The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-2-2023
29th CIPA Symposium "Documenting, Understanding, Preserving Cultural Heritage:
Humanities and Digital Technologies for Shaping the Future", 25–30 June 2023, Florence, Italy

INTEGRATION OF HBIM/GIS TO PRESERVE INFRASTRUCTURE HERITAGE ALONG THE CHINESE EASTERN RAILWAY

J. Xu[1,*], M. Garramone[1], Y. Wang[2,3], M. Scaioni[1]

[1] Dept. of Architecture, Built Environment and Building Construction (DABC), Politecnico di Milano, Milan, Italy
email: (jianzhuo.xu, manuel.garramone, marco.scaioni)@polimi.it

[2] School of Architecture, Harbin Institute of Technology (HIT), Harbin, P.R. China – email: ayan97@126.com

[3] Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, Harbin, P.R. China

KEY WORDS: Chinese Eastern Railway (CER), Heritage Conservation, HBIM, GIS, Integration, Railway Infrastructure.

ABSTRACT:

The infrastructure heritage is the symbol of the highest standard of the technical construction and design methodologies of the Chinese Eastern Railway (CER). As an important component of the cultural heritage of the CER, their conservation hasn't attracted more attention than the architectural heritage part. However, some heritage infrastructure components have been already demolished while others were threatened by urban expansion and natural degradation during the past hundred years. In this study, we have analysed structural features based on the original drawings and fieldwork for the reconstruction of the vanished and invisible parts of CER. HBIM will be used to support the conservation of the surviving elements. In addition, we collected geographical coordinates of the heritages using on-site GNSS records and Google Earth®. We propose a method to facilitate the preservation of this historical infrastructure by building a database that integrates HBIM and GIS, including information about historical data and the status quo. In this way, this database will not only be useful for planning purposes by the government and the conservation agencies, but also it will benefit the entire society and the public through its online display and information collection.

1. INTRODUCTION

According to the suggested justifications and criteria of the four well-known heritage railways on the World Heritage List (WHL) selected by UNESCO (see Table 1), they have two common features: culture communication and excellent infrastructure engineering construction. These railways always spread through isolated regions with ancient civilizations and serve as a link between them and contemporary culture. Because of physical boundaries that made it impossible for mature civilizations and cultures to expand during a period when transportation was mostly powered by human and animal power, these areas are known as cultural peripheries. With the emergence of rail technology, the introduction of modern civilization into those areas became a reality. This is due in large part to the development of infrastructure construction such as bridges, tunnels, and spiral lines.

Railway heritage	Opening time	Region	Date of inscription
The Semmering Railway	1854	Austria	1998
Rhaetian Railway in the Albula/ Bernina Landscapes	1888/1904	Italy/ Switzerland	2008
Mountain Railways of India	1908	India	1999
Trans-Iranian Railway	1938	Iran	2021

Table 1. The Selected Railway Heritage on the World Heritage List (WHL)

These cultural and technical characteristics can be also found in the Chinese Eastern Railway (CER), which connects Russia with the northeastern region of China that is far from the cultural centre of China. As the easternmost part of the Great Siberian Railway (GSR), originally the CER was designed by the Russians to connect the two important harbours of, Dalniy and Vladivostok, and the far-east part. Dalniy, now called Dalian, is the southmost harbour in northeast China with a relatively short freezing period during winter. The main line of CER starts from Manchuria and extends via Harbin, the only first-classed station and railway hub on the line, to the east border station (today called Suifenhe). From there, the south branch line reaches Dalniy. Between 1897 and 1903, diverse and numerous classifications of infrastructure elements such as bridges, culverts, tunnels, and spiral/loop lines were designed and built to overcome the terrain obstacles, including rivers, gorges, ravines, and the complex and varied topographical conditions along the line (Chinese Eastern Railway, 1900; Liu and Wang, 2018; Liu et al., 2020). After Russia lost the Russian-Japanese War in 1904, the southern section from Kuanchengzi to Dalniy along the south branch line was controlled by the Japanese-coined South Manchuria Railway Co. (SMR), which eventually took over the left sections of CER from the Soviet Union in the 1930s. Kuanchengzi, now known as Changchun, was the capital city of Manchukuo and now is the capital city of Jilin Province, China. Meanwhile, double lines were built in some sections to increase shipment capacity and operation efficiency. To achieve this objective, SMR adds a number of new infrastructure elements, which enriched the diversity of the heritage classifications (see Fig. 1) (The Lvshun Museum, 2007).

