# <Consideration of human factors during the construction or modernization of a line>


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### INTRODUCTION

Over the last few years, the railway sector has become more complex, not only due to the progress of technology, but also due to the multiplication of actors coming into a fragmented environment. Whereas only one historical railway company existed before, dealing with every matter: projects, renewals, upgrading, maintenance, operation, etc., there are now a lot of different actors working on the same project, all of them assuming their own responsibilities. With this new context it is necessary to ensure that all risks, especially these related to human factors, are covered while developing projects.

The object of this paper is to present, through an actual example, the consideration of human factors during the construction or modernization of a line, in order to significantly reduce safety risks.

The chosen example is the one of the modernization project of a French network single track line between Bourg en Bresse and Bellegarde-sur-Valserine, called the Haut-Bugey line.

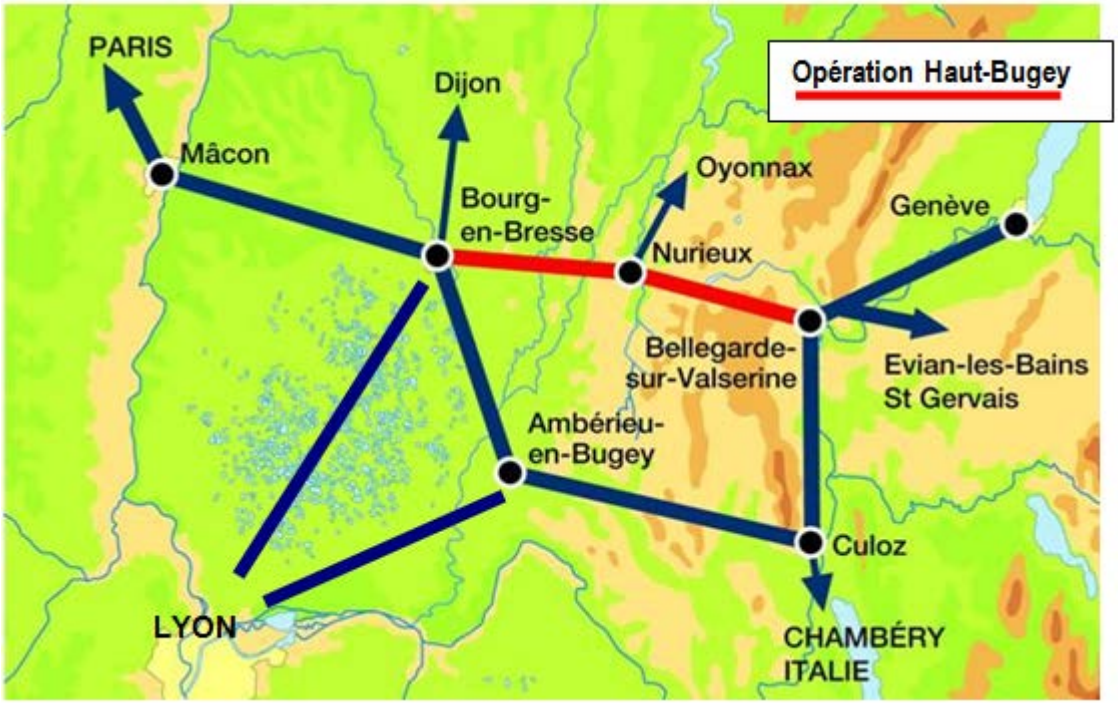



***Figure 1: The Haut Bugey line***

**A VERY CHALLENGING LINE TO OPERATE**

Built in 1876, closed in 1990 and renovated in 2010 to link Paris and Geneva in only 3 hours as opposed to 3:20 before), the Haut-Bugey line is at the very outset, a very challenging line to operate .

## Environmental features

Located in a mountainous region, its route is particularly tortuous with several curves of radius below 300 m. Besides this, there are many steep gradients that can result in significant risks of runaway (steep gradients are greater than 10 mm / m on 50% of the line and greater than 20 mm / m on 25% of the line).

