Corentin Stalder, Myriam Lewkowicz, Guillaume Ducellier (2022): The potential of a digital twin to design computational coordination mechanisms. The case of the French railway infrastructure. In: Proceedings of the 20th European Conference on Computer-Supported Cooperative Work: The International Venue on Practice-centred Computing on the Design of Cooperation Technologies - Exploratory Papers, Reports of the European Society for Socially Embedded Technologies (ISSN 2510-2591), DOI: 10.48340/ecscw2022_ep08

The potential of a digital twin to design computational coordination mechanisms. The case of the French railway infrastructure

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Abstract.
The digital twin is a key technology of Industry 4.0. It offers a digital replica of a physical system. As part of research work with SNCF Réseau, we have sought to explore the role the digital twin can play to support coordination mechanisms. We conducted a multi-sited ethnography, which allowed us to define a technology probe to explore our research question in-situ. This exploratory work shows that the digital twin enables the rapid design of computational coordination mechanisms. Furthermore, we raise the point that a digital twin can bind descriptive information about the physical system and information used in coordination practices to move towards effortless coordination.

Keywords: Digital twin, railway infrastructure, coordination mechanisms, technology probe.

1 Introduction

The digital twin has been a trending topic in academic research and the industry since 2017. More than 2500 papers[1] were published on this topic in 2021. Gartner identified the digital twin as the fourth most strategic technology trend in 2018, ahead of virtual reality (Gartner, 2017).

The digital twin is a multi-scale, digital representation of a physical system, updated in real-time and defined as a mirror of the physical system (Tao et al., 2018a).

It has emerged in the product lifecycle management (PLM) community and aims to overcome the lack of digital continuity that may exist between the product design and its management, while taking advantage of the possibilities offered by IoT and big data.

However, even if one of the objectives of the digital twin was to enhance cross-business cooperation (Grieves, 2015), few socio-technical studies have studied it (Tao et al., 2019b; Lamb, 2019). We propose here an exploratory study conducted at SNCF Réseau, where a digital twin of the railway infrastructure has been built (Costa D'Aguiard et al., 2019). Our aim is to explore the potential of the digital twin to support coordination among the different actors involved in the maintenance of the railway infrastructure. Our research falls within the digital twin industrial program of SNCF Réseau that has been leading the railway system's digital twin development for three years now (Gautier et al., 2019).

In order to study the potential of the digital twin to support the coordinative practices in place for managing the infrastructure, we have conducted a multi-sited ethnographic study of the work scheduling activity at SNCF Réseau. We have chosen to focus on this activity due to its criticality and the multiplicity of actors involved. This study allowed us to clarify the organizational context and to identify the coordinative practices implied. We then used the coordination mechanisms (Schmidt and Simone, 1996) framework, as it conceptualizes a socio-material entanglement of articulation work to analyze fieldwork practices and computerized coordination mechanisms (CCM) to support articulation work. From this analysis, we have designed a technology probe (Hutchinson et al., 2003) using the digital twin to prospect its technological capability to support the articulation work that is involved in the work scheduling activity.

2 Industrial Context

SNCF Réseau is the French railway infrastructure manager. Its task is to operate, maintain and develop the 30,000 kilometers of lines that compose the railway network (Ministère de l'économie et des finances, 2019). The railway network is a complex system, first because of its geographic geographical extent, and secondly

[1] The number of articles is calculated from the analysis of the search result on Scopus with the query: TITLE-ABS-KEY ("digital twin")

because of the number of subsystems that compose it (rails, energies, signaling, infrastructure...). This system is ageing and therefore requires a lot of maintenance work. Indeed, the railway network is at the heart of current concerns for low-carbon mobility in Europe and it represents a crucial mobility hub, with highly exploited lines, which has accelerated the degradation process. On top of that, the 2024 Olympics games in Paris will increase mobility needs. Thus, in 2019, 2.7 million euros were invested in the infrastructure, which has led to the renewal of 942 km of lines. In addition, 2.2 million euros were invested in network development projects (electrification, creation of new lines, increase of existing lines' capacity, etc. . .), which has also resulted in infrastructure works (Guinet and De Nicolay, 2019). To face this situation and to improve the management of its infrastructure, the company is engaged in a major transformation of its activity. This transformation is both organizational and digital. One of the digital transformations is the development of a digital twin. SNCF Réseau defined the digital twin of the railway infrastructure as follows (Costa D'Aguiard et al., 2019, p. 3):

