Chapter 9
Ground Survey: An Integrated Survey for Urban and Architectural Heritage Conservation and Management

Franco Guzzetti, Nelly Cattaneo, Grazia Tucci, Lidia Fiorini, and Alessandro Conti

Abstract Recording is a key activity in the cultural heritage conservation management. Conservation-related information is usually obtained (certainly in the case of this project) from multidisciplinary research activities. In such teams, geomatics build a framework to connect all members' contributions both in preliminary studies and in project development and applications.

In this project, the documentation approach used the most sophisticated surveying techniques to properly capture the geometries of the "sample area": the pilot area, as well as the whole Multan Walled City, is made of very articulated buildings, with façades rich in decorations, and the urban pattern created by these buildings is very intricate. Metrical data acquisition of such a wide, complex, and crowded urban area with traditional survey techniques would request a lot of work, involving many people for a long time.

The rapid rise in new technologies has revolutionized the practice of recording heritage places. The advantage does not rely only on time saving, but mostly on accuracy and management of digital data. Digital tools and media offer many new opportunities for collecting and disseminating information about heritage sites. From a methodological point of view, an integrated survey has been planned combining topographic and laser scanning technology.

In pilot area, two macro-areas were selected and subdivided in six different sites.

A reference frame connecting all sites was created by a topographic survey carried out with total station. In the meantime, detailed survey was carried out using a laser scanner in all sites.

F. Guzzetti (✉) • N. Cattaneo
Department of Architecture, Built Environment, Construction Engineering
Politecnico di Milano, Milan, Italy
e-mail: franco.guzzetti@polimi.it

G. Tucci • L. Fiorini • A. Conti
Geomatics for Conservation & Communication of Cultural Heritage Laboratory (GeCO Lab), DICEA – Department of Civil and Environmental Engineering, Università degli Studi di Firenze, Florence, Italy

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The fieldwork is only the smallest part in this kind of survey. Subsequent activities were carried out in Florence and Milan during the following months producing a digital model to create 2-D drawings and 3-D models. Graphic outputs were used by other work teams for many different tasks: conservation/restoration, structural analysis, architectural and urban planning, mapping, and so on.

9.1 Premises and Tasks

Surveying is one of the first steps in the comprehension and knowledge of a place (Letellier 2007; Eppich et al. 2007). Nowadays, technologies provide a wide set of possibilities in methodological approach. However, a cultural approach, which has been a permanent guideline in this work, consists on defining the method referring to the object to be surveyed: that means that the object to be investigated suggests the main rules in choosing and using any surveying techniques (Santana Quintero et al. 2011). In order to plan a survey in Multan Walled City, it was necessary first of all to get to know the city: no photo and no aerial map could help in understanding such a lively, mazy, rich-in-detail urban area. In this area, a traditional topographic survey might not be so effective: to proceed from a general survey to a more and more detailed one in this case may not make sense. Everything is a detail in Multan Walled City, that means everything is meaningful as a structure and as a decoration at the same time. That is why, in consideration of all the technologies now available, the use of general criteria in a descending order that is, providing the main geometries to be then enriched in details by celerimetric survey would not be fully appropriate. The use of techniques and technologies which enabled an uninterrupted collection of details connected with each other was considered more correct, providing on the side just a basic topographic reference frame.

Geometric survey is not an end in itself. Besides the acquaintance of the place, it is also important to understand which are the real needs related to the place itself in order to outline a truthful purpose of the survey. This theme is very relevant because, as a team of technicians coming from abroad, it is very easy to define purposes and targets that do not fit the real dynamics, uses, and needs of the place. For example, at a first glance, it would come natural to promote a cadastral map similar to the Napoleonic and Austro-Hungarian ones, which were intended to provide order and data for administration. This could be an interesting purpose, but in Multan Walled City, a cadaster may be more useful and fitting if considered as a fact-finding and cognitive instrument: it should be already oriented in providing information about the modification constantly occurring in this part of the town and in producing guidelines in the process of urban renovation. In this way, this cadaster should include many layers able to describe more and more deeply all the visible and not so visible aspects of Multan Walled City. A “smart” geometric survey able to face Multan’s challenges must have both an overall view (as a map does) and a detailed sight from the inside. Moreover, it is important to remark that in the general project a broad set of experts is involved, each one focusing on a very detailed aspect of the area. In this situation, a ground survey must provide a set of data as wide in contents as the experts involved are, with a high and homogeneous level of accuracy. Moreover, so various geomatic techniques are used to create a reference base that enables all members to meaningfully participate in both investigative procedures and project development (Tucci et al. 2009).