Its structures are numerous and imposing (10 tunnels of different lengths, 49 railway bridges, 5 viaducts ...). The large number of detectors and protection nets from rock falls (presence of large rock walls along the line) means that the risks of false alarms due to weather conditions (thunderstorms, snow, thaw) are high. Climatic conditions are difficult (120 rainy days per year, 65 days of frost, 27 days of thunder, heavy snow, ice formation in tunnels) and can lead to risks of wheel-slip, wheel-lock, and risks of track shift.

To this is added:

- high passenger numbers in winter,
- numerous tourists during summer that may potentially cause a risk of unauthorized presence on tracks,
- the construction of central platforms in all the stations including the construction of one located just at the end of a tunnel, at a gradient of 22 ‰ and a curve of 300 m making access to TGVs difficult,
- the majority of track crossings being boarded crossings multiplying the risks of passenger accidents,
- the presence along the line of 42 level crossings located in high traffic areas or in tourist zones, or even in areas of difficult track geometry,
- and since the renovation of the line, the existence of rare, not to say, unique installations on the French national railway network making the operation of the line much more delicate and more complex.

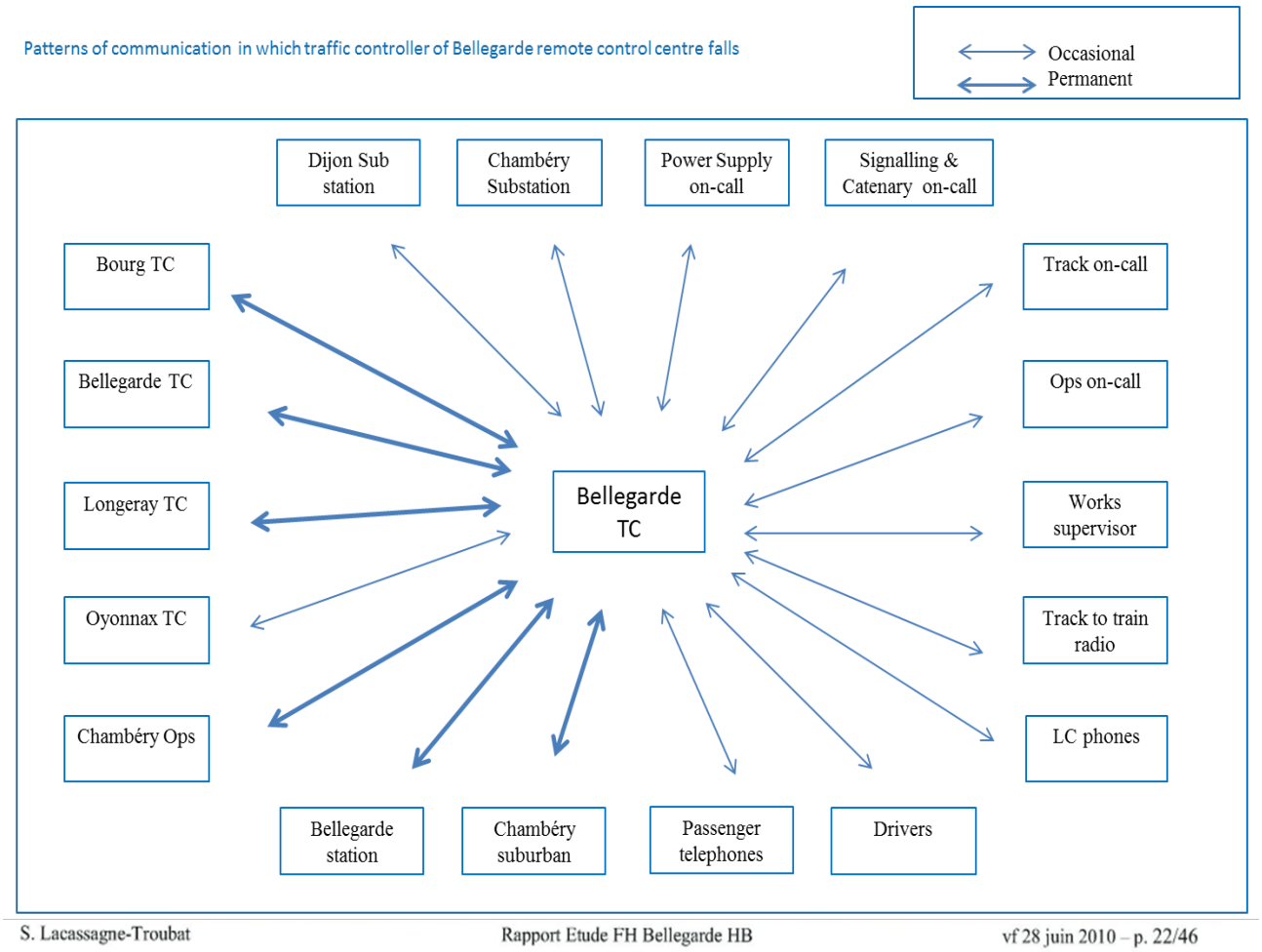
These rare or unique installations are:

