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**Abstract**

Chacarita is one of the most traditional neighborhoods of Asuncion, the capital city of Paraguay. In spite of its major social and cultural relevance and its proximity to downtown, this community has been historically an enclave of exclusion. This situation is observed in the lack of adequate infrastructure, sanitation and housing, but also extends to the area's representation in the city's official cartography. Indeed, Chacarita has been, for years, a blank area on city maps. This situation has only recently been reversed, within the framework of the Integral Neighborhood Improvement Project. This essay explores methods used to overcome Chacarita's "cartographic gap", combining state-of-the-art technologies and participatory approaches. The work was undertaken by a group of teachers, professionals and students of the Faculty of Architecture, Design and Arts of the National University of Asuncion, in partnership with the NGO Habitat for Humanity Paraguay.

Its products include 2D and 3D high precision cartographic documentation and the characterization of physical-urban elements within the action polygon bounderies of the Chacarita Alta project. Volunteer students were trained to carry out the characterization of physical-urban elements, which was then synthesized using free licensed GIS software. Complementary technologies such as drone produced high resolution imagery and real time kinetik GPS allowed to perform the work with high efficiency, both in terms of cost and time. This experience allowed to put into practice a method to address the task complexity, given its limited resources and deadlines. We hope this work constitutes a meaningful contribution on the topic of how to approach databases creation processes that may foster positive transformation of segregated communities, so common in Latin American urban areas.

**Keywords:** Cartography, Participatory mapping, Urban planning, Vulnerable communities, Free software

## 1 Background

### 1.1 About institutions involved in the process

In 2013, the Faculty of Architecture, Design and Arts of the National University of Asuncion established the Center for Research, Development and Innovation, CIDi. Supported by the Paraguay National Council of Science and Technology (CONACYT Py) and funded by the Mercosur Structural Convergence Fund, CIDi is an advanced center for research and services, aimed at: 1. promoting the culture of digital manufacturing in Paraguay, 2. providing consulting services; and 3. promoting research and training projects. From its foundation, CIDi has become a national reference in the area of urban planning, as part of an international researchers network.

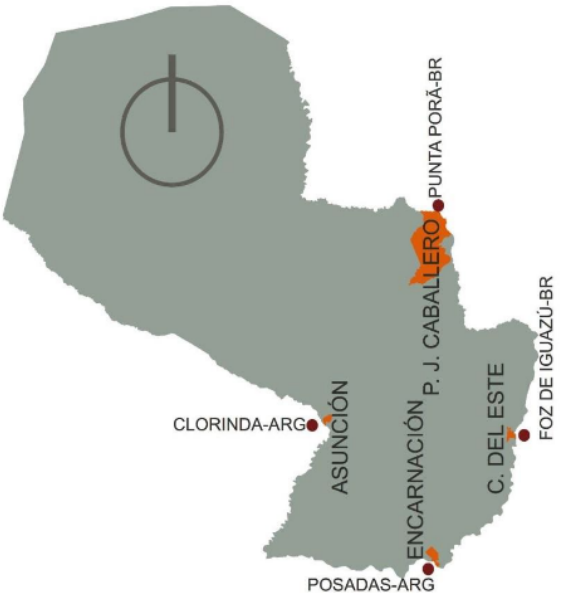


**Fig. 1**: The Republic of Paraguay map. Source: Authors

The NGO Habitat for Humanity Paraguay was hired to lead social processes in the context of the Chacarita Alta Comprehensive Neighborhood Improvement Project, promoted by the National Secretariat of Housing and Habitat - SENAVITAT, and funded by the Inter-American Development Bank. Habitat for Humanity is financially supported by the Multilateral Investment Fund of the Inter-American Development Bank. Based on this action platform, HPH Py has promoted several basic studies on the community, including a census of beneficiary families carried out by the Development Institute (ID, 2016), and the mapping and characterization of the Chacarita Alta neighborhood housing and public spaces.

To develop the aforementioned mapping and characterization work, HPH Py organized a public call for technological development centers or research centers which gathered interest, relevant experience and trained professionals to promote such a process, with few precedents in Paraguay. CIDi responded to the call and was thus selected.