* Corresponding author

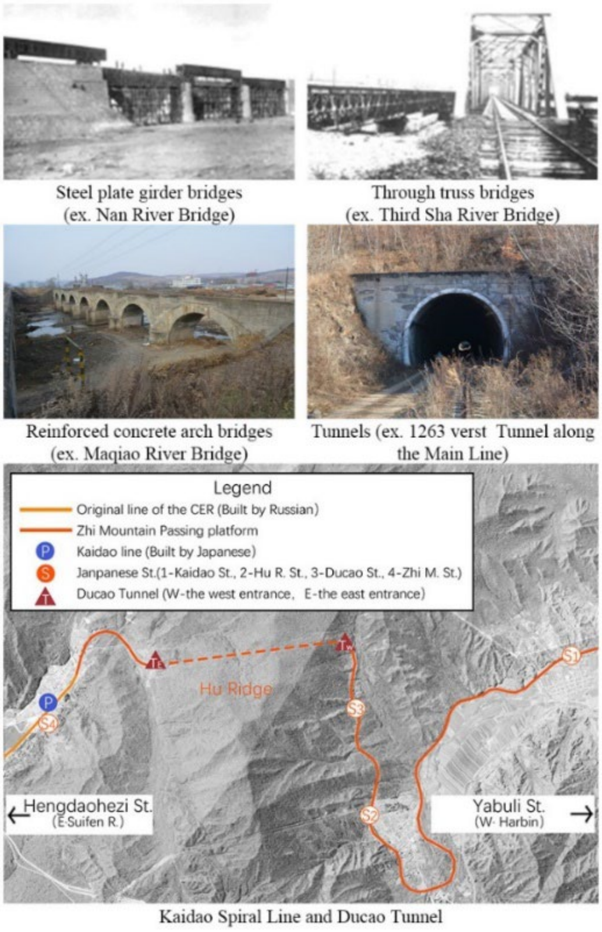


Figure 1. Classifications of the new infrastructure built by the Japanese along the Chinese Eastern Railway (CER). Verst and sazen are ancient and now obsolete units of measurement in the Russian Empire,1 verst = 500 sazen = 1.067 km, 1 sazen = 2.134 m).

According to the Nizhny Tagil Charter (TICCIH, 2003), infrastructure heritage is an important component of a historical railway line that is representative of the highest technical achievements. However, compared to the architectural heritage located in the cities and towns along the railway, the conservation of infrastructure heritage has rarely attracted attention from the public, researchers, and the administration in China.

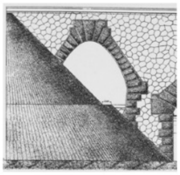
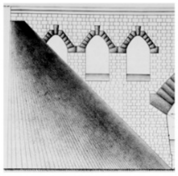
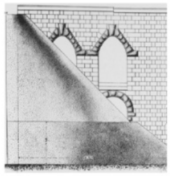
This study is based on the original design drawings and on new fieldwork aimed at the analysis of structural features for the reconstruction of the lost parts of CER and the documentation of the remained elements. In addition, we collected geographical coordinates of the heritage items using on-site GNSS (Global Navigation Satellite System) records and Google Earth®. We propose a method to facilitate the preservation of this historical infrastructure by building a database that integrates HBIM (Heritage Building Information Modelling) and GIS (Geographic Information System), including information about the history and current photos, materials, structure, and so on. In this way, this database will not only be useful for government planning and conservation agencies but also would benefit the entire society and the public through its display online and information collection.

2. STRUCTURAL FEATURES AND DESIGN METHODOLOGIES

Except for the King'an Tunnel, the construction of the entire infrastructure was completed in six years due to the advanced methodologies of standardized design and modular construction. Moreover, the design methodology adopted a combination of universal design for small and medium-sized infrastructures and individual design for large infrastructures, which decreased the construction and preparation time. Furthermore, the fact that most infrastructure elements have been used for more than a hundred years demonstrates the reliability of the infrastructure's structure with little conservation measures (Xu, 2022).

2.1 Standardized structure design

Piers and abutments all adopt a standardized design. There are three general span units with a length of 10.7 m, 21.3 m and 32.0 m, which were designed to cross small-scale rivers, ravines and valleys. All the abutments were designed to be U-shaped with 17 formats and most of them have an arch on both sides, which is decorated with different formats of arches to decrease masonry volume. Only the abutments of large-scale stone arch bridges have different amounts and tiers of arches for terrains, masonry construction, and flood discharge (see Table 2).

Classified by number of arches and tiers		
		
Spandrel wall with an arch in one tier	Spandrel wall with multi-arches in one tier	Spandrel wall with multi-arches in two-tier

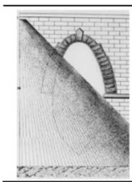
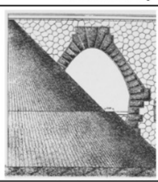
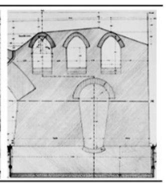
Classified by shapes of arches			
			
Spandrel wall with a sharp arch	Spandrel wall with an ellipse arch	Spandrel wall with a semi-circle arch	Spandrel wall with multi-type arch

Table 2. The abutment of bridges with different supports has diverse arches (Chinese Eastern Railway, 1900).

Compared to the abutment design, the influencing factors of the pier's design not only consist of topographic factors (e.g., the depth of the river and the valley) but also include hydrographic factors. Therefore, the upper formats of piers have the same shape (Fig. 3) and the lower part styles were decided by the flux, speed and direction of the river flow, the flood, and the span length.

The melted ice flows at the start of spring and continuous heavy rainfalls in summer always arouse the format changes in the lower part design. The basic type of the cutwater's plan is a rectangle, and the style of its front and back ends can be interchanged with a semi-circle or sharp angle (Fig. 4).

For the multi-span bridge, the design of their total length and the span-unit length all adopts the modular design methodology. Both temporary bridges and diverse permanent bridges were designed in this way. The temporary bridge was built entirely of wood with three types: the beam bridge, the strut-framed bridge, and the truss bridge (see Table 3). They were only used during the construction time. The bridge's total length has two combination methods. The first one accumulates with the same length span units and is widely applied to small-scale or universally designed ones.

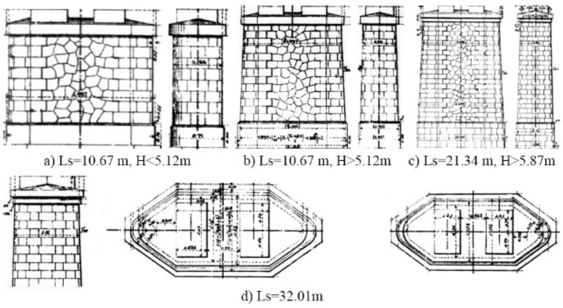


Figure 2. The standardized formats of the pier with different span units (L_s=length of the span unit, H=river depth) (Chinese Eastern Railway, 1900).