- a remote control centre in Bellegarde station,
- a catenary switching device from 1500 V dc to 25 kV ac linked to the route, also in Bellegarde station,
- a 25 kV ac catenary power supply feeder to be used in case of emergency.

If each of these features taken individually can be easily handled; once gathered together they lead to real and important operation and maintenance risks including some which are linked to human factors.

## Specific Installations

Due to the installation of a remote control centre in Bellegarde station, the personnel has had to adapt to a new mode of rail traffic control and to new technology: from an originally active and sometimes physically taxing role, the job of the rail traffic controller, has evolved to one of monitoring, the management of alarms takes a more important place in the controller's work, his communications which are crucial in his occupation greatly increase (they may even be saturating in crisis situations), become less frequent with local players and more frequent with distant players.



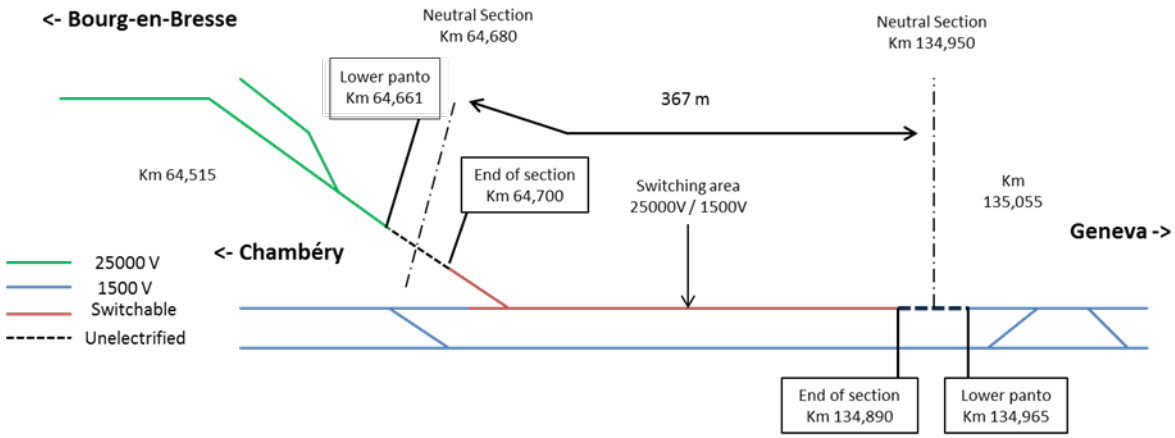

*Source: translated from Dossier de sécurité - Rénovation de la ligne du Haut Bugey V3 du 10/11/2011 – Annexe 29*

***Figure 2: Patterns of communication of traffic controllers in charge of Bellegarde remote control centre***

An inadequate adaptation of staff to new technologies could lead to incorrect application of procedures in case of disruption, to immobilization of trains and to the presence of passengers on the track.

Another installation complicating the operation of the Haut Bugey line, is the installation in Bellegarde station of a unique type of catenary switching device from 1500 V dc to 25 kV ac linked to the route.

