REVERSE ARCHITECTURE: AN OPEN STANDARD DIGITAL TWIN FOR HERITAGE BUILDINGS

- Case-study: the Simplon- Orient- Express station in Vallorbe, Switzerland -

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This paper discusses the technical aspects for the simulation of transformation of historical buildings and the guarantee of sustainability and infinite reuse of related data. BIM (Building Information Modelling) requires the development of transnational planning methods for transformation of monuments based on the use of ISO (International Organization for Standardization) open standards.
Simulations were performed on a national monument as part of a pilot project. The monument is the Vallorbe Train Station [Fig. 1] on Simplon-Orient-Express line. For this project only open formats were used, the models that constitute the digital twin are in IFC.
The pilot projet is divided in three phases; 1, production of the architectural model, based on point clouds by surveyors; 2, creation of a digital twin[1] that includes the architectural model, objects from SBB infrastructure as well as a link between these objects and a database. 3, simulations of transformations.
This project also explored the cultural aspects of the Vallorbe station, as it is undergoing successive reductions of institutional use, an alternative concept for its redevelopment was sought. The concept used for the transformation simulation is a destination station, such as the Pavlovsk railway station in St Petersburg. This exemplifies transnational exchange of ideas.

Keywords: Transnationalism, Reverse architecture, Digital twin, transformation simulations, National monument, Simplon-Orient-Express, Swiss Federal Railways, Building Information Modeling (BIM), data preservation, open format, IFC.

1. Introduction to transnationalism and digital planing methods for conservation

In « Planing Perspectives[…] » N.H. Kwak[2] argues that « The practice of planning relied on global exchange of ideas as well as a transfusion of everyday practices and ideals across nations and empires ». This paper will exemplify her argument using the case study on the national monument[3], the Vallorbe train station [Fig. 1] and focusing on two aspects: firstly the historical precedent of a fictive transformation of this national monument has been taken up several times in different countries; and secondly the development of planning practice – or methods – in the digital era for conservation requires the use of ISO certified open formats.

Figure 1 – Architect's drawing of the Vallorbe Station, 1911.

Transnational exchange of ideas can be illustrated by the reproduction of London’s Vauxhall Pleasure Gardens in Pavlovsk, St Petersburg.
In the 19th century, Vauxhall Pleasure Gardens (whose design was noticed by gardener and witter John Evelyn in 1661[4]) was dedicated to the emerging gentry. Within the compound, carefully-designed gardens surrounded concert halls and music pavilions – an idea that rapidly became fashionable, resulting in the construction of several further examples all around Europe[5]. Once Russia’s first passenger railway was built, the lane ran between St Petersburg and the Pavlovsk park 26 km south of the city. The engineer who initiated the project proposed an amusement park at the end of the line in order to attract passengers. It included a restaurant, reception rooms, a promenade, and galleries in a garden. The “musical railway station”, as R.Dayanov[6] called it, linking the two functions of train station and concert hall within a pleasure garden, was an innovative idea and a resounding success.

The idea was so strong, that the train stations “vokzaly” or вокзáл were named after Vauxhall. The concept of a station that attracted passengers rather than being merely a functional walk-through building for train users is again relevant in the 21st century, as the question of reusing magnificent and protected railway stations is being raised across Europe and beyond. This concept also inspired the fictive transformation of the Vallorbe digital twin discussed in this paper

Today in the digital age, transnational exchange in everyday planning practice is dominated by a handful of multinational software companies. These companies deeply influence our planning methods regardless of the regional specificities of the built environment. The pressure to progress and the business competition forces architectural practices to upgrade their software almost every year.
This constant and rapid development of software, also linked to hardware development, has both advantages and disadvantages;. software development makes extremely powerful tools available to small and medium-sized companies (which constitute most of the architectural and engineering firms in Europe); these tools are now capable of processing huge amounts of data on a standard personal computer[7] to model entire building complexes. The method of producing plans has within two decades been revolutionized[8]: today architects no longer draw plans but extract them from the models they have build using algorithms [Fig. 2]. The disadvantages are the obsolescence of these tools and the risk of digital dark age[9], where historic information becomes lost due to either the hardware or the software being no longer available.

