The management of excavation data in accordance with the WBS for the Mont Cenis Tunnel

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The GIS represents an effective and useful digital tool for managing various types of information in order to be able to use it as required.
In this context, a geological portal has been created within TELT since the beginning of 2000s on a GIS basis in order to classify, sort and record all geotechnical/geological parameters.
The IT portal is set up with a database in an SQL Server and a GIS mapping representation. It has been populated over time with data from the different project phases which have characterised the Lyon-Turin project.
The database includes data from exploratory investigations, measurements of the water resources in the areas involved in the new railway line and data from the construction of the first underground works (face surveys, excavation progress, geotechnical monitoring, TBM excavation parameters).
Within this huge information structure, data is organised with a WBS or Work Breakdown Structure. The breakdown of the base tunnel into smaller, identifiable elements allows the huge mass of data to be better tracked and organised and to make information accessible to all operators on a common dictionary basis. In addition, the possibility of using a single structure allows to avoid duplication and the exponential growth of available data. In conclusion, the organisation of GIS data according to a single WBS becomes particularly important in big projects in order to create lean tools capable of responding in an increasingly efficient and effective manner.

1 INTRODUCTION

Telt, the public promoter in charge of the construction and operation of the cross-border section of the Lyon-Turin line, is now right in the middle of the final works. In addition to the construction of the main work (the 57.5 km-long Mont Cenis Base Tunnel), a lot of specific construction sites have been put in place for other works to ensure the functionality of the main work (e.g. safety sites, connection branches, technical caverns, ventilation shafts, international railway stations). Therefore, the company's objectives have shifted from those of the studies and construction of preliminary works, such as access works to the main work (Saint-Martin-La Porte 2,329-m-long access adit + 1,745.5-m-long access adit 3a, La Praz 2,480-m-long access adit, the Modane 4,036-m-long access adit) and exploratory tunnels (on Italian territory the 7,020-m-long Maddalena tunnel and on French territory the 10,583-m-long Saint-Martin-La-Porte tunnel) to those of the final works. And if the nature of the technical data coming from the study phase does not roughly change for the works phase (tunnels, geognostic surveys, geotechnical monitoring systems), the way data are managed and the need for their usability do. For this reason, the technical data that populate Telt's geological/construction IT system are enhanced and organised by the WBS attribute.

2 PORTAL DESCRIPTION

TELT's geological/construction portal is an example of advanced interfacing between the functionalities of a web portal based on a relational database and a consultation tool such as GIS. It was created to provide the company with a single system (for Italy and France) where technical data could be uploaded and used in a simple, fast and effective manner for the purpose of near real-time monitoring of the progress of construction sites by the Project owner.

Since the 2000s, TELT has pursued the evolution of this tool as a solution for collecting and consulting data of a geological, geotechnical, geophysical, cartographic, water monitoring nature, data from geognostic and environmental surveys carried out on the surface, and data from underground excavations, such as face survey, excavation progress, instrumented sections, and mechanised excavation machine parameters. All surface data are georeferenced according to the international (metric) reference system UTM WGS 84 and in the local system of LTF2004c, whose name goes back to the former name of the Telt company. Underground data, on the other hand, are linked to the metric progressions of the tunnels. Therefore, it is possible to view the data on a map system where search and consultation are also possible thanks to the webgis functionality.
On the TELT portal the webgis projects have followed the realisation of the different preliminary works (e.g. La Praz adit) and the various project phases (e.g. Final Reference/Variant Project). Specific cartographic projects were also realised for the consultation of all the information stored (surveys, springs, investigations, etc.).
At the moment, cartographic projects have been configured to follow the implementation of the final works by subdividing the projects by operational construction sites.

The data on the portal are stored in a relational database first based on the Oracle RDBMS database, which was updated and migrated, in a second phase, to the SQL Server Enterprise 2016 RDBMS.