The search for existing maps at urban scale must be and has been indeed the first step, and evaluations on every documents acquired must be pursued. When we first approached Multan Walled City, we had no useful metrical data we could refer to: an aero-photogrammetric map dated 1992 in a local reference system was the most important cartographical base. Although its scale was quite high, at a first visit in the city, it was immediately evident that this level of detail was not sufficient for any of the survey's tasks: in such a dense area, a map at scale 1:2000 could not even be used for rough planning. The pilot area, as well as the whole town inside the walls, is made of very articulated buildings; the urban pattern created by the blocks cannot be reduced to simple geometries: even important covered passages are not represented on the map.

Owing to the existing maps, the most appropriate approach for the survey of Multan Walled City would consist in a set of activities:

LiDAR survey: An airborne laser scanner provides a dense georeferenced point cloud. From this point cloud, an accurate digital terrain model can be derived, useful for a first basic hydraulic planning, and a digital surface model which can help studying, for example, urban microclimatic conditions. The well-defined shape of buildings from the point clouds can be helpful in the correct interpretation of remote sensing imagery.

TLS: Point clouds acquired with terrestrial laser scanner must integrate data acquired with LiDAR technology, thus providing accurate data at the architectonic scale of representation and reducing the "shadow areas" normally resulting from both kinds of survey.

Traditional topographic survey must be carried out with three main purposes and three different instruments (1) differential GPS to provide ground control points for the accurate orientation of the LiDAR dataset and to connect the other surveys to the same reference system, (2) total station to control the alignment of the terrestrial laser scanner point clouds, and (3) geometric leveling to provide accurate data in order to accurately project the sewerage system.

The purpose and the role of each of these activities must be clearly defined, because on the field many problems may prevent from respecting any step previously planned: for example, the permissions for a flight over Multan is not easy to obtain, and the LiDAR flight has not been fulfilled yet, as well as finding information on ground points already measured for the production of local cartography. This means that, on the field, little and partial steps are made and each one must be valid and useful in itself, and at the same time non regardless of the whole surveying plan.

9.2 Urban Setting

Choosing the proper surveying technology had considered also problems which can be defined practical or logistic (Tucci et al. 2011b). Multan is a very lively and busy town, in particular in the bazaar area where the pilot area is located, that means that during the day it is not possible to place a topographic instrument for the time necessary to acquire data and, even in case it is, too many accidental obstacles may affect the result. Therefore, the nighttime is the best moment to carry out the survey on the field. The terrestrial laser scanner proves to be the proper technology in working independently from sunlight, being based on an active device (Bonora 2007).

Moreover, it acquires 3-D coordinates from all the surfaces visible from the scanning position and, depending on the selected scan resolution, allows surveying details as window wooden frames, crevices in the walls, wells, and open drains on the streets, thus providing the wide set of data necessary for the whole project. It would not be possible to reach the same level of detail and accuracy with other surveying technologies.

As mentioned in the premises, the pilot area, as well as the whole town inside the walls, is very articulated; the urban pattern created by buildings is often unexpected: important passages are covered, and sometimes normal doors are the access to courtyards leading to other courts, thus organizing the block as a conventional street would do. As open space is shaped by constructions around, masonry is shaped by decoration: surveying these edifices means surveying their details. Many historical buildings are affected by structural problems, and using laser scanner we can easily estimate out of plumb and deformations of the walls (Tucci et al. 2011a).

Summing up, the 3-D "point clouds" are a real database, an extremely dense and accurate "information depot" that can be explored as a significant referent of the object and from which experts can derive all requested graphic outputs on demand.

9.3 Planning the Survey

A proper survey planning is essential, particularly when fieldwork must be streamlined in a complex urban fabric as Multan Walled City is. Planning consists in preparing and scheduling all survey operations to collect requested data.

As often as not, it is possible to plan accurately survey only on-site. First inspections were done during daytime, together with other teams and consulting local representatives. The most meaningful elements in pilot area were found, selecting the parts that were possible to survey during the mission.