One way of avoiding this obsolescence is by using open source software and open formats that respond to ISO standards. For the building industry and the BIM digital planning method, the open format is IFC, Industry Foundation Classes (ISO 16739). The institution that develops this format and delivers certifications for it is buildingSMART, originally this international organisation was called International Alliance for Interoperability (IAI, 1994-2005)[10]. BuildingSMART is an important international platform for the exchange of ideas, technoloy and methods aiming at sustainable solutions and which must also include heritage buildings.
The SBB currently implements the BIM method in three steps, aiming to evaluate 24 pilot projects until 2020. From 2023 on, they will implement the process and directives of international standards (e.g. ISO, CEN [European Committee for Standardization]). In 2025 the method shall be fully implemented and allow the SBB to plan and build using, if needed, cost and/or time simulations. As an active member of buildingSMART International, the SBB collaborate on the development of the IFC5 for infrastructure.

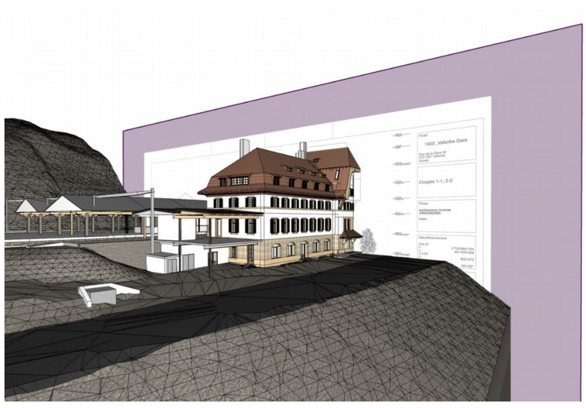


Figure 2 – Algorithmic extraction of a drawing – here a cross section – from the Vallorbe Station model.

The field of research of the Vallorbe Station pilot project, is between two planning phases: the phase of facility management (once the building is in use) and the preliminary-draft for a major transformation of the building, when the digital model used for the first design will be reused [circled on Fig. 3].

The current state of the art allows architects and engineers to produce IFC digital models of buildings for almost all planing phases: design, construction plans and management. However the potential reuse of IFC two or three decades after the building has been realised for a major transformation is still little understood. The authors argue that this lack of knowledge is due to the fact that the real uses of this format started less than two decades ago and buildings built with the BIM method are still too recent to be transformed.

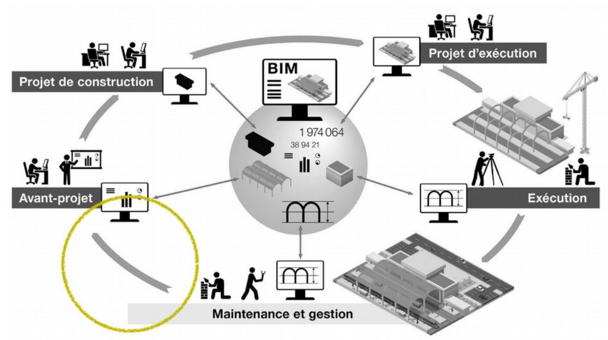


Figure 3 – The five phases of the BIM method (from left, clockwise): 1. Preliminary design, 2. Construction design, 3. Execution project, 4. Execution, 5. Maintenance and facility management. The current projet explores data reuse between phase 5 and 1 (circled). The average time span of the loop is estimated to 50 years[11].

For example a LOD 200[12] model for preliminary design of an historic industrial complex produced in 2002 with a CAD (computer aided design) software can no longer be used because the operating system no longer runs. Today, such a model can therefore neither be reused nor read. However, by publishing the model into IFC 2[13]; in 2020 it was possible to recuperate most of the model's geometry and some information of its composing entities (e.g. wall, roof, door)[14]. This supports the argument that, an IFC model produced today will still be exploitable in twenty years time and it will be possible to extract plans that respond to architectural norms (see Bibliography).
To demonstrate that the reuse of an IFC model is not linked to a specific software, it was processed through CAD from different developers (here a European: CAD 1, and an American: CAD 2) [Fig. 4A].

