregation mechanism that would allow for a shift from a short-term emergency response to a long-term sustainable planning framework, the data structure of the app was designed in an **agile** manner to allow for the grouping and visualization of information into dynamic sets of categories and subcategories. For that purpose, a NoSQL real-time database was chosen its non-tabular framework allows for more flexibility than SQL databases. A

tagging system was used to dynamically group the data points in layers. The layer menu was appended based on a reference JSON file, which was progressively updated by the team of curators to adapt to the evolving data inputs and priorities. For instance, the layers appearing on the web-app during the first week were mapping: Active Hospitals, Red Cross Units, First Aid Tents, Ground Relief Bases, Debris Dumps, Food Distribution Tents, Food Shelters, Active NGOs, Donation Zones, Volunteering Units, among others (fig. 6 in appendix). As the weeks went by, the emergency response layers progressively shifted towards long term sustainable development actions such as: Heritage Preservation, Waste Management, Social Needs Assessment, Structural Building Analysis, Energy, Mobility, etc. This dynamic layer structure allows the user to customize cross-sector data visualizations in real-time. For instance, 'Beirut: the immuno-responsive city' is a series of maps created by the authors using Emerge and presented as part of the Beirut Shifting Grounds project at the 17th Venice Biennale of Architecture (fig. 7 and 8 in appendix). Refer to paragraph A.4 in appendix for information about the programming of the web-app, mapping and data visualization.

4.3 User-centered design strategies: participatory design and prototyping

The platform was co-designed by a multi-disciplinary team using a design thinking methodology that merged a bottom-up user-centric approach with a top-down planning strategy, and incorporated stakeholder inputs in the form of collaborative ideation, focus groups and pilot deployments. Interviews with actors on the ground with different roles were conducted, and the dashboards were co-designed through brainstorming and testing sessions. Priority was given to user-friendliness to maximize inclusivity on the platform and enable access to complex humanitarian and planning data to a diverse pool of professional and non-professional users through color-coding and the use of infographics. The Emerge Beirut initiative was not funded nor incorporated, and was fully based on collaborative volunteering contribution. This model proved useful in the context of emergency response as it allowed any interested citizen or organization to take part in the action. Yet, for a long-term implementation of the platform, the volunteering based non-profit non-funded model has its challenges (refer to paragraph A.2 in the appendix for more information about the team behind pilot version of the web-app).

5 CONCLUSION

At-risk population percentages are increasing due to a multitude of simultaneous and sequential humanitarian challenges. The challenges, whether climatic, health, or economic related have two underlying factors, their speed and volatility in spilling over globally. These issues necessitate that we take a serious look at how resilient our communities are, and their ability to support real-time responses that are efficient, inclusive and open. The case of Beirut demonstrates the resourcefulness of citizens in self-organizing relief efforts, co-mapping, and co-planning. The research aims to extract learnings that could benefit similar post-disaster settings and enable a shift from reactive to proactive responses. Citizen engagement, when prioritized, can thus lead to more sustainable governance models. However, in the case where the government sidelines citizen efforts, e-participation through a decentralized platform could help bridge the gap between bottom-up and top-down. The paper thus elaborates on such platform and how it can help achieve digitization and systemization. In order to shift from pilot to implementation stage, the organizational structure of the project needs to be reconsidered, three options arise: (1) full open-source model incentivizing the contributors using digital currency and circular economic frameworks, (2) funded non-profit entity handling the maintenance and development of the platform, (3) e-governance model linking the web-app to official authorities as well as democratic systems of citizen engagement. Considering the difficult political climate of Lebanon which is lacking transparency and accountability, the latter is difficult to implement on the short term. The second, although feasible, imposes a rather static centralized form of governance of the platform which could compromise the very nature of the project, unless framed as a decentralized autonomous

organization (DAO). The first seems to be the most promising on the long run yet is difficult to achieve without dedicated volunteers or funding. We conclude that the most convenient model would start with a pre-funded DAO (2) that works to create and release the version 1 of the platform which will operate as an open-source project incentivizing its contributors (1).

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A APPENDICES

A.1 Figures

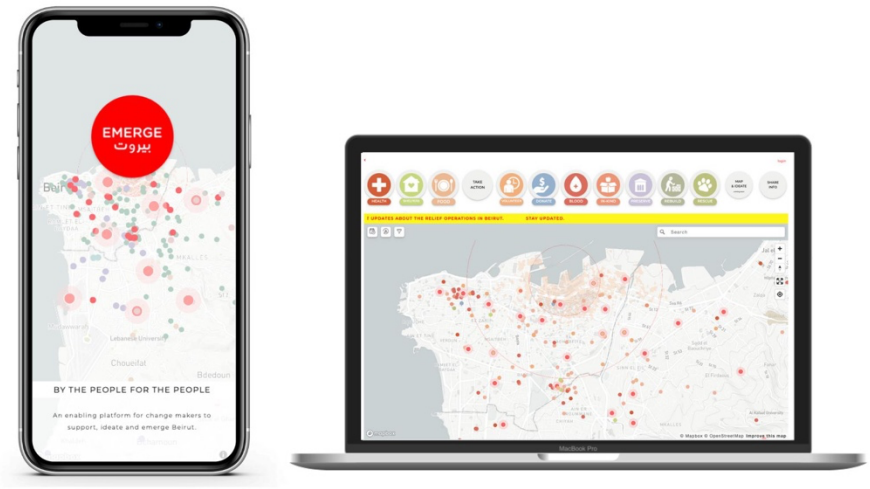

Figure 1: Pilot Version of Emerge Beirut Digital Platform: Mobile Homepage and Interactive Map Page on Desktop Device (own source)