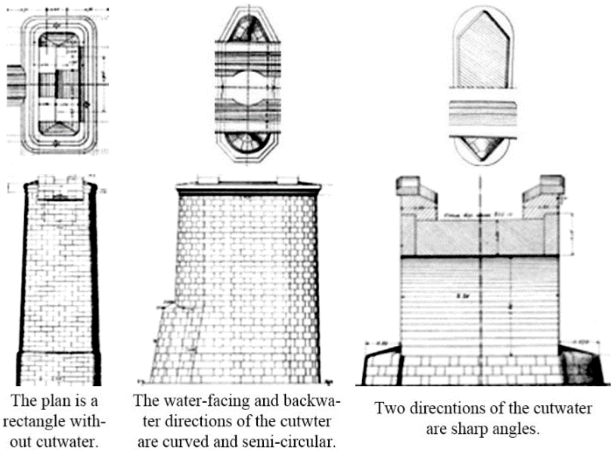


Figure 3. The plan and the elevation along the water flow of three main cutwaters (Chinese Eastern Railway, 1900).

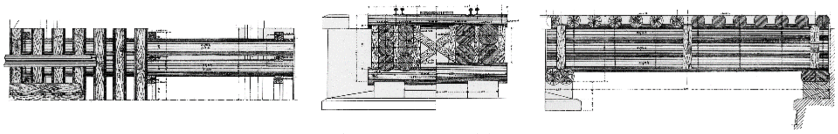
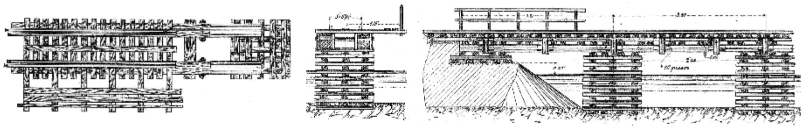
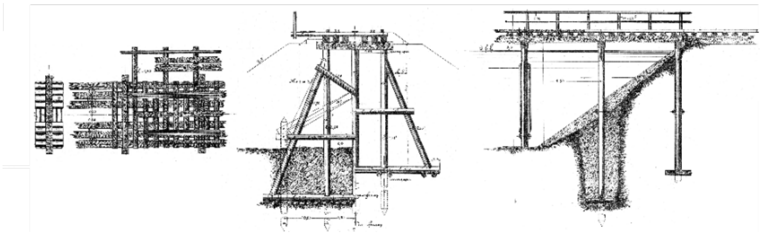
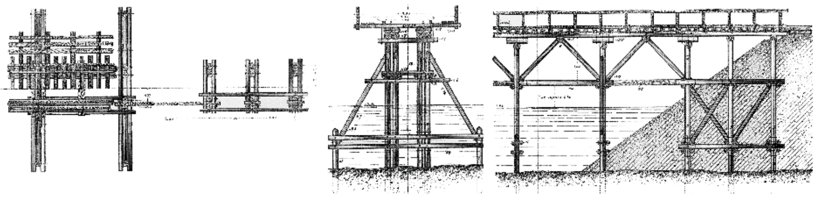
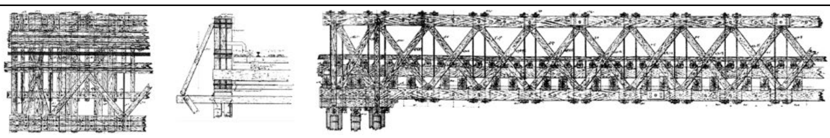
Classifications of the Bridge	Drawing Pictures	Examples
The Beam Bridge	 The One-span Bridge	 834 verst Bridge
	 The Continuous Beam Bridge supported by Cages	 The Qing River Bridge
	 The Continuous Beam Bridge supported by Piers	 The Taizi River Bridge
The Strut-framed Bridge		 The Yalu River Bridge
The Truss Bridge		——

Table 3. The classification of timber bridges (Chinese Eastern Railway, 1900)

Another type of bridge is structured on span units featuring different lengths. This combination method was applied for the most individually designed bridges. The specific manifestations are truss bridges crossing rivers combined with two or three span-unit of the same or different truss types. For example, the Nuoni River Bridge has six 74.7 m curved chord trusses and six 32 m and two 21.3 m two types of deck trusses. The combination method of the First Songhua River Bridge is eight 74.7 m curved chord trusses and eleven 32 m deck trusses. For other examples along the line of the combination types see Table 4. Except for the former three units, 10.7 m, 21.3 m and 32.0 m, every type of bridge has its modular span units (see Table 5).

The name of bridges	Half-through Truss	Curved chord though Truss	Deck Truss
The Yimin R. B.	21.3 m × 6; 32 m × 3		
The Nuoni R. B.		74.7 m × 6	21.3 m × 2; 32 m × 5
The First Songhua R. B.		74.7 m × 8	32 m × 11
The Ashi R. B.			21.3 m × 3; 32 m × 2
The Second Songhua R. B.		74.7 m × 5	21.3 m × 2; 32 m × 10
The Foxhole Village B.			21.3 m × 2; 32 m × 1
The Qing R. B.		74.7 m × 4	32 m × 16

Table 4. The combination types of bridges with diverse span units (river and bridge are in short with R. and B.).

Material	Structure form	Span-unit length (m)
Timber bridge	Continuous beam bridge with piled piers	3.2
	Continuous beam bridge with cage piers	6.8, 8.5, 10.7
	One-span beam bridge	2.1, 4.2, 5.3
	Strut framed bridge	4.2
	Truss bridge	21.3
Stone bridge	Arch bridge	2.1, 4.2, 5.3, 6.4, 8.5, 10.7, 12.8, 21.3
Steel bridge	Plate girder bridge	0.9, 1.1, 2.1, 3.2, 4.2, 5.3, 6.4, 8.5, 10.7, 14.9, 17.1, 21.3, 32
	Truss bridge	21.3, 32, 74.7
Reinforced/rail concrete bridge	Beam bridge	2.1, 4.2, 6.4

Table 5. The span-unit of all classifications of bridges.