**1. 2 La experiencia del Plan CHA y el mapeo del Centro Histórico de Asunción**

During the second semester of 2014 and the first semester of 2015, several members of CIDi technical team took part in the development of the planning of the historic center of Asuncion, the PlanCHA. This plan has been object of an international competition promoted by the National Secretariat of Culture. Under the leadership of Belinda Tato and José Luis Vallejo, the Spanish office Ecosistema Urbano won the competition, joining later Juan Carlos Cristaldo as a local professional, to form the Urban Lab Consortium, responsible for the PlanCHA development.[1]

One of PlanCHA's major challenges was to create databases that would allow to formulate and discuss urban proposals based on facts. It was required to create a baseline of cartographic information able to describe fundamental variables for the project. Such variables included the buildings conservation status, usages of the ground floor and other levels, presence of heritage assets not described in official records, existence of empty buildings or plots occupied by parking lots, among others.

To respond to these and other needs of the project, a working group called #LABCHA was created, starting from an initial workshop under the same name, held at the Cultural Center of Spain Juan de Salazar, in Asuncion, between October 28 and November 7, 2014. The #LABCHA worked throughout the development of PlanCHA, mainly involving young professionals and students of different careers, with a predominance of architecture students. This group of people highly committed to their city was trained to work collectively in the production of a complete mapping of the 300 hectares of the historical center. Volunteers and professionals from #LABCHA also worked in promoting urban actions and organizing a final exhibition at the Casa de la Independencia Museum.

**1.3 Mapping all Paraguay: the ITT 60 Py 14 experience and Map PY OSM**

Prior large-scale mapping experiences developed at CIDi were the "Infrastructure and Territorial Transformation in Paraguay 1960-2014 (ITT 60 Py 14) Project", and the "Participatory Mapping of Paraguay on the Open Street Map platform (MAP Py OSM)".

The "Infrastructure and Territorial Transformations in Paraguay 1960-2014 (ITT 60 Py 14) Project" focuses on three regions of the country which have undergone intense territorial transformations in recent decades. The project deals with the so-called Triple Frontier, formed by Ciudad del Este, Foz de Iguaçu and Puerto Yguazú, and transformed by the construction of the Itaipu binational dam; the Yasyreta Lake region, which includes the cities of Encarnacion and Posadas, strongly modified by the Yasyreta binational dam; and the urban-rural territory of the Paraguayan Central Chaco, which includes the cities of Filadelfia, Loma Plata, Neuland and Mariscal Estigarribia. In terms of analytical cartography, all three regions presented severe gaps in terms of available geospatial information. Regarding the whole Paraguayan national territory, there is a national base of lots provided by the National

Land Registry (SNC), and also a database of points of services and points of housing provided by the National Bureau of Statistics, Surveys and Censuses (DGEEC).

However, the shape of buildings, which in turn allows defining characteristics of urban plots, are not mapped systematically in these cities. Nor are systematically mapped the masses of vegetation in the country's urban areas. This is why it was important to produce databases that would allow us to analyze in depth the cities involved in the 60 PY 14 Project. For the CIDi team, the challenge was to create a simple, economical procedure and of high precision, which allowed the production of geospatial data required by the project, thus combining information produced by CIDi with those provided by the SNC and DGEEC official bases. Several months of work led to refine a methodology based on the use of free software platforms such as Java Open Street Map (JOSM), Open Street Map (OSM) and Quantum GIS (QGIS). The first cities completely mapped through this method were the four communities of the Paraguayan Central Chaco: Philadelphia, Loma Plata, Neuland and Mariscal Estigarribia.

From the methodological results of the 60 Py 14 Project, the CIDi team has developed, within the same line of research, the Paraguay Participatory Mapping project on the Open Street Map platform (MAP Py OSM). This latter is a systematic, participatory and open response to the lack of basic geospatial data on the country's urban areas. It combines activism, research and training, and ultimately aims to produce a high-quality cartographic database of all Paraguayan cities, systematically mapping three key variables: buildings, masses of urban vegetation and artificial water bodies. At the present time, and since April 2017, thirty-four cities in Paraguay and several cities in neighboring countries had been mapped by researchers or volunteers related to the project. Nineteen out of these cities already have more than 80% of their urban fabric duly registered.