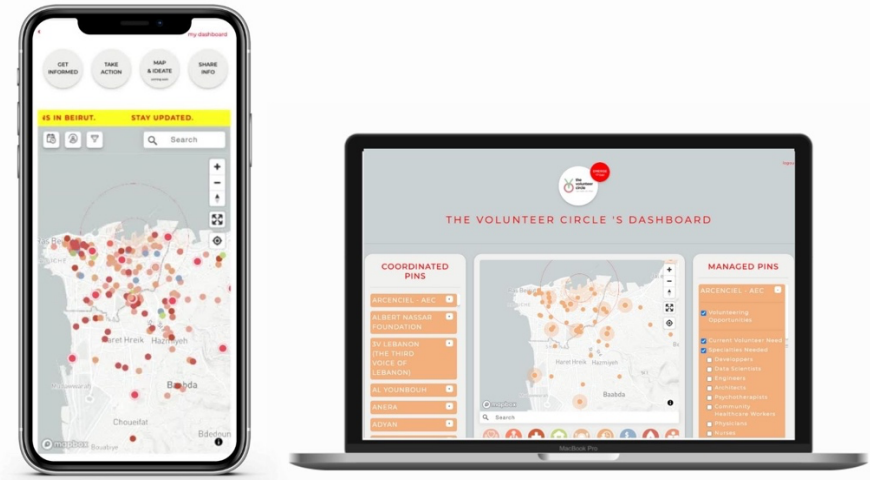

Figure 2: Pilot Version of Emerge Beirut Digital Platform: Interactive Map Page on Mobile and Coordinator Dashboard on Desktop (own source)

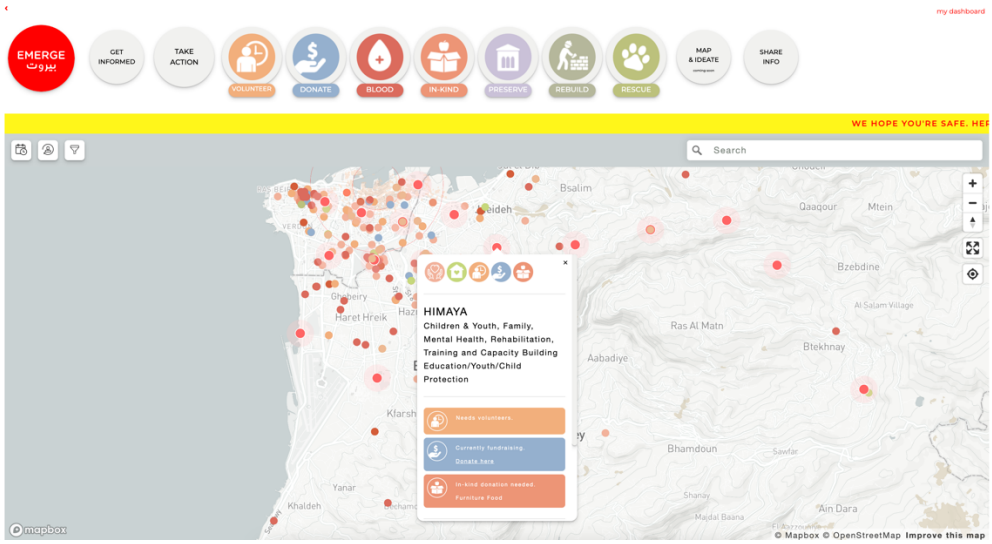

Figure 3: Pilot Version of Emerge Beirut Digital Platform: Interactive Map Showing the Take Action Layers and Pin Pop-Up on Desktop (own source)

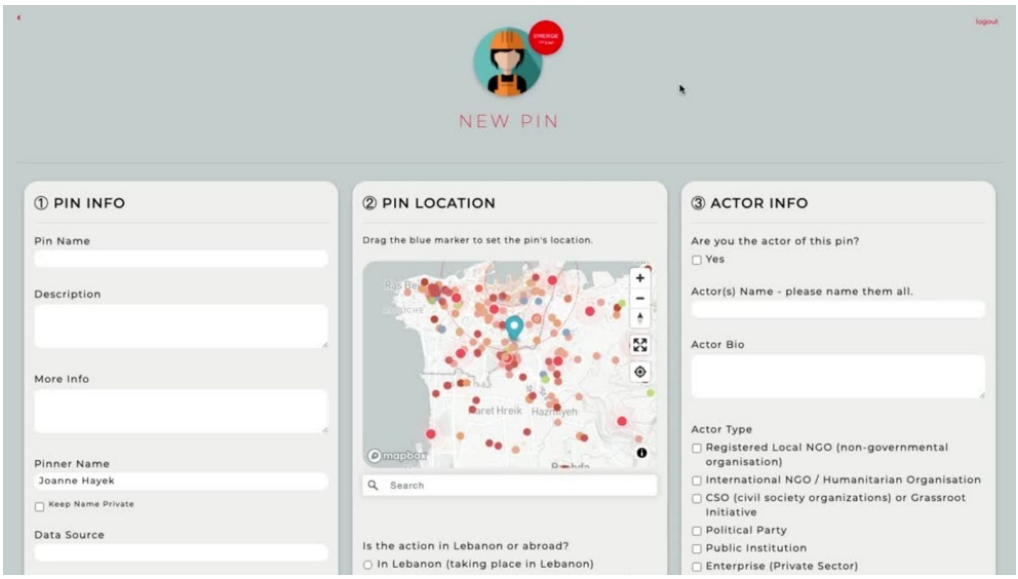

Figure 4: Pilot Version of Emerge Beirut Digital Platform: New Pin Page, Main Info (own source)

Figure 5: Pilot Version of Emerge Beirut Digital Platform: New Pin Page, Dynamic Layer-based Data Categorization (own source)

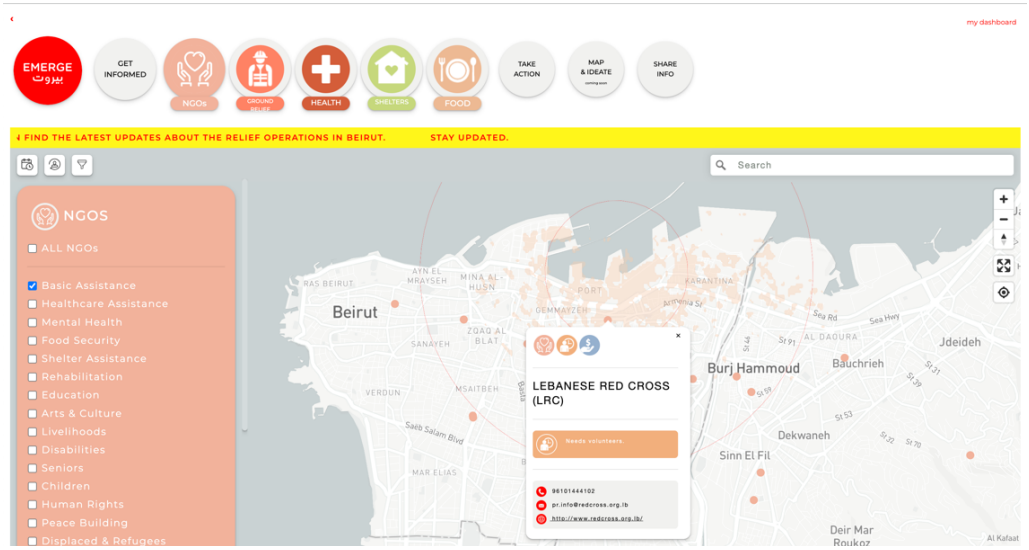

Figure 6: Pilot Version of Emerge Beirut Digital Platform: Interactive Map, Dynamic Layer-based Filtration and Pop-Up Features (own source)

