Project Deliverable

Number	**D3.4**
Title	**Report on Validation**
Month	**M33**
Language	**English**

Revisions record

Rev. N.	*Author*	*Notes*	*Date*
0	Gabriele Guidi	Document framework	April 17, 2018
1	Maria Peppa	NCL Contribution	May 9, 2018
2	Pablo Rodríguez Gonzálvez	USAL contribution	May 11, 2018
3	Beata Hejmanowska	SSSA Contribution	May 14, 2018
4	Sara Gonizzi	Polimi contribution	May 23, 2018
5	Gabriele Guidi	Final form of the document	May 25, 2018

USAL

The criteria for evaluation will be based on the following measures: performance; reliability; contribution in connection with project aims; usability; and sustainability. In the following table are listed the items considered in the questionnaire in relation to the five key aspects:

Aspect	Questionnaire item
Performance	Q1 – The 4D model is easy to understand. Q2 – The viewer was well designed visually. Q3 – The viewer response is enough to be fast.
Reliability	Q4 – The 4D model is presented appropriately. Q5 – The 4D viewer works stably.
Contribution to project aims	Q6 – I learn better about history through 4D modelling in historical buildings/sites. Q7 – 4D modelling is an innovative way to conserve the historical sites/buildings. Q8 – The 4D models raised my awareness about local Cultural Heritage. Q9 – The 4D models allow to visualize Heritage evolution.
Usability	Q10 – It is easy to be accustomed to using the viewer. Q11 – The navigation through the 4D model was easy. Q12 – Informing historical sites/buildings is more interesting through 4D models.
Sustainability	Q13 – Conservation of historical sites/buildings using 4D models is highly necessary. Q14 – 4D modelling promote sustainable tourism. Q15 – You want to use the 4D model in practice.

For the questionnaire form employed a 5-point Likert scale level of agreement[1]:

- 1 – Strongly disagree.
- 2 – Disagree.
- 3 – Neither agree or disagree.
- 4 – Agree.
- 5 – Strongly agree.

In the following figures is show the results for the different items for a population of 24 persons, which ranged from restorers and conservators to institutional users and planners.

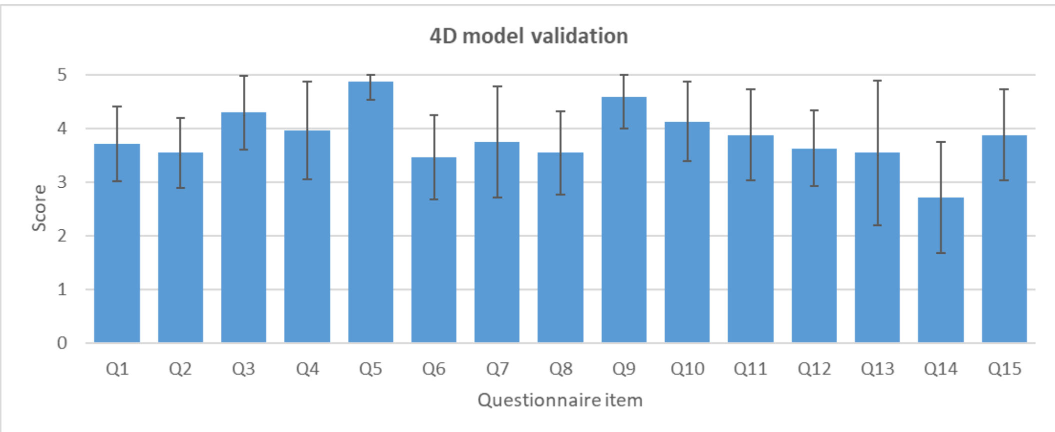

Figure 1 - Questionnaire items results.

[1] Vagias, W. M. (2006). Likert-type Scale Response Anchors. Clemson International Institute for Tourism. & Research Development, Department of Parks, Recreation and Tourism Management, Clemson University.

