3D Digital Systems for the Documentation and Representation of the Wooden Heritage Between Finland and Russia: Survey Methods and Procedures for Detailed Analysis

Sara Porzilli and Stefano Bertocci

Abstract This contribution presents research experiences carried out on historic wooden heritage located between Northern Finland and Russia. Many cultures all over the world hold their own testimony related to historic wooden architecture (Iori 2005), different in their constructive techniques and compositional results but at the same time full of common features. For this reason we can assume that wooden architecture represents one of the oldest building systems adopted all over the world by people who developed specific approaches in building with timber material while respecting local tradition (Pryce 2005). This vast and unique wooden world heritage strongly needs today to be surveyed and documented with a deep level of detail and accuracy by using the most accurate survey methods and digital systems. The contribution describes three specific case studies located in different geographical areas: The Unesco World Heritage Site of the Pogost Complex on Kizhi Island and rural settlements in Karelia (Russia), The Wooden Farm House of Lamminaho in Vaala region (Finland) and the residential wooden district of Raksila in Oulu (Finland). The research experiences presented have the aim to offer a wide viewpoint on how survey operations and analysis should be performed and which are the main strategies and procedures useful for obtaining specific results. From 2012 until now European Funding has supported researches on Wooden Architecture with a Seventh Framework Programme, Marie Curie Actions People (years 2012–2014) and from 2017 until 2019 with a Marie S. Curie Individual Fellowship held by Post Doctoral Researcher Sara Porzilli, actually based in Oulu, Finland.

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F. Bianconi and M. Filippucci (eds.), *Digital Wood Design*, Lecture Notes in Civil Engineering 24, https://doi.org/10.1007/978-3-030-03676-8_22

Keywords Wooden architecture · Timber structures survey
Parametric timber engineering · Laser scanning · Photogrammetry

1 Introduction

Wooden Heritage represents one of the oldest example of architecture developed by different cultures from all over the world, who developed specific features with unique compositional solutions (Zwerger 2012). In Northern Europe as well as in Russia, wooden buildings existed already during the early 17th century (Anker and Snitt 1997). They were built in a tight connection with the surrounded environment creating intimate relationships with the landscape. Materials belonged to the near forests, decorative motif and details took inspirations by the Nature and its elements (Fig. 1). In many occasions, craftsmen and artisans, direct authors of these unique heritage, were "simple" skilled experts of the place, inhabitants of the surrounded areas, people of whom we often have not today any precise information. Today, because of negligence, sudden events like fire, or even because of absence of accurate plans of preservation most of our world wooden heritage is already reduced, part of it is dramatically abandoned or totally vanished without any documentary testimony (Fig. 2).

However, even if historic wooden buildings and timber structures were not considered enough important in the past, evidently due to a greater preference and attitude for the more ancient stone and brick architecture, part of the wooden heritage still survived until now and it is still present in many regions (Hansen Hans 1969).

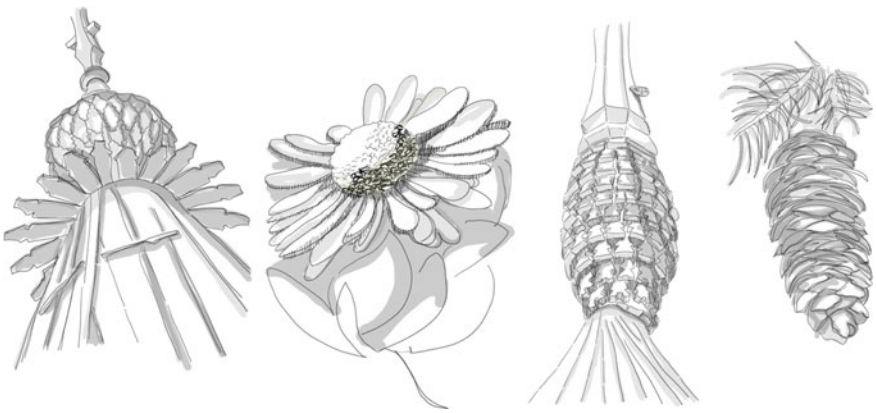


Fig. 1 Historic wooden architecture from Russia and Finland has many examples of constructive and decorative details that seem to explicitly emulate the forms of Nature. Perhaps also, for this reason, wooden buildings and landscape appear harmoniously integrated creating a unique cultural landscape in which architecture and northern forests live together

Fig. 2 The historic wooden settlement of Jylhämä in the region of Vaala, Finland. This place it used to be a former outdoor museum along the Oulujoki River. After years it was sold to privates that are today the owners. Buildings are in a serious state of abandonment. The vegetation has already started to surround the architecture. Timber structures are dramatically compromised. Now there are not any documentary actions of intervention for repairing this heritage, which is destined to disappear if specific restoration activities will not start soon

From the first approach on this typology of heritage, it appeared clear that the documentation of historic wooden architecture constitute today a precious testimony not only for the understanding of specific construction techniques used in the past but also for a sensible dissemination of a wider documentation related to social customs and traditions existed in many different cultures.

Because for these reasons the research is proposing a specific study approach in which multidisciplinary methodologies of documentation together with specific and updated technical approaches are deepened in order to propose new digital methods for the documentation of wooden heritage. The research approach intends to highlight not only the architectural value of the cases studied but also wants to increase and improve their cultural, symbolic and environmental importance. For this reason during years of researches, the activities have included not only singular timber monuments but also examples located in evolved contexts, places where the original environment and townscape changed and where general functions lived sensitive modifications.

Two main objectives settle this research: the necessity to improve and develop updated digital survey techniques applied specifically on wooden heritage and timber structures; the volunteer to produce detailed inventory analysis with the main scope to increase the visibility and sensibilities for authorities, inhabitants and responsible of these heritage in order to active specific protection programmes.

The two goals appear even more connected if we consider that the process of knowledge through accurate analysis is in itself the first step towards a deeper awareness and education for the preservation of the architectural heritage for future generations.

In addition to these aspects, it is also evident that digital survey methods and procedures are nowadays increasingly requested because for the accuracy that can be achieved and for the level of detail that can be represented in 2D and 3D dimension. Guidelines and methods for preservation need today to be always updated and implemented, registering changes by updating the data. Evidently, this process is meant to be entirely digital and will not avoid the utilization of the newest technologies by using specific software of detection and representation as for instance BIM systems.

The contribution explains the strategies, methods and procedures used by showing three different case studies. Naturally the knowledge of the state of the places, the survey of the dimensional and material aspects, constitutes in these works the first fundamental step for the conservation. Through analysis and survey operations, the aim is to demonstrate that the value of an architecture consists not only in its monumentality and in its richness of details and decorations, but mainly in the identification of its tangible and intangible traits. The identification of the value of an architectural object (as well as for a group of buildings) in the history and development of the place, can represent the only real and authentic testimony of a specific part of the history of our culture.

1.1 The Support of European Funding Schemes

Wooden Architecture represents one of the main research topic carried out on international scale by Departments DIDA from Florence and DICAr from Pavia with the support of important institutions and universities from Finland and Russia. In 2007, Prof. S. Bertocci[1] and S. Parrinello[2] organized the First International Conference on Wooden Architecture, defining a first important network of relations between academy, business companies and singular experts (Bertocci and Parrinello 2007). In 2009, a Second International Conference improved definitely the common consciousness about the belief that today this vast and unique wooden heritage needs to be documented and preserved (Bertocci and Parrinello 2009a). Expeditions to Kare-

[1]Prof. Arch. Stefano Bertocci is Full Professor at the Department of Architecture DIDA of the University of Florence, Italy.

[2]Prof. Arch. Sandro Parrinello is Associate Professor at the Department of Civil Engineering and Architecture of the University of Pavia, Italy.

lia and Northern Finland started during the same years, with the aim of survey and study interesting examples of traditional wooden villages and specific buildings. The approach was already at that time aimed to increase at the same time documentation of inedited places while deepening research methods and scientific approaches.

From 2012 until 2014, the first European Funding (Seventh Framework Programme, Marie Curie Actions People) supported the activities. "Wooden Architecture" European Project[3] allowed early researchers Ph.D. Sara Porzilli and Ph.D. F. Picchio coordinated by same professors of the university of Florence and Pavia, to perform intensive and massive survey expeditions to Karelia (Russian side). This opportunity allowed the arrangement not only of trips and of investigations to Karelia, but also encouraged educational activities with the organization of summer schools in Karelia, involving international students, Ph.D. students and professors for working all together to this topic (Fig. 3).

During the massive survey analysis several wooden heritage, villages and monuments were documented. The research team implemented technical survey procedures and methods of representation for the documentation of these contexts. This contribution intends to present and explains part of the results obtained.