> [The digital twin is] a digital replica of a physical system, connected to the railway infrastructure and work practices. Its input comes from the reference databases, and sensors fitted in the infrastructure that serve to keep this data up-to-date in real time throughout the system life cycle. This digital replica is designed to simplify the decision-making process, and is structured through three service levels (information, analysis and configuration management). Each rail system user/persona will have access to different views (dashboards, spreadsheets, forms, 2D diagrams, 3D objects, etc.) of the digital twin depending on their functions and access rights.

In other words, the digital twin of the railway system ensures the description of the infrastructure, the recording of all the operations done on the infrastructure, feedback from the field through reports and sensors to update the digital twin and support for decision-making through data analytics. The digital twin of the railway system is composed of the data model, the data warehouses, the update process, and the end-user applications. The data model is now defined and has been implemented in data warehouses. A manual update process is in place and several end-user applications are in production.

The data model aims to be a unified and unique description model of the railway system: a topo-functional model (International Railway Solution, 2016). In other words, the model defines the objects of the infrastructure from a functional point of view and the topological relationships between objects. This model structures data warehouses. Data warehouses are a set of databases exposing data through REST web services. Each object in the model is associated with a web service. Moreover, with the data relationships, it is possible to navigate between objects using objects relationships. For example, it is possible to know tracks composing a line with the line request. It allows the application designer to get a rich description of the infrastructure with different levels of abstraction. It enables the designer to adapt to a wide variety of needs while using a single data source. In the end, users can enjoy a wide variety of representations that are all consistent, and with possible bridges among them. (International Railway Solution, 2016)

Data warehouses are updated with a manual process. It means that the update is done manually; data contained in documents are rewritten in the data warehouses. Finally, the updated data are used in the end-user applications. The end-user applications focus on specific use cases and use data from data warehouses.

3 Related work

In this section, we first present the technological concept of the digital twin, emphasizing the few works that foresee this technology for supporting cooperative work and therefore the originality of the program launched by SNCF Réseau in which we participate.

We then focus on the challenges when engaging with computational coordination artifacts to frame our analysis of the digital twin capability to produce "in-between" coordinative artifacts.

3.1 Digital twin

The digital twin, a digital replica of a physical system, is a key concept of industry 4.0 (Pires et al., 2019). Grieves offered the first conceptualization in 2015, defining a digital twin as a "digital equivalent to a physical product" (Grieves, 2015, p. 1), and structuring it in three main parts:

- The physical products in the real space, for example a rocket or the railway infrastructure.
- The virtual products in the virtual space, for instance a digital mock-up of the product, or a database containing all the data related to the properties, the behavior, and the state of a product.
- The connections between data and information that link the virtual and the real spaces together.

Following Grieves' work, Tao and Zhang (2017) worked on a multi-scale, multi-source and multi-sector representation. On top of the data, the virtual entity and the physical entity, Tao and Zhang introduce a service layer to the digital twin concept. The digital twin can then be described through five dimensions: (1) the data is the center, it drives (2) the physical system (composed of humans and machines), (3) the digital system (the digital model of the system) and (4) the service system (the enterprise information system, computer tools ...). Each of these dimensions communicate through a (5) data flow in order to achieve a continuous optimization of the shop floor (Tao and Zhang, 2017, p. 20420-20421).