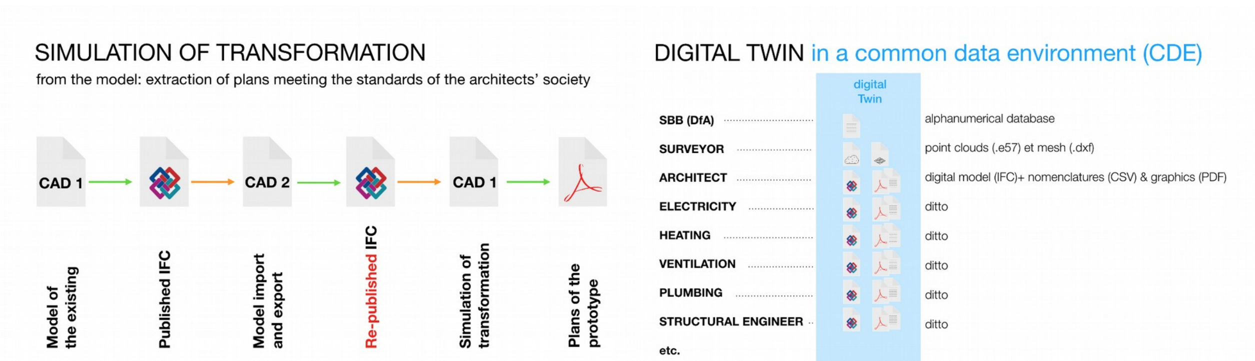


Figure 4a – Diagram for the production of plans after multiple reuses of the IFC by different software.
Figure 4b – Schema of the Vallorbe station digital twin based on open standards.

2. The Vallorbe station, a national monument on the Simplon-Orient-Express line

In addition to the fact that the Vallorbe station is a national monument, it was chosen for the pilot project because of its geometry, relative complexity, its representative size (similar to the station from former West German capital Bonn) and the question of its use after 2024; an obsolete infrastructure located in the building[15] will be dismantled and the station is isolated in the mountains by the french border.

After the piercing of the Simplon tunnel in 1906 –one major link through the Alps and the longest tunnel worldwide for more the 75 years– a direct route for the Orient-Express between Paris and Venice was sought. Instead of passing through Geneva, a shortcut through the Jura mountains with a new tunnel under the Mont-d'Or peak was chosen. As there were no major cities to host proper railway facilities on the french side, the train companies of both countries jointly planned and used a complex for their employees and the travellers, including customs buildings on the Swiss side[16].

The mountainous topography linked to the important new railway infrastructure required massive earthworks, that is with 600 000m3 probably the country's biggest earth move.

The federal authorities wanted an architecturally representative building to demonstrate to the British gentry on their journey to the Orient, that after having passed the Mont d'Or tunnel, they had arrived in Switzerland. The train station was designed according to Heimatstil with local features deriving from Art Nouveau and known as Style Sapin by architects Taillens-Dubois[17][see Fig. 1].

As the Vallorbe Station had to be built on the slope of the mountain, stones excavated from the tunnel were used to build the foundations of the traveler's main building. But the slope was so steep that a second basement level had to be built in order to reach the right height for the ground floor. This second level was never drawn by the architects, who planned a single basement only. Probably because of the lack of a plan, this remarkable level -2 in between the raw stones taken from the tunnel has never been used [see Fig 6a, plan produced within this pilot project (with fictive design)].

After World War II, several changes decreased the activities and reduced the prestige of the Vallorbe Station site. The electrification of the line made the operators redundant. The abandonment of the Orient-Express train took Vallorbe off the international traveller's map and the change of customs procedures made the two dedicated buildings vacant. Throughout this slow decommissioning, no accurate documentation of the complex was carried out; architectural plans dated from the 1950's and the sections and facades from the construction date of 1911.

3. Reverse architecture, Phase I of the pilot project

As no up-to-date documentation of the building was available to build an accurate digital model, the project involved scanning the station in order to obtain a series of point clouds[18]-. As experienced through archeological documentation[19], point cloud capture rapidly all objets that define space with the accurate precision needed by the architecte.
This process of production of a digital model from an existing building based on point clouds is here called reverse architecture. This term term –used by R.L. Krikhaar in computer science[20]– derives from reverse engineering and is the process by which a man-made object is deconstructed to reveal its designs.

As the site's morphology is complex, 3D meshes from the federal office of topography (swisstopo) were used as reference for the terrain.
Yet the topographical model must be remodelled for two reasons: firstly, the Lidar based mesh is non parametric and can therefore not be modified for the project. Secondly, the representation of topography with a Lidar mesh is not comparable to contour lines and is not readable in a plan view.

For documenting the station, in the first instance, geomatic engineers from a university of applied science used photo- and lasergrammetry to record the facade and the interior of the building. The point density of the cloud is about 1 point / cm2. The point clouds they produced are georeferenced in accordance to the Swiss reference system LV95[21].

One constraint for the planner is that for the production and development of digital models, CAD software requires its own coordinate origin and not that of the georeferenced data. The precision will otherwise be reduced and the calculation for 3D visualisation and movements will be increased by the large numbers of the coordinates.
The georeference however to be kept as the point clouds are imported in the CAD software and reintegrated in the model during the IFC publication procedure.
Georeferenced IFC allows planners to link all models spatially and a building owner such as SBB, to locate one object within a lager model that will contain all of their assets. Eventually the architect's models could complete the GIS (Geographic Information System) model from the public authorities[22].