More recently, from September 2016, Ph.D. Sara Porzilli applied and won a Marie S. Curie Individual Fellowship[4] by presenting a research project entitled: "Preserving Wooden Heritage. Methods for monitoring wooden structures: 3D laser scanner survey and application of BIM systems on point cloud models". From June 2017 European Funding is supporting her researches, which are related to wooden heritage and the application of the latest digital methods for its preservation. Part of Porzilli's research includes dissemination activities and secondments to expert partners chosen from the beginning in order to increase technical skills and cooperate with a wider group of different skilled experts. An experience in which she is representing the key-figure and link between Academy and Business environment by using the general formula of the "teaching-and-training" method. The study is now

[3]Complete data of the European Project: Seventh Frame Programme Marie Curie Actions People International Research Staff Exchange Scheme. Full title: "*Wooden Architecture. Traditional Karelian Timber Architecture and Landscape*". Identification number: 269185. Departments involved: Department of Architecture DIDA of the University of Firenze, Department of Civil Engineering and Architecture of the University of Pavia, Department of History of Architecture and Restoration Studies of the University of Oulu (Finland), Engineering Faculty of the Petrozavodsk State University (Fed. Russia). Scientific Responsible Prof. S. Bertocci from the Department of Architecture DIDA, Prof. S. Parrinello from the Department of Civil Engineering and Architecture in Pavia. Thanks to this research opportunity of international collaboration, participants have undertaken a series of missions to the Karelia regions and carried out research experiences.

[4]Complete data of the Marie Skłodowska Curie Project: European Commission, Horizon 2020—Research and Innovation Framework Programme. Marie S. Curie Actions—Individual Fellowship. Call: H2020-MSCA-IF-2016. Scientific Panel: ST-ENG. Duration of the Project: 24 months. Title of the Project: *Preserving Wooden Heritage. Methods for monitoring wooden structures: 3D laser scanner survey and application of BIM systems on point cloud models*". Beneficiary: University of Oulu (Finland). Researcher enrolled Ph.D. Arch. Sara Porzilli. Supervisor of the research: Prof. Anna-Maija Ylimaula. The Marie Skłodowska Curie Grant Agreement protects project results. Mitta Oy Company, official partner of the project based in Oulu, has provided the equipment used.

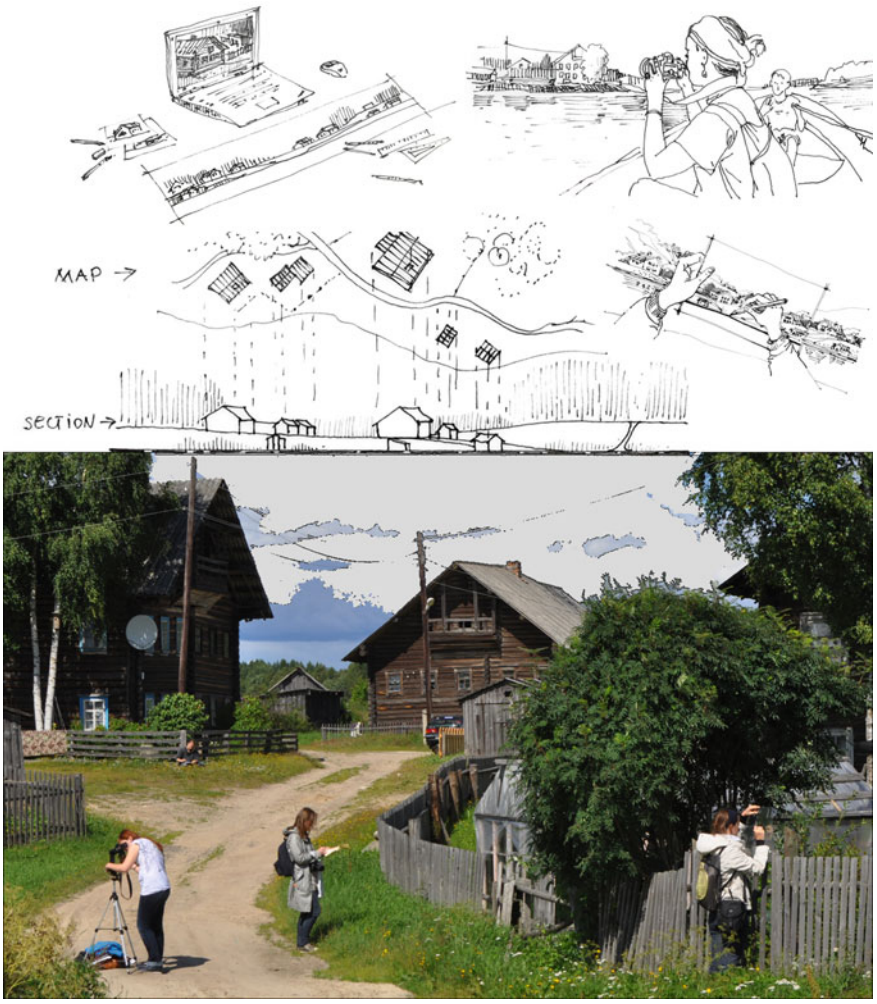


Fig. 3 Within the European Project "Wooden Architecture" dated between 2012 and 2014 many students from Italy, Finland, Russia and Israel have taken part in summer schools and survey activities carried out in Karelia. Main goals of the researcher were the documentation of historic testimonies of wooden settlements and architecture by using all different level of analysis, survey and representation. Observe, draw, sketch-fixing notes helped the recognition of the place in order to proceed with the elaboration of more technical and detailed material

mainly concentrated in developing digital methods of representation, deepening the relation between laser scanning survey of wooden structures and BIM systems.

2 The Case Studies Between Russia and Finland

The three case studies chosen are located in different areas, characterized by specific and unique features related to their own cultural context, constructive techniques and functions. Even if these cases are noticeably different from each other in terms of the nature of the object investigated and location, they have all contributed to the increasing of knowledge deepening a "technical consciousness" on how to conduct detailed surveys on wooden heritage. In this process of documentation both environment, landscape, architecture, structures have been investigated and treated as equal parts of a same process, aimed at the elaboration of a complete recognition of the site.

First case study[5] is the World Unesco Heritage Site of the Pogost Complex on Kizhi Island with detailed investigations of other rural settlements located in Karelia, Russia (Fig. 4). These surveys generated a precious contribution in the understanding of how to handle a wide amount of metrical data. The representation of the wooden structures in 2D and 3D for technological assessment analysis and the elaboration of highly detailed technical drawings have represented the main goal of this work. The complexity of the wooden structure of the Church of Transfiguration and the presence of a dense metal support structure transformed this survey into an interesting challenging experience.[6] The researches on the wooden settlements have produced interesting experiences on how to develop digital census analysis, elaboration of descriptive atlases and experimentation of 3D photo modelling results from the general scale of the entire village until the description of a singular detail.[7]

The second case study is the historic Lamminaho Farm House located in Vaala region, Finland (Fig. 5). The place preserves and documents the original features of a traditional historic Finnish wooden complex dating between the 18th and 19th century. The place was initially built as a private farmhouse and it was then used often by anglers because for the strategic position along the Oulu River. For almost two centuries, Lamminaho was a private property. In 1992 the entire place was donated

[5]Researches carried out on the Pogost Complex on Kizhi Island were developed during year 2011. The elaboration of results, analysis and technical drawings showed belong to Sara Porzilli's Master Thesis in Architecture, defended in July 2011. Title of the Thesis: "The Pogost Complex on Kizhi Island. Laser scanner survey for the architectonical analysis of the structure of the Church of Transfiguration". The analysis on the rural settlements in Karelia were developed within the First European Project "Wooden Architecture", which has involved researchers, professors and students thanks to the organization of international summer schools and events.

[6]Responsible and Coordinator for the survey operations and post production supervision is Prof. S. Parrinello, from the University of Pavia (Italy) and Prof. S. Bertocci from the University of Florence (Italy). Surveyors involved in the laser scanner survey of the Pogost Complex are Sara Porzilli and Aurora Sorini, both authors of the post production phase and of all the results obtained.

[7]The studies on Karelian villages were developed during the First European Project "Wooden Architecture" thanks to the organization of two main Summer Schools, which have contributed with important insights the progress of the research. For a detailed study consult Porzilli (2015), *Rilevare l'architettura in legno. Protocolli metodologici per la documentazione delle architetture tradizionali lignee: i casi studio dei villaggi careliani in Russia*. FUP—Firenze University Press, Firenze.

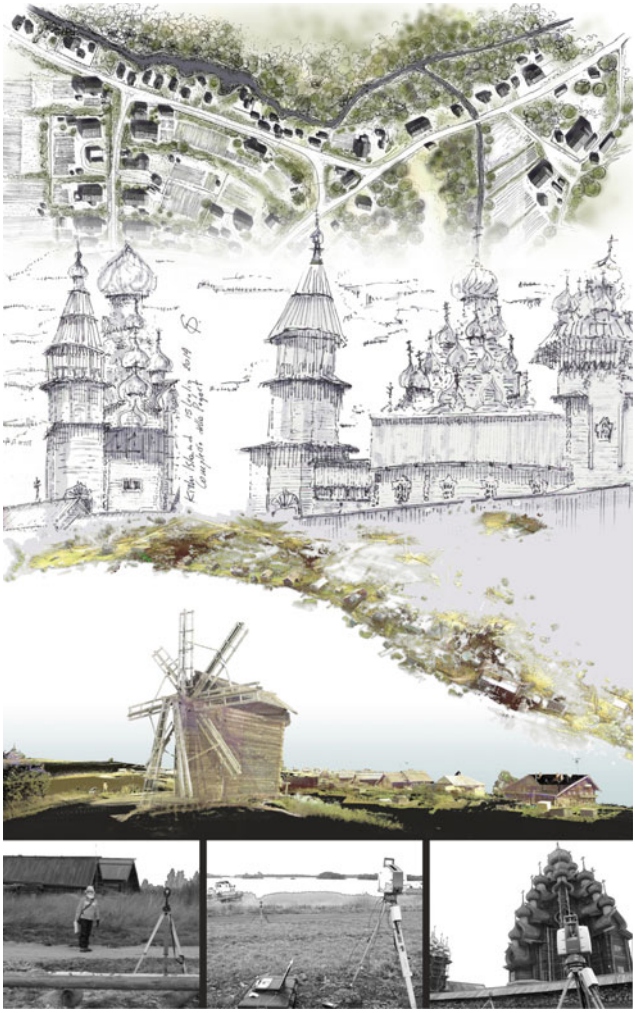


Fig. 4 General views and representations of the wooden settlements and architecture analyzed in Karelia. From the upper part: the hand drawn map of the historic village of Korza located in the Vedlozero region. Preliminary sketches of the Unesco World Heritage Site of the Pogost Complex. Point cloud result of the laser scanning survey of Yamka wooden village with its authentic windmill. General images of the survey activities carried out on Kizhi Island, located in the archipelago of the Onega Lake