**1.4 Considerations on the team's previous experiences**

Recalling the reasons that have led us to build expertise on mapping is curious, as, in principle, this area was not of special interest to CIDi researchers. We felt requested to give a technical response to gaps in geospatial information in Paraguay, which have always been described as insurmountable. Our team's interest in mapping techniques lies in the desire to produce better design proposals, and raise the level of democratic debate on urban realities. Mapping is an extremely meticulous technical process comprising detailed discussions about procedures, quality checking methods, labels to be used to describe drawn entities, among others, which can be profoundly abstract to ordinary citizens. At the same time, the mapping of urban reality is a socio-political process, for two reasons. First, because people who develop cartographic skills stop being mere consumers of representations of the territory and become producers of such representations. This is not a minor difference, and sets a huge difference, not only in the academic sphere, but, for example, for the leaders of a community, or for a small municipality technicians. The second reason is that more accurate, current representations, produced at low cost, with simple methodologies - and therefore, transparent - can feed more interesting discussions with communities on what is the current state of their cities and what constitutes adequate responses for the future.

The above mentioned experiences helped the team to capitalize knowledge and adapt it to the presentation of an offer of consulting services for mapping the Chacarita Alta neighborhood. CIDi proposal was thus selected for the execution of the consultancy for the planimetric, altimetric and mapping of urban data, within the framework of the "Comprehensive Transformation Project of the Chacarita Alta neighborhood in the metropolitan area of Asuncion, Paraguay - PR-M1032 ".


**Fig. 2**: Map prepared by the project team based on the Cadastral Plan of the City of Asuncion. Source: CIDi team, 2002.

**2 Situation, problem and hypothesis**

> *[...] Given the presence of informal settlements in almost all Latin American jurisdictions, their demarcation as well as their incorporation into official cadastral systems is essential for the development of integral and effective urban policies that result in the decrease of informality (Erba; Donovam, 2017, p. 60, our translation).*

Chacarita Alta [Upper Chacarita] is one of the most traditional Asuncion neighborhoods. Studies by Bosio, Causarano and Chase (1989) indicate that it has been inhabited since the first half of the 18th century, still in the Colonial period. Alongside with the enclave of Loma San Jeronimo, Chacarita - whose official name is Barrio Ricardo Brugada - houses the largest population living in the Historic Center of Asuncion. Its territory is defined by Florencio Villamayor Street, to the North, Gondra Street, to the South, the projection of Iturbe Street, to the West, and Capitán Fulgencio Leguizamón Street, in the vicinity of Caballero Park, to the East.

Its area, which totals 16 hectares, is crossed by two channels that come from the Historic Center to the South and cross the neighborhood, ending in the Bay of Asuncion, to the North.

These channels do not have proper names and are designated by the streets with which they approximately coincide. Thus, from East to West we have the Mexico Channel first and the Antequera-Tacuari Channel second. This polygon is not subject to periodic floodings of the Paraguay River, which often affect a significant portion of Bañado Norte and Bañado Sur neighborhoods. Chacarita Alta is a highly consolidated neighborhood, which requires initiatives to improve urban infrastructure, eliminate risk areas, provide new homes for relocated families, among others. These are precisely the objectives of the Integral Improvement Project of Barrio Chacarita Alta (MIB).

However, despite a broad technical and social consensus on the Chacarita Alta MIB project, the lack of reliable and up-to-date baseline information has always constituted a major obstacle. Some previous academic, technical studies (Bosio, Causarano, Chase, 1989, Granada, 2011, Garay, 2014) were generally based on secondary data, with a degree of precision just enough to have a general idea of the scale of problems, and to formulate project principles and guidelines. In order to progress to the level of licitable executive projects, and to the design and implementation of social strategies for resettlement and regularization of land ownership, it was vital to have a complete and updated physical and demographic database. This cartographic and demographic baseline did not exist.