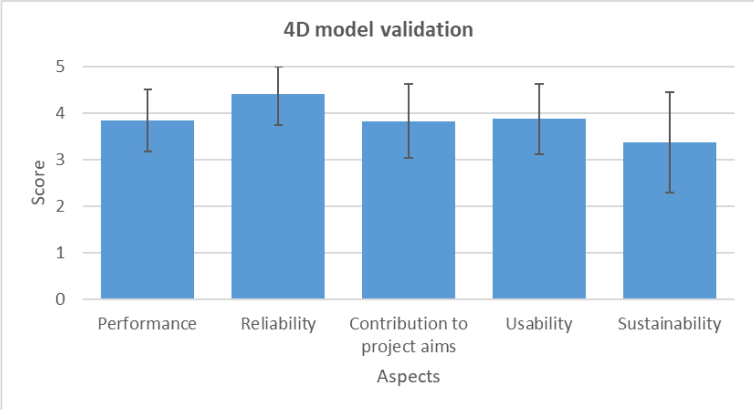

Figure 2 - Main aspects results.

The global score of the 4D model validation is 3.83. However, without the low score of item Q14, the global score raises to a 3.91 which implies an agreement of the final 4D models.

As final conclusion, it is really important to receive support from the national and local Administrations, especially when we are focused on historical buildings and monuments. This type of buildings and monuments enclose a huge value which require high costs for its maintenance and sustainability through time. Thanks to this tool (4D platform) we can put in value the motto "*prevent is better than cure*" and try to provide a tool for the analysis of cultural heritage through time. In addition, these 4D models can be enriched with historical and additional information under a database providing an excellent tool for the management of cultural heritage. As a result, we can promote preventive culture between users and owners and thus guarantee that our cultural legacy is preserved and put in value.

NCL

While some Hadrian's Wall sites, such as Birdoswald and Beckfoot, have seen dramatic change as a result of natural processes in the last couple of decades, at others such as Corbridge, the transformation is less obvious, but nonetheless profoundly significant. Whether we are looking at fluvial erosion (Birdoswald), coastal erosion (Beckfoot), or a combination of repeated flooding and intense farming (Corbridge) being able to quantify and communicate the rate and pattern of change is of vital importance to the care of these cultural sites. Modelling 4D change allows us to do this, but it also helps advance research into such sites more generally.

First, it offers further depth to archaeological GIS-aided analyses. Not only does the process of generating 3D models for different periods from aerial photographic data complement the need to consistently reappraise historic sources for archaeological sites in the light of advancing skills of interpretation, it also generates further layers of information that can be cross examined. Second, the draping of geophysics plots and historical maps over an accurate DEM is always useful, but the fact that these models allow us to drape such plots over multiple DEMs of different periods spanning the last few decades helps deepen our understanding. The scale of change our landscape has undergone in the recent time is often underestimated by even seasoned fieldworkers. At several points along Hadrian's Wall, landscape transformation has impacted the site more dramatically in the last few decades than it did in the entire first millennium following the end of the Wall's use by the Roman Empire. Recent changes have often concealed or destroyed vital evidence, so even being able to appraise an historic landscape in multiple dimensions as it might have appeared a few decades ago is a great advance.

Finally, the 4D approach of CHT2 has the potential to help us critically appraise retro-projections of landscape change. The capacity to map recent landscape change with vastly higher resolution opens up the possibility of adding a further form of controlled modelling of longer-term trajectories to be set alongside other sources of environmental data for ancient sites. CHT2 has already left several important legacies on Hadrian's Wall, its methodology is already being discussed in the preparation of the new Hadrian's Wall Research Framework, it has contributed to the rationale for a new Iappetus-funded PhD on the modelling of environmental change and its impact on Hadrian's Wall, and, furthermore, it has also enriched the data of ongoing field projects at both Beckfoot and Corbridge. To this must be added the fact that CHT2 data offers a vital indication of just how at risk our 'at risk' sites really are.

Polimi

The case study of the Polytechnics of Milan's unit concerned the 4D reconstruction of the Roman Circus of Milan.
The peculiarity if this monument is that is entirely covered by modern buildings and that the most of its parts are lost because of the substantial changes occurred in that part of the city. The few remains are hidden in cellars, gardens, and basement of private buildings, and are impossible to be seen. Sometimes, even the owners of the apartments in the buildings don't know the existence of the roman remains.
The 4D reconstruction was finalized to the superimposition of the 3D model of the ancient monument on the current city, to identify better the area occupied in antiquity by the building and to let the non-expert understanding both the overall dimension, that was majestic.
This process was done georeferencing the ground level of the actual city with the 3D models derived from the surveys of the few remains still visible (most of which underground) and the 3D model of the reconstructed circus. In this way, it is much easier to understand the development not only of the monument itself but also of the modern city, that was partially influenced by the remains: this is especially visible in the southern part where the disposal of the contemporary private buildings seems to follow the curvature of the ancient circus.
The most important part of the validation of the reconstruction was the strict collaboration between the POLIMI team and the superintendence of Milan. This process provided a diachronically accurate reconstruction and, more important, permitted the superintendence to study in deepen a monument that, before this project, was not thoroughly investigated.