to the National Board of Antiquities[8] who started a documentation which have had a precious updating during the survey activities shown in this contribution. Lamminaho represents a unique, well-preserved example of wooden heritage, a place where restoration and repair interventions have been undertaken by respecting the so-called *genius loci* (Norberg-Schulz 1992), by using traditional techniques, which have preserved the authenticity, without compromising the *spirit of the place*. Today experts and responsible of the place[9] are promoting the idea of using this place as an open-air museum. For this reason, the National Board of Antiquities and Senate Properties[10] have commissioned an important survey including not only the architecture but also the surrounded environment. The survey of the architecture jointly with the documentation of its environment gains a complete framework of the actual situation of the place. The main aim has been to set up a documentary corpus for supporting all the different technical actions. This research project has contributed of increasing important practical strategies for carrying out laser scanning survey of wide areas taking measurements of both the environment and the architecture by implementing the metric database with additional survey phases along a certain period of investigation.

The third case concerns the laser scanning survey and analysis of the residential wooden district of Raksila in Oulu, Finland (Fig. 6). This residential area was planned during the early century of the XX century as a regular district, characterized by wooden buildings aligned along the main streets. The image of this place did not changed during the years and today it almost appears in its authentic configuration. Among this, still there are not specific guidelines of interventions and technical recommendations for the preservation of its authenticity. In some parts it is possible to identify inaccurate interventions and actions on restored buildings with the addition of volumes, use of non-original materials and organization of the private yard not totally conformed with the original plan of the place. For this main reason, the survey of Raksila has involved the architecture and its main environment as two essential

[8]National Board of Antiquities (NBA or *Museovirasto* in Finnish language) is responsible, together with other authorities and the museum field, for protecting Finnish environments with cultural historic value, archaeological culture heritage and architectural heritage. It operates under the Ministry of Education and Culture in Finland and it has the responsibility of Finnish properties even abroad. The Mission statement is to recognize and nurture the ever-changing culture. "*The Board ensure the maintenance and accessibility of cultural heritage, produce and mediate new information about cultural heritage together with its partners, and participate in social value discussion on the significance of culture, the state of the cultural heritage, and the direction in which it should be developed*". More detailed information are explained on the official webpage: http://www.nba.fi/en/index.

[9]Museovirasto—National Board of Antiquities (NBA) which has the main office based in Helsinki (Finland) represents the first responsible of Lamminaho Farm House. Senatti Properties is the second partner, which has financed the activities jointly with NBA the research activities carried out by Ph.D. Sara Porzilli.

[10]Senate Properties is a Company working in the field of work environment and specialist partner of the Finnish government. The company has the main responsibility to manage the government's property assets and their efficient use. Official webpage: https://www.senaatti.fi/en.

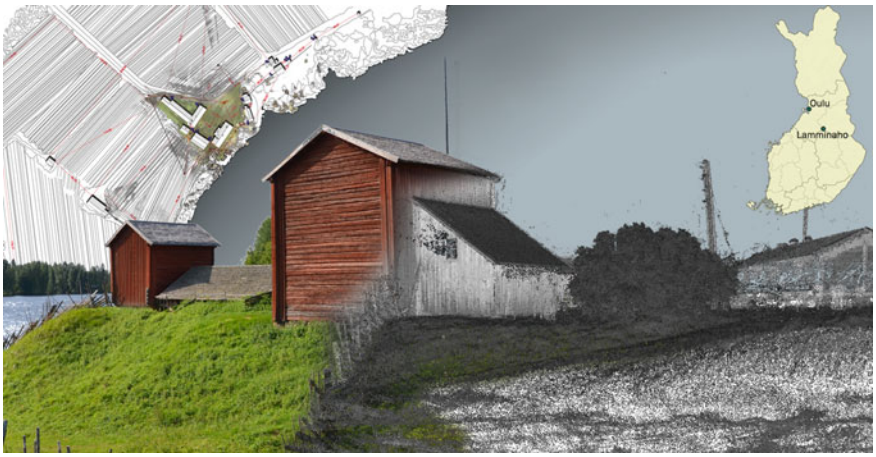


Fig. 5 The historic village of Lamminaho has represented a pilot project for the "Preserving Wooden Heritage" European Project. Starting from laser scanning survey activities it has been developed a detailed scientific report with the representation and description of all the buildings preserved in this area. A sort of technical dossier available for technicians and experts, responsible for the preservation of this Heritage

Fig. 6 The study case of the historic district of Raksila in Oulu, Finland. Laser scanning survey, analysis and documentation of the street facades with census activity of the architecture and its environment. Analysis and results included in the report Özlem Özer-Kemppainen (edited by Özer-Kemppainen 2017)

parts of the same research topic. The laser scanner survey of Raksila is part of Ph.D. Sara Porzilli's ongoing research project "Preserving Wooden Heritage".

3 Research Approach and Criterions

All the research cases presented here arose from the idea that accurate surveying operations nowadays constitute the fundamental basis for designing any kind of architectural project and critical analysis. Innovative methods for surveying architecture and its environment allow technicians to acquire exact knowledge of the status of the object studied and give exact information in order to produce effective intervention strategies. True metrical information and data are fundamental for understanding the formation and development of an architectural entity, village, or city, as well as for planning conservation and restoration projects starting from the present state of a building. In order to get the maximum information from a survey campaign, an integrated[11] research project requires detailed organisation of the different activities carried out combined with an indicative time line.

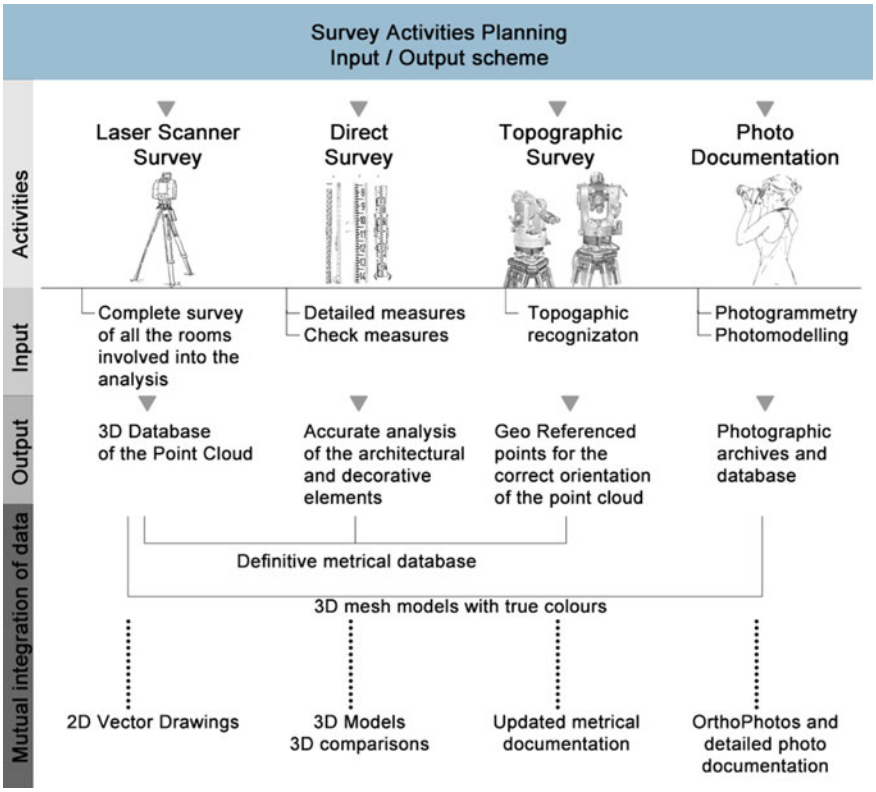
In order to obtain certain and specific results from each type of research activity, it is always fundamental to approach the study with a careful planning of all the theoretical and practical phases involved. During the preliminary phase, it is important to define the activities involved in the process, elaborate operational schemes on which to affix notes in order to identify all the different typologies of data obtained and to understand the achievable results. "Input-Output" schemes, tables and lists help the researcher in the organization of the works and can give important insights in the elaboration of cross checks and transversal implementations (Table 1).

Second fundamental aspect is the identification of the different levels of studies according with the aim of the research. Different activities relate in fact to a different scale of investigation and should be handled by using a process, which from the general aspects includes progressively the details and the particular items (Fig. 7).