Two areas were selected, the first one focused on a section of Haram Bazaar (Fig. 9.1) (from the Haram Gate and the surrounding square to an interesting old wooden house, Fig. 9.4) and the second one including a part of Sarafa Bazaar, the Darbar of Musa Pak Shaheed, and the square in front of his Mausoleum (Fig. 9.2).

Then topographic network was planned to connect all areas and measure the targets used to align laser scanner range maps.

For a proper laser scanner survey, it was necessary that canvas obstructing the acquisition of building top in bazaars would be removed. Then, depending on available space and visual lines, optimal scanner and target positions were determined. Along bazaars, considering street width/height ratio, scanner stations were located every about 10 m.

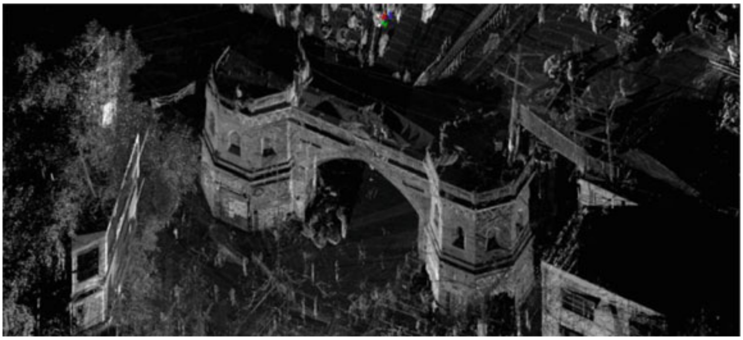

Fig. 9.1 Point cloud of the Haram Gate and its surroundings

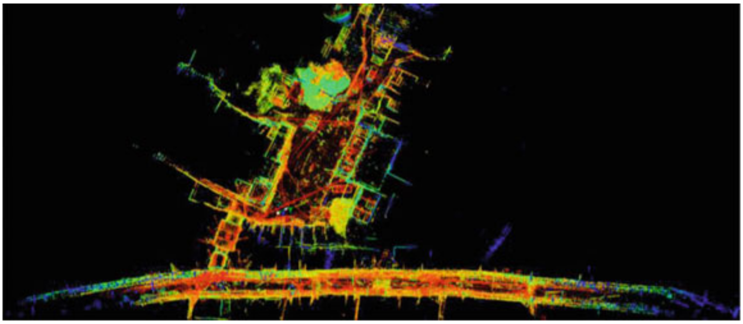

Fig. 9.2 Overall view of the Sarafa Bazaar and Musa Pak Shaheed Mausoleum square

So the whole work was split in six subtasks feasible in a single night session. Total station and a laser scanner teams worked simultaneously to be sure that targets would be not removed.

9.4 The Topographic Network

The topographic surveying was carried out with a total station (Leica TCR 307) and was used to define the three-dimensional position of specific points, in a local reference system defined on purpose for this step of the survey. The on-site survey in the pilot area has been divided into the following sequential phases:

– The survey traverse
– Measuring targets required for laser scanning
– Detailed surveying

The survey traverse is composed by a set of consecutive observations, whose lengths and directions have been measured with the use of the total station. Closed