The production of an architectural model is carried out by placing objects (e.g. walls, slabs, windows) in space using the point cloud as reference [Fig. 5: section through the building complex point clouds and digital model]. Currently some additional software eases the production of digital model in the point clouds but it has not yet been automatized. Algorithms that recognise shapes within point clouds and insert pre-fabricated objects from a database at the right position exist in laboratories[23] and might be offered as tool on the market for the production of models within a decade. Nevertheless for historic buildings, the realisation of a data base containing historic objects (e.g. doors, bathtubs, convection heater from all centuries) does not make sense as almost all objects are unikats made by artisans.
Therefore the production of a digital model of historic buildings will remain a manual task for qualified people.

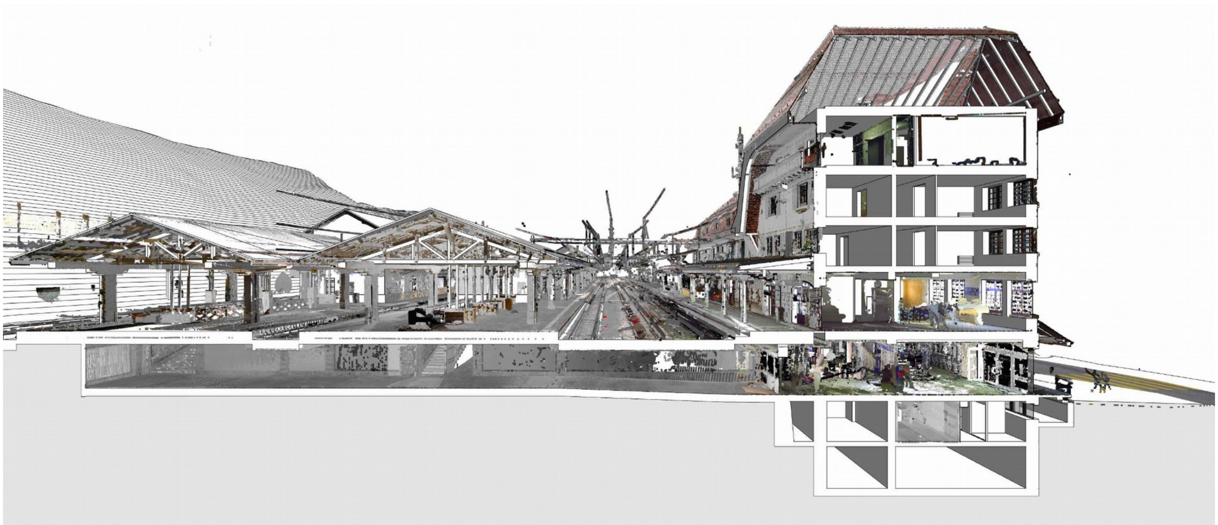


Figure 5 – Outcome of phase I. Reverse architecture: cross section on the point clouds from surveyor and the digital model architecture (LOD 200 and georeferenced).

4. Creation of a digital twin, Phase II

Railway stations host and support technical infrastructure that undergoes constant development. One part of this infrastructure aims to inform and serve railway passengers; displays and automatic vending machines fulfil their needs. The service life of these items is about half of the building renovation cycle [see Fig. 3].

In this phase, the SBB gave the engineer of the Vallorbe team a small library of 16 digital objects to be found in almost every train station (e.g. ticket machine, the famous Hans Hilfiker design clock) with the task to create a link between these objects in IFC and an existing alphanumerical database of these items.
An average station has hundreds of objects and each of them are recorded in a database that contains information such as: the factory's details that build the object, when was it build, the company that mounted it on site, when this occurred, how long is the warranty of the object valid etc. The level of this informations is high (LOI 500) and all informations of all objects would not fit in a digital model.
Using the IFC architecture model as template, the electrical engineer produced a second IFC containing only the SBB objects and linked them to the databank.

The SBB could follow the step-by-step building of the architecture and technical models as they where compiled in a web-based collaborative platform that included an IFC viewer. The stakeholders agreed to have a weekly update of the models. During this project two platforms were also tested (see bibliography).

Eventually a set of files on the Vallorbe train station has been created: the SBB object databank, the mesh and buildings volumes of swisstopo, the point clouds of the surveyor, the architectural model and the SBB objects for the station. All these files are in a common data environment (CDE). As the "team Vallorbe" wanted to mention all different digital models and the set of data to which they were linked, the term "digital twin" used by A.Pilling [Op.Cit.] seemed the most appropriate. The entire set of data constituting the building is then the Digital twin for the Vallorbe Station [Fig. 4b].