From the general	→	To the particular
Analysis of available material	Goal setting (elaboration of the main purposes of the research)	Structuring of activities with an "input-output" method. Each activity generates results (=output) which should represent the "input" of the next phase
Analysis of the context (territorial scale)	Survey of the architecture (architectural scale)	Analysis of the details (detail scale)
Identity and authenticity of the place	Analysis of the architectural values	Documentation of the particular elements

[11] The term "integrated" is specifically intended for those research projects where different types of survey activities are carried out concurrently.

Table 1 Survey activities planning: instruments, input, results, possible crossing checks and outputs



The necessity to go through accurate analysis is today supported by the sensible development of digital technologies and methods thanks to with it is possible to link for instance census activities with surveys, or point clouds with mesh models, and again 3D models with GIS databases.

The interdisciplinary and the connection of cross-thematises support the identification of the new interesting insights and features of an entire place as well as of a singular architecture. These features are again responsible of the identification of intrinsic and extrinsic aspects related to the style, the authenticity, the identity, the *narrativity* and reversibility, all elements, which transcend evidently above Time and Place being responsible of the real comprehension of the object analysed.

Investigations and survey activities follow some main criterions:

- Preliminary recognition of the area, by concerning also archive investigations and historic analysis available;
- Definition of objectives, final results and limits;

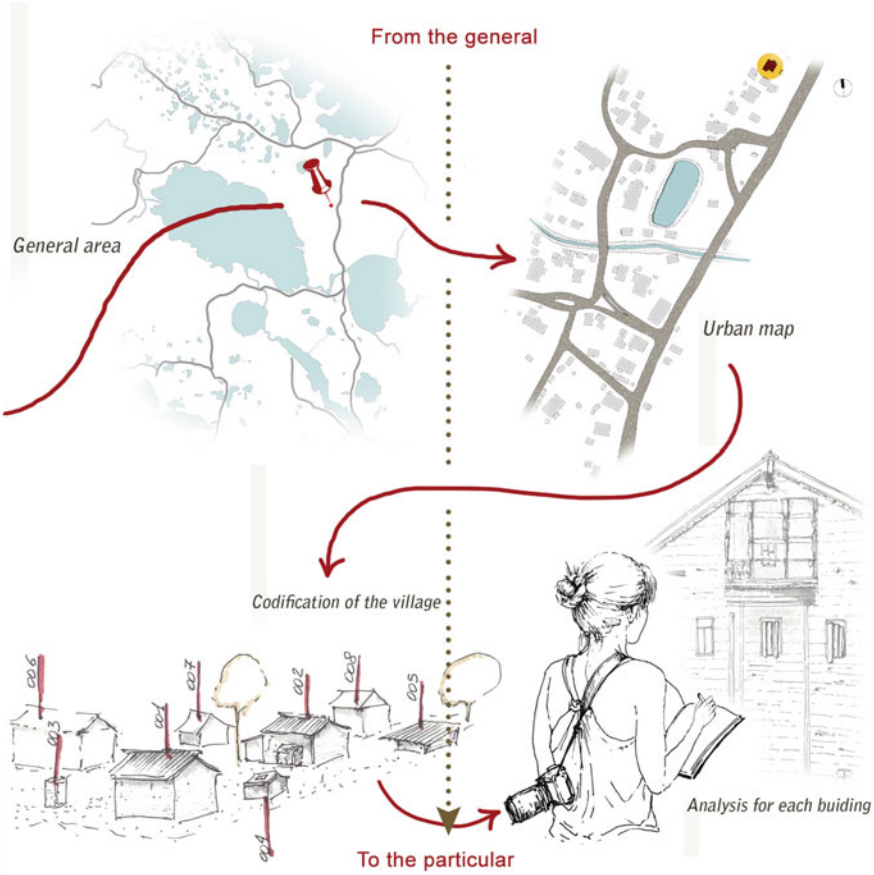


Fig. 7 From the general recognition of the place through the analysis of the singular details of a certain building. The understanding of the investigated object require the practicing of a constant zoom-in zoom-out analysis in order to include the detail in the over-all point of view and keep the general aspects while detecting a particular element

- Identification and organization of the documentary and survey activities by producing time schedules, Gantt charts and table of contents.

This type of organization appear even more necessary if we consider that different level of analysis produce different scale of values and conclusive considerations which contribute to the elaboration of a multidisciplinary research, that consider the object of investigation in its whole material and immaterial configuration.

Within the field of the analysis for documentation, preservation and restoration purposes, survey activities define the preliminary *key-points*, thanks to with it is possible to increase the consciousness of the place and deepen the understanding of the architectural structure. Each case study has represented in fact the testing ground for the elaboration of useful principles both in theory and in practice.

4 Digital Survey Methods and Procedures for the Documentation of Wooden Heritage

According with the objectives defined during the preliminary phase, the activities carried out started with a first recognition of the available documentation and a second step more concentrated in collecting updated information and metrical data on site. A third step regards the post production activity. The first two phases include:

1. Preliminary and propaedeutic activities for supporting the survey analysis and investigations:
   - Archival researches with general understanding of the available material;
   - Meetings with people and responsible of the architectural theme investigated, or in charge with the place;
2. Practical survey activities:
   - Laser scanner survey, from which obtain a complete point cloud both of the architecture and its environment.
   - Topographic survey, in order to georeferenced the point cloud and be able to allocate different parts of point cloud in a mutual geometrically and georeferenced correct position. The topographic survey helps also in the reduction of the error during the registration phase of wide areas (for example for the case study of the Pogost Complex and the Karelian villages and for the case of Lamminaho Farm House in Finland);
   - Direct survey, by using simple tools, for measuring details and parts which the other survey operations should be not able to surveyed with enough metrical accuracy;
   - Photo Documentation for general observations, for the photo-mapping of facades, sections, floor plans;
   - Photo modelling reconstructions, by using the possibility to reproduce from 2D photos (obtained through specific and accurate photo documentation) 3D models with the so-called *structure-from-motion* process;
   - Census activities, for the creation of descriptive inventories and technical atlases of the buildings investigated;
   - Additional activities: landscape analysis, studies related to environmental and cultural aspects by using interviews and external supports from other specialized technicians.

Archival documentation, made by historic pictures, drawings and representations of the Pogost Complex and of the whole island of Kizhi, gave to this case study important insight for the understanding of the original situation both of the architecture and of the landscape. During the last decades, the Church of Transfiguration has been in fact under careful restoration and consolidation activities. The original inner parts, characterized by the presence of an ancient wooden iconostasis surmounted by a timber ceiling, which reproduced the vault of the sky, were disassembled and

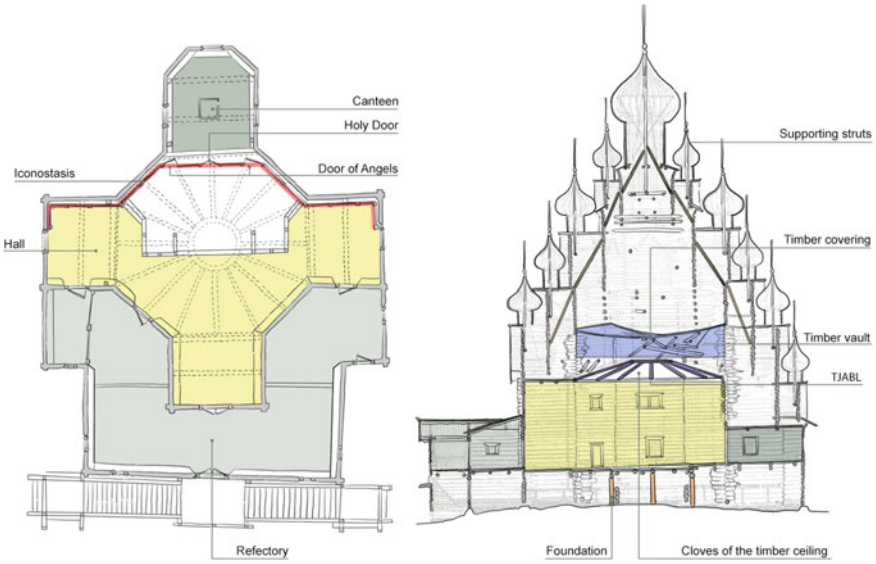


Fig. 8 Scheme related to the architectural composition of the Church of the Transfiguration on Kizhi Island. Thanks to the historic previous documentation it has been possible to understand and know about the original composition of the building. Which where the main elements and how they were located in the structure

stored in order to build a metallic structure for restoration operations. Nevertheless, the architectural parts supporting these structures, remained in the church as an integral part of the main wooden structure. During the survey and analysis, it was fundamental to reconstruct and understand deeply these parts and how they were originally built in order to be able to carry out an accurate survey and a coherent redrawing of the real state of the timber structures (Fig. 8).

In addition to this aspect, previous old drawings have allowed the correct understanding of architectural details as for example the wooden onion domes which characterize the roof structure of the Church (Fig. 9). In other occasion the support of preliminary drawings, although indicative, have supported the organization of the survey.

During the survey activities on the karelian villages in Russia, a preliminary archival documentation was on the contrary almost inexistent. Only for few cases it has been possible to approach the research starting from some available data and technical documentation, mainly linked to the initial representation of the settlement. This type of information was clearly useful for undertaking comparison and dating of buildings, identifying the origin and development of settlements, documenting the lost and destroyed buildings and defining the additions (Fig. 10).