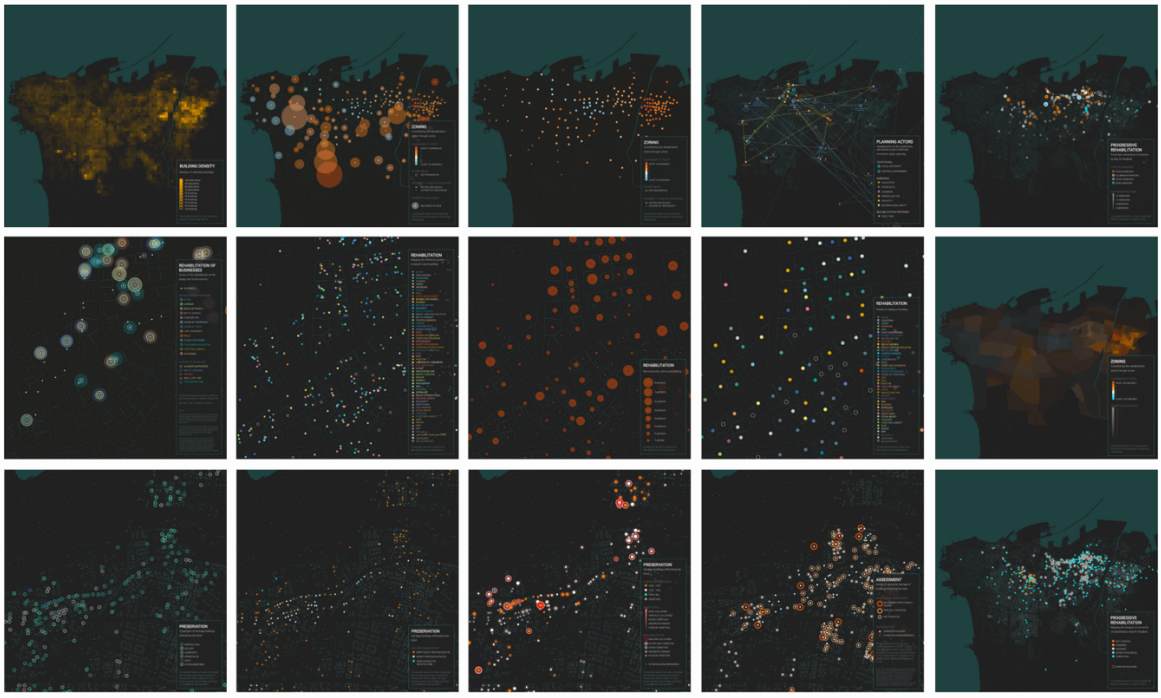

Figure 7: Use of Emerge Beirut Functionalities for Computational Mapping of Post-Blast Beirut. Extracts of maps as part 'Beirut Shifting Grounds' Hayek, Joanne, and Balsam Madi. 2021. *Beirut Post Blast*. Digital. Venice: Venice Bienale - Arsenal Exhbition Co-habitats - Beirut Shifting Grounds.

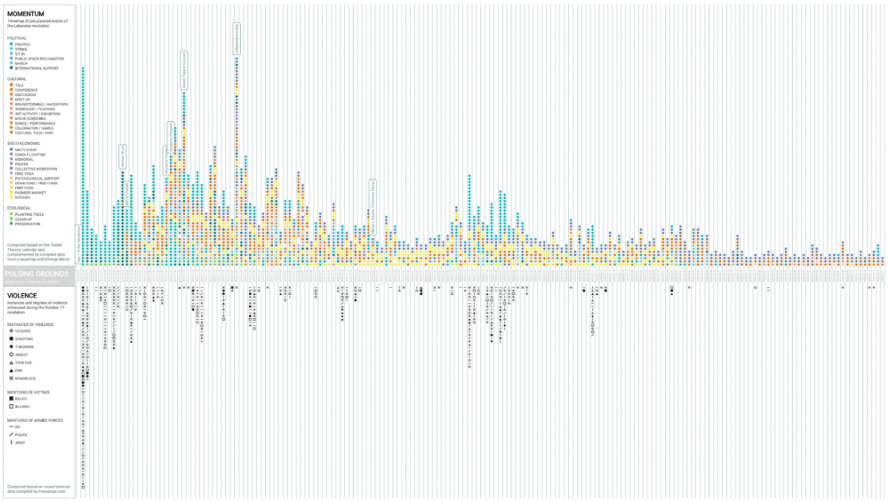

Figure 8: Use of Emerge Beirut Functionalities for Computational Mapping of Post-Blast Beirut. Extracts of time map presented as part 'Beirut Shifting Grounds' Hayek, Joanne, and Balsam Madi. 2021. *Beirut Pulsing Grounds*. Digital. Venice: Venice Bienale - Arsenal Exhbition Co-habitats - Beirut Shifting Grounds.