In other words, a digital twin refers to a virtual copy (a replica) of a physical system, connected to it via sensors; it permits the fusion of data coming from the sensors put on the physical system and data coming from simulations. Finally, the service layer ensures the management of both the physical and the virtual entities. In the digitization program of SNCF Réseau in which we are involved, the physical system is made of the railway assets (tracks, catenaries ...) and the workers (maintainers, switchmen...), the virtual system can be a 3D point cloud linked to a digital mock-up and the service system can be the train scheduling system, the maintenance management system, etc.

Even if the development of the digital twin obviously presents technological challenges (how to merge different data sources, how to update the digital twin in real time ...), it also presents socio-technical challenges. In particular, how to build representations that are intelligible for users and how these representations could ease complex cooperative work.

So far, these socio-technical challenges do not seem to be fully addressed in the literature. Indeed, despite the digital twin being built in order to offer a real-time, integrated and collaborative representation of the infrastructure (Tao et al., 2019b; Grieves, 2015), little research work addresses the use of the digital twin as a means to communicate, coordinate or cooperate (Tao et al., 2019b; Lamb, 2019). Of the 471 articles on the digital twin studied by Lamb (2019), 27% were focussed on performance issues (efficiency, productivity ...), 22 % were product-centered (asset health monitoring, life cycle management ...), only 8% were interested in the potential of the digital twin for collaboration and 8% were adopting a human-centered approach.

However, we can see a recent evolution, as shown in the work presented by Nochta et al. (2021)], that offers a socio-technical study of the city of Cambridge's digital twin. This work tackles the difficulty of building representations that are understandable by users of digital twin models.

In our work, we aim to contribute to this discussion regarding the potential of the digital twin by addressing how the railway system's digital twin could offer a common representation allowing more effortless coordination of work conducted by the diverse actors involved in its maintenance. Hence, even if the CSCW research community has studied CAD and BIM systems (Møller and Bansler, 2017; Bjørn et al., 2021; Schmidt and Wagner, 2004), to our knowledge, the potential of the digital twin technology to support cooperation has never been addressed. However, we believe that the digital twin, such as BIM, can offer new opportunities to make cooperative work in complex industrial settings more practical.

SNCF Réseau's digital twin vision is closed to Tao's model. Thus, the digital twin of the railway infrastructure is not a one-piece application, but a data and service network aiming to facilitate infrastructure management and cooperation among services. This digital twin paradigm is close to the development of an information infrastructure (Susan Star, 1999). The coupling between artifacts is automated and systematized, which makes the relationships between artifacts invisible (Bossen and Markussen, 2010).

3.2 Supporting coordination - the potential role of the digital twin

The articulation work is all the work that consists of adapting to unforeseen events (Star and Strauss, 1999); it is a fundamental component of cooperative work. The complexity of articulation work increases with the number of actors, the distribution of work and the interdependencies between the actors. To deal with this complexity, artifacts are used (Schmidt and Simone, 1996). By studying articulation work and how to support it using digital tools, Schmidt and Simone (1996) proposed the concept of coordination mechanisms: a construction composed of a protocol instrumented by artifacts. The protocol is a resource for action consisting of a set of procedures and conventions defining the coordination work between different actors. Coordination mechanisms describe the way practitioners reduce the complexity of articulation work (Schmidt and Simone, 1996).

Coordinative artifacts are not necessarily digital; there are many examples of tangible coordination artifacts (e.g. kanban, form, checklists, etc.). Their materiality offers a better affordance and malleability but present constraints in terms of updating and visibility when they are shared. To overcome these limits, Schmidt and Simone (1996) proposed the concept of computational coordination mechanisms (CCM) that aim to digitize a part of the protocol and offer a symbolic support of the protocol through a digital artefact.

Schmidt and Simone (1996) raise two main issues regarding the design of CCM: malleability and connectivity. Indeed, practitioners need to shape and reshape the CCM in order to adapt it to the evolution of the protocol (over time or punctually) to local practices and to different contexts. As for connectivity, a CCM must be connected to other information systems, in particular business information systems and other coordinative artifacts.