At this point, we must emphasize that, in Paraguay, this lack of fundamental data to implement rational public policies in a transparent manner is not typical of communities that are enclaves of concentrated poverty. Such lack of basic information found in Chacarita Alta also exists in many formal urban areas in the country. The cartographic model now predominant in Paraguay is insufficient to expose the specificity and complexity of contemporary urban life in general. In this sense, the experience promoted by the CIDi team at Chacarita Alta can contribute to promoting similar processes of participatory mapping in other precarious settlements in the city of Asuncion and Paraguay, while indicating ways to produce high quality urban information at low cost.

## 3 Theoretical framework

### 3.1 Incorporating participatory mapping as an ethical dimension and operational mechanism to address this type of challenges

The elaboration of geospatial databases and thematic maps for initiatives such as the Chacarita Alta MIB Project frequently faces the challenge of combining high quality with limited resources and demanding deadlines. In this sense, the strategy of combining the contribution of professionals, student volunteers and residents is a powerful operating mechanism. The concerted effort of these actors allows to register - in an economic, precise and transparent way - the current state of the community, and to build a clear and objective baseline that serves as a reference to measure the project progress.

**Fig. 3**: Jornada de trabajo en la Pastoral Social del Barrio Chacarita Alta. Voluntarios universitarios de distintas carreras y el equipo del CIDi. Fuente: Osvaldo Vega.

On the other hand, participatory mapping efforts have a clear ethical dimension. By involving different social actors - neighborhood's residents, professionals and students, public administrators, Non-Governmental Organizations, among others - participatory mapping allows democratizing the access to the methods employed and the information produced, guaranteeing its accuracy.

### 3.2 Cartography as a tool for visualizing and recording environmental urban patterns

As indicated in a previous work (Cristaldo, 2011), the word pattern applied to the context of architecture and urbanism was first employed by the architect Christopher Alexander in his book "A Language of Patterns" (1977). The basic thesis sustained by Alexander is that it is possible to formulate patterns to analyze the built environment, and to formulate solutions to concrete architectural and spatial problems.

Patterns are relatively stable and coherent sets of relationships between parts of the built environment. Or, in other words, between buildings and lots; between lots and public spaces, consisting of streets, pedestrian passages and stairways; between buildings and the environmental support system composed by topography and hydrography, among other aspects.

Therefore, we propose here that the participatory cartography construction of a specific neighborhood enables the actors involved in the process to detect urban environmental patterns that define conflicts and potentialities.

### 3.3 Mapping as a creative act

In his essay "The agency of mapping", James Corner (Cosgrove, 1999) establishes a duality between cartography as a tracing simply reproducing already known elements of reality, and cartography as mapping, which helps reveal new aspects not yet perceived, progressing in the construction of overcoming projects. The author states:

> *The distinction here is established between the mapping that equates to what is (tracing) and the mapping that equates to what is and what is not yet. In other words, the mapping deployment potential is most effective when its description capability also establishes the conditions for new physical and eidetic worlds to emerge. Unlike tracing, which propagates redundancies, mapping discovers new worlds from past or present worlds; inaugurates new foundations on the hidden traces of a living context (Corner, in Cosgrove, p. 214, 1999, our translation).*

This is the last conceptual aspect that has inspired and guided our work in Chacarita Alta. We hope that a rigorous and up-to-date database will allow all key actors involved in the process not only to understand what it is, but to envision what it can be. We hope that this cartography will not only reproduce reality, but will also contribute to reveal potentialities and conflicts able to guide the debate and the formulation of public policies.

## 4 Employed methodology

### 4.1 Collective construction

From the beginning of our activities, we assumed that given the complexity and unprecedented nature of the project in Paraguay, a number of meetings and workshops would be needed to jointly build agreements and concepts with the key actors. This allowed to adjust the initial forecasts of the terms of reference, and clarify steps and procedures to follow.