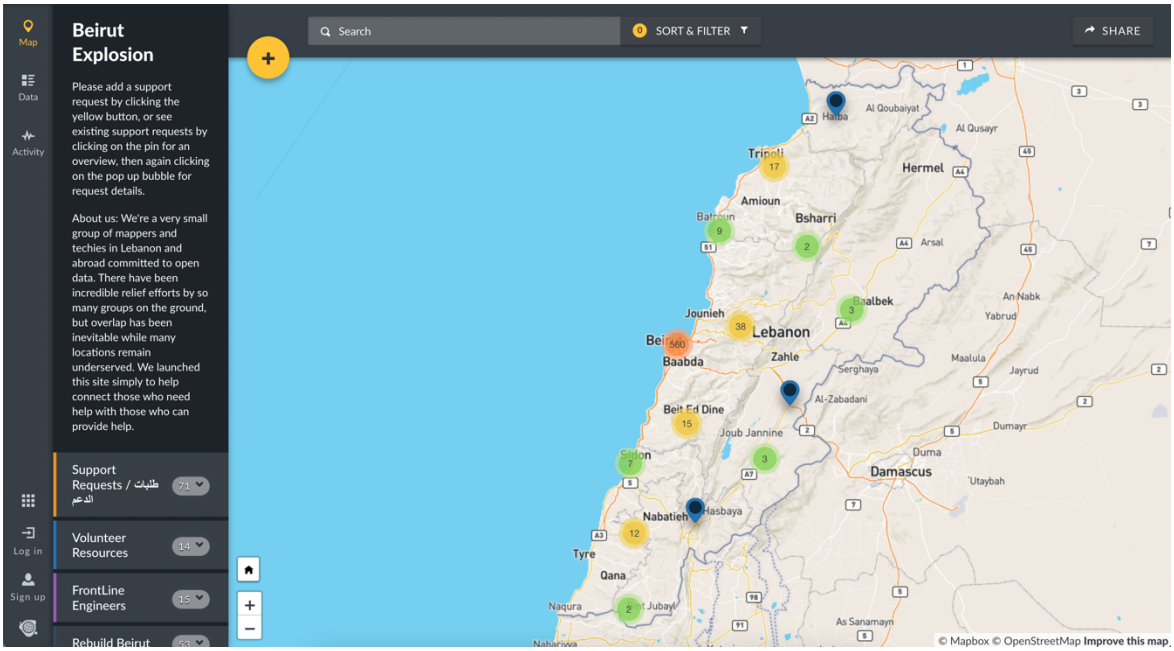

Figure 9: Screenshot of Ushahidi Beirut Map (https://beirut.ushahidi.io/)

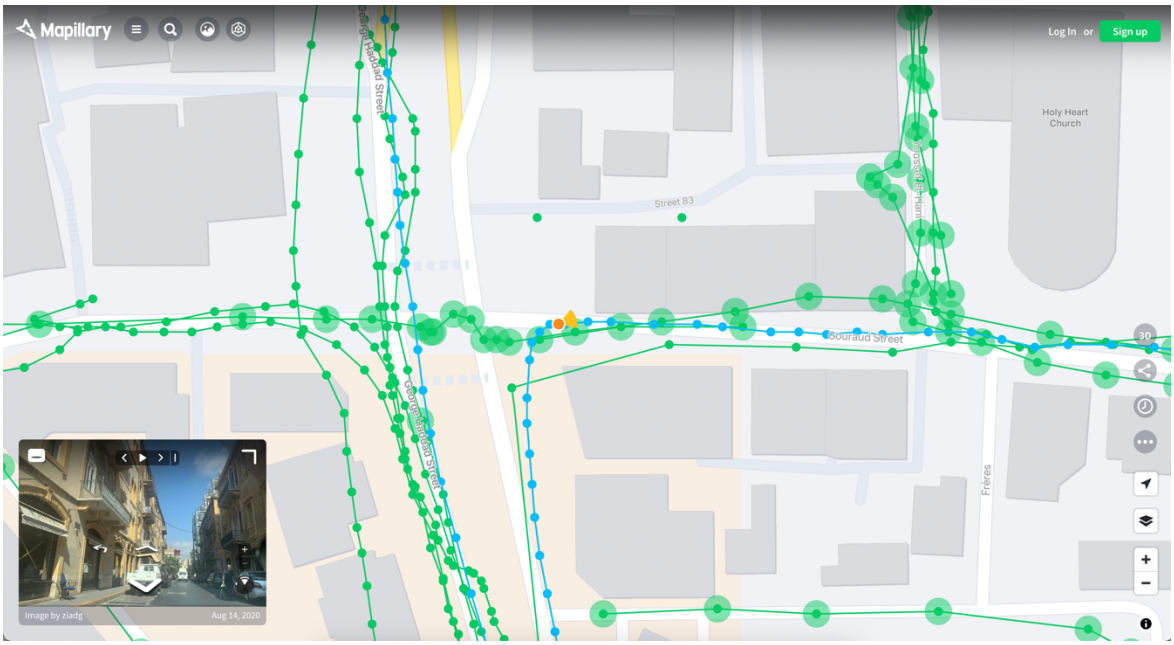

Figure 10: Screenshot of Mapillary Beirut (https://openmaplebanon.org/street-level-imagery)

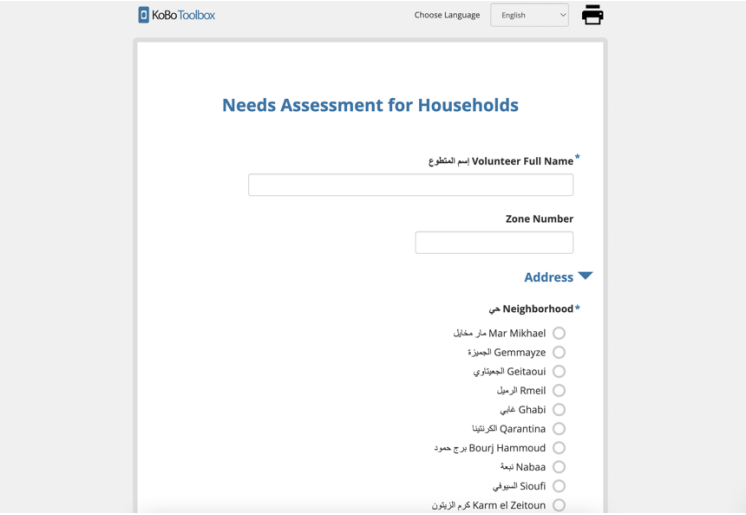

Figure 11: Screenshot of Needs Assessment for Household Survey used by volunteers in post-blast Beirut created using KoBo Toolbox (https://ee.humanitarianresponse.info/x/Mqcg4LPJ)