5. Simulation of transformation, Phase III

Ideally the digital twin should live a parallel life to the building: during the building maintenance, small updates should be performed with a simple tool[24] on the IFC model. After about 50 years [4/5 of the BIM cycle. See Fig. 3] the IFC model should be re-imported in a CAD to simulate a major transformation of the building.

In Phase III the question is, how can the geometry and the basic information be retrieved from the IFC in order to plan a major transformation of the building?
As seen in § 1, it is foreseeable that the IFC will still be readable in 20 years. But today, instead of using open format, buildings models are often archived in proprietary formats; any later modifications of these digital models are then done with the software from the architect or the engineer that produced them. Otherwise, as proprietary digital models can not be opened with a CAD from another software editor, the model will have to be entirely reproduced.
It then had to be demonstrated, that the IFC model could be reused to produce architectural plans independently from the software that produced it and that plans could be extracted from it to meet current standards for architectural drawings (see Bibliography).

At the beginning of this phase, two different IFC of the building have been published to compare between parametric IFC and B-REP (Boundary representation) IFC. The main difference between these two types is the conservation mode of non-standard geometry. In opposition to the mainstream contemporary architecture produced with the BIM method, historic buildings have a complex geometry. In the case of the Vallorbe Station the exact shape of the gambrel roofs above the two aisles and crossed by the one from the main central structure, had to be conserved in the IFC. It was also important to conserve the geometry of the monumental swing stairs from the central hall including the banister.

Once it had been defined how the model in CAD1 should be set for a publication in IFC and which type of IFC had to be produced, it was given to a colleague user of a software from the competing editor of the CAD. The colleague only imported the IFC in CAD 2 and published it again [see Fig. 4a].
The re-published IFC was re-imported in CAD 1 to perform the simulation of transformation

Prior to executing the transformation simulation, a quality analysis and preparation work for the IFC are required. With the quality analysis, the structure of the data will be understood. Currently, a widely used CAD software produces a poor data structure that will force the architect who retrieves a model produced with this tool to double the amount of preparation time (for Station almost a week). Some objects have been degraded (objects have lost their fill entity and must be replaced) or become more complex (e.g. slabs with indentations or projections loose their single borderline and are replaced by a multitude of polygons, they also have to be replaced) and some objects attributes will be mixed. In this last case, for instance a wall can be spatially in a correct position (the 3D model will appear correctly) but the CAD will attribute it to a wrong floor[25].

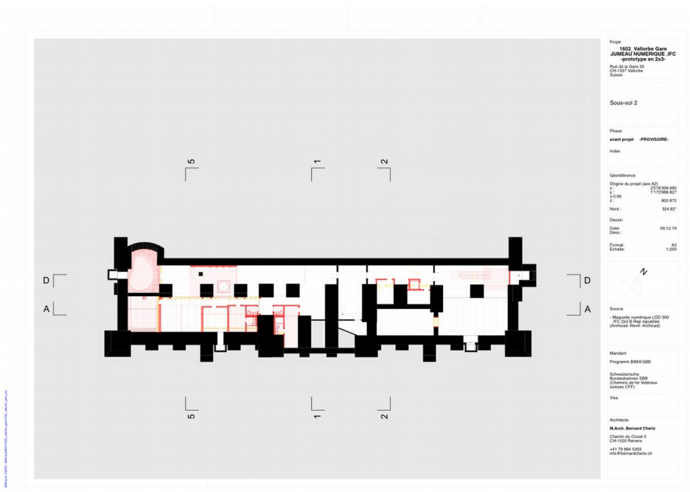
After all corrections performed, the IFC is prepared and the simulation of transformation can start. This can follow the usual method of modelling by giving the entities the attributes related to the three status types "existing" (colour: black), "to be demolished (yellow) and "new" (red) as given by the norm.
The objects that require transformation can be processed according to three different operations that all buildingSMART certified CAD softwares should perform (this supposition would need further investigations). These operations start with basic vectorial corrections and end with new 3D parametric objects.

Finally the architectural model with the fictive design could be used to publish plans and sections on the scale of 1/250 and on the scale of 1/50 with a few graphic mistakes [Fig. 6a & b].

6. The open format IFC for a continuous re-use and documentation: a state of the art.

The prototype of the Vallorbe Station Digital Twin showed the possible continuous re-use of the IFC and therefore the feasibility of a digital twin that has a parallel life to the building. For historic monuments with complex geometry, possibly undergoing two major transformations per century, such a digital twin represents a great advantage for the planners and the building owner (or his real estate manager).