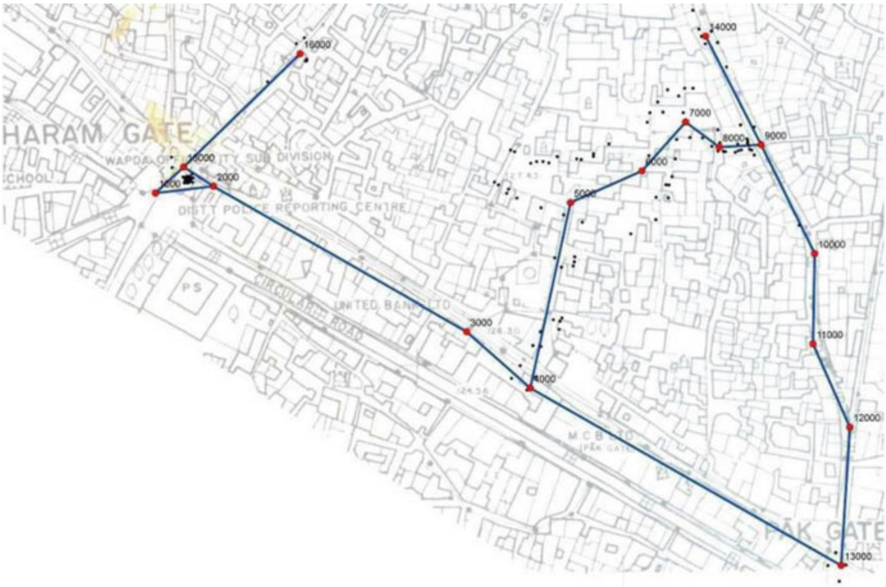

Fig. 9.3 Layout of the whole traverse, including the two traverse legs

traverses, which means that the first stationing point and the last coincide, are generally preferred in order to check the final results of the survey and to enable the application of the most rigorous adjustment procedures. All the stations have been materialized and then carefully sketched and located by measuring their distance from a nearby fixed object in order to ensure their future identification. Station locations have been selected in such a way as to ensure complete coverage of the surveyed area. The reference frame produced during the surveying campaign in Multan is composed by 16 main stations plus 2 additional ones. The position of these 16 points has been selected in the field in order to achieve the following aims:

– Collecting the coordinates of the target markers used for the alignment of the point clouds acquired by laser scanning: 50 targets have been collimated
– Defining a unique local reference system useful to refer all the surveyed spots, which are not contiguous
– Making metrical evaluations about accuracy of existing maps and aerial imagery available at the time of the survey

Although preferable, only ten stations, from 4,000 to 13,000, belong to a closed traverse. As shown in Fig. 9.3, the street system of the pilot area does not facilitate a closed traverse. To reach all the areas interested by this first investigation, two traverse legs have been carried out.

Regarding the detailed surveying, in the pilot area, 170 points have been collimated with two main purposes:

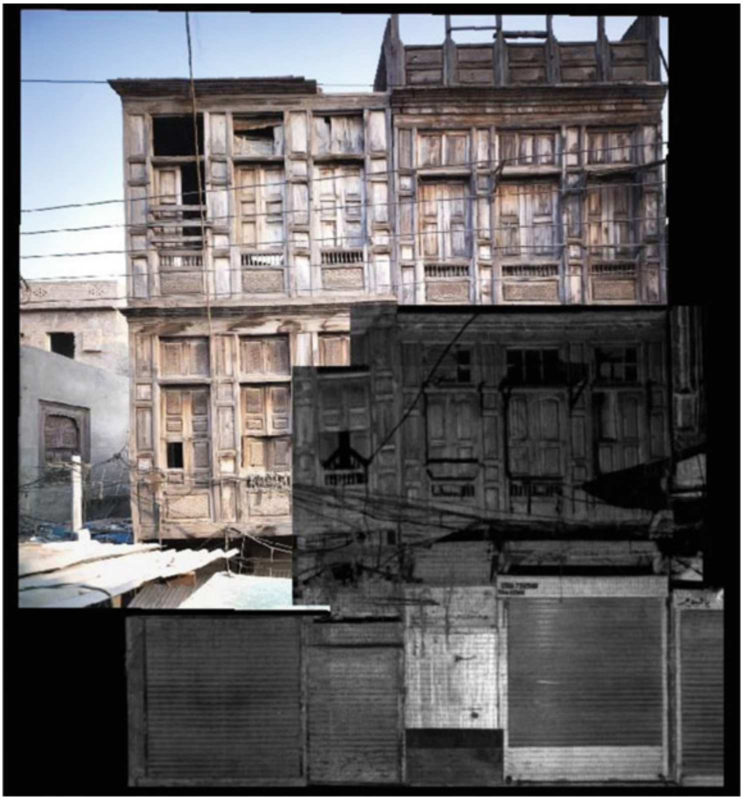

Fig. 9.4 Comparison between "wooden house" rectified image and point cloud (Ph. M. Introini)

– Achieving the layout of the correct profile of the area between the Circular Road and the Musa Pak Mausoleum, where a wide demolition had been carried out which is not represented on the maps available at the time of the survey
– Outlining the irregular geometries of the eastern tower of the Haram Gate, interior ground floor (Aga Khan Trust 2012)

The topographic network has been extended in the following months by local topographers to enable the correct interpretation of remote sensing imagery in those areas where no data could be acquired at the time of our first mission.