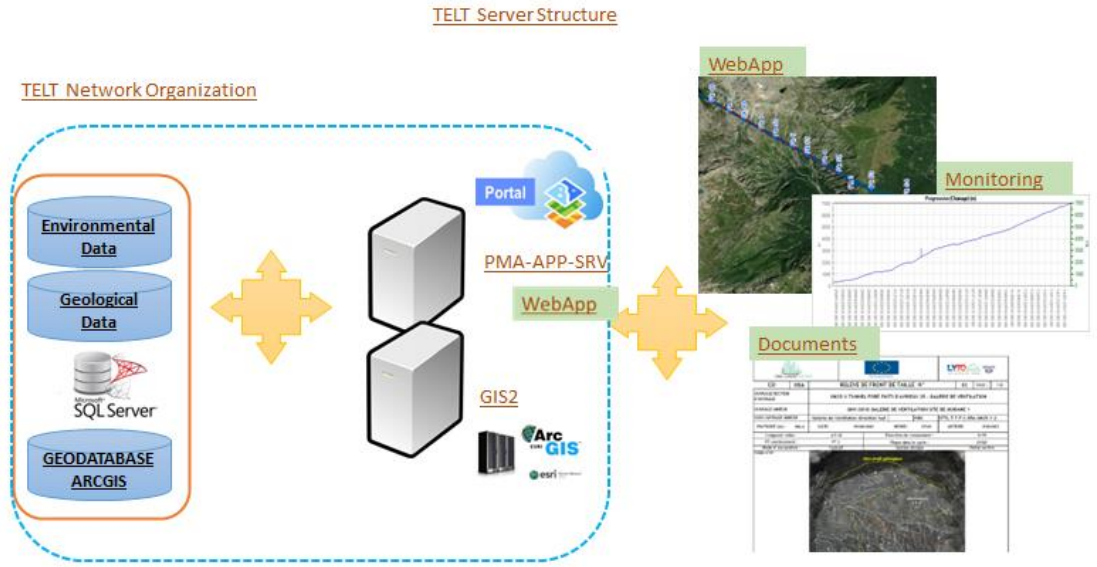

Figure 1 TELT server structure

At present, there are more than 5,000 measurement points with related information on the geological/construction portal database, broken down as follows.

Table 1. Number of measuring points

Type	Number
Geological surveys	1536
Water points (springs)	1148
Instrumented sections	1877
Environmental surveys	108
Geophysical surveys	151
In-situ tests	26
Tracing points	68
Surface Water Bodies	67

For the excavation of the underground works already completed there are to date:

- Progress for 30 km of excavation as at 31 August 2022
- 5,600 face surveys
- Excavation parameters of 2 TBMs for a total of 48 million data records

With regard to the cartographic information on the database, the software used is ESRI.
The cartographic information was organised in the geodatabase by configuring the data with the ArcSDE tool, which later became ArcGIS Server, and providing a visualisation based initially on ESRI ArcIMS and subsequently on ESRI ArcGIS Server version 2016 and ArcGIS Portal 10.6.
The TELT database is loaded with data from manual uploads as well as data from automatic procedures.
In particular, for 2 tunnels excavated using the mechanised method, the TELT geodatabase allowed the real-time loading of TBM parameters and a consequent automatic update of the cartographic view to show the excavation progress of the works.

Figure 1 Excavation progress on webgis

One of the ways of consulting the data is by means of graphs. This mode allows checking the progress based on the excavation time or progress for the machine parameters of the TBMs, and on the time for information related to geomechanical parameters of the face surveys, the water flow rate of the springs and the water flows in the tunnels.
Uploading data onto the portal involves a distinction of roles between those who upload the data, those who verify it, and those who use it for consultation. The upload phase is carried out by the site operators and construction management, a subsequent verification phase is carried out by TELT to ensure the consistency of the uploaded information with the needs of the TELT portal.

3 THE TELT WBS

The backbone on which the data on the portal is organised is the WBS, i.e. the Work Breakdown Structure.
The WBS of TELT is a hierarchical structure created to organise and manage the works of the cross-border section including:

- the works in the Saint-Jean-de-Maurienne plain with the international station, the connection to the Historic line and the crossing of the Arc and Arvan rivers;
- the Mont Cenis cross-border base tunnel through the Saint Martin la Porte, La Praz, Villarodin-Bourget-Modane, Maddalena adits;
- the crossing of the Susa Plain with the international station, the works for the interconnection with the historical Turin-Modane line and the crossing of the Dora Riparia.