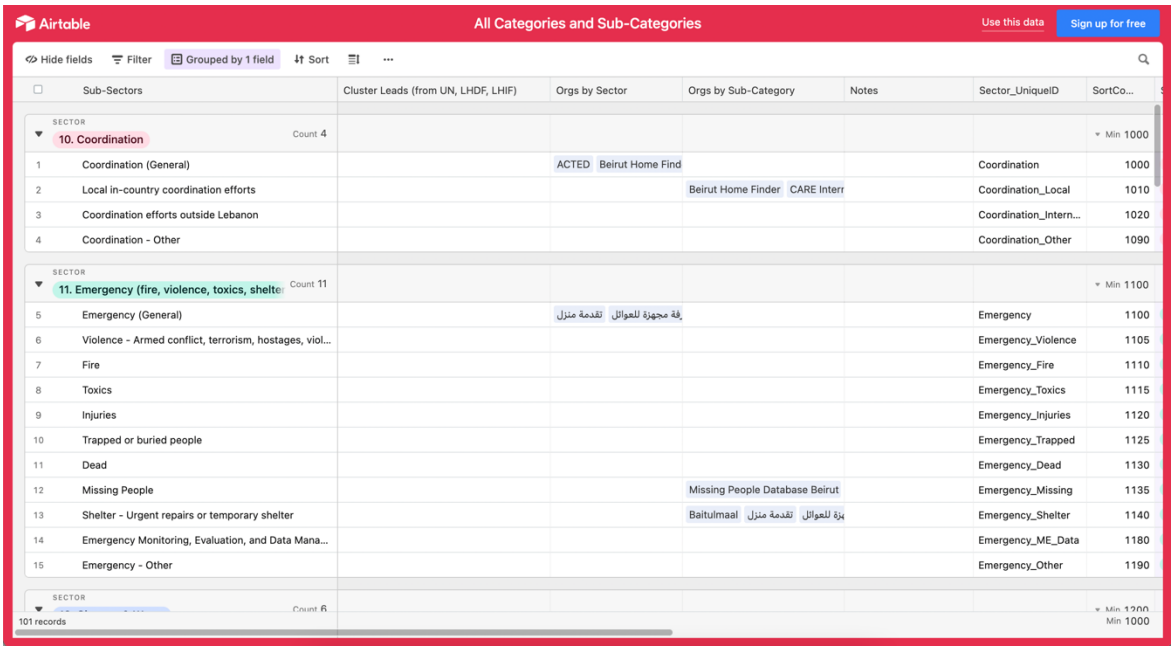

Figure 12: Screenshot of directory created on Airtable (https://airtable.com/shrbIDxps063KzcqI/tblirEbErsp3Tcr88)

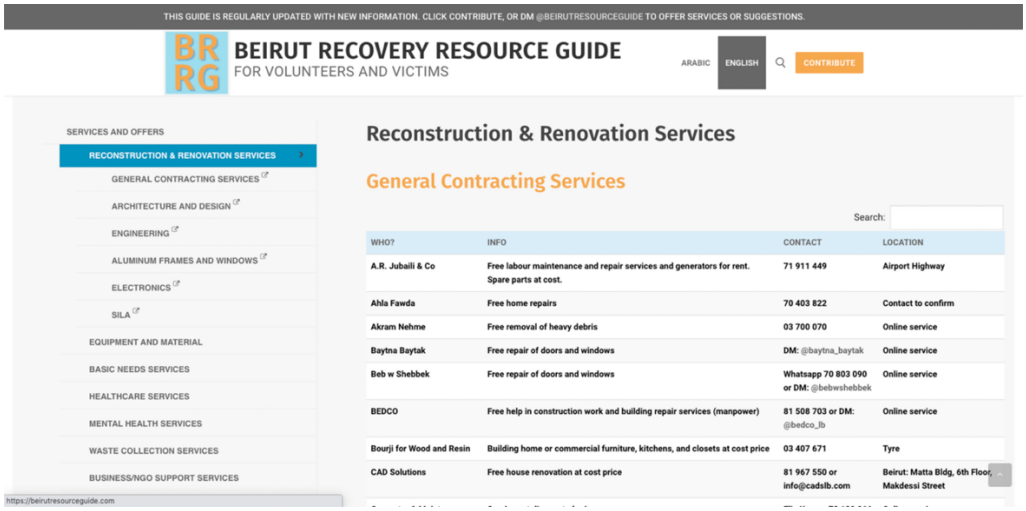

Figure 13: Screenshot of the Beirut Recovery Resource Guide (https://beirutresourceguide.com/)

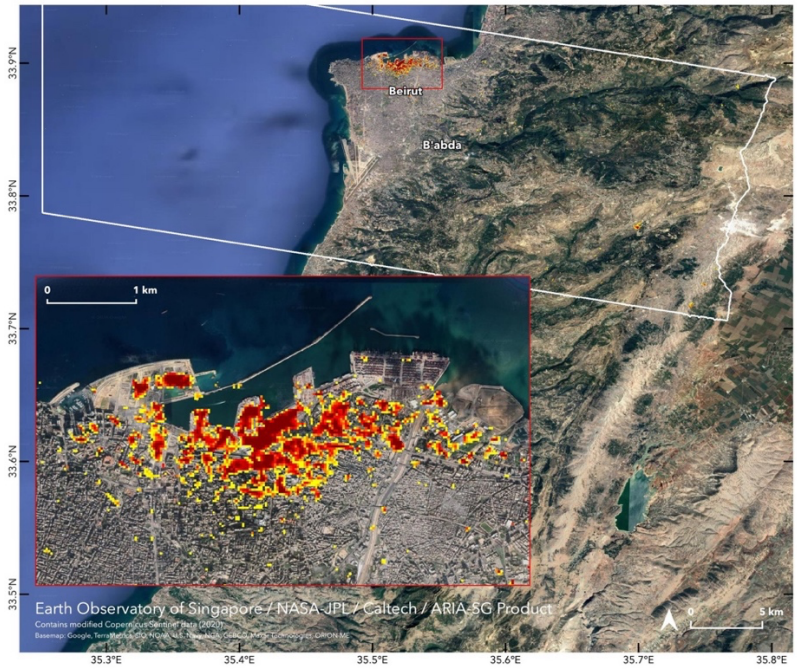

Figure 14: ARIA Damage Map: Beirut Explosion Aftermath (https://www.jpl.nasa.gov/images/pia23692-aria-damage-map-beirut-explosion-aftermath) – Credit: NASA/JPL-Caltech/Earth Observatory of Singapore/ESA