9.5 Laser Scanner 3-D Data Acquisition

Laser scanning describes a method where a surface is sampled using laser technology. It analyzes a real-world environment to collect data on its shape and possibly its appearance (e.g., color).

Laser scanners are line-of-sight instruments, so multiple scan positions are required to ensure complete coverage of a structure.

Laser scanners function as a total station: they measure lengths and angles in a 3-D space. The advantage of laser scanning is that it records huge amounts of points with high accuracy in a relatively short period of time and using entirely automatic procedures. It is like taking a photograph with depth information.

Once the instrument is set and positioned, it performs a “scan” of all the surrounding space by sending a laser spot with high frequencies and a very small angular step. All points measured on the surface produce a “cloud” that is a digital three-dimensional model of the object.

It is obvious that the correspondence between the object and its model is proportional to the resolution used and to the density of the points. In Multan Walled City pilot area, the distance between scanner and buildings never exceeded a few tens of meters in order to obtain an average resolution of about a centimeter.

The automatism that characterizes the measurement phase means that it surveys everything visible from the scanning position: in the final model, not only the walls are acquired but also everything around—electric plants and cables, trees, canvas, cars, and, above all, people. It has been just to avoid the usually crowded streets that work was done during nighttime.

The device used is an HDS 6000 (Leica Geosystems) laser scanner, with a rapid rate of acquisition (up to 50.000 points a second): each scan required between 3 and 10 min.

9.6 Data Elaboration

Fieldwork is only one side of this kind of survey. Subsequent work was carried out in Florence and Milan during the following months. On one hand, traverse was calculated; on the other hand, point cloud cleaning and alignment were carried out.

Each scan is initially acquired in an intrinsic reference system, which origin is the scanner itself. The transformation of the data acquired from all the intrinsic systems to adapt it to the topographic reference system takes the name of “scanning alignment”; this process uses the abovementioned targets as control points. As the target coordinates are known both in the intrinsic scanning system and in the topographic one, it is possible to compute the rotation and translation that has to be applied to all points of each scan to align them to the topographic system. Target recognition can take place automatically, thereby speeding up the alignment phase and limiting operator intervention to the verification of the results obtained. If a scan does not have at least three clearly recognizable signals, then natural points can be identified manually.

After the scans have all been aligned, it is possible to carry out global compensation: an ICP algorithm is applied to further reduce any residual distance between corresponding surfaces in adjacent scans.

Fig. 9.5 Darbar of Musa Pak Shaheed façade (Pakistan/Italian Resource Centre in Multan team)

As the whole database was really big and it's difficult (and useless) to manage always all data together, data was divided according to project subareas. In this way, it was possible to make available for other teams selected data to create georeferenced 2-D drawings and 3-D models.

9.7 Use of Data for Specialized Studies

The data acquired in the pilot area provided a multitasking set of information. As said, the team involved in the project includes different professional skills. Some examples of deliverables by other working teams show different uses of survey data.

The architects involved in conservation could dispose of a highly accurate 3-D description of the buildings, including wall cracks and deformations and masonry texture (Fig. 9.5). The direct survey data could be referred to the point cloud set of data.

The structural engineers, starting from point clouds, created models to study dome deformation in Haram Gate (Fig. 9.6).

The urban design group produced the layout of the elevations on the Sarafa and the Haram bazaars, using the ortho-images extracted from the point cloud and a set of high-definition pictures. The result enables to describe the sequence of the buildings and the texture of the street fronts (Fig. 9.7).

The outlines of the ground floors were used to define the polygons describing plots and blocks in the geographic information system of Multan Walled City (Fig. 9.8).