The result of the 4D reconstruction was submitted to different groups of consumers and to experts in the archaeological and historical field.
The first testers appreciated:

- The easy navigation in the virtual environment.
- The possibility to visualize the seven different time-varying scenarios in the web page, comparing two by two the historical periods with the use of a slider.

The experts evaluated the tool positively not only for the same reason listed above but also because:

- It allows to visualize and comprehend the area, now densely built with modern architecture, as a whole.
- It provides a precise mapping of the existing archeological remains currently available, in term of number and georeferenced positioning, putting them in relationship with the current shape of the city.
- It represents a shared platform for showing clearly the set of available data, easing the discussion and validation of possible historical hypotheses, and allowing a better management of any conservation activity.

This tool is, in their opinion, useful for the conservation of the remains, for better programming future interventions in the area without the risk to destroy some important structures, and as a start for new studies, researchers and hypothesis regarding the topography of the ancient city and the monument itself.

For both the target groups, the only thing that can be implemented is the possibility to add some images and text to the virtual visualization in order to make the tool more complete.

SSSA

The entire modeling process was validated. 3D models were created basing on the historical maps, plans, ALS, TLS and UAV. In table 1 there are selected objects form Krakow Fortess. Some of the objects were discarded due to the accuracy or completeness errors.

An example of comparison between UAV optical imagery and TLS was presented in Fig. Figure – Fig. Figure. Histogram of distances between the points' clouds are in Fig. Figure. Generally, if the measurements are properly made the comparison is ca. cm. Other parameter which was validated was quality of 3D modeling form points cloud. Some surfaces are tedious for modeling (Fig. Figure). The most important is validation of geometrical accuracy. Example of accuracy analysis is presented on the base of Fort Kleparz, Bastion III (Fig. Figure) during data integration building model 4D. Following data were used: model from historical cadastre maps 1927, TLS point cloud and tachymeter measurements. Model form historical maps and form TLS were built independent. Then was transformed to PL 2000 coordinate system (to the base map). Some problems appeared with the scale (xy 1/800 and z 1/400) but internal accuracy was 0,005 m. Next problem we met with the fitting to the base map (shifts and scale problems).

Integration of the point clouds was internally 0,02 m. In next step models and tachymeter measurements (some distances: heights and widths) were compared.

Some results are presented in the Table 2 and Table 3. Generally the error reach value: 0,73 cm and more. This model as and example of rejected objects due the accuracy reason (Fig. Figure).

Table 1. 3/4D models obtained with different techniques for selected forts (in yellow with success, in light brown still in preparation or failed from data accuracy or completeness).

Name of object	CAD	TLS	ALS	UAV
Kościuszko	+	+	+	+
Batowice	+	+	+	+
Węgrzce	+	+	+	+
Bastion III	+	+	+	-
Marszowiec	+	-	+	-
ŁysaGóra	+	-	+	-
Sudoł	+	-	+	-