In the case of large-scale coordination, Schmidt has proposed the ordering system concept. There are systems that bring order to the collection of artifacts used to support coordination, as shown in the practices of an architectural design office (Schmidt and Wagner, 2004). This study showed that, in this office, coordinative practices were organized into clusters of artifacts that make it possible to organize production and monitor changes. Overall, they reduce the complexity of coordination. For example, a drawing system is a cluster made up of a catalog of components, detailed drawings and a list of drawings, all these artifacts being linked together by references. It is the conjunction of these artifacts that allows the actors to have an overall view of the cooperation process, to know where they are and what remains to be done. This reduces the complexity of scheduling and monitoring the project.

We can identify that in the conceptualization of the digital twin there is a tension between Grives' model and Tao's model. The first model aims at proposing a single virtual space. The second model aims at breaking down Grives' model into a multitude of spaces, based on the data federating the services, the virtual replica and the physical system.

4 The overall organization of the work scheduling activity

In this section, we present the work scheduling activity that we have observed.

First, work is performed on a complex and dangerous system and in a tense economic context. Site workers are highly exposed to two major occupational hazards that can lead to fatal injuries: impact risk and electrical risks. To avoid these risks, it is necessary to cut off or reroute traffic from the work area. Then procedures define how to work in a safe manner. There are two main types of procedures: S9 procedures to remedy the risk of collision and S11 procedures to remedy electrical risks. The application of these procedures implies action from site workers and switchmen.

In addition, there are two types of work: development work and maintenance work. Development work aims to develop the capacity of a section's infrastructure (increase the number of trains per hour, safety or speed). They are major works carried out over several months or even several years. The maintenance works aim to maintain the capacities of the system in the face of its natural deterioration (due to its use) or exceptional (storms, falling trees, vandalism, etc.). Maintenance works are small or medium scale (a few days, a few weeks). Maintenance work also includes infrastructure monitoring.

To ensure the safety and the execution of maintenance and development work, three establishment types are involved:

- *Infrapoles* are in charge of the maintenance work management in their geographical sector. They are responsible for the technical safety of the train traffic (e.g. if a train derailed due to the infrastructure state; the local Infrapole is legally accountable).
- *Infralogs* are in charge of the development works execution in a geographical sector. They manage the organization of several development works. They are the interface between external railway construction companies (who carried out the works) and SNCF Réseau (who define how it should be done).
- *Railway traffic establishments* manage the train routes, regularity and safety over a geographical sector.

Over this structure, we have observed work scheduling teams that lead the work scheduling process. They are co-directed by the traffic establishment and the infrapoles and they are made up of two task forces:

- The anticipation task force, which defines an anticipation, schedule from two years before to eight weeks before the work.
- The coordination and scheduling center (called coordination center in the remaining parts) which schedules the works during the pre-operational phase from eight weeks to the day before the works begin. They adapt the anticipation schedule according to the context.

In the following, we will use the notations Y-X, W-X, D-X (with X a number), for indicating respectively X years, weeks, days, before the year, week, or day the work will be carried out.

Finally, the work scheduling activity is a long-term process. It starts two years before the work, up to the day before the work. Our study focuses on the pre-operational phase, from W-8 to D-1. This phase is interesting because it requires a lot of articulation work among actors who must coordinate to adapt the anticipation schedule according to hazard or schedule modification (e.g. late work). The process starts at W-8; from W-8 to W-6 work requests are sent to the coordinator in the coordination center. It ends the day before the work with the editing of a daily work notice sent to the switch posts.

A key moment of the process is the coordination meeting at W-6, chaired by the coordinator. During the meeting, the requesters and the coordinator discuss the schedule, the incompatibilities, and the co-activities. They deal with unexpected events in order to "work things out" (Corbin and Strauss, 1993).

5 Method

Motivated by understanding how we could make use of the railway infrastructure's digital twin to support the coordination among stakeholders of the work scheduling activity, we have collected data through an ethnographic study in two coordination centers.