In this sense, several workshops for methodological formulation were realized, which are defined below:

Workshop to adjust indicators and elements to be surveyed: the final list of variables to be surveyed, with the help of university students, was prepared jointly by HPH Py technicians and the CIDi team. This list of variables was also reviewed and approved by technicians from the Asuncion local government. In addition to this list, the collection instrument formats, such as the field cards, were also agreed with the institutional key actors.

**Fig. 4**: Inter-institutional working day at the Social Pastoral of Chacarita Alta neighborhood. Authorities + technical/social team of HPHPy and the CIDi team. Source: Osvald

Workshops for validation of the final product formats: The formats of the final cartographic products (in CAD, GIS and 3ds formats) were agreed by the key actors. In the same way, the publishing of books containing the results of the sector-by-sector data collection process in the neighborhood were discussed in several work days.

Continuous training workshops for volunteers: All the student volunteers who participated in the project were trained from the beginning of their work process.

Construction of procedures, evaluation, and traceability: The procedures of work, both in the field and the office, and the protocols to ensure data consistency and traceability were formulated by the CIDi team and discussed by all key actors. The goal of such procedures was not only to establish concrete ways to collect data, but also to guarantee the complete traceability of all collected information. Therefore, for each data collected, it is possible to know who was in charge for its collection and processing.

### 4.2 A hybrid method of field data collection

Cartographic construction and the mapping of Chacarita Alta were based on a triangulation of procedures and contributions, briefly described below:

A registry of the neighborhood "arterial system": Streets, corridors, stairways, squares, channels and topographical accidents were surveyed by topographers, using Topcon and Kolida Total Stations (see annex of technical specifications and equipment). Public spaces' remarkable elements, such as poles, trees and path lanes, were also consigned through the same procedure.


**Fig. 5**: GIS mapping (through Q-Gis), classification of public space. Prepared by the CIDi team from the aforementioned hybrid method. Source: CIDi.

A registry of houses and buildings' materiality and dimensions: This has been produced by university volunteers. Each building was measured with a tape measure, and its materiality and state of preservation was registered. All these data were consigned in cards, complemented by photographic records.

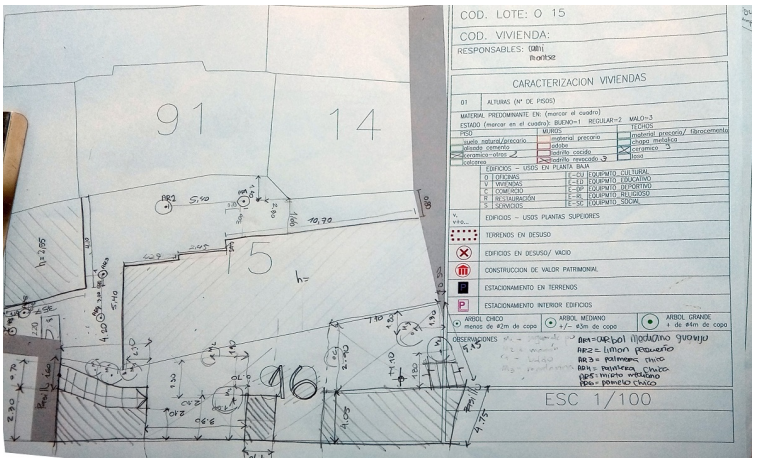


**Fig. 6**: Example of technical sheet. Source: CIDi.

A qualitative registry of public space: Also produced by university volunteers. The materiality of each segment (especially defined for this survey) of the public space - street, corridor, plaza or stairway - was described. Conflicts (e.g., garbage accumulation points) and qualities (e.g., sites of cultural or landscape value) were also recorded, if applicable.

The geometry of sectors, lots and buildings: It was compiled with the help of previously collected data, and supported by drone produced orthophotographs.

**Fig. 7**: Adaptation of the orthophoto used for photointerpretation, process by which the basic geometries of the interior of the apples were built. Image obtained by SkyCam (Daniel Roiko + Christian "Guru" Nuñez). Source: CIDi.