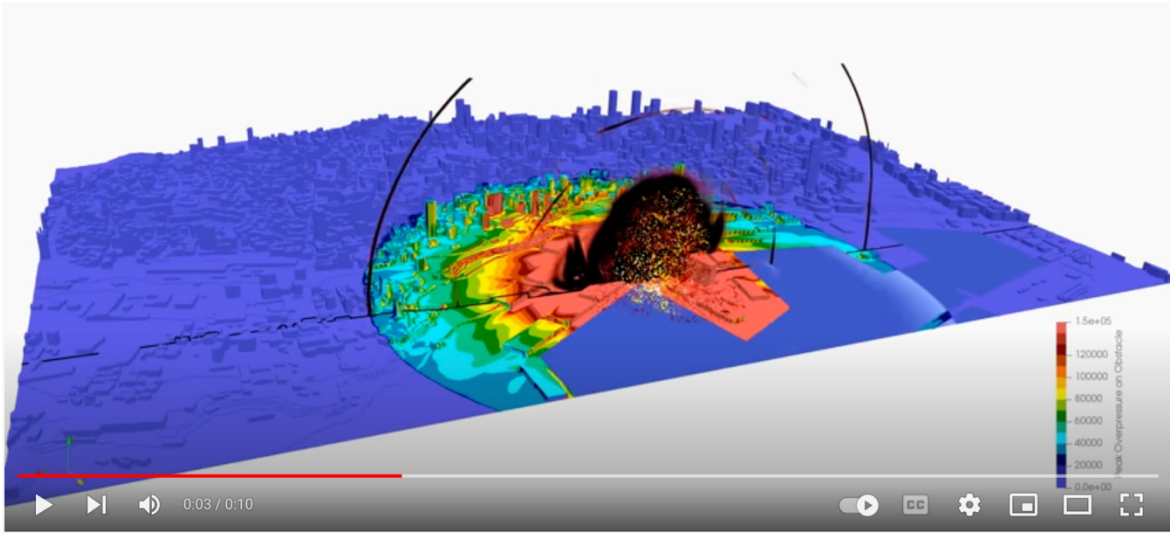

Figure 15: Screenshot of Beirut Ammonium Nitrate explosion simulation – ArupGroup with Viper:Blast (https://www.youtube.com/watch?v=niEoMkdJaQA&t=3s)

Figure 16: PIX4Dcloud map by Augment (https://eena.org/blog/the-beirut-explosion-drone-mapping-for-recovery/)

Figure 17: Extract of Forensic Architecture's Beirut Port Explosion investigative report. Image match of a photograph showing the position of bags of ammonium nitrate within the warehouse overlaid on a 3D model of the warehouse. Original image from anonymous source, January 2020. (Forensic Architecture, 2020)) (https://forensic-architecture.org/investigation/beirut-port-explosion)

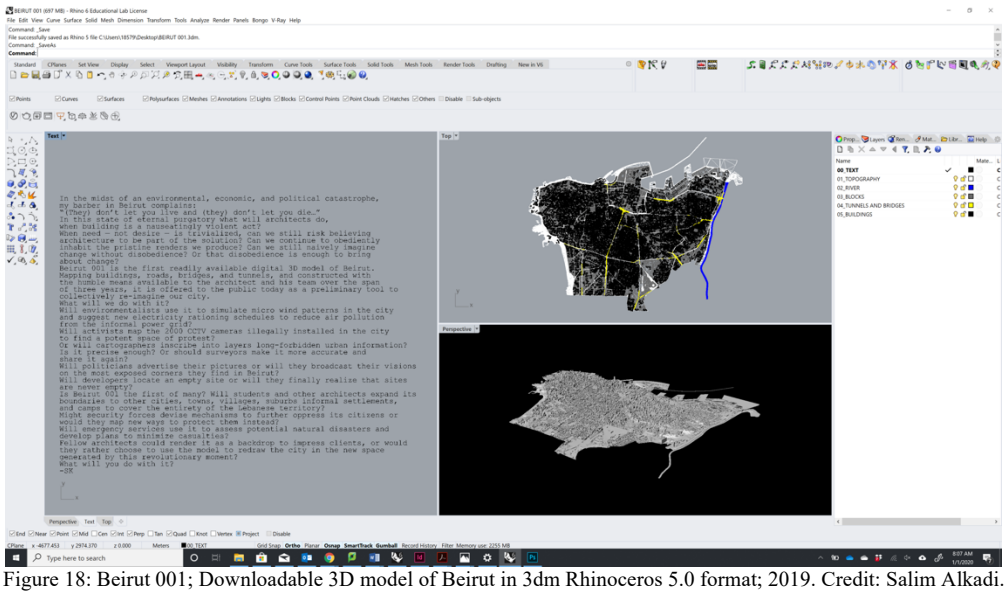

Figure 18: Beirut 001; Downloadable 3D model of Beirut in 3dm Rhinoceros 5.0 format; 2019. Credit: Salim Alkadi. (http://www.salimalkadi.com/07_beirut-001)

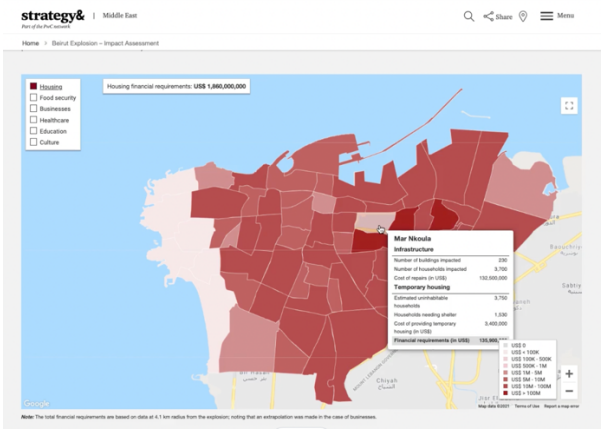

Figure 19: Screenshot of needs assessment microsite created by Strategy& Beirut (https://www.strategyand.pwc.com/m1/en/beirut-explosion.html)

Figure 20: Screenshot of web publication of collaborative paper and strategy by The Zovighian Partnership 'Beirut Explosion: Drafting A National Social Investment Strategy To Fund A Citizens-Centered Emergency Response' (https://www.zovighianpartnership.com/beirut-explosion/drafting-a-national-social-investment-strategy)