In particular, the Base Tunnel, with a length of about 57.5 km, of which about 45 km on the French territory and approx. 12.5 km the Italian territory, consists of two single-track tunnels with an average spacing of 40 m and connection branches every 333 m. These features have led to structuring the TELT's WBS with nine levels as follows:
- level 1 (project): identifies the project as a whole;
- level 2 (promoter): identifies the promoter according to the intervention phase
- level 3 (macro-activity): identifies the work phase (Engineering, Construction, Expropriations, etc.);
- level 4 (country): identifies the country;
- level 5 (activity classification): identifies the discipline to which the generic activity refers;
- level 6 (operational construction site): identifies the operational construction site;
- level 7 (work site): identifies the individual works of the relevant work site;
- level 8 (work section): identifies a further spatial subdivision of the works;
- level 9 (work part): identifies the individual elements of the work

In addition, the WBS code consists strictly of 25 digits.

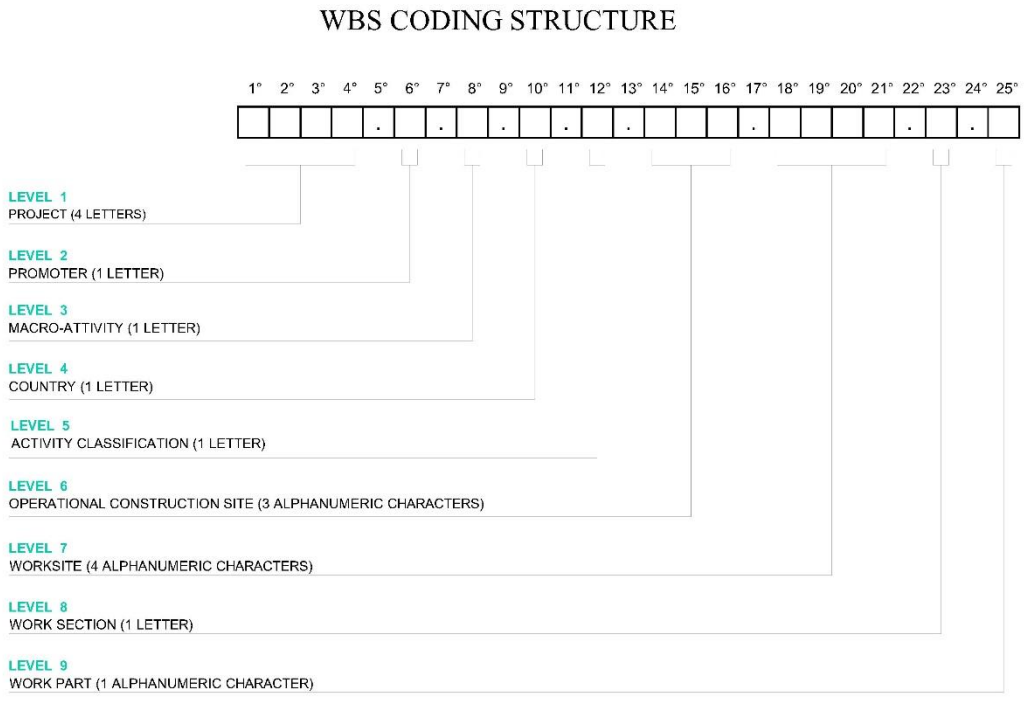

Figure 2 Extract of Annex A WBS Prescriptions - TELT's WBS coding structure

The WBS therefore allows the project to be broken down into smaller, more manageable parts with the purpose of better tracking and organising the huge amount of data with the ultimate goal of making the information accessible to all operators on the basis of a common dictionary.

Underlying the creation of the WBS is the 100% work rule, which guarantees the completeness of the project. This rule applies to all levels of the hierarchy so that the sum of the work of the "child" levels must be equal to 100% of the work represented by their "father".
The cross-border section also presents the WBS as a common element for all subject areas of TELT, developing a single, centralised system in all information systems such as the "ERP" management systems, the computation and accounting software, the scheduling software as well as within the BIM methodology where the GIS represents a necessary interface and integration point in order to make data interoperable and usable.

In the construction level, the WBS becomes fully operational from level 6 (operational construction site). Specifically, the cross-border section is made up of 12 operational construction sites of which 9 are construction sites, 2 operational construction sites for the management of excavated material and 1 operational construction site for railway and other equipment, shown below