Bellegarde station is located at the interface of two voltage areas (25kV ac between Bourg-en-Bresse and Bellegarde and 1500 V dc between Bellegarde and Geneva). Thus in order to allow better traction of trains at the exit of Bellegarde station on the rising gradient to Bourg-en-Bresse and to take into account the project of electrification at 25 kV ac of the section of the line between Bellegarde and the Swiss border, the installation in Bellegarde station of a unique type in France of catenary switching device from 1500 V dc to 25 kV ac linked to the route and remote controlled by Bellegarde remote control centre, was considered the best solution.



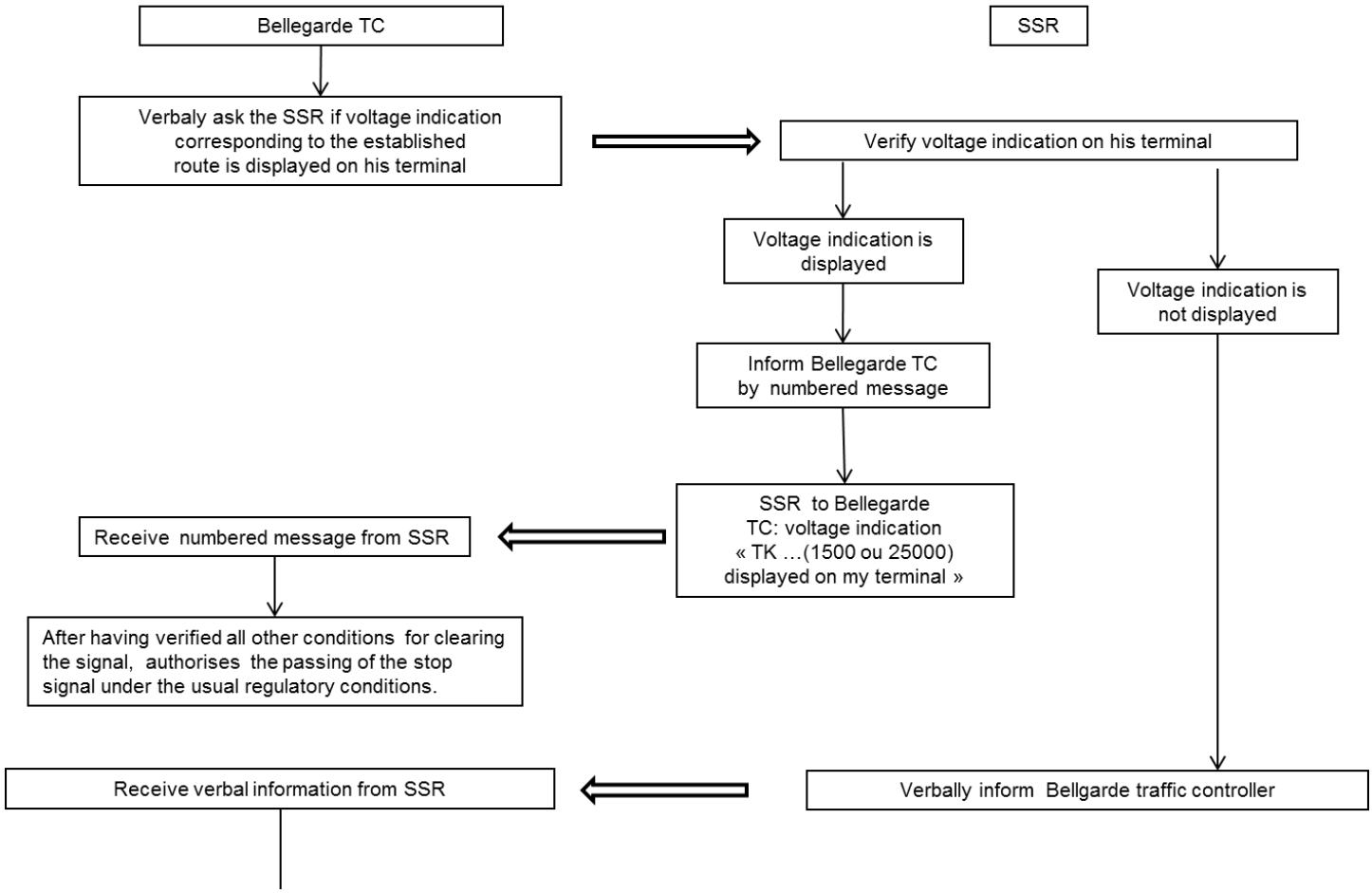

*Source: translated from Dossier de sécurité - Rénovation de la ligne du Haut Bugey V3 du 10/11/2011*