Both for the survey of an architecture as well as for an entire settlement the laser scanning survey should be always linked to a topographic survey or to a GPS data set of points. Wide and complex survey operations can produce in fact geometrical errors

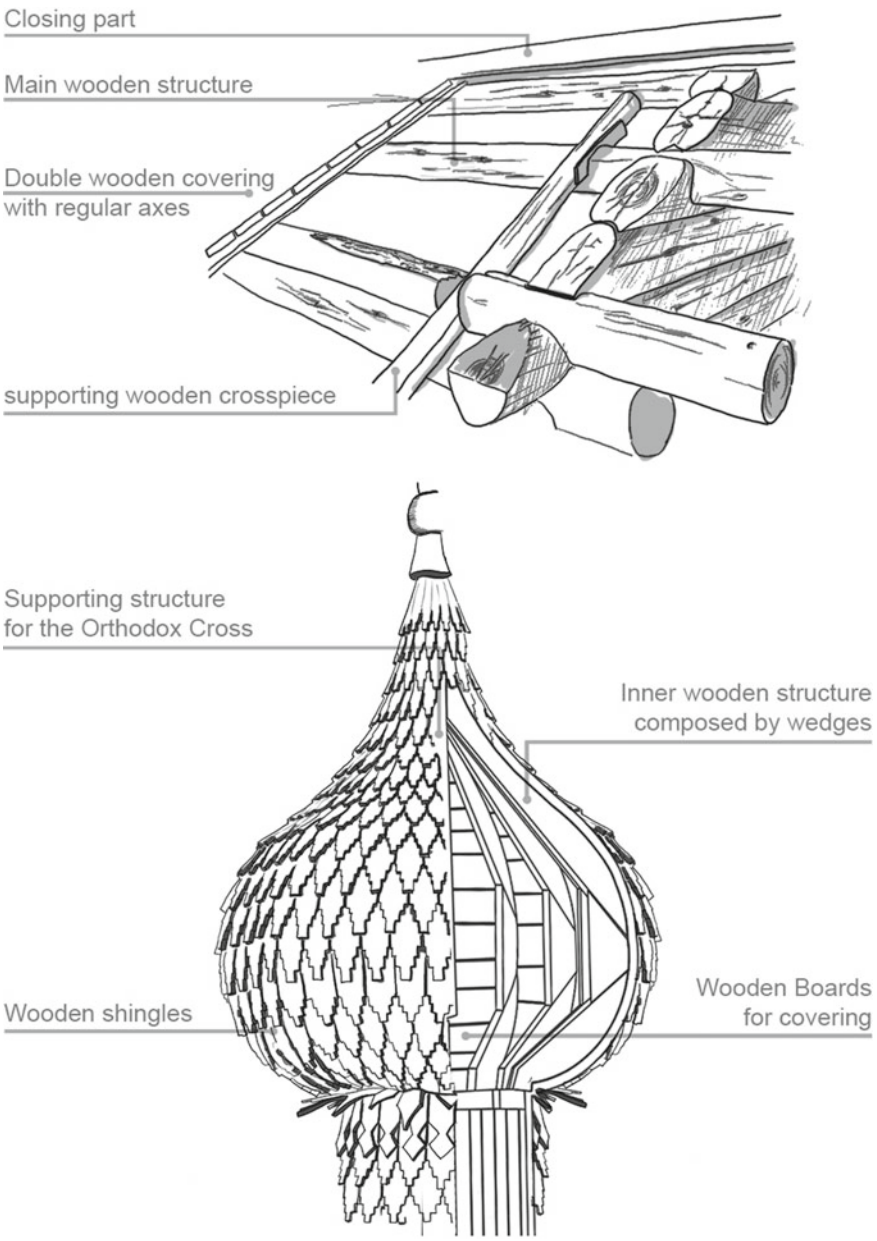


Fig. 9 Constructive details related to common architectural elements present in the Karelian Wooden Architecture. Below the structure of a traditional timber roof, below the composition of the onion domes, one of the main architectural features present in the orthodox Russian churches

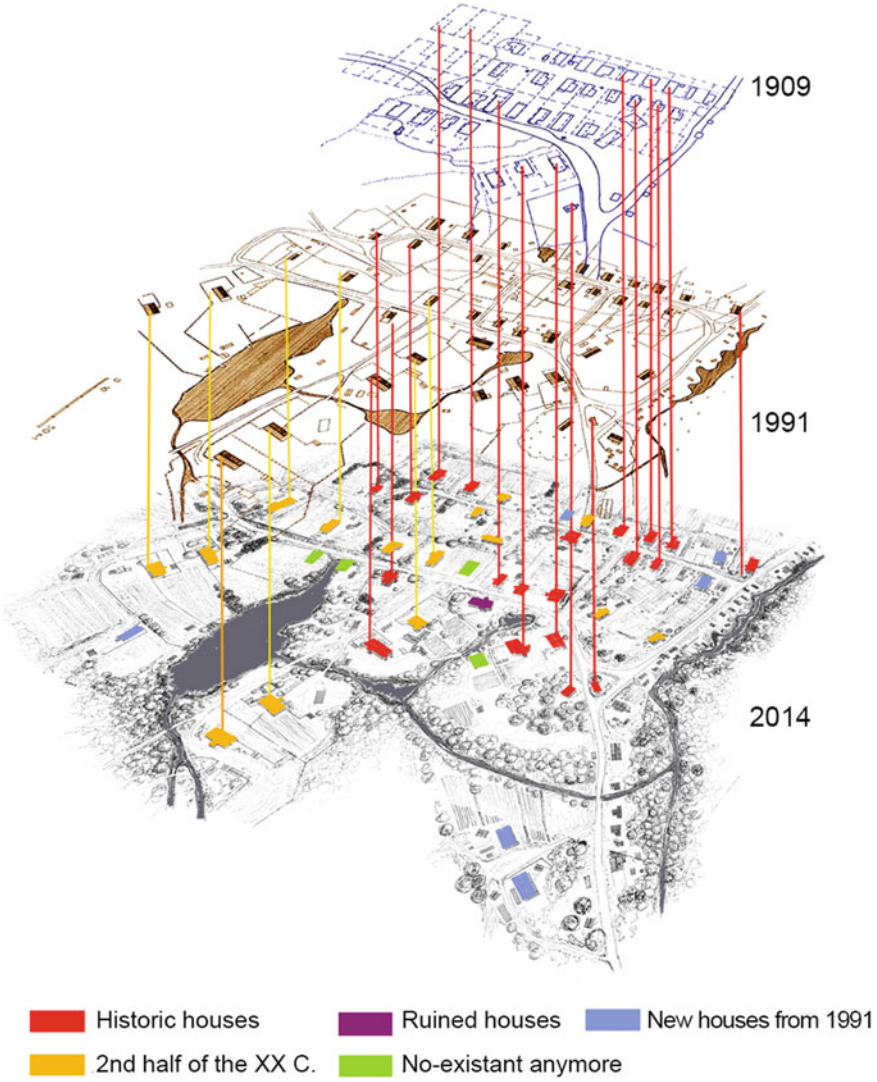


Fig. 10 Comparison and analysis of different maps related to the evolution of the Karelian settlement of Korza

during the registration process.[12] A topographic recognition as well as georeferenced information can help the surveyor in decreasing sensibly the amount of error in order to obtain a result with a high metrical accuracy. In addition to this, it can be also

[12]The term "registration" represents a technical way to indicate the operation of connections of the singular scanwords made during the re-processing of data after the laser scanning operations on field.

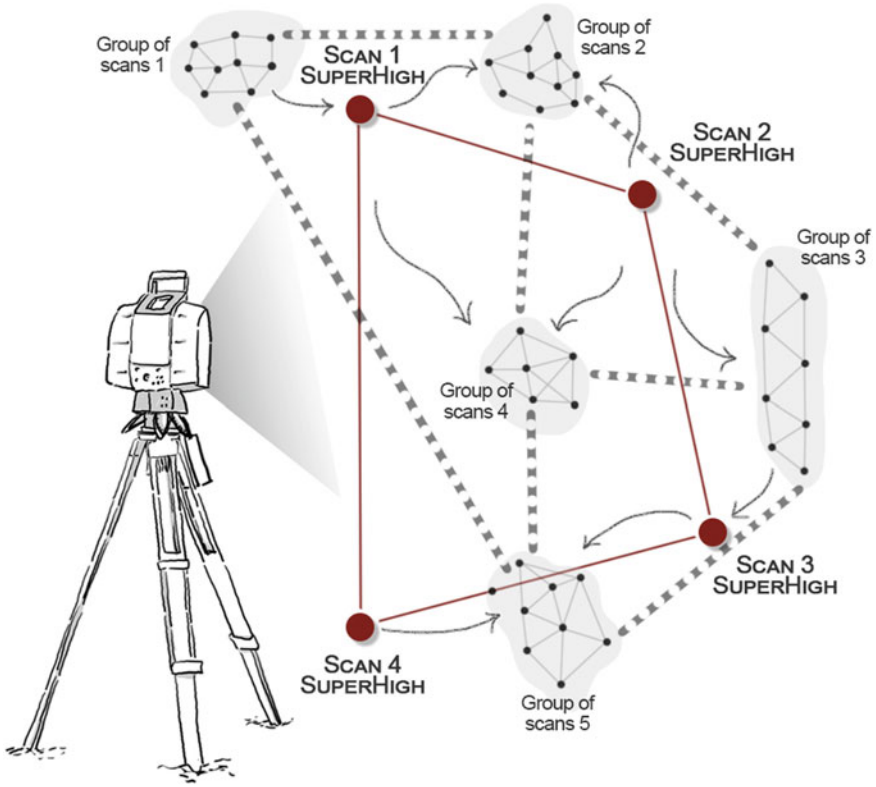


Fig. 11 In the organization of wide digital survey, it could be useful to use different levels of resolution for performing the scan words defining specific polygonals. In this image Scans 1, 2, 3, 4 have "super high" resolution and they create a close polygonal loop. On this basis, the other scans registered in smaller groups, can be linked and find a correct mutual position. By registering each group of scans with the main polygonal of super high scan words, each group will be definitely also correctly linked with the other groups of scans

useful to conduct ultra-high resolution scans for connecting different areas of the same survey. These connecting-scans have the main role to acquire enough metrical information of the environment and architecture and be the key-connections in-between different groups of scans (Fig. 11).