We started with two interviews with two managers of the work scheduling team in the first center. Our discussions with a strategic director of work scheduling activity enabled us to identify that the practices of this center were different from other coordination centers. We therefore decided to extend our study to a second coordination center. Our study aims to identify the coordination mechanisms involved in the work scheduling activity during the pre-operational phase and to design a technological probe (Hutchinson et al., 2003) to identify the potential use of the digital twin to support coordination in complex situations. We began by identifying when the articulation work was the most intense and focused our analysis on the coordination protocols and the artifacts in use.

We report here data collected between February and December 2020:

- Center 1: two interviews with two managers, one interview with an applicant, and observation of a 2-hour coordination meeting.
- Center 2: an interview with a coordinator, three interviews with three applicants and the observation of three coordination meetings for a total duration of 3 hours 40 minutes.

The first author conducted all the semi-structured interviews. Due to the COVID-19 pandemic, two interviews were conducted online, and all the meetings were observed online. During the interviews, we collected documents and took pictures and videos of artifacts in use. Subsequently, the interviews were transcribed. The transcripts and the materials collected were analyzed, paying attention to conventions and artifacts. We then compared our results from the two observed centers and highlighted the differences and the similarities between the practices in these two centers. The analysis was conducted by the first author, then shared and amended by the two others. Our analysis allowed us to identify three coordination mechanisms, on which we have based the design of a technology probe to try out the role of the digital twin and to challenge our understanding of the work scheduling practice (through the use of the probe by practitioners in real settings).

6 Scheduling the Maintenance Work: A Cooperative Activity

Our fieldwork has highlighted a network of protocols and a cluster of artifacts used to coordinate work requests. We first briefly expose the observed protocols and artifacts, and focus on the detection of scheduling clashes.

6.1 The Protocol

First, to discuss the scheduling of works during the coordination meeting, coordinators build a pre-schedule. In center 1, the pre-schedule is made up of a local schedule constructed by scheduling assistants in infrapoles and infralogs. In center 2, the pre-schedule is made up of work requests sent by local managers in infrapoles and infralogs. The pre-schedule is sent to requesters (scheduling assistant in center 1, local managers in center 2) the day before the coordination meeting (at W-6).

Then, the coordination meeting chaired by the coordinator and gathering together all the requesters takes place. In center 1, the coordination meeting is about work requests at W-6, whereas, in center 2, the coordination meeting is about work requests at W-6, W-3, and W-1. In both centers, the pre-schedule is reviewed. To do so, the coordinator checks each request: the information composing it, details about the work execution, and the scheduling.

During the coordination meeting, the coordinator also resolves scheduling clashes. Indeed, if two works are scheduled at the same place and at the same moment, the requester must find an arrangement. If the works are compatible, they can be done together, but special procedures must be set up: this is called co-activity. If the works are incompatible, a trade-off has to be found or the coordinator's hierarchy will arbitrate.

After the coordination meeting, the coordinator sends a final schedule to the requesters. From W-6 to D-1, changes occurring on the final schedule due to hazard or work rescheduling. Finally, at D-1, the coordinator sends a daily work notice to switch men in switch posts. In the end, the daily work notice is less than 80% reliable in both centers.

6.2 The Artifacts

Scheduling practices use different kinds of documents.

First, S9C and S11 diagrams that respectively describe the protection procedure that has to be followed before work on the tracks or the catenaries takes place. S9C diagrams (figure 1) indicate the elementary protection zones (ZEP) for each station and line. ZEPs are track sections where the work can take place, and S11 defines elementary catenary sections (SEL) where work can take place.