Some aspects of the digital twin requires further development, such has the environment that hosts his data, the CAD softwares and some formalities should be implemented by buildingSMART.
Regarding the common data environment (CDE) that hosts the twin, the major issue concerns linking the different data and formats. Plans sections and elevations will still be needed, their algorithmic extraction from the model changes only the way they are produced. In the project phase the sections represents the location where the architect can guarantee that the informations are correct, (in historic buildings half a meter ahead and the section might be completely different).
The now open format PDF[26] is the standard for archiving but as in CAD, the models and the plans are intrinsically linked [cp Fig. 2], but this link is not permanent after publications in IFC and PDF and each file can be compared as a silo of information.
The issue of the missing link also occurs between the digital model and point clouds as they are in different formats (e.g. e57 for the second). By the documentation of a building in operation, the point cloud could be incomplete; as in Vallorbe where 40% of the building could not be scanned (e.g. the rented apartments). Therefore the model produced will have two qualities, one extremely precise while based on the point cloud and the other, based on plans that might be incorrect.



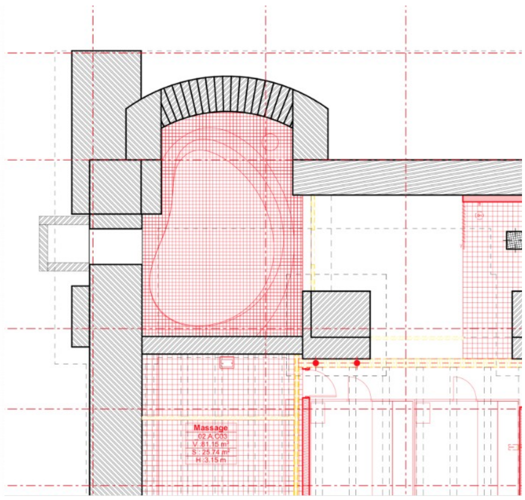


Figure 6a – Plan at scale 1/250 extracted from the model in LOD 200.
Figure 6b – Detail of a plan at scale 1/50 extracted from the model in LOD 300 showing the need of improvement by software developer: the wall was fragmented in IFC to reproduce its geometry, as the fragments are not associative they disrupt the graphic of the wall.

7. For a sustainable transnational exchange of idea and planning praxis.

In many other countries, the oversized Vallorbe station would have been sold in a procedure of investment reduction by the owner. The Swiss government has instructed the state-owned company SBB to make their property assets profitable, therefore they are seeking solutions for the future of the Vallorbe Station once the infrastructure for the railroad switches will be dismantled. Currently the building hosts several apartments and a restaurant that should remain.

During this project several scenarios have been developed. The current trends in terms of mobility have been studied by the SBB and the most suitable for an decentral and small area, such as Vallorbe, has been chosen.
The station square, currently used for traffic, is liberated for socio-cultural activities.

The idea of a station as a destination in itself, such as Pavlovsk, rather than a walk-through building -has again become relevant for a station such as Vallorbe in the 21st century. The design for the transformation integrated several cultural and recreational programmes; an exhibition area in the re-opened majestic hall from the time of the Simplon-Orient-Express; a cine-club and an oriental bath, between the remarkable stones of the Mont-d'Or tunnel from the forgotten basement as well as a pension under the roof and in the rooms left empty by the obsolete infrastructure.
These proposals supplement the lack of cultural, leisure and touristic facilities in the town of 4000 inhabitants, which have slowly been closed down parallel to the decline of the population (about 16%); the only cinema closed in the 1970's and there is only one small hotel.

The proposed transformation of Vallorbe also represents a planning culture where the architect is commissioned directly by the building owner. After a certain project maturity, engineers, were called in., also receiving a direct commission.
The design of CAD software responds to this specific planning culture

In continental Europe, architects and engineers work as independent practitioners to realise medium-sized building complexes. CAD is specific to the different professions: architects civil engineers and mechanical electrical or plumbing engineers[27]. Here, in the case of a planning mistake, a lawyer will be engaged to define the responsibility of each party engaged and divide the costs according to the responsibility of the planners. This costly procedure might have heavy consequences for the planner therefore he will pay great attention to the plans – now respectively the models – he produces. The use of the open format IFC to exchange models amongst stakeholders during the planning phase is therefore important.
In the Anglo-Saxon, American and Oceanic planning cultures, building firms that include architects and engineers working as interdisciplinary teams, frequently realise either serial balloon-frame or high-rise building types. For this purpose, CAD is made to fuse digital models amongst colleagues from different disciplines with as little data loss as possible. In this case interoperability with open format is less relevant.