Figure 3 - Fort Wegrzce – points cloud UAV – optical images

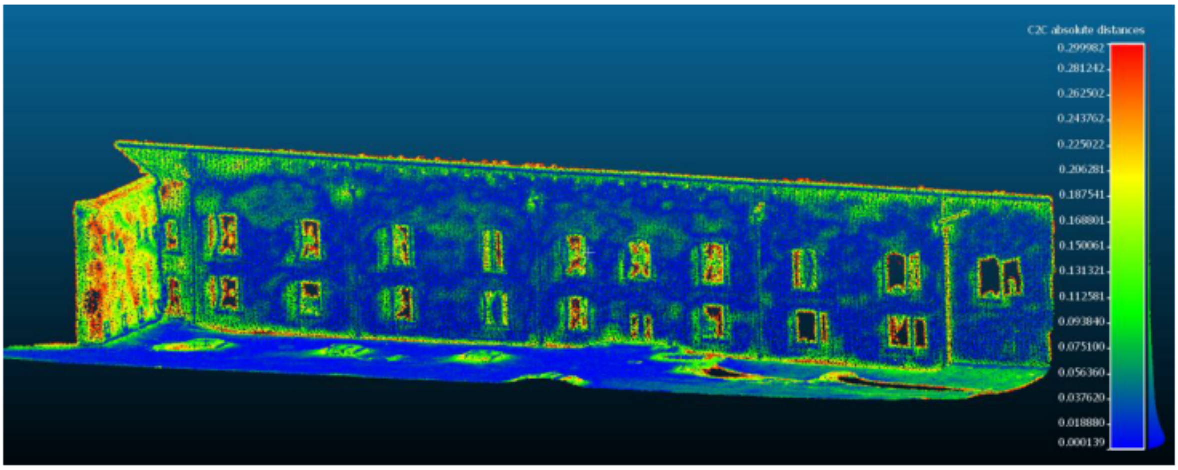

Figure 4 - Comparison between points clouds form UAV and TLS (distance between the points cloud); 0 blue, 0,3m red)

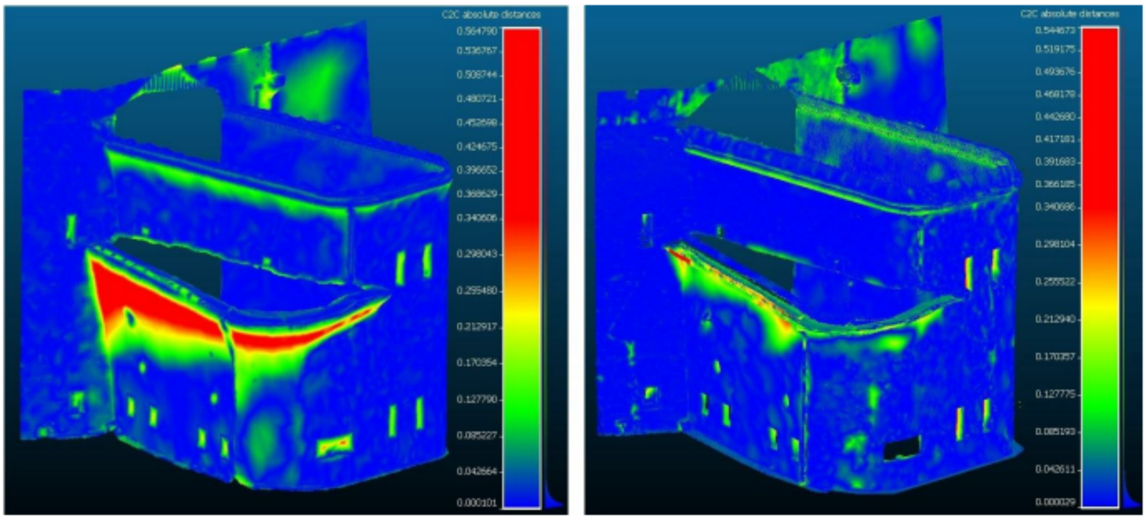

Figure 5 - Comparison between points clouds form UAV and TLS (distance between the points cloud); 0 blue, 0.5m red); differences between the UAV height (left higher than right)