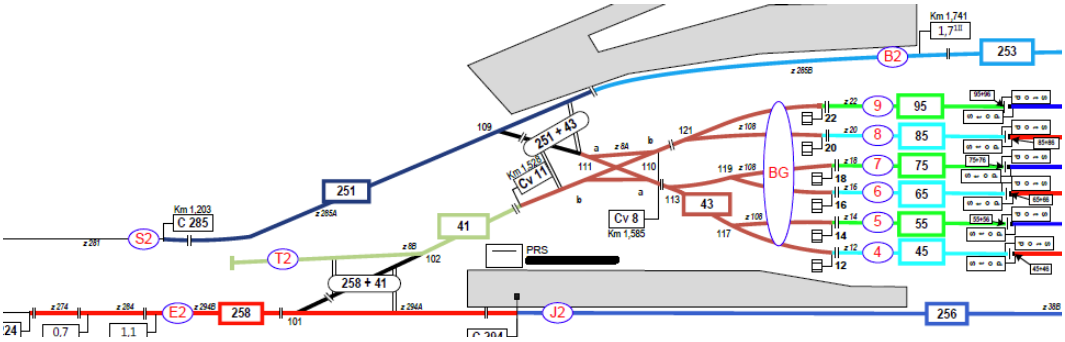

Figure 1. Extract of S9C diagram. Colored tracks show the ZEP areas, with ZEP numbers.

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On top of S9C and S11 diagrams, practitioners use temporary work instructions, which are local and temporary S9C or S11 instructions used to overcome some complex situations.

Finally, the coordinator uses three other artifacts:

- Corse: An application from the information system to manage work requests.
- Spreadsheets called local schedule, pre-schedule summary or final schedule summary (depending on the scheduling state). The spreadsheets list all the work requests for an area, with details for each request.
- Coordination diagrams: S9C diagram with work areas being colored (figure 2).

Those three artifacts mobilize the S9C or the S11 information.

In both centers, the schedule summary and the coordination diagrams are used to support the articulation work. Initially, Corse was designed to support articulation work between requesters and coordinators, but we have noticed how the coordinator is using spreadsheets to workaround Corse in order to bypass the built-in workflow.

6.3 The clash detection

Clash detection is one of the main issues of the work scheduling activity. In order to prevent scheduling clashes during the coordination meeting, the coordinator must identify them before. Clashes are defined as two works scheduled at the same time and place.

Clash detection relies on the pre-schedule summary spreadsheet, the S9C and the temporary work instructions. To detect a clash, the coordinator identifies the work area of each request. To do so, they review each work request listed in the pre-schedule summary (spreadsheet). Indeed, for each work request, the day, week, starting and ending times are indicated. ZEPs, ZEPs' groups, switch posts,

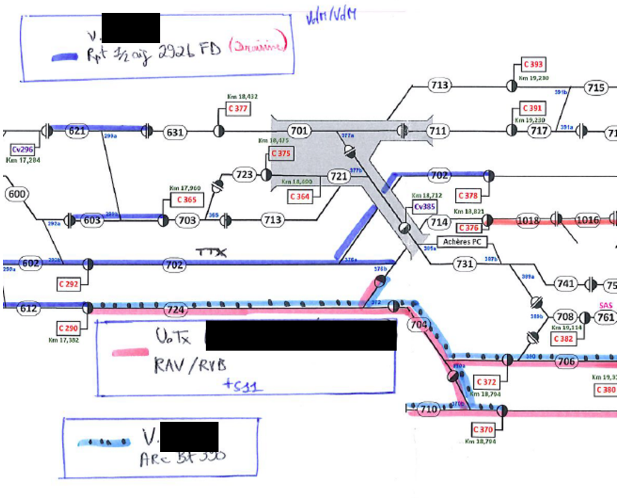

Figure 2. Extract of Coordination diagram. Colored tracks show the work areas, with ZEP numbers in the oval.

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elementary catenary sections, and stations also help to identify where works are scheduled.

Therefore, in order to identify clashes, the coordinator looks, for each night, the ZEP or the ZEPs groups that are planned to be used during the night. If it is a ZEPs group, the coordinator breaks it into ZEPs, following the S9C. The coordinator then colors the work areas. If he identifies two works in the same area on the diagram, he then raises a clash. The coordination diagram identifying clashes is then sent to the requesters before the coordination meeting in which the clashes will be discussed.