***Figure 3: Catenary switching device***

The catenary is thus supplied at 1500 V dc or at 25 kV ac depending on the route established by the remote control centre (the clearing of the controlled protecting signal being conditioned by the presence of catenary voltage). The voltage is monitored by a programmable controller.

Consequently, control / command incidents at the remote control centre (circuit breaker or switch dysfunctions...), could lead to command and control failures for the route to Haut Bugey, prolonged immobilization of trains before station platforms, passengers on tracks, train running on sight and power trip. These degraded situations could cause stress for remote control centre staff, which in an environment as restrictive and complicated as the one at Haut Bugey, might make situations worse if they are not trained to the particular characteristics of the installation and do not have the ability to work with many people of different disciplines and remote from the centre. It is known that communications dysfunctions in rail traffic control predominate in the majority of incidents.

After setting a route, the signal does not clear and the corresponding voltage indication (« KT 1500 » or « KT 25000 ») is not displayed




*Source: translated from Dossier de sécurité - Rénovation de la ligne du Haut Bugey V3 du 10/11/2011 – Annexe 29*

***Figure 4: Extract from safety installations instructions of Bellegarde control centre***

These difficulties are exacerbated by the existence of a standby 25 kV ac catenary power supply feeder to be used in emergency.

This emergency feeder has been installed as there is only one 225 kV /2*25 kV substation on the Haut Bugey line and the 25 kV ac section between Bourg-en-Bresse and Bellegarde is located between two sections electrified at 1500 V dc. Use of the emergency feeder can be complex in case of accidents or incidents on the catenary and in case of intervention of maintenance staff. By definition it represents a serious electrical hazard and requires the acquisition of essential job skills.

From these elements, we can legitimately conclude that:

- the operation of the renovated Haut Bugey line is complicated both for the train traffic controller in charge of the remote control centre (workload potentially high, dealing with multiple incidents), other operators, maintenance staff, central substation staff, drivers ...
- the risks of incidents derive from both technical components and organizational and human factors.

Thus in order to contribute to handling the risks and to facilitating decision making in the context of a degraded situation, the Infrastructure Manager (Réseau Férré de France) identified, well before the end of the project, the need to provide human factors support.

**PROVIDING HUMAN FACTORS SUPPORT**

According to F. Daniellou « Facteurs Humains et Organisationnels de la Sécurité industrielle : un état de l'art », Avril 2009, Institut pour une Culture de la Sécurité Industrielle (ICSI) : "Unlike automated systems,

the human being is capable of handling the changeability of situations, adapting responses to context or correcting errors. Human contribution to safety is globally positive and should be facilitated".

Therefore, Réseau Férré de France instigated during the implementation stage of the Haut Bugey line, over a period of 6 months, a dedicated study of human factors. This study was carried out in cooperation with a human factors specialist and specialists of operations, maintenance and electrical installations.

The requirements of this study were to:

- prepare local agents for technological change,
- develop tools for traffic management in both normal and degraded situations,
- establish process for dealing with degraded situations,
- estimate the admissible staff workload.

The study was conducted in two parallel lots:

- the first consisted of contributing to the control of the risks associated with the catenary switching device from 1500 V dc to 25 kV and the emergency catenary power supply feeder, by working in collaboration with staff at the design stage, in order to ensure that they had identified and understood all risks of dysfunctions and their corresponding procedures.
- the second lot consisted of assessing the robustness of Bellegarde remote control centre's planned organization by identifying in documentation and at similar sites, elements that could contribute to the reflection on the organization of Bellegarde remote control centre.