For all the case studies a precise organisation of the scan positions was defined in advance in order to set the practical activities and quantify the amount of work necessary in the field. This procedure is recommended because it gives a real and practical understanding of the work and obligates the surveyor to elaborate in advance all the necessary work strategies useful for carrying out the research and obtaining the results. This type of method allow also a recognition of the estimated time of the activities of field. The organisation of the scan positions is generally determined by specific factors, for example:

- The presence of obstructions which obligate the surveyor to move the instruments into different positions in order to avoid the possibility of missing data;
- The necessity to create the right connections between external areas and inner parts;
- The necessity to survey the object investigated with the highest resolution, avoiding, when possible, shadows and holes in the point clouds (for example with the case of the Church of Transfiguration).

For the Lamminaho project two different types of laser scanner and software were used and tested (the first campaign was performed in 2015 with a Leica GeoSystem and the second in 2017 was performed with a Zoller + Fröhlich laser scanner). This possibility offered interesting comparisons of the data acquired and better understanding of different procedures (Fig. 12). During the second campaign, a massive project was developed in addition to the first one, by making more than 90 scans in order to survey all the external and inner parts in detail. These scans were registered with Z + F Laser Control Software giving the possibility to visualize all the scans with a top view mode directly on the map generated and recognise each singular scan position and navigate within it (with a double click on the blue sphere).

Same laser scanner has been used also for the documentation of Raksila district in Oulu. In this case the object of the analysis were concentrated to the documentation of the townscape of this particular example of historic wooden district. The survey operation has been carried out elaborating the scans along all the main roads of the district. The massive presence of the tree crowns obligated the definition of the scan positions systematically during the activities. The map illustrates in fact that the positions are organized along a zig-zag open polygonals (Fig. 13).

For the registration processes, two methods were adopted:

– use of targets: they are specific points which give the possibility to elaborate geometrical links between different scan words during the registration operations. The target needs to visible in all the scans involved in the process of registration. The laser ScanStation 2 from Leica Geosystems uses generically targets which have reflector parts, this aspect helps the recognition of the exact point from the software used. With ZF lasers is possible to use black and white paper targets, metallic orientable targets on tripods, or sphere targets.
– cloud-to-cloud alignment system: this method can be used only when wide surfaces are acquired by different scan positions. The software used for the registration gives the possibility to make a geometrical pre-alignment of two scans just by moving and overlap a scan to another one. When the pre-alignment is done the software can proceed with the accurate final alignment recognizing the same surface in both the different scans. This method needs to be done with attention and only in those situations where the point clouds have enough areas for overlapping each scan to another one.

The two methods can be used concurrently in order to increase the level of accuracy and for reducing the geometrical error.

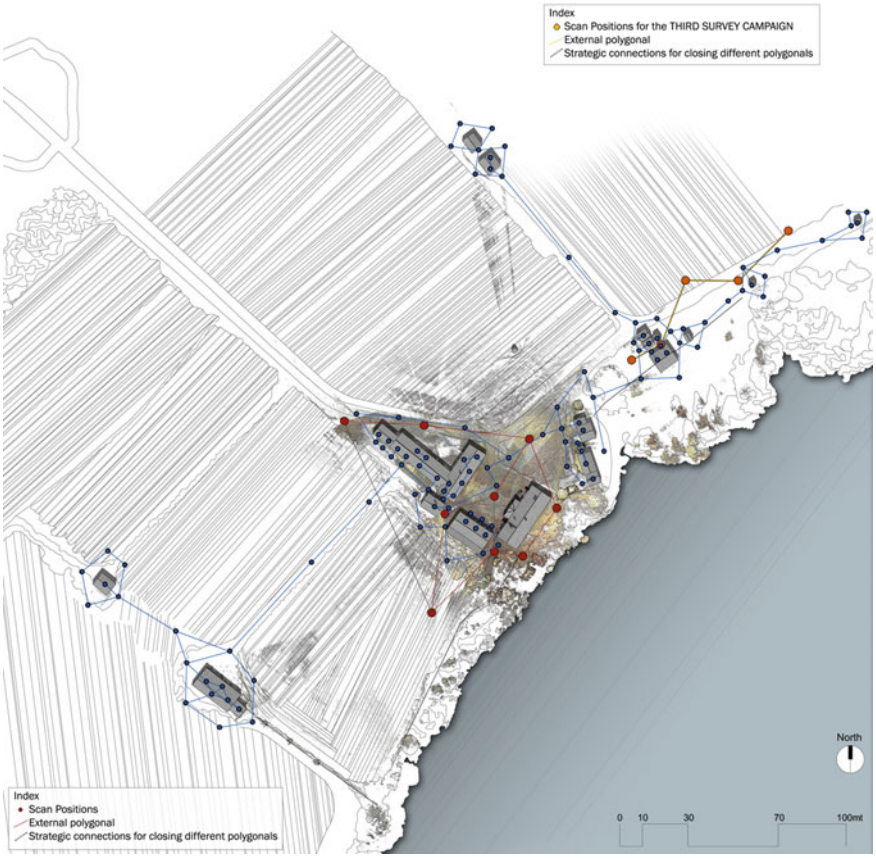


Fig. 12 Representation of the scan positions for the laser scanning survey of the wooden Farm House of Lamminaho in Finland. In red color is the first survey campaign (2015). In yellow color the second campaign (2016) and in blue color the third campaign (2017)

4.1 Post Production Phase and Out-Puts Obtained from the Data Acquired

Analysis and survey activities produce a large volume of updated documentation and information, characterized by the different typologies of data:

- Metric databases, point clouds;
- Vector bidimensional drawings obtained from the elaboration of the point clouds, in particular: general plans, environmental sections, vertical and horizontal sections, detailed technical drawings for specific analysis and observations;
- Three-dimensional models obtained through the elaboration of the point clouds.

Fig. 13 Scan positions of the laser scanning survey of the wooden district of Raksila in Oulu, Finland. The main aim of the survey has been the study of the streets facades of this historic place and the recognition of the present townscape

For each case study presented detailed 2D CAD drawings were produced, using different metric scales according to the purposes planned, as well as 3D models and/or simulations and photomaps to represent the architecture in its real aspect. It can be useful to summarize in detail the main purpose of each project and the technical materials produced:

– Pogost Complex Project: Analysis and understanding of the architectural structure of the Church of the Transfiguration. Documentation of the island and its rural settlements for landscape analysis and for general dissemination useful for touristic purposes too. Material produced is environmental sections in 1:50 scale, floor plans, longitudinal and transversal sections with a 1:5 scale of resolution, 3D model of the first octagonal basement and different tests of modelling straight from the point cloud information. Photomaps of each CAD drawing (plans, sections and facades) completed the documentation using photo documentation built up during the survey campaign (Fig. 14).
– Lamminaho Project: Documentation of the entire area in terms of both architectural and environmental aspects for preservation and restoration activities. Materials