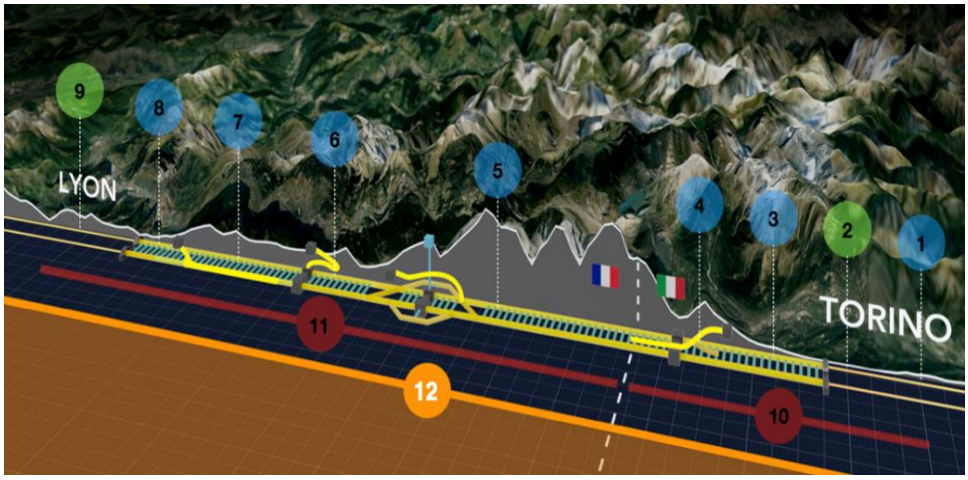

Figure 3 TELT Operational Construction Sites - CO01 Bussoleno interconnection, CO 02 Susa Plain, CO 03 East entrance - Maddalena, CO 04 Maddalena - Clarea, CO05 Clarea - Modane, CO06 Modane - La Praz, CO07 La Praz - Saint Martin la Porte, CO08 Saint Martin la Porte - West entrance; CO09 Saint Jean de Maurienne Plain, CO10 exploitation of materials and storage on the Italian side, CO11 exploitation of materials and storage on the French side, CO12 railway and non-railway installations

On the other hand, level 7 (work) of the WBS represents a fundamental level for identifying the project's works and is structured through the union of the two-letter code identifying the family of the work and a sequential code (e.g. GN15 Natural Tunnel, Site of Modane).
Below this level is level 8 (work section) which allows the characterisation of tunnel types through the identification of a unique code for the entire GN family, for example with the following result:
STTL.T.F.C.050.**GN15**.*P* - **Natural Tunnel, Modane Site** *Even track*
STTL.T.F.C.050.**GN15**.*D* - **Natural Tunnel, Modane Site** *Odd track*

Finally, level 9 (work part) allows identifying and breaking down the execution phases of a certain work and therefore within the "GN" family we can find for example:
STTL.T.T.F.C.050.GN15.P.1 - Preconsolidation
STTL.T.T.F.C.050.GN15.P.2 - Excavation
STTL.T.T.F.C.050.GN15.P.3 - Support
In addition to the WBS coding there is a parallel grouper called "Minor Work". This is fundamental to trace and univocally identify all the elements of the Base Tunnel and in particular the punctual ones such as niches, branches, launch caverns, technical caverns, etc. (e.g. GNN.0140 - niche 14)

4 APPLICATION OF WBS TO THE GEOLOGICAL/CONSTRUCTION PORTAL

With the end of the geognostic surveys and the beginning of the works for the construction of the Base Tunnel, the data on the database were reorganised according to the different operational sites and at the same time the information of the new works have obligatorily required the WBS.
In this way, within the various functionalities of the portal, it was possible to organise and present the information and technical data using the various levels of the WBS.
Thus, for example, within the face survey, level 7 and 8 of the WBS were added and highlighted in the initial part of the WBS that immediately characterises the analysed work in addition to the identification code of the minor work.