For those small-scale infrastructures, the application of the standardized design for those small-scale infrastructures can save construction time and materials. Meanwhile, engineers can focus on key projects such as the Khing'an Tunnel and other large-scale bridges. This method was applied in infrastructures including culverts and stone arch bridges. They have the same classification and appearance but different span lengths, their appearance was designed into a uniform form. For example, the standardized design of the homotypic stone arch bridge reflects in many fields such as the bridge's plan and elevations, the structure of abutments and piers, and the lower part of the pier and cutwater. Engineers can flexibly choose a suitable span unit among 8.4m, 10.7m and 12.8m to cross small rivers and adjust the height of the pier and abutments (see Table 6). Moreover, the culvert and the elevations of most tunnels' entrances were designed with a universal appearance (Fig. 5). Except for the largest one-span culvert (span length = 9.4 m), which locates on the junction point of the ground and the upper spiral lines for passing trains, others were designed for 10 span types, and every type has its standardized elevation and structure (Fig. 6).

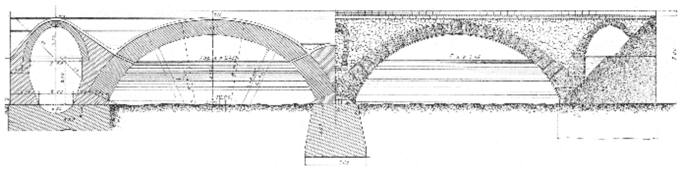
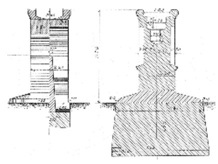
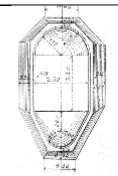
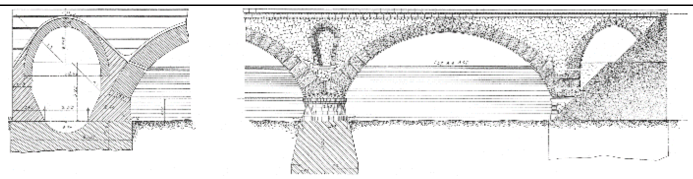
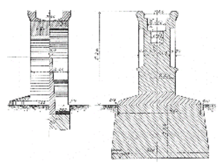
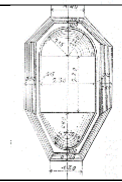
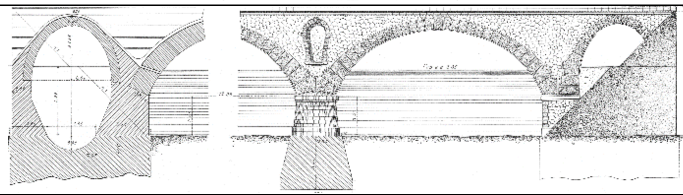
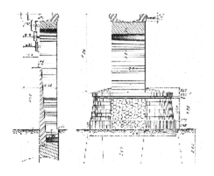
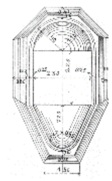
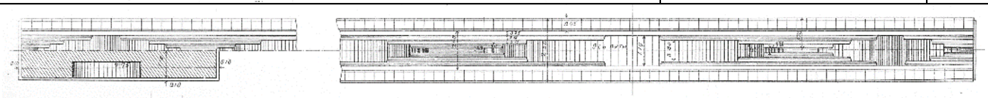
Span Unit Length (m)	Longitudinal Elevation and Structure Details	Cross-section Structure	Cutwater
8.4			
10.3			
12.8			
Universal Plan			

Table 6. The universal design of a small-scale two-span stone arch bridge (Chinese Eastern Railway, 1900)

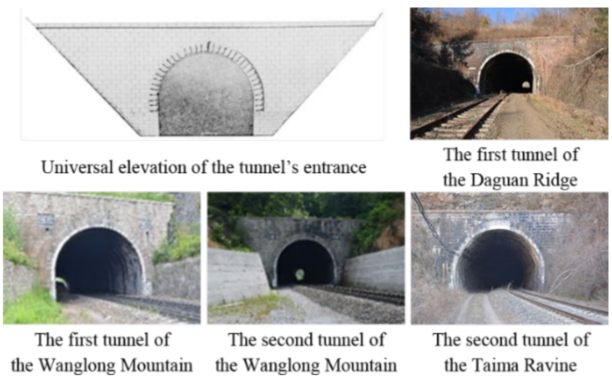


Figure 4. The universal design drawings in the 1900s (Chinese Eastern Railway, 1900) and the current real view of tunnels.

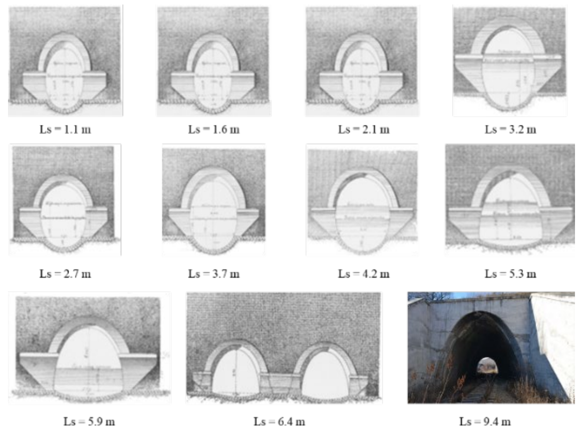


Figure 5. The classification of culverts along the CER.