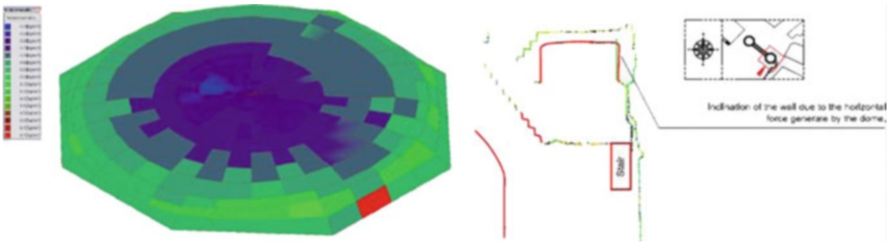

Fig. 9.6 The laser scanner survey used to create a model for structural analysis (Haram Gate conservation project team)

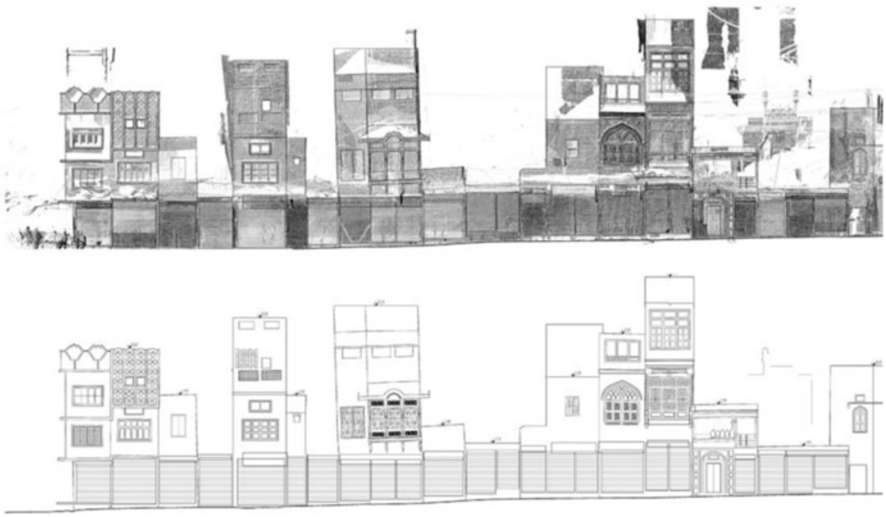

Fig. 9.7 Layout of elevations along Haram Bazaar (urban design team)

9.8 Conclusions

Integrated geomatic techniques allowed to collect in few days a huge amount of data useful for all teams in Multan Walled City Project. Even if work done during this mission covers only a part of the overall mapping project, as explained in premises, the used methodology always allows integrations at every scale, from LiDAR data to direct survey.

The accuracy and resolution of the point cloud model recorded the selected areas as a 3-D photography which will constitute a benchmark to verify every urban transformation in future.

A further remarkable aspect is the interest by Pakistani scholars and officials on scanning technologies, which enriched relationships and collaboration on this project. There again, new and unusual technology attracts itself, people curiosity about instruments helped us to explain our tasks, and we wish to make people more aware about the relevance of their own cultural heritage.

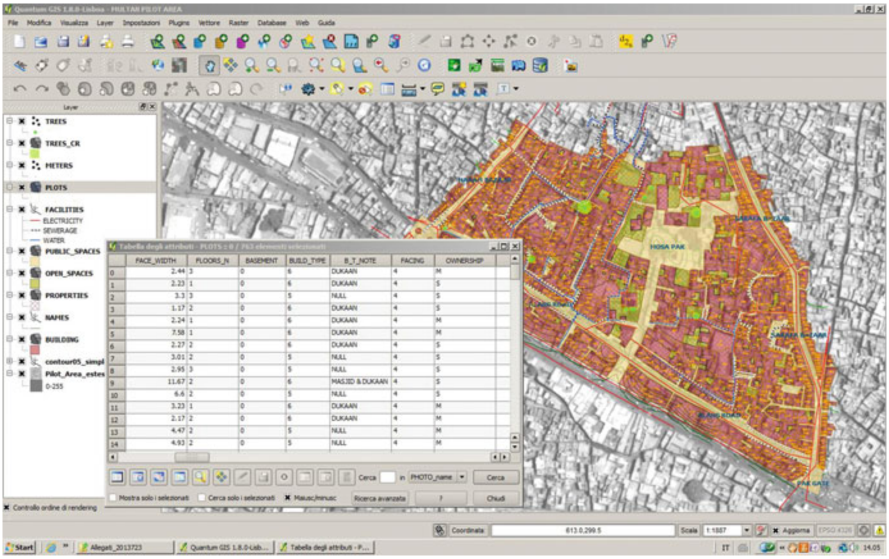

Fig. 9.8 The ground floor outlines used to define pilot area GIS (urban planning team)

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