Complementation and verification of data in X, Y and Z: The cartography of each sector, lot and building was complemented and checked through two procedures. First, several lot bottom lines were verified, sector by sector, by using a Total Station. Second, open spaces' points in Z were densified - such as patios or slabs - by using a Real Time Kinetik GPS.

### 4.3 Data consolidation and verification in office

Data collected in the field by all previously described means were then consolidated in the project office. Each data was rigorously recorded and verified, comparing independent cartographic sources, like orthophotograph, total station and manual measurements. In addition, the cartographic base was compared with census records, consolidating a single urban-demographic database. Final products include drawings in CAD, GIS and 3ds.

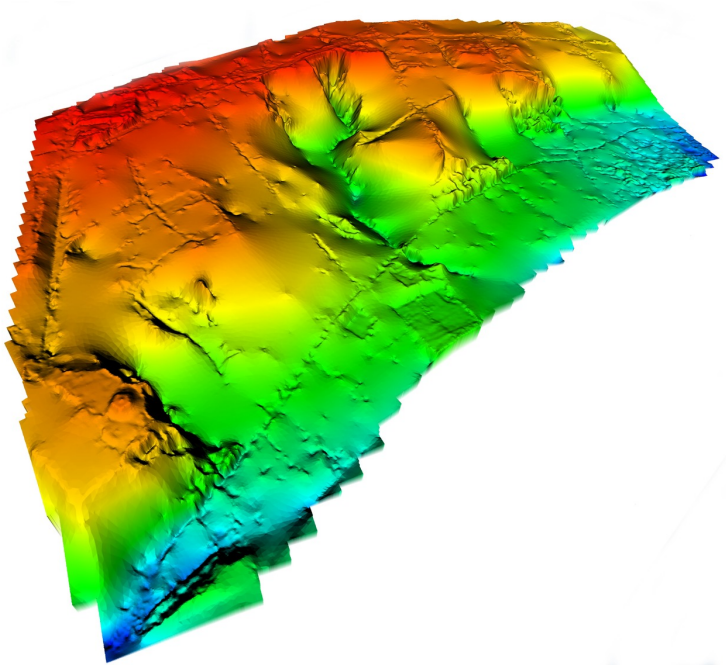

**Fig. 8**: Axonometric view of the *.dem file used for the complementation of heights. Image obtained by SkyCam Paraguay (Daniel Roiko + Christian "Guru" Nuñez). Source

**4.4 Accompanying the Habitat for Humanity Paraguay team and community leaders, and delivering results to the community**

Professionals of the Habitat for Humanity Paraguay social team as well as community leaders accompanied the whole fieldwork of CIDi technicians and volunteers. In addition, at the time of writing these lines, the CIDi team is organising a number of documents to disseminate results, after completing the process of data collecting and processing.

These documents will present a synthesis of data by sector, in order to provide a return of the collected information to the community, and ensure with the residents' help that all data is current and accurate. We believe that socializing results is essential for the community empowerment process, since it provides each resident with accurate information on the conditions of its own home and sector, fostering the debate to progress towards the formulation of concrete proposals.

**5 Analysis and discussion of results**

**5.1 Limits detected**

Two technical processes implemented in this project proved inadequate. The first one has to do with how to take points using the Total Station. Initially, the survey team recorded all possible points from each observation site, but the procedure has been proved inefficient. We then opted for a gradual approach, surveying the entire public space at first, then defining the polygons of each sector, and finally surveying and drawing the interior of the blocks.

The second process that proved inappropriate is the use of GPS RTK technology as a total replacement for Total Station measurements. Our experience has indicated that in contexts of rugged topography and high density of buildings and vegetation, as is the case of Chacarita Alta, the GPS RTK application is very limited. Instead, it is useful and appropriate to use GPS RTK in open sites such as patios or flat roofs. In these cases, the accuracy ranges of the raised points and the duration of data collection make the use of this technology reasonable.