2.2 Design methodologies of the large-scale bridges

Bridges are the largest size infrastructure type along the CER and may be also considered as the most representative high-tech symbol. Russians and Japanese had already carried out the design and construction of many large-scale railway bridges in their countries and accumulated excellent experience. To shorten the construction time and complete the construction works as soon as possible, as well as to minimize the threat of river flow damage to the bridge safety, CER and SMR applied more advanced and mature bridge structure design methodologies in the medium/large-scale bridge and added abutment and pier protection measures.
As part of the individual design's objects, selecting truss forms for these bridges is the key point. We can find three principal truss forms: (1) the Howe Truss; (2) the Pratt Truss; and (3) the Warren Truss. Russians adjust some details for those truss forms to improve their mechanical property to make them suitable for multiple terrains. Firstly, the Howe Truss was only applied in the temporary timber truss bridge because of the long winter and harsh weather conditions in northeast China (Tongji University et al., 1961). This truss was widely used in the construction of the Nikolaev Railway (from St. Petersburg to Moscow in Russia) in 1847 with 64 bridges among all 187 bridges (Si, 2020). However, their reliability was affected by the shrinkage of the timber components just a few years after the opening of the line operation. In view of this, the Howe trusses were not applied in the permanent bridges of CER crossing through the regions with a similar climate to the GSR.
Secondly, in a different way from the general forms, the Pratt Truss in the CER is unique with two subtypes. For the parallel chord one, to improve the stability of the bottom chord and prevent it from deformation, the designer has double webbed the diagonal webs in the middle part to improve the compression resistance of the bridge. This type is always designed in a half-through truss. The second one is the curved chord truss with a 75 m span length, which is the longest one among all trusses and was designed to cross the main shipping lane of the wide river such as the Nuoni River, the Songhua River and the Second Songhua River. This truss not only reduces the impact on the navigable area of the river but also reserves sufficient river clearance to meet the needs of large ships passing through. An example is the First Songhua River Bridge built in 1901, which is a nearly 1,000 m (949.63 m) long and consists of 8 spans of 75 m curved chord truss and 11 spans of 32m deck truss (Fig. 8).

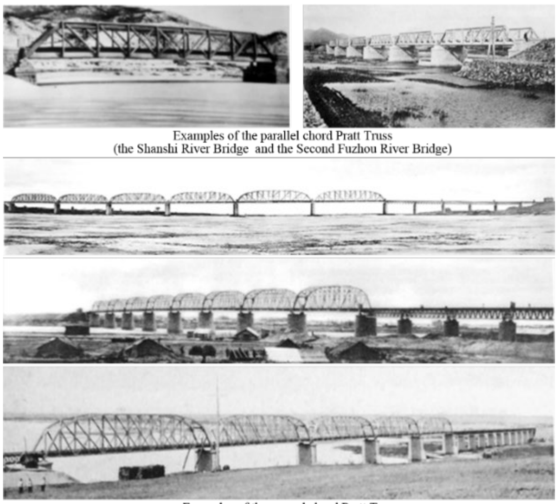


Figure 6. Bridges were designed with the Pratt Truss.

The third widely used truss along the CER is the Warren Truss. This truss consisted of several equilateral triangle chord component units and was connected only by the top and the bottom crossbeams along the longitudinal direction. Owing it can be assembled on-site with the same size chord components, it is very suitable for prefabricated modular deck truss bridges to overcome two types of rivers. One type is the small-scale river with a narrow width and shallow water. Another type is some large-scale rivers, like Taizi River and the Mudan River, which have a large width, but the water depth is not adequate for large vessels. The Warren Truss applied in CER has two forms. The first one has two parallel chords at the upper and lower part. The second one has diagonal bars between the first and last three sections of the lower chords. Furthermore, for increasing the tensile strength of this truss, the engineers added small diagonal webs to the upper part of the former to improve its mechanical properties and to add uprights to the latter for support (Fig. 9).

The Taizi River Bridge   The Shia River Bridge

Figure 7. Bridges were designed with the Warren Truss

Except for the technical features of the truss bridge, we can review the construction and design level of the Russian part by analysing the structural characteristic of the stone arch bridge.
Two factors, the total length and the maximum single span length, reflect the design standard and technical strength of the Russian side of the CER. As mentioned before, most multi-span arch stone bridge consists of many standard modular span units. For example, the Muling River Bridge keeps the record to be the longest stone arch bridge (128 m length) along the CER, consisting of six elliptical arches with a single span of 21.3 m. The triple-centred pointed arches and flat arches were widely applied, while single-centred flat arches can be rarely seen. The triple-centred pointed one is only designed for the main arch with a 4.2 m span. The flat one has numerous examples, ranging from 6.3 m to 21.3 m, which can be seen among small-scale rivers, deep valleys, and gullies. Compared with the first two, the single-centred pointed flat arch is rare, being found only in single-span stone arches of 12.8 m (see Table 7).
By analysing the design of the substructure, we can see that the Russian engineers have done a lot of localised design and consideration into the design of the infrastructure. The regions passing the CER have a long winter with freeze and frequent rainfalls and snowfalls. Under the influence of long time soaking and washing of the meltwater and the effect of freezing and thawing, the structural safety of the bridge could be severely affected. Therefore, the medium/large-scale stone arch bridges are equipped with drainage pipes at different locations to keep the safety of infrastructures (see Table 8). Though the Russians surveyed and mapped the hydrological data along the CER before the design and construction, they did not know well about the historic data. Thus, protective dikes on the waterfront side of bridge abutments were built at river bends, whose function is the same as the cutwater to piers (Fig. 10).