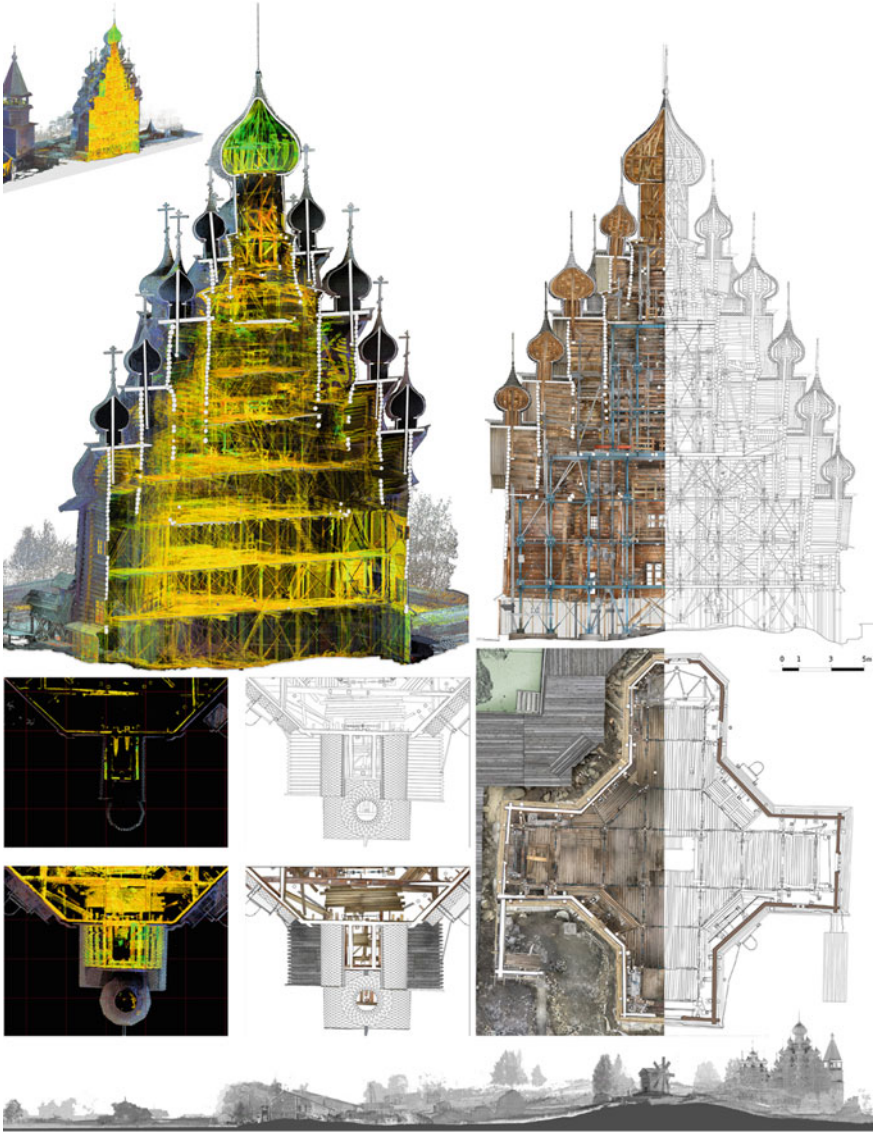


Fig. 14 Different phases of the reprocessing data for the digital survey of the Pogost Complex on Kizhi Island, Russia. For this projects, the post production has involved accurate elaboration of technical drawings for the representation and comprehension of traditional timber technologies and architectural aspects

produced: elaboration of environmental sections (metric scale 1:50) for an updated recognition of the landscape; updated measures of the river bank area; analysis of the relations between buildings and open areas. For each building produced: floor

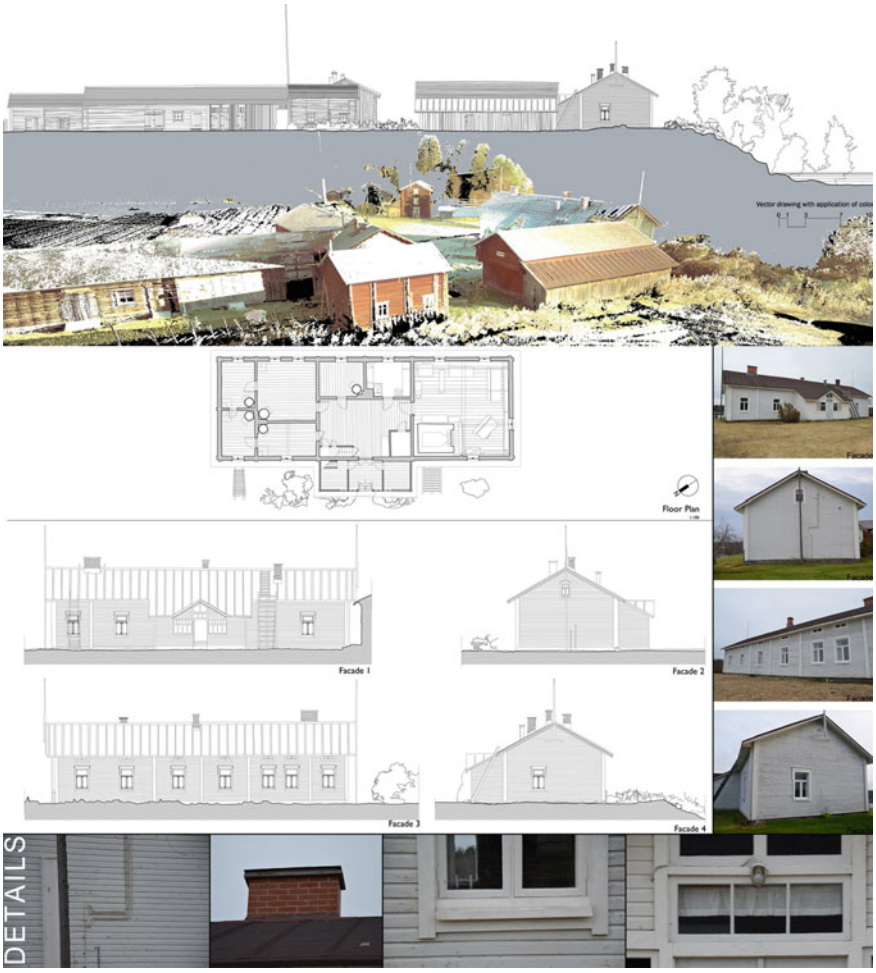


Fig. 15 The case study of the Farm House in Lamminaho in Vaala region, Finland. The place is under a careful plan of intervention and analysis for the restoration of the architecture and its landscape. Digital survey, technical drawings by using different scales and photo documentation have been produced in order to help experts and technicians in this important process of conservation

plans, technical drawings of the facades, longitudinal and/or transversal sections in 1:50 scale. Each façade has a real photomap elaborated in 1:20 metric scale (Fig. 15).

– Raksila Project: Documentation and survey of all the streets of the district. Analysis of the architecture and its environment for the elaboration of updated environmental sections (metric scale 1:50). Census and inventories about buildings with detection of the main characteristics related to the main structures, architectural elements and details, state of conservation with recognition of possible damages.

Fig. 16 Digital survey and preliminary results of the wooden district of Raksila in Oulu, Finland. The work is still under processing and it will constitute a new updated digital documentation of this historic area in Raksila. This case study is part of "Preserving Wooden Heritage" European Pro-ject held by Post Doc. Researcher Sara Porzilli assisted by stud. Francesca Messeri

3D model of the whole area in order to link the information collected in the census analysis with the singular building represented in 3D. Each environmental section has a vector CAD drawing and photomaps of the buildings elaborated thanks to a detailed photo documentation. The resolution of photomaps is 1:20 (Fig. 16).

In the post-production phase it is important to check each ScanWorld and clean them one by one from different types of noise and useless element scanned, for example objects in the field, furniture, presence of people passing in front the laser. In addition to this, it is possible to separate the point cloud into layers in order to have a more cleaned organization of the data within the point cloud file. The elaboration of the sections has been done with Cyclone software from Leica Geosystem. The surveyor create and defines the cut-planes necessary for making the sections, then it is possible to elaborate the orthoimages and export them in a .bmp file. These images are loaded into a CAD file and moved in their specific reference positions

thanks to the coordinates assigned by the software while exporting the orthoimage (the reference positions and all the necessary geometrical information are listed in the text file generated at the same time with the orthoimage). When all the orthoimages are loaded into the CAD file it is possible to start drawing. For the 2D drawings a technical layer list is set and defined in AutoCAD according to the main rules for the representation of the architecture and environment (Bertocci and Bini 2012). All the material produced needs to be archived with specific organization in order to give to different operators and technicians the possibility to handle the quantity of data and navigate within the database without compliance. For this reason, laboratories, units and departments should define and agree specific storage systems for the organization of their research work.

4.2 Final Results: Digital Documentations and Representations

Alongside the technical-operational aspect, this experience has also involved a theoretical and an academic approach for the advancement of the new integrated digital survey systems and for increasing the 2D and 3D post-production methods in order to obtain the newest and most up-to-date procedures for systematic analysis.

It is interesting to notice that even if each case study had a specific output and purpose, all started from accurate survey operations. The challenging aspect of this method and procedure is being able to cover many necessities even in different scientific areas while approaching the subject with these specific activities and consciousness. Landscape analysis, study of architecture in its history, engineering approaches and experimentations, dissemination needs, sociological analysis and historical and archival studies can start from survey recognition on site and find a deep help from the scientific sector of the survey and representation. It is certainly possible to assume that a laser scanning survey may be necessary for not only the main reason for which it can be requested but also crucial for future reasons that may arise later on. The research experiences illustrated in this contribution have definitely underlined and confirmed that today our world heritage should have as a rule metric documentation performed through a laser scanner survey, in order to generate documentation available for the next generation.

In the specific sector of Wooden Heritage digital survey methods are giving important insights and positive results. Because for the structure and nature of the material it should be in fact extremely difficult to achieve accurate results from survey operations without considering the contribution of a digital survey systems.

In all the three cases showed, there has been an updating of the state of the art of the subject investigated. The responsible of the place received not only the metrical database of the investigated area but also the additional elaborations.

For the Pogost Complex the attention has been put on the representation of the timber structures achieving a full description of the technologies used and construc-

Fig. 17 Post production results of the case study of the Church of the Transfiguration. In order to understand the wooden structure nine floor plans and four sections were produced by elaborating orthophotos by using the photo documentation elaborated on field and detailed technical drawings

tive techniques adopted. Detailed and updated drawings help the understanding of how this magnificent building was built and how it was planned (Fig. 17).