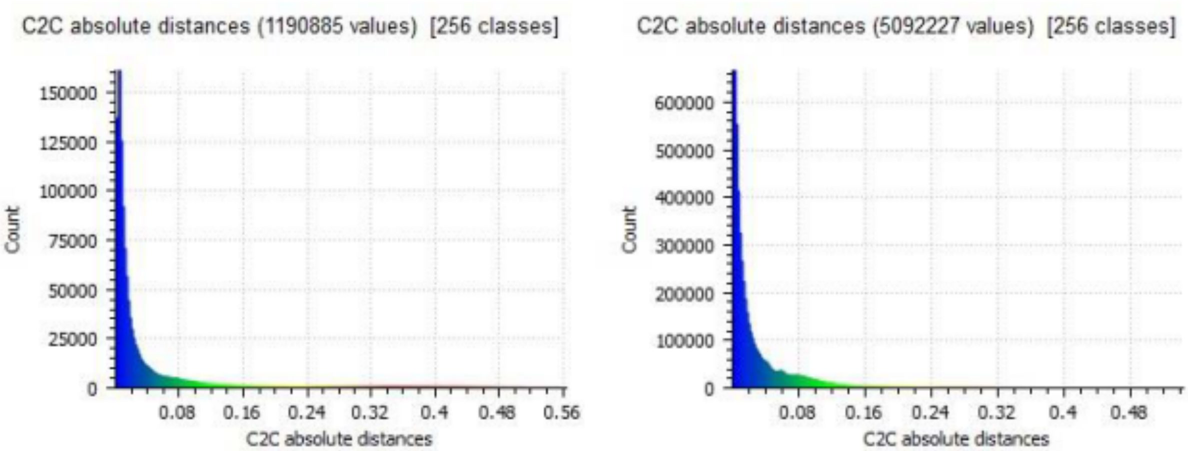

Figure 6 - Histogram of the distances on the objects in Fig. Figure

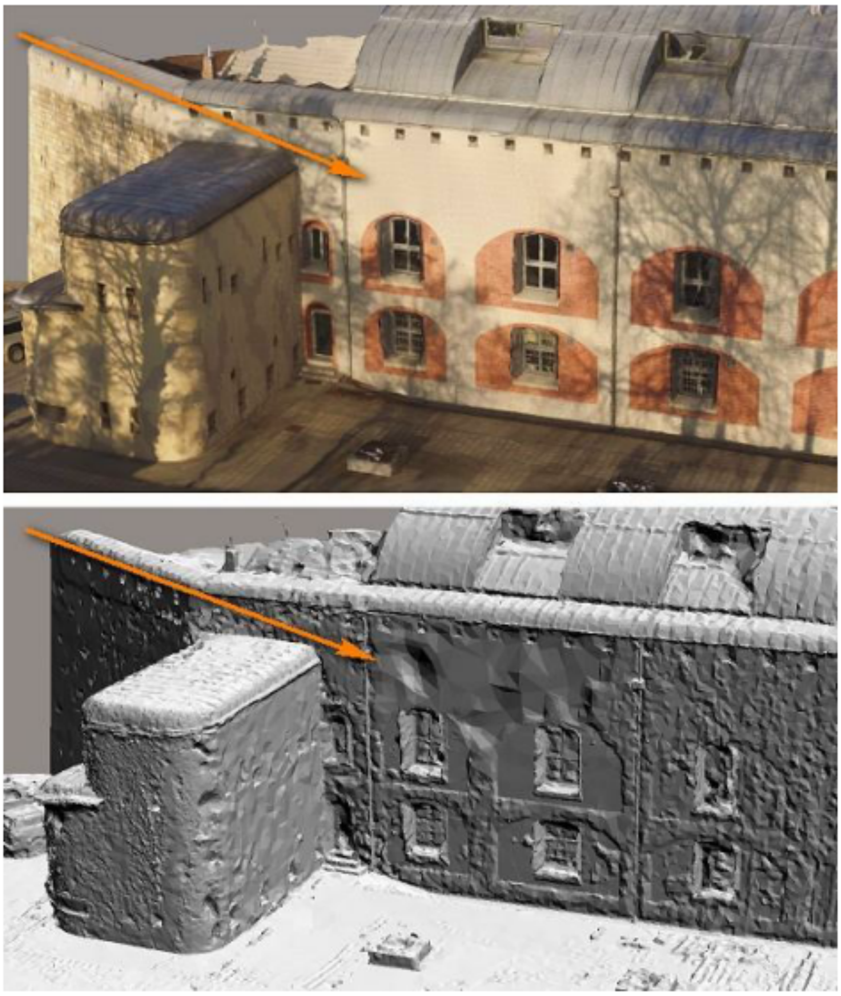

Figure 7 - Influence of the surface on the 3D reconstruction

Figure 8 - Airborne historical image 1919 (left), current ortophotomaps 2015 (ortophoto)