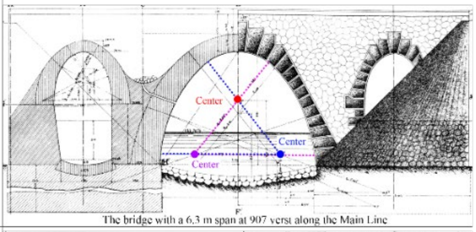
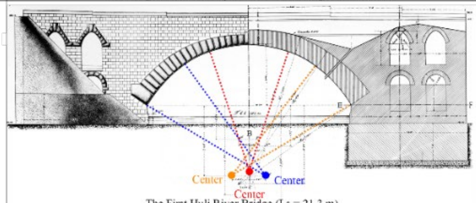
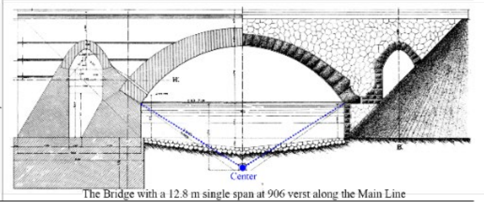
Types	Examples
Pointed arche with triple-ceter	 The bridge with a 6.3 m span at 907 verst along the Main Line
Flat arch with triple-ceter	 The First Huli River Bridge (Ls = 21.3 m)
Circular arch with a single-center	 The Bridge with a 12.8 m single span at 906 verst along the Main Line

Table 7. Types of the main arch.

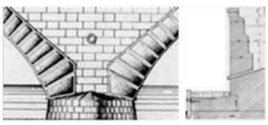
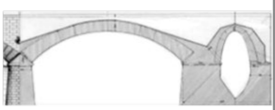
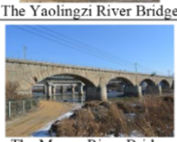
Drainpipe on the side wall		 The Maqiao River Bridge
Drainpipe on the arch soffit		 The Yaolingzi River Bridge
Both		 The Mayan River Bridge

Table 8. The location of drainpipes on the stone arch bridge.

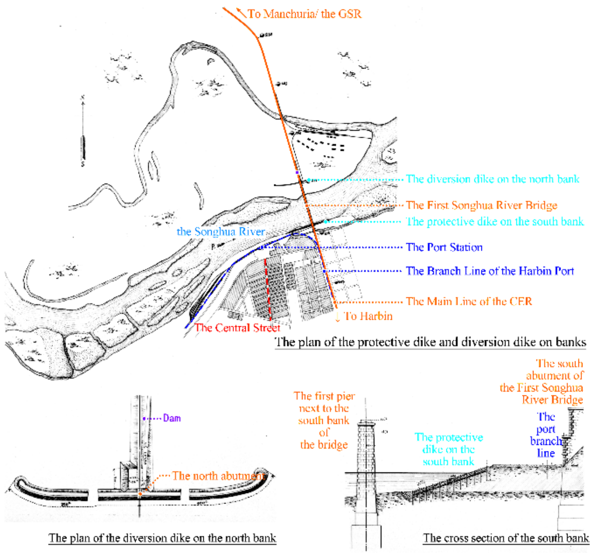


Figure 8. The protective measures on banks for the abutments of the First Songhua Bridge

3. INTEGRATION HBIM/GIS

In addition to the individual architectural heritage, the conservation of that infrastructure heritage along the CER has its own characteristics and differences. The distribution of infrastructure heritages is wide, isolated, and linear except for those heritage groups consisting of infrastructures and buildings such as heritage groups of the Khing'an Spiral Line and the Daguan Ridge Spiral Line. From the perspective of data collection, the work of surveying and mapping them is harder than in other cases to the problems to reach those mountain places. Moreover, the difficulties of reusing them are also much harder and more low-profitable than architectural heritages having physical space and distributing concentration, because most of them were built among remote towns and untraversed places like forests and mountains. Furthermore, as a series of heritage sites designed during a specific time and constructed by multiple companies, the conservation work should also be based on deep knowledge and on interdisciplinary cooperation. Therefore, the mentioned reasons also cause the current protection dilemma of that infrastructure heritage.

Since BIM (Building Information Modelling) technology has been introduced into the field of cultural heritage conservation, it is regarded as an innovative methodology for accurate recording, flexible collecting of data and saving protection costs (Logothetis et al., 2015). In terms of the research objects of this study, the advantages of BIM are useful and helpful to solve those dilemmas. On the one hand, BIM can reappear that concealed technical heritage and reconstruct the vanished heritage. Take caissons as an instance, this method was applied to build the basement of the large-scale truss bridges' piers, which locate in the centre of the river with wide channels and larger depths such as the Nuoni River, the Songhua River, and the Taizi River. Based on the original design drawings published by CER (Chinese Eastern Railway, 1900) and historical document of the bridge built in Russia at that time (Красковского et al., 1994), we reconstructed the model of caissons (see Fig. 11). The reconstruction of the heritage, which has lost all its structure, can be also obtained with the assistance of BIM.

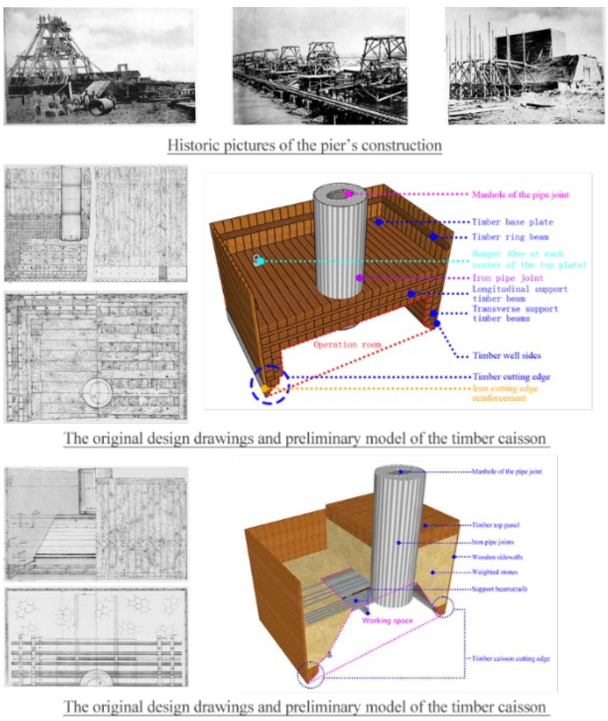


Figure 9. Caisson's details and construction scenery.