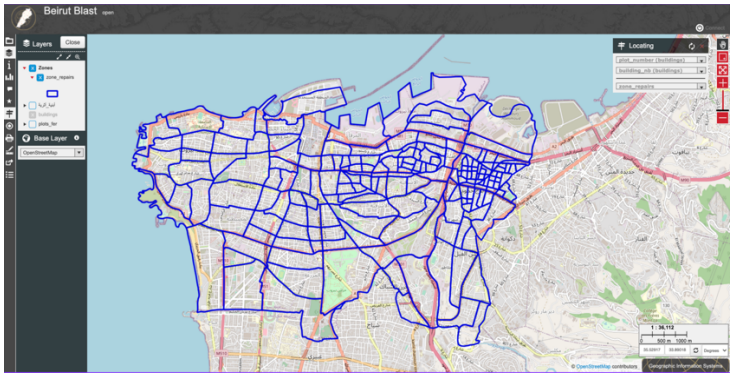

Figure 21: Screenshot of BeirutFER (Beirut Forward Emergency Room) Platform, 2021. (https://beirutfer.com/)

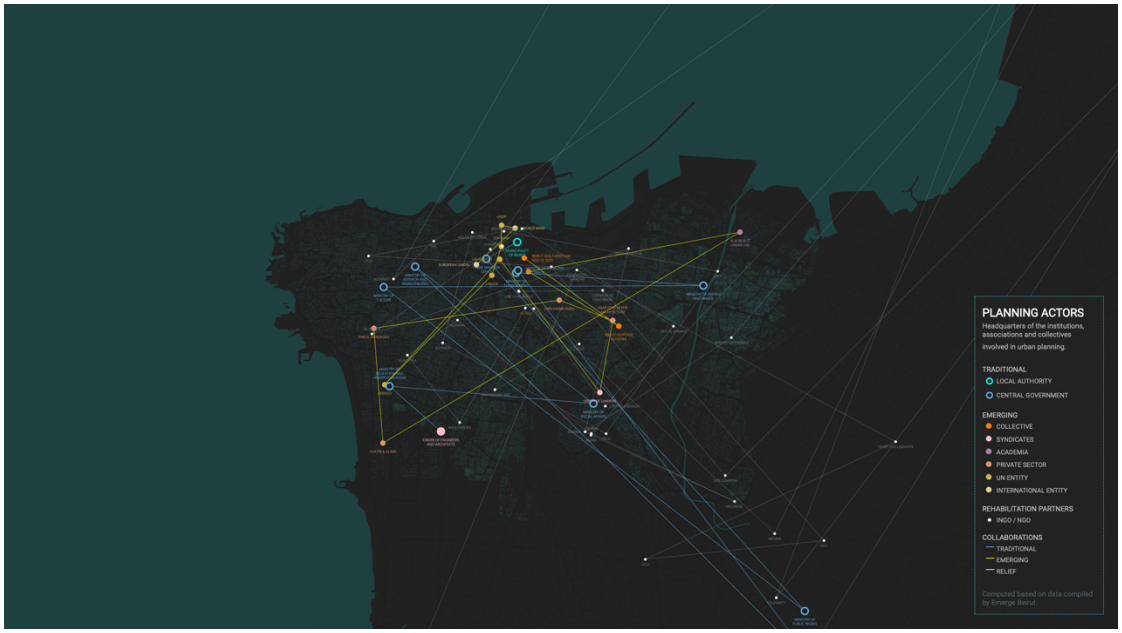

Figure 22: Scattered actor-relational network of post-blast Beirut. Map presented as part 'Beirut Shifting Grounds' Hayek, Joanne, and Balsam Madi. 2021. *Beirut Post Blast*. Digital. Venice: Venice Bienale - Arsenal Exhbition Co-habitats - Beirut Shifting Grounds.

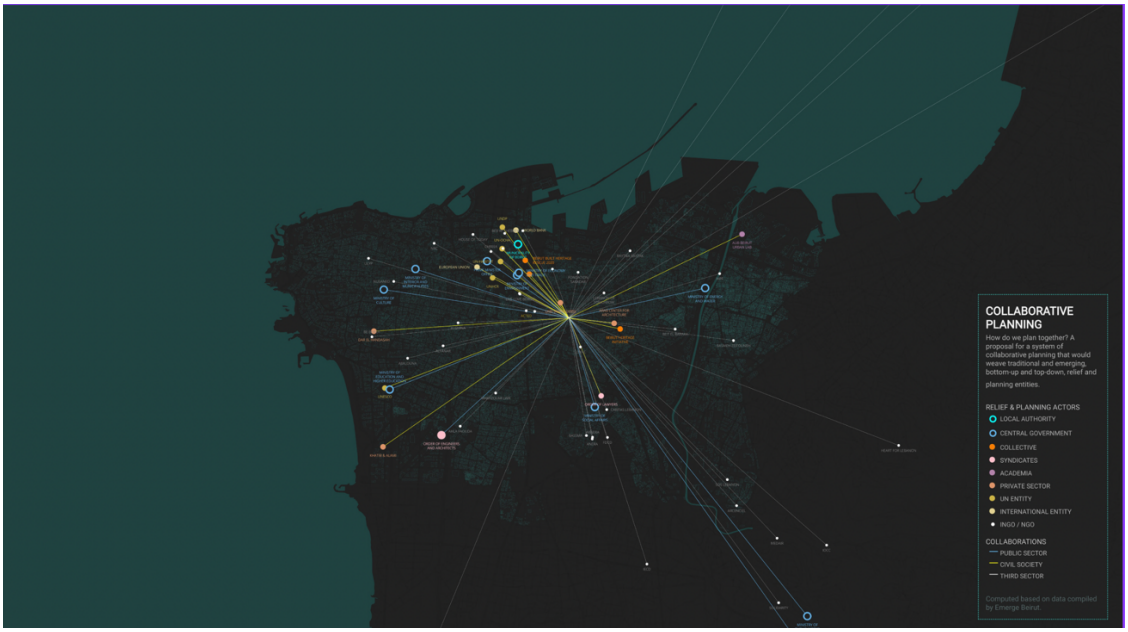

Figure 23: Need for systematizing the ramified actor-relational network of post-blast Beirut. Map presented as part 'Beirut Shifting Grounds' Hayek, Joanne, and Balsam Madi. 2021. *Beirut Post Blast*. Digital. Venice: Venice Bienale - Arsenal Exhbition Co-habitats - Beirut Shifting Grounds.