For the Lamminaho Project the laser scanning survey has been the starting point for the elaboration of an updated documentation, represented in form of catalogue of the entire village. Each building has a full description both in the inner and exterior parts. Point cloud, cad drawings, photomaps of the facades, sections and detailed photo documentation are from now available for the responsible of the restoration project.

More recently, the case of the wooden district of Raksila has demonstrate that even well preserved urban areas needs in any case to be checked and controlled activating strategies of documentation. Survey information and accuracy in the representation of the data have represented two main aspects of the same purpose. The census elaborated for the buildings in Raksila has produced an important descriptive inventory in which the main information are catalogued in digital form. This means that it will be easily updatable in the future collecting the history of each building and supporting the actions of future interventions. Digital instruments and documentation will definitely allow technicians to switch from a static method to a new dynamic and more efficient scientific approach.

5 Conclusion

According to the state of the art related on wooden heritage and methods for its documentation, researches carried out have increased the knowledge and the digital archive related on this topic along with the "Wooden Architecture" and "Preserving Wooden Heritage" European Projects. Both projects started out from the evident and urgent necessity to keep and preserve wooden architecture by developing systematic analysis including 2D/3D representations for diagnostic analysis and cataloguing all the elements with census activities. According to the preface of the Conservation of Historic Timber Structures manual (Larsen and Marstein 2016): "*There are no standard technical solutions which can be applied universally. Our experience is that repair approaches must be geared towards the specific cultural, architectural and environmental challenges in the country or region where the historic timber structure is located. With this background, one of our most important tasks […] has been the development of the Principles for the Preservation of Historic Timber Structures*".

The research experience is having the important challenge and purpose of operating within the ICOMOS Principles for supporting technicians and operators involved in different types of activities: restoration, documentation, re-assessment and re-designing necessities, re-use, accessibility projects and preservation needs. Alongside the technical and operational aspect, the experiences illustrated here have also involved a theoretical and academic approach for the advancement of the state of the art related to the new integrated digital survey systems for improving 2D and 3D post-production methods. All the analysis presented have been done in respect of the Research-Theory-Practice triangular scientific approach.

This research proves that laser scanner survey represents nowadays a fundamental documentary base that any heritage site should have and request. From a laser scanner, in fact, many different types of project can be formulated with intentions ranging from the simple updating of cartography and technical drawings, up to restoration and consolidation projects. In addition, even projects related to more educational aims for dissemination purposes such as touristic info should find a powerful benefit from digital surveys. The results of these research activities have highlighted that the development of intervention strategies for the preservation of cultural heritage must today be based on updated documentation. It is evident that the careful acquisition of data has a fundamental role in validating each decision in any sector of detection. The importance of the documentation becomes even higher considering conservation in its widest sense, thinking about "physical characteristics" and "immaterial intrinsic elements", in consideration always of the principle of the "minimum intervention and maximum retention of materials" (Larsen and Marstein 2016). Today the main urgent needs are related to the ascertainment that:

– Nontraditional materials are altering and undermining the structural image of wooden heritage;
– A renewed necessity for skilled carpenters needs to be resolved in order to keep specific knowledge alive and available for future generations;

– Traditional materials, crafts and craft techniques must be disseminated and spread by using training programs and specific studies addressing the sustainability of traditional materials and craftsmanship[13];
– Related to practical strategies with laser scanners and monitoring assessments, it would be useful to leave in place the surveyed documentary targets in order to obtain the same metrical joint system throughout the years. Periodical surveys can aid the technical and deep understanding of timber structures in order to check their state of maintenance and operate with fast, safe coherent actions when needed.

The loss of knowledge of this wide wooden heritage, the disappearance of the traditional cultural identity, the memory of these places and the loss of knowledge of craft techniques are seriously compromising the conservation of wooden traditional architecture. The elaboration of new typologies of analysis and intervention strategies for wooden heritage represents a strong, highly urgent necessity. Companies, academic units, and state entities should start to invest in this sector, asking for updated documentation and financing courses for carpenters and craft technicians in order to keep this precious part of our history of architecture alive and available for the next generations.[14]

Credits

Stefano Bertocci is author of paragraphs "1. Introduction" and "1.1 The support of European Funding Schemes", "5. Conclusion".

Sara Porzilli is author of paragraphs "2. The case studies between Russia and Finland", "3. Research approach and criterions", "4. Digital survey methods and procedures for the documentation of Wooden Heritage", "4.1 Post production phase and out-puts obtained from the data acquired", "4.2 Final results: digital documentations and representations", "5. Conclusion".

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The Marie Skłodowska Curie Grant Agreement of the Researcher Ph.D. Arch. Sara Porzilli, PostDoctoral Fellow at the University of Oulu (Finland) protect project results of Lamminaho and Raksila surveys and results located in Finland. These two projects have been financed by European Commission | Horizon 2020—Research and Innovation Framework Programme MARIE S. ACTIONS—INDIVIDUAL FELLOWSHIP. Call: H2020-MSCA-IF-2016. Project title of the Research: "Preserving Wooden Heritage. Methods for monitoring wooden structures: 3D laser scanner survey and application of BIM systems on point cloud models". Mitta Oy Company

[13]These principles are already underlined and treated in the ICOMOS International Wood Committee's Principles. This contribution aims to underline and confirm these urgent necessities with practical examples.

[14]The same principles and considerations are published in S. Porzilli, "Laser Scanning Surveys of Wooden Heritage and Timber Roof Structures and their Post-production. Methods for Detailed 2D and 3D Representations", in M. Huttunen, L. Eerikäinen, L. Laine, P. Saarinen, P. Savolainen (a cura di) "Ruotsin suurvalta-ajan vesikattorakenteet suomessa". Grano Oy editore, Helsinki, 2018. pp. 196–211. ISBN 978-952-7239-38-4.

based in Oulu with a "Survey Lab." has provided the equipment used for performing the laser scanning survey. External collaborator for the case study of Raksila is stud. Francesca Messeri, who is developing her master thesis in Architecture collaborating within the "Prewoodenheritage" European Project.

Some images and information are already published in S. Porzilli, "Laser Scanning Surveys of Wooden Heritage and Timber Roof Structures and their Post-production. Methods for Detailed 2D and 3D Representations", in M. Huttunen, L. Eerikäinen, L. Laine, P. Saarinen, P. Savolainen (a cura di) "Ruotsin suurvalta-ajan vesikattorakenteet suomessa". Grano Oy editore, Helsinki, 2018. pp. 196–211. ISBN 978-952-7239-38-4.

References

AA.VV (1994) The language of wood. Wood in Finnish sculpture, design and architecture. F.G. Lonnberg, Helsinki (Finlandia)

Anker L, Snitt I (1997) Our Nordic Heritage. World heritage sites in the Nordic countries. Kom Forlag Vagevein, Norvegia

Bertocci S, Bini M (2012) Manuale di rilievo architettonico e urbano. Città Studi edizioni, Torino

Bertocci S, Parrinello S (a cura di) (2007) Wooden Architecture in Karelia. A collaboration programme for the preservation of the traditional Karelian timber architecture, Edifir, Firenze

Bertocci S, Parrinello S (a cura di) (2009a) Wooden Architecture in Karelia II. Timber architecture as a phenomenon of National Culture, Edifir, Firenze

Bertocci S, Parrinello S (a cura di) (2011) Carelia. Segni, immagini, momenti, OOO Sezam-print, San Pietroburgo, Russia

Hansen Hans J (1969) Architetture in legno. Vallecchi Editore, Firenze

Iori I (2005) Elementi di persistenza e di tradizione nelle forme del costruire. In: Bertozzi P, Ghini A, Guardigli L (a cura di), Le forme della tradizione in architettura. Esperienze a confronto, FrancoAngeli, Milano

Larsen KE, Marstein N (2016) Conservation of historic timber structures. An ecological approach, Oslo

Norberg-Schulz C (1992) Genius loci. Paesaggio ambiente, architettura, Mondadori Electa Milano. Ed. orig. Genius Loci: towards a phenomenology of architecture. Edinburgh University Press, Edimburgh

Özer-Kemppainen Ö (ed) (2017) Historiallisen Kaupunkimiljöön Suojeluatlas: Oulun Raksila" (English translation: Historical urban environment protection class: Raksila in Oulu) Oulun Yliopisto: Oulu

Porzilli S (2015) Rilevare l'architettura in legno. Protocolli metodologici per la documentazione delle architetture tradizionali lignee: i casi studio dei villaggi careliani in Russia. FUP—Firenze University Press, Firenze. ISBN 978-88-6453-354-4 (print). ISBN 978-88-6453-355-1 (online)

Pryce W (2005) Architettura del legno. Una storia mondiale. Bolis Edizioni, Bergamo

Soikkeli A (2000a) Management of the European Wooden Building Heritage, University of Oulu, Department of Architecture, Oulu, Finland

Soikkeli A (2000b) Restoration of Old and Modern Wooden Buildings, University of Oulu, Department of Architecture, Oulu, Finland

Zwerger K (2012) Wood and Wood Joints. Building Traditions in Europe, Japan and China. Birkhauser Basel, Germania