7 Technology probe

The analysis of our fieldwork based on coordination mechanisms has allowed us to identify that the scheduling activity makes use of a cluster of five main artifacts (S9C, S11, Corse, schedule summary, and coordination diagram). When focusing on the clash detection practice, we identify that coordinators use the schedule summary, S9C, and coordination diagram as follows:

- The schedule summary lists all work requests, ZEP name identified work areas
- The S9C defines the ZEP localization and associates a name for each ZEP
- The coordination diagram, made by the coordinator, transcribes the schedule summary into a diagram using the ZEP definition in the S9C.

To study if we can design end-user applications supporting coordination based on the railway infrastructure's digital twin, while continuing to understand the work scheduling practices, we have designed a technology probe that is a computational version of this identified coordination mechanism. This CCM would automatize the clash detection activity and let the human actors focus on resolving the conflicts. Regarding the symbolic aspect of the artifact, we have tried to design an artifact close to the coordination diagram that is currently used. However, track diagrams cannot be easily digitalized, so we have chosen a cartographic interface to depict work areas and clashes.

The input data are the digital twin data (that contains information that is in the S9C), the work summary and pre-schedule summary spreadsheets. Comparing data from the digital twin with the pre-schedule summary spreadsheet allows the identification of areas of work requests and therefore clashes.

The probe consists of five components:

- A script to structure ZEPs and ZEP's group data. It initiates a local cache database that stores ZEP data from requests on the digital twin into a cache database structured by switch post and station. It initiates the probe.
- A script to automatically translate work summaries into geographical data. It takes the work summary and the cache database as input and for each request: It identifies the switch post or the station, then the ZEPs or ZEP's groups involved in the request, searches for the geographical ZEP features in the database and associates request information to the ZEP shape. Finally, the script associates all the requests into a GeoJSON work summary (request.geojson) where each work request is described by a geographical feature.
- A script to automatically translate work summary into geographical data. It takes the GeoJSON work summary as input and makes a geographical intersection between work requests. If the intersection is not null, a clash object is created with the shape of the intersection and the properties of both conflict requests. All the clashes are aggregated into a clash.geojson
- A cartographical platform to visualize work requests and clashes on a map. Both files, "request.geojson" and "clash.geojson" are interpreted by the ArcGIS online platform (Esri, 2020). By using the web app-builder, we have made a web application that shows a map with requests and clashes.

The application then allows the visualization of request and clash details, to filter requests and clashes by day, and to navigate through the requests in a table. (figure 3)

To update the cartographical representation, the coordinator has to run the second and third script to produce an updated "request.geojson" and "clash.geojson" that he can drop on the cartographical platform.

This probe demonstrates two things: firstly that the data contained in the SCNF Réseau digital twin are compatible with the ones that are contained in the artifacts that support the actual practice (S9C and ZEP). Secondly, building end-users applications on the digital twin can benefit practitioners. Indeed, in our case, the coordinator puts a lot of effort into coloring the coordination diagram, based on all the requests. The probe, which integrates the digital twin's data (S9C and ZEP), can then link the schedule summary and the coordination diagram and therefore automate clash detection.

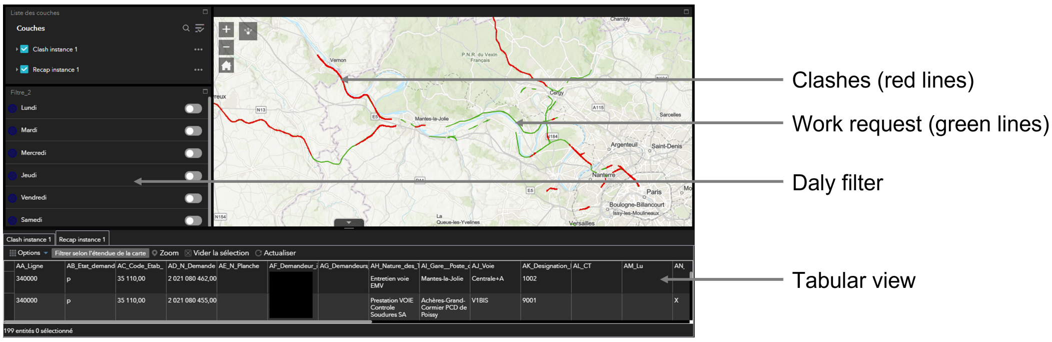

Figure 3. Cartographic probe user interface.