On the other hand, BIM/HBIM (Heritage BIM) is not only useful for the documentation of the remaining structure, including the integrated heritage and the remaining structures, but also contributes to congregating all the historic data such as design drawings, historic photos, and current research outcomes (Cursi et al., 2022). Especially for those bridges and tunnels which were built by SMR, the implementation of HBIM will change the forepassed conservation situation, which lacks first-hand data. Based on some recent research which focuses on important infrastructure monuments, for instance, Ízbor Bridge (1860) in Spain (León-Robles et al., 2019), and Azzone Visconte in Lecco, Italy (Barazzetti et al., 2016), applying HBIM to record stone arch bridges along the CER seems to be a feasible plan in the following study based on current the research of the NURBS-based modelling (Barazzetti et al., 2015). Besides, since there is only little relevant research focused on the HBIM for 20th-century steel structures (Morganti et al, 2019), the research on the reconstruction and scanning of steel bridges such as truss bridges and plate girder bridges is also an important part of the following study.
HBIM has an aptitude for 3D modelling for the individual monument through parametric elements selected from the common libraries. However, for linear heritage or heritage groups, it still has two problems, querying the reconstruction of complex spatial and integrating the modelling in its surroundings. GIS (Geographic Information System) mainly focus on three items: (1) analysing spatial data, objects attribute, and the relationship between different elements, (2) managing, and (3) querying. Meanwhile, it’s not only a management and analysis tool but also a modelling tool that has been widely used to procedurally model large-scale heritage scenes (Schwarz et al., 2015). GIS can be used to establish databases for monuments at regional and national levels (Von Schwerin et al., 2013). Based on the mentioned reasons, the importance of the integration HBIM/GIS has been demonstrated by several works in architectural heritage conservation (Isikdag et al., 2008; Yaagoubi et al., 2015).
In the conservation and management of. infrastructure heritage, integrating HBIM/GIS is an effective and appropriate method. Indeed, the HBIM approach allows the reconstruction and modelling of individual elements, while GIS allows considering the geospatial extension of the historical railway line (Garramone et al, 2020; 2022). Especially for the infrastructure heritage along the CER with numerous and diverse types of elements, introducing this new method to preserve the heritage will build a solid and cooperative background for both conservation sectors and stakeholders from two sides. The reasons are as follows. Firstly, based on the urgency and necessity of this heritage sustainable conservation, during the past three-year fieldwork, we collected geographical coordinates of the heritages located in places that are easy to reach using on-site GNSS records. For the reasons of management and terrains: (1) infrastructures locate in the Border Management Area, (2) infrastructures are operated by the Administration of Railway, (3) infrastructures locate in remote areas inaccessible, we collected the data of them with Google Earth®. Then we created a basic profile for every remaining heritage using ArcGIS® 10.2 and add historic information (Cursi et al, 2022) based on the systematic collection and collation (Fig. 12). This profile consists of the following items of every infrastructure: identification code, region, geographic coordinates, type, structure form, status quo, protection level, current function, status description, technical achievements, design drawings, and historical photos. Meanwhile, facing such a massive volume of data and the compatibility of different software packages, it is worth exploring problems like efficient processing data storage and integration of data cross-platform.

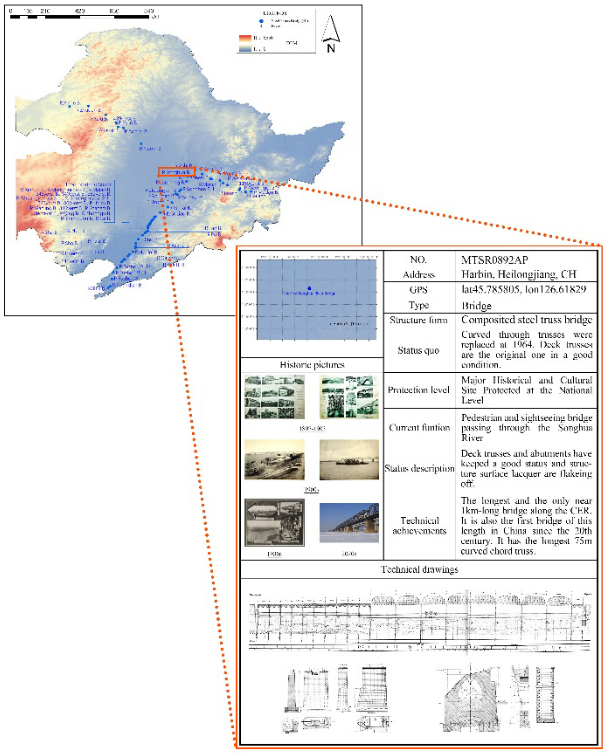


Figure 10. The distribution of the truss bridge built by the CER and the examples of the database in this stage for the first Songhua River bridge.