**5.2 Validated procedures**

Combining working with Total Stations, GPS RTK, drones, and manual measurement and registration by volunteers has proven to be a viable way to produce high-quality information, at a reasonable cost way. Such combination of devices and procedures has generated the following advantages:

+ Comprehensive understanding of specific situations, based on the drone produced orthophotograph, which allowed to improve the planning of field work;

+ Thanks to the drone produced orthophotograph, we have had access to the interpretation - and consequent cartographic representation - of priorly inaccessible points due to the density of built elements;

+ The registry, by volunteers, of constructed reality has produced a set of rich data through simple mechanisms and procedures;

+ The use of Total Stations and their complementation with GPS RTK technology has proven to be a suitable formula for a detailed recording of public spaces, including the perimeters of each sector and the lot bottom lines, i.e., the "ribs" of each sector;

+ This combined procedure resulted in the reduction, up to 40%, of the deadlines for delivery of final topography products;

+ In turn, this reduction in time allows reducing direct and indirect costs for hiring surveying services in future projects.


**Fig. 9**: One of the final products. High precision CAD plane, with deviations of +/- 15cm. Source: CIDi.

In addition to inherently technical aspects, there are also social aspects. It is worthy to emphasize that the construction of agreements among all key actors and the support of community members during the whole process are also central points, both from an ethical point of view and a pragmatic perspective. Dissemination, discussion and validation of the collected data with the community will be carried on at the project closure, when the eyes of the entire neighborhood will help us detect any errors or inconsistencies that have escaped our efforts.

## 6 Conclusions

In this essay, we have explored the efforts and procedures of various actors of Paraguayan society - neighbors, academics of the National University, professionals, students, members of non-governmental organizations - who have worked together, funded by FOMIN, aiming to overcome the "cartographic gap" of Chacarita Alta.

The text proposed a brief review of previous experiences of participatory mapping developed by the CIDi-FADA-UNA, linking previous initiatives to the mapping project presented here.

Subsequently, based on a recognition of the current situation of the community and a review of the conceptual theoretical framework, the text described the methodology of participatory mapping employed in this project.

In the analysis of results, the learning process has been made explicit. We highlight the idea that a hybrid mapping methodology, which combines the work of volunteer students, residents, professionals and academics, produces high quality results. The combined use of diverse tools, such as Total Stations, drones and GPS RTk, has allowed to increase efficiency and reduce costs.

The effort to perform precision mapping is certainly justified by the need to have reliable and updated data, in the context of the project of Integral Neighborhood Improvement of Chacarita Alta. It is essential to have better baseline data in order to improve the quality of public policies, and build democratic urban debates based on facts.

But besides being an instrument for the project future stages, the initiative to "put Chacarita on the map" is itself a process of social empowerment that aims to promote the inclusion of the Chacarita Alta residents in the city of Asuncion. Being in the formal city map helps to strengthen the neighborhood as a place for debate and urban reflection. Being on the map helps to make visible - and so reveals - the neighborhood, its inhabitants, and their living conditions.

We hope that this participatory mapping project, its products and the methods used to reach them will contribute to other similar initiatives in Paraguay, or in other lacking and still invisible communities of the Global South.

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*1* PlanCHA is a plan to revitalize the Historical Center of Asuncion, promoted by the National Secretariat of Culture. It has been recognized by the Executive Power through Decree 2985/2015, and by the Municipality of Asuncion through the Framework Agreement of Interinstitutional Cooperation of 05/26/2015.

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Technical Support: Ma. Paz González - field support and digitalization; Ismael Vera - field support and operator.

**Drone Team (Skycam py)**
Piloting and image processing: Daniel Roiko
Image capture: Christian "Gurú" Nuñez

**Tools for field measurement**
Total Stations: TOPCON serie GOWIN TKS-402R, KOLIDA KTS 442
GPS RTK equipment: GPS - GNSS south Series GALAXY G1
Equipment complements for orthophotography:
Drone: INSPIRE 1 model T600.
Camera: Sony Nex 5
Software for processing: Pix4D

**References for georeferencing**
Coordinate system used: U.T.M. - EPSG WG84 21S
Main anchor point: Point indicated by the Military Geographical Institute (IGM), the starting point is located at the headquarters on Avenida Artigas and has the following coordinates: x= 438210.4662 y= 7204009.1586 z= 77.8920