## Lot one: controlling risks associated with the catenary switching device and the catenary power supply feeder

Regarding the first lot and specifically risk control related to the catenary switching device, the issues were:

- to understand operation of the catenary switching device,
- to identify possible malfunctions related to the operation of the catenary switching device,
- to define managing procedures of these malfunctions,
- to include these procedures in documentation,
- to prepare on-site staff to manage those situations.

Specifically, behaviour of a single or multiple unit vehicles in case of accidental immobilisation under the catenary switching device following an incident involving the train or the installations was studied. It was found that the management of such an incident (especially operational dialogue between the train driver, substation controller and the traffic controller in charge of the remote control centre) differed according to the specific location where the train was immobilized, the direction of travel and the composition of the train.
Also studied was how staff would deal with programmable controller malfunctions (lack of voltage monitoring).

Following this, it was decided:

- to write a special operating procedure for the management of train distress scenarii under the catenary switching section,
- to include this process within the procedures for Bellegarde traffic controllers, substation controllers and staff that could be called to intervene on the catenary switching device in case of its failure,
- to include relevant information in driver training,
- to produce documents on the conditions of intervention on the switching catenary device for maintenance staff.

Once this done, it was decided to:

- ensure good understanding by the staff of what they should do in case of an accident involving the catenary switching section. To this end, it was decided to incorporate simulation exercises in their training,
- to check the consistency of the documents on the subject to facilitate mutual understanding of agents who will have to manage these situations together,
- to specifically monitor during, the operation of the switching catenary device for the first few months and to take particular care on incident feedback involving the section, especially with respect to the training and communication components.

Still on the subject of the first lot but regarding this time risks related to the 25 kV dc catenary power supply feeder, issues were:

- to understand its operation,
- to define its use and operation conditions,
- to write those conditions in documentation,
- to facilitate the appropriation by staff at the design stage the limits and conditions of use of the catenary power supply feeder.

So after clarifying the synchronisation of maintainers' local interventions and the repowering of the feeder to rescue a train on the line, the human factor working group advocated:

- the organization of knowledge sharing on the basis of catenary power supply feeder instructions,
- the organization of an exercise to test its use in conditions close to real operations.

## Lot two: assessing the robustness of Bellegarde remote control centre's planned organization

Regarding the second lot, the study consisted of assessing the robustness of Bellegarde remote control centre's planned organization both in normal and degraded situations.

Issues of this study were:

- to prepare local staff for the technological change of operating mode by training them,
- to develop tools for traffic management in both normal and degraded situations,
- to establish a process for managing degraded situations,
- to estimate the admissible staff workload.

Further, particular attention was paid to:

- operation of novel installations,
- clarity and readability of procedures,
- document accessibility,
- procedure consistency,
- remote control centre ergonomics,
- alarm management,
- tools and installation maintenance,
- competency profile,
- training,
- management,
- workload,
- team composition.

It was consequently decided at the end of the human factors study:

- to adapt Bellegarde traffic controllers' training to their specific situation,
- to organize meetings between train traffic controllers and players with whom they will have to work in order to avoid communications errors,
- to regularly ensure, before the definitive operation of Bellegarde remote control centre, rotation between the old and the new control centre so that traffic controllers keep their knowledge of the remote control centre particularities,
- to adapt the ergonomics of Bellegarde remote control centre.

**CONCLUSION**

Over the last few years, the railway sector has become more complex, not only due to the progress of technology, but also due to the multiplication of actors coming into a fragmented environment. With this new context, risks are increased and it becomes essential to take into account human factors notably during the construction or modernization of a line, as they have a significant effect on the level of safety.

Indeed, since human factors studies have been carried out on the Haut Bugey line and despite its complexity of operating, no accident related neither to specific installations nor to new technologies or even nor to communications dysfunctions has occurred since the line has become operational.

**APPENDIX 1:**

**APPROVAL TO PUBLISH PAPER**

I/We ..Frédéric Hénon and Sarah El Saad
.....

of Company (if applicable) Etablissement Public de Sécurité Ferroviaire
.....

hereby give permission to the International Railway Safety Conference 2012 (IRSC 2012) to publish the paper titled:

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