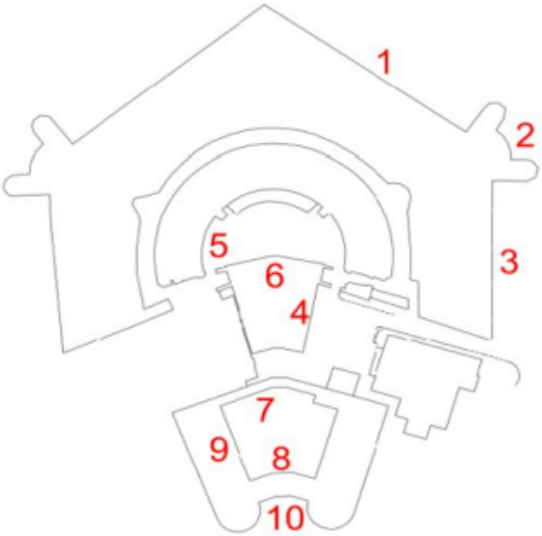

Figure 9 - Control measurements on the 3D historical model and TLS points cloud

Table 2 Control measurements on the 3D historical model and TLS points cloud

	3D historical model	TLS points cloud
1 – wall before caponiere	L: 93,51	L: 93,64
2 – east caponiere	H: 9,42, D wall: 13,5	H: 9,55, D wall: 13,39
3 – wall after caponiere	L: 65,61	L: 65,52
4 – internal caponiere	L: 40,92	L: 41,10
5 – redit (internal)	H: 9,97	H: 9,78
6 – caponiere internal	L: 19,02 x 19,00, H: 4,61	L: 19,00 x 18,97, H: 4,75
7 – corridor south	H: 4,18	H: 4,01
8 – caponiere south	L: 9,10 x 7,60 x 9,07, H: 8,40	L: 9,15 x 7,65 x 9,11, H: 8,49
9 – caponiere south (western part)	L: 33,57	L: 33,48
10- caponiere south (suth part)	H: 8,68	H: 8,75

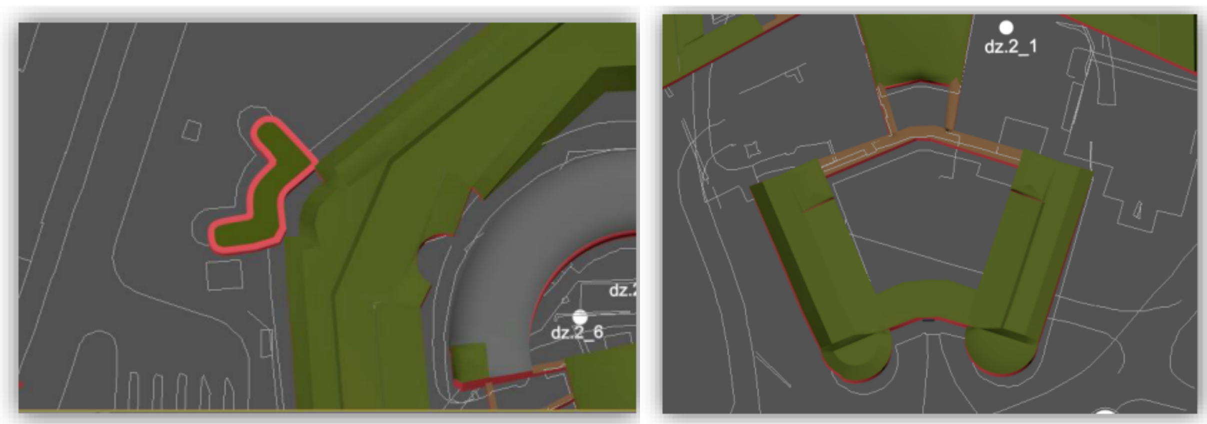

Figure 10 - Comparison between model from historical map and current base map (shifts and scale error)

Table 3 Differences between distances measured on the models and using tachymeter (m)

1) 3D historical model	2) 3D TLS	3) tachymeter	3)-1)	3)-2)
3,97	4,66	4,70	0,73	0,04
9,24	9,51	9,54	0,30	0,03
3,97	4,07	4,03	0,06	-0,04
19,08	19,03	19,01	-0,07	-0,02
3,97	4,66	4,70	0,73	0,04
3,96	4,05	4,03	0,07	-0,02