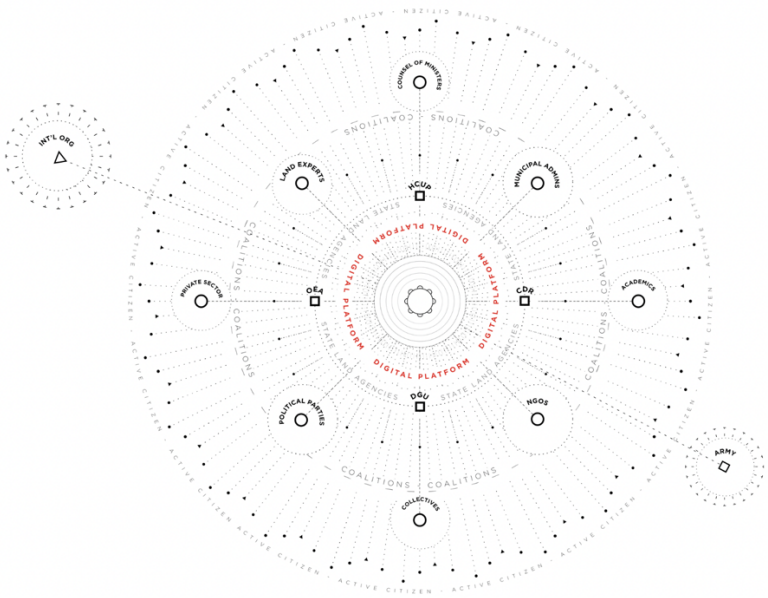

Figure 24: Collective Governance Model Proposed for Lebanon: linking top-down to bottom-up (own source).

A.2 Collaborators

A.2.1 Emerge Beirut

Emerge Beirut was co-founded by Joanne Hayek, Rawan Bazerji, Adib Dada and Fadi Katergi, and was co-designed with the support of Balsam Madi, Nayla Hage-Chahine, Mitcha Sleiman, Lynn Dakkak, Roula Salamoun, Hussain Zaarour, among others. It was coded by Joanne Hayek with the help of Michel Doumet.

A.2.2. Beirut Shifting Grounds

Beirut Shifting Grounds, research project was led by Sandra Frem and Boulos Douaihy in collaboration with ArD/ AUB faculty Carla Aramouny, Rana Haddad, Nicolas Fayad and Joanne Hayek- exhibited in the Co-Habitats Section of the 17th International Architecture Exhibition - La Biennale di Venezia curated by Hashim Sarkis.

A.3 Collaborative Surveying Efforts

Beirut post-blast was lacking a digitized cadastral mapping th … The below paragraph documents some of the actors and mechanisms that enabled the collaborative surveying efforts conducted in post-blast Beirut:

- Emerging volunteer organizations and groups such as The Volunteer Circle, Live Love Beirut, the Basecamp, and Nation Station helped mobilize citizens and grassroot efforts to collaborate on post-blast surveying and data collection.
- The Beirut Built Heritage Rescue (BBHR2020, under the aegis of the General Directorate of Antiquities), along with the collective Beirut Heritage Initiative and the Arab Center for Architecture, conducted a series of surveys of heritage buildings

in the areas affected by the blast to inform the preservation and rehabilitation strategies (https://issuu.com/beirutheritageinitiative/docs/beirut_heritage_initiative_-_report_2020-2021)

- Similarly, the Order of Architects and Engineers, along with coalitions of architecture and engineering firms and student groups, mapped the structural and architectural damages along the main streets affected by the blast. In the months that followed, further surveys were conducted, also including a mapping of the impact on the social and economic fabric of the areas.
- The Relief Center's citizen scientists conducted a survey of buildings in the area of Mar Mikhael, comparing their status to pre-blast conditions to understand the scope of the damage on the built and social fabric. In the same area, NGOs and collectives such as the Women Collective, Al Fanar and Together LiBeirut mapped the businesses and livelihoods affected and their impact on the neighborhood community.
- The army also conducted its own survey of all affected areas, which led to a revision of outdated cadastral maps of the areas.
- The army also collaborated with academic research labs such as the Beirut Urban Lab and RICE Spatial Studies Lab as well as grassroot collectives such as Open Map Lebanon to visualize the progress of the rehabilitation to help identify gaps.
- The Red Cross collaborated with UNHCR to create a Multi-Sector Needs Assessment Geosplit, fragmenting the city into subzones and assigning the responsibility of each subzone to an NGO or INGO.

A.4 Code Architecture of Emerge Beirut Pilot Web-app

The following paragraph details some of the programming frameworks used for the pilot version of Emerge Beirut developed in 2020:

- Coding languages and libraries used: HTML, CSS, Bootstrap, Javascript, Mapbox JS, Mapbox GL, Turf.js.
- Data: the database chosen was the Firestore by Firebase, a real-time noSQL database. Data inputs were structured using the GeoJSON format which enabled both spatial and temporal cross-sector visualizations.
- Firebase Authentication was used to authenticate users and grant role-based read and write rights.
- The layer-based visualization of the geospatial data was done using the Mapbox GL, a client-side JavaScript library for building web maps. Fetching data in real-time from the Firestore database as GeoJSON format, Mapbox.js functions are used to display interactive layers on the map.
- The Mapbox geolocation feature and Mapbox Geocoding API were implemented to facilitate the navigation.
- The base-layer of Mapbox features Open Street Map data customized on Mapbox Studio and complemented by other polygon layers prepared through QGIS by aggregating relevant publicly accessible shapefiles and datasets.
- The Turf.js Javascript library for spatial analysis was used in concordance with Mapbox.js to create grid-based heatmaps and animated storytelling.

For the creation of the Beirut Shifting Grounds mapping, a further development of the beta version of the Emerge platform was developed in 2021 to incorporate a new feature: personal customization of maps and data structure with the possibility to create and extract animated interactive maps and timelines that retrace the grassroot deployment across space and time. Further development of this feature proposes to use the D3 and Sigma Javascript libraries for the further development of the interactive diagramming features.