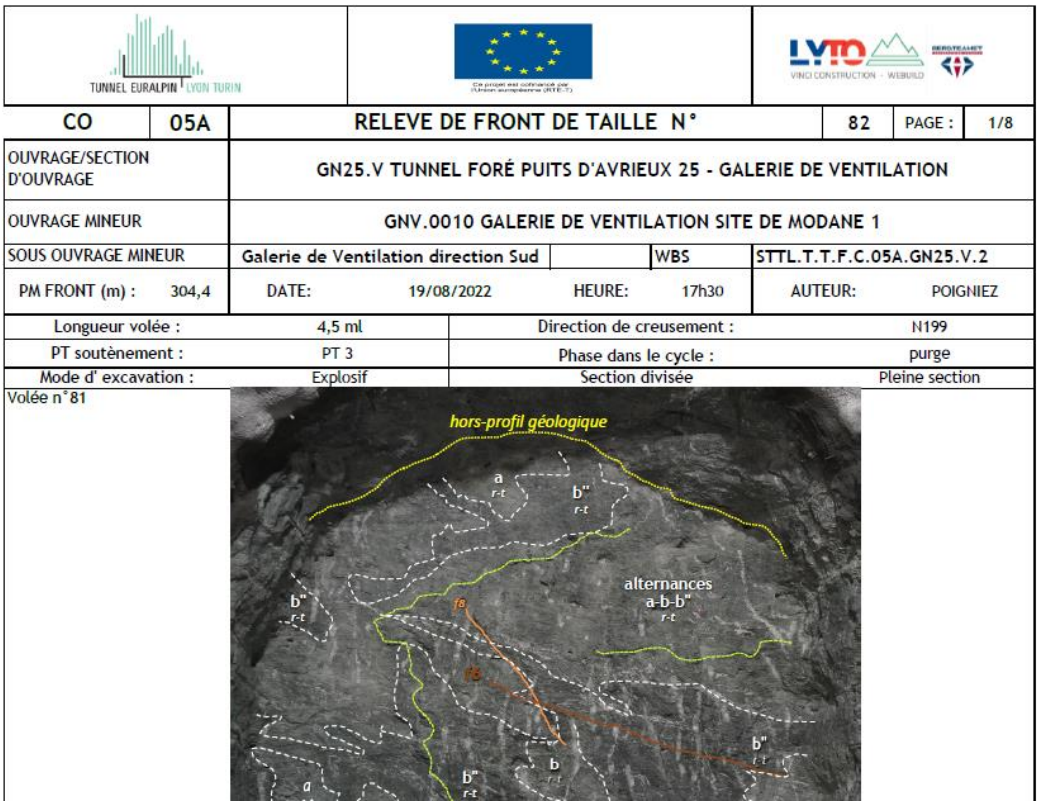

Figure 4 Face survey and data related to the WBS GN25.V Avrieux shaft natural tunnel - ventilation tunnel and minor work GNV.0010 Ventilation tunnel, Modane site 1

This allows, both in the loading and consultation phases, to record the data with a single reading key capable of aggregating or disaggregating all the information. The WBS therefore represents the "pivot" element on which it is possible to collect and order the data in a precise manner, leaving little space for interpretation in both the compilation and consultation phases.

Figure 5 Data search mask

The most effective final summary of all this information is the representation of the excavation progress where the entering of the data from the various sheets of the face survey makes it possible to create an immediate graphic summary of the state of progress of the excavation.