The Vallorbe prototype has been created with a non exhaustive series of digital tools from both the European and Anglo-Saxon planning cultures, using a method only for the planning of new buildings, as methods for transformation do not yet exist. There are major differences in the use of digital tools in the different planning cultures. This differences appeared especially in the processing of open format which is essential in this project and for data conservation.

The exchange of ideas and practices are intertwined. Ideas need practices to be implemented and practices need ideas to demonstrate their pertinence. Building plans are an important source of knowledge which needs to be preserved. In the digital era as plans are extracted from the model, the model itself becomes the source of knowledge and it's conservation becomes of equal significance. Therefore only open formats such as IFC can guarantee a sustainable transmission of planning practices such as N.H. Kwak suggests.

Acknowledgements

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Disclosure Statement

No potential conflict of interest was reported by the authors.

Notes on contributor(s)

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Based in Lausanne (Switzerland), Bernard Cherix, received his Master in Architecture by Research from RMIT University, Melbourne 2001, under Leon van Schaik & Matthias Sauerbruch, also winning the Australian-European Award Program to carry out the research.
Currently working on a digital twin to be applied on heritage buildings for the Schweizerische Bundesbahnen (SBB), Bernard taught openBIM at EPFL to master students in architecture and civil-engineering from 2016 to 2018.
At neighbourhood scale, Bernard has been involved in voluntary collaborations with Pr. Jean-Bernard Racine, in particular regarding resident participation and the development of the newly completed neighbourhood's house in le Desert, Lausanne.

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Within this position he co-wrote the "BIM strategy paper" for the SBB.
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Billal hold his master degree in Civil Engineering 2014 from the EPFL by Prof. Michel Bierlaire on "Exploring approaches to model financial decisions".

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– Swiss Norm 506 400 "Elaboration des dossiers de plans dans le domaine du bâtiment" Zurich 2000
– Swiss Norm 592051 " Building Information Modelling (BIM) - Bases pour l'application de la méthode BIM" Zurich 2017 (this method is for new buildings only and does not concern the processing of GIS data)

Note: developers and software's names are available on request at <info@bernardcherix.ch>
– Computer Aided Design (CAD) software
G*** A*** / A*** R***
– Web based collaborative platform (or common data environment, CDE)
A** B**, C** B**
– IFC Viewer
N*** S***, A*** U***
- IFC analytical software
N*** S***

Endnotes:

1 This term is used by André Pilling in “ BIM —Das digitale Miteinander, Planen, Bauen und Betreiben in neuen Dimensionen” Berlin 2017 Although, the author remain vague about the constitution of the Digital Twin

2 Introduction to the Virtual Special Issue Transnational Planning History, N.H. Kwak, « Virtual Special Issue Planning Perspectives: An international journal of history, planning and the environment.» Abingdon. 2013

3 Swiss Federal Office for Civil Protection: <https://www.babs.admin.ch/fr/aufgabenbabs/kgs/inventar/a-objekte.html>. Retr. 31.10.19

4 <http://www.vauxhallgardens.com/vauxhall_gardens_fullchronology_page.html>. Retr. 09.03.20

5 Ponte, Alessandra « Public Parks in Great Britain and the United States From a +Spirit of the Place+ to a +Spirit of Civilisation+ » dans « The History of Western Gardens » S.Moser & G.Teyssot ed. Cambridge 1991

6 Dayanov, Rafael ‘The History of Pavlovsk’s Musical Railway Station’ in “Station Russia” S. Mikhailovsky Ed. Berlin 2018

7 For the production of Vallorbe Train Station digital model, 60 Gb of datas (point clouds) were processed on a laptop (4.2 GHz, 16Gb RAM, 512 SSD)

8 Personal computers could only process small 3D models and vectors drawings. But vectors do not add value to what they represent. Since about 2010, the increase of calculation power by personal computer – processor (e.g. 64 bits), video card – allows them to process and visualise objects making up complex buildings. These objects in the BIM method can be informed and all kinds of simulations be performed with both, the geometric and graphic of objects as well as with the information they contain. The use of the digital model in architecture for algorithmic extraction of construction plans became possible as the author showed on his application of open-BIM method for the renovation of switzerland’s first sky scraper: <https://www.youtube.com/watch?v=EnoGWvZRM24>. Retr. 01.03.20