4. CONCLUSIONS AND FUTURE WORK

The paper illustrates the structural features and design methodologies of the infrastructure heritage along the CER (Chinese Eastern Railway) and proposes an integration HBIM (Heritage Building Information Modelling)/GIS (Geographic Information System) way to preserve and valorise this cultural heritage and its historic data in a sustainable way.
Rarely received attention, the infrastructure heritage along the CER is vanishing and being threatened by both human and natural factors. The reconstruction of these remained, vanished, and concealed heritage with BIM (Building Information Modelling)/HBIM required support from the clear illustration of structural characteristics. Meanwhile, geographical data collection and the creation of a preliminary database of the heritage in this stage provide a solid basement for heritage management using GIS. Moreover, introducing the integration of HBIM/GIS will become a shared and sustainable platform for conserving the heritage, which is an effective and profound way to integrate all types of historic data.

ACKNOWLEDGEMENTS

The work reported in this paper was supported by the China Scholarship Council (No. 202206120044), the China Geospatial Data Cloud, ArcGIS® and Autodesk Revit®. The support of fieldwork and study from Prof. Daping Liu and Dr. Qi Li (Harbin Institute of Technology) and Dr. Daoguang Si (Suzhou University of Science and Technology) is appreciated.

REFERENCES

Barazzetti, L., Banfi, F., Brumana, R., Previtali, M., 2015. Creation of Parametric BIM Objects from Point Clouds Using Nurbs. *The Photogrammetric Record*, 30, 9–362.

Barazzetti, L., Banfi, F., Brumana, R., Previtali, M., Roncoroni, F., 2016. BIM From Laser Scans not Just for Buildings: NURBS-Based Parametric Modeling of a Medieval Bridge. *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, III-5, 51-56. doi.org/10.5194/isprs-annals-III-5-51-2016.

Chinese Eastern Railway, 1900: A*lbum of structures and standard drawings of the Chinese Eastern Railway (1897-1903)*. Moscow.

Cursi, S., Martinelli, L., Paraciani, N., Calcerano, F., Gigliarelli, E., 2022. Linking external knowledge to heritage BIM. *Automation in Construction*, 141, 104444.

Garramone, M., Moretti, N., Scaioni, M., Ellul, C., Re Cecconi, F., Dejaco, M.C., 2020. BIM and GIS Integration for Infrastructure Asset Management: a Bibliometric Analysis. *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci.*, VI-4/W1-20, 77–84.

Garramone, M., Scaioni, M., 2022. IFCAlignment for Raster-to-Vector GIS Railway Centreline: a Case Study in the South of Italy. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.,* XLIII-B4-2022, 39–45. doi.org/10.5194/isprs-archives-XLIII-B4-2022-39-2022

Isikdag, U., Underwood, J., Aouad, G., 2008. An investigation into the applicability of building information models in geospatial environment in support of site selection and fire response management processes. *Advanced Engineering Informatics*, 22 (4), 504-519.

Красковского, Е. Я., М. М. Уздина et al., 1994: *History of Russian railway transport, Vol. 1: 1836-1917*. Saint-Petersburg-Moscow.

León-Robles, C.A., Reinoso-Gordo, J.F., González-Quiñones, J.J., 2019. Heritage Building Information Modeling (H-BIM) Applied to A Stone Bridge. *ISPRS Int. J. Geo-Inf.*, 8(3), 121.

Liu, D., Bian, B., Li, Q., 2020: *Architectural Cultural Heritage of Chinese Eastern Railway*. Harbin: Harbin Institute of Technology Press.

Liu, D., Wang, Y., 2018: *The Construction and Technology of Heritage Buildings along the Chinese Eastern Railway*. Harbin: Harbin Institute of Technology Press.

Logothetis, S., Delinasiou, A., Stylianidis, E., 2015. Building Information Modelling for Cultural Heritage. *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci.*, II-5/W3, 177–183. doi.org/10.5194/isprsannals-II-5-W3-177-2015.

Morganti, R., Tosone, A., Di Donato, D., Abita, M., 2019. HBIM AND THE 20TH CENTURY STEEL BUILDING HERITAGE – A PROCEDURE SUITABLE FOR THE CONSTRUCTION HISTORY IN ITALY. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W9, 515–522 doi.org/10.5194/isprs-archives-XLII-2-W9-515-2019

Schwarz, M., Müller, P., 2015. Advanced procedural modeling of architecture. *ACM Trans.* Graph, 34 (4), 1-12.

Si, D., 2020. Research on Technical Characterization and Development of Chinese Eastern Railway Early Modern Buildings. PhD dissertation, Harbin Institute of Technology, Harbin, Heilongjiang, CHN.

The Lvshun Museum, 2007: *Historic Pictures of Manchurian Railway: Historic Pictures of Manchurian Railway in the Lvshun Museum*. China Renmin University Press, Beijing.

TICCIH, 2003. The Nizhny Tagil Charter For The Industrial Heritage. Charter, TICCIH, Nizhny Tagil, Sverdlovsk Oblast, Russia.

Tongji University and Other Three Universities, 1961: *Bridges and Artificial Infrastructures for Roads*. China Communication Publishing & Media Management Co., Ltd, Beijing.

Von Schwerin, J., Richards-Rissetto, H., Remondino, F., G. Agugiaro, G., Girardi, G., 2013. The MayaArch3D project: A 3D WebGIS for analyzing ancient architecture and landscapes, *Lit. Linguist. Comput.*, 28 (4), 736–753,

Xu, J., 2022. Research on the Traffic Infrastructure Heritage along the Chinese Eastern Railway. MA thesis, Harbin Institute of Technology, Harbin, Heilongjiang, CHN

Yaagoubi, R., Baik, A., Boehm, J., 2015. Integration of Jeddah Historical BIM and 3D GIS for Documentation and Restoration of Historical Monument. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XL-5/W7, 29-34. doi.org/10.5194/isprsarchives-XL-5-W7-29-2015