8 Discussion

Our work provides two contributions. The first consists of demonstrating the interest of a digital twin to rapidly deliver an application that supports coordination practices that were not easily supported before; In other words, the digital twin probe is a starting point towards an information system supporting effortless coordination (Schmidt, 2002). Indeed, thanks to the existing data model, data warehouses, and the updating process, we were able to deliver the probe with the definition of 1,508 ZEPs and 605 ZEP's groups. The needed data was requested with 35 HTTP requests. By relying on these technological capacities, and with the help of a cartographical platform, we were able to design the probe that shows requests and clashes over three months. To go further, we have identified two key factors enabling the implementation of the CCM. Firstly, as the semantics of the digital twin have been co-constructed with the practitioners, the objects, their definitions and their links are consistent with the rail network elements' technical definitions and with the terminology used by the practitioners. Secondly, as defined by Tao and Zhang (2017), the digital twin is a physical, virtual system and a set of services evolving around a common data set. In the SNCF Réseau information system architecture, this translates into data warehouses requested by several services. Thus, the data is normatively defined (by the data model) but its use is not pre-defined. Getting a global view of the infrastructure just requires requesting a unique data repository. The data warehouses then significantly simplified the development of the probe.

Our second contribution is related to the potential of the digital twin for infrastructuring. Indeed, the technology probe we have designed bridges the different coordination artifacts through the data it embeds, which profoundly transforms the information system from an ensemble of disconnected applications and artifacts to an ordering system and towards an information infrastructure. This finding supports the conclusions of Susan Star (1999) , Bossen and Markussen (2010): digitization makes it possible to automate the links between the artifacts used by the practitioners, which reinforces the coupling between the artifacts but also makes the links between them invisible, which tends towards the construction of an information infrastructure. We therefore claim that the digital twin is a step towards the infrastructuring of the ordering system.

9 Conclusion

The digital twin is one of the technologies at the heart of Industry 4.0. Even if one of the intended uses of the digital twin is to support the cooperation between different businesses by providing a shared digital representation, few studies have investigated this opportunity.

Thus, in this exploratory study, we sought to examine the role the digital twin can play to support articulation work. We conducted a multi-sited ethnography in two work scheduling centers, which allowed us to highlight the entanglement of practices and artifacts that coordinators and requesters mobilize. Based on this study, we have designed a technological probe based on the digital twin. The results of this study firstly show that the work scheduling practice requires complex articulation work. Secondly, practitioners articulate around a constellation of artifacts, and the links between these artifacts are performed manually. Thirdly, we quickly achieved the design of a technological probe that supports a part of the protocol. Fourthly, this probe highlights that the digital twin tends to automate the links between artifacts. Finally, we argue that the digital twin participates in the creation of an information infrastructure. In this infrastructure, we have identified the importance of referential data: data shared between different professions, normatively considered as true.

Acknowledgements

We thank the coordinators and the managers of the coordination centers, unit managers, local managers, assistants, and all the other actors of SNCF Réseau for their participation in this study. We also thank Eddie Soulier for his management of the UTT/SNCF Réseau research program. Finally, we would particularly like to thank the actors of the digital twin at SNCF Réseau, in particular Bruno Landes, Sofia Costa D'Aguiar and Jean-Christophe Michelin who made this research possible. This research is funded by SNCF Réseau in the framework of the BIM and digital continuity program.

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