9 Kunny Terry, “A Digital Dark Ages? – Challenges in the Preservation of Electronic Information – 63RD IFLA Council and General Conference. <https://archive.ifla.org/IV/ifla63/63kuny1.pdf>. Retr. 01.03.20

10 <http://www.ifcwiki.org> Retr. 07.02.20

11 Swiss Norm 506 480 “Calcul de rentabilité pour les investissements dans le bâtiment” Annexe B. Zurich 2016

12 Level of Detail according to buildingSMART Switzerland: <https://bauen-digital.ch/assets/Downloads/de/180222-BdCH-SwissBIM-LOIN-Verstaendigung-web.pdf>. Retr. 21.02.20

13 The version of IFC 2 is now outdated but can still be exploited. The current version is IFC 4. Development is been made to integrate infrastructure (e.g. rail, road, tunnel). <https://www.buildingsmart.org/the-infrastructure-room-progress-report/> Retr. 26.02.20

14 BIM World Munich 2018, Breakout Sessions<https://www.bim-world.de/wp- content/uploads/2018/12/BernardCherix_REVERSE_ ARCHITECTURE. pdf> Récup. 09.10.19

15 This infrastructure is related to the commands of the railway switches for the site around the station and are located within the building. These commands are currently being centralised for the whole of western Switzerland

16 Le chemin de fer à Vallorbe, une épopée internationale…, (page 25) Vuadens, G. Vallorbe, 1993

17 « Vallorbe, Bâtiment du domaine ferroviaire. Etude historique et architecturale » N.Maillard. CFF, Bern 2009 (Unpublished)

18 A point cloud is a three-dimensional digital representation of an object recorded by photo- or lasergrammetry. It consists of a set of data points in a three-dimensional coordinate system. These points are defined by the coordinates x, y and z. They do not have a dimension, but can have a greater or lesser density depending on the needs – e.g. the documentation of land morphology, buildings or watches –. They are often used to represent the facade of the object and can document the colour or be in black and white.

19 Alby, E “Point cloud vs drawing on archaeological site”. Strasburg 2015. <https://www.researchgate.net/publication/281131722_Point_cloud_vs_drawing_on_archaeological_site>. Retr. 09.03.20

20 R.L. Krikhaar (Amsterdam 1997, ISBN: 0-8186-8013-X) referring to software maintenance, in this paper it is applied to architectural redesign.

21 <https://www.swisstopo.admin.ch/en/knowledge-facts/surveying-geodesy/reference-frames/local/lv95.html> Retr. 16.09.19

22 E.g. web view from a swisstopo model of Vallorbe in LOD 2 (GIS) <https://map.geo.admin.ch/?topic=swisstopo&lang=fr&bgLayer=ch.swisstopo.pixelkarte-grau&layers=ch.swisstopo.swissnames3d,ch.swisstopo.swissbathy3d-reliefschattierung&lon=6.37039&lat=46.70382&elevation=1971&heading=360.000&pitch=-45.569>. Retr. 26.02.20

23 Example in the GIS field: « Combined use of airborne laser scanning and hyperspectral imaging for forest inventories », M.Parkan, F.Golay, LASIG. EPFL 2019 <https://infoscience.epfl.ch/record/262809> Retr. 06.11.19
<http://filip.biljecki.com/publications/2016_3dgeoinfo_semantic_classificationPDF> M. Rook, et. Al. TU-Delft. 2016. Retr.14.11.19
<http://filip.biljecki.com/publications/2017_ceus_inferring_heightsPDF> F.Biljecki, J.Stoter, et. Al. TU-Delft. 2017. Retr. 14.11.19

24 For this purpose a IFC viewer that includes basic CAD features has been tested within this project

25 To verify that the poor IFC quality is issued from the software and not from the operator, the information structure of the model were compared with the buildingSMART example: <https://www.researchgate.net/publication/282988389_Automated_Extraction_of_Information_from_Building_Information_Models_into_a_Semantic_Logic-Based_Representation>. Retr. 15.01.20. The digital model was produced by the National Institute of Building Sciences (USA).

26 PDF is an ISO open format since 2008: <https://www.iso.org/standard/51502.html>. Retr. 26.02.20.

27 The planning culture by proxy is reflected by the buildingSMART certified software online list which contains a majority of small European software companies specialised in architecture, civil and MEP engineering.

Image sources

Image 1: Drawing by Taillens-Dubois architectes, 1911. SBB Archiv
Figure 3: SBB <https://company.sbb.ch/en/the-company/projects/national-projects/bim/short-and-concise.html> Retr. 21.02.20.
Figure 2; 4, 5; 6: Bernard Cherix.