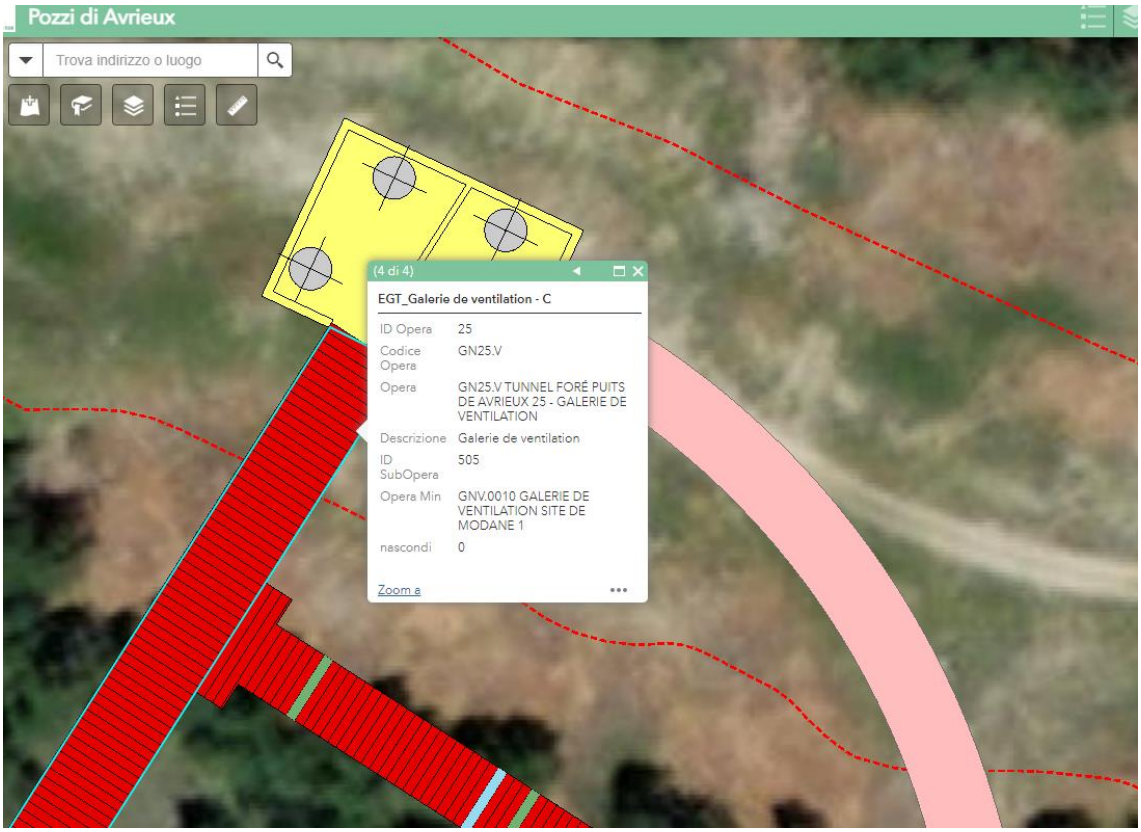

Figure 6 WBS information for works

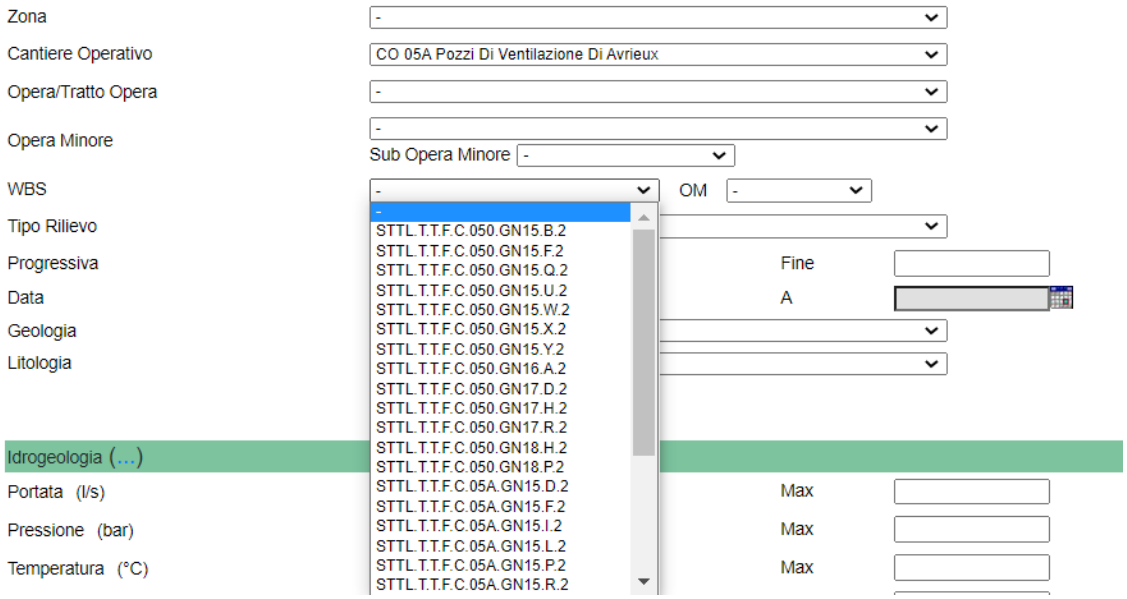

Figure 7 Data search for WBS

5 CONCLUSIONS

The creation of the GIS-based geological information portal, within the project of the cross-border section of the Base Tunnel, involves the management of a large amount of data.
Hence the need for an efficient IT platform, an orderly and specialised database for the data resulting from the management of the excavation of underground works, and a complete and refined management method capable of guaranteeing the identification and monitoring of all the elements in the tunnel through the WBS.
In particular, it is a structured and organised tool on about 30 Works at level 7, more than 100 sections of works at level 8 and almost 6oo elements within the list of Minor Works. On the basis of these "WBS" labels, all data are and will be entered and archived, creating a collaborative space capable of responding in real time to the most complex needs while looking to the future with an innovative and pragmatic vision.
The creation, therefore, of a huge digital library on the basis of which the WBS becomes the cross element that allows the different systems in the TELT company and all stakeholders to interact.

6 REFERENCES

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