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# METROPOLITAN TRAFFIC CONTROL ACTIVITIES AND DESIGN OF A SUPPORT SYSTEM FOR THE COORDINATION OF ACTIONS IN FUTURE CONTROL ROOMS

**J. Theureau, G. Filippi**

## Abstract:

The present study concerns the analysis of the collective organization of the multiple courses of action in a metropolitan traffic control room, and the design proposals for future control rooms it allows to make in terms of support system for coordination of actions. Through this study, we present the different notions of support system for the coordination of actions, course of action, global and local dynamics of the course of action, significant unit of course of action, collective organization of multiple courses of action, along with the different methods being used in data collecting and analysis (continuous observation, instigated verbalizations, self-confrontation, analysis into significant units).

**Key words:** computer supported cooperative work, work practice analysis, support system for the coordination of actions, course of action, global/local dynamics of the course of action, significant unit of course of action, collective organization of multiple courses of action, continuous observation, instigated verbalizations, self-confrontation, analysis into significant units.

## 1. SUPPORT OR PROSTHESIS?

The investigations which we will be presenting here form part of a research programme whose objective is the design of computer systems in terms of **support systems for users**. This research programme was initiated fourteen years ago by an investigation aimed at designing a system for a data collection and coding station (Pinsky 1979). Since then, it has been developed in various work situations: offices, hospitals and other services, management of sequential and continuous industrial processes, air and urban traffic control and agriculture.

Such a design in terms of support systems for users involves: helping the user to understand the situation and take action himself, including the search for information; relieving the user as much as possible (within technical and economic limitations) of the details of data supply and the fulfilment of action, in so far as these are unnecessary for an understanding of the situation. The computer system is, in that case, a tool among others, one element in a support system which, apart from itself, is composed of **documentation**, **training**, **organization**, and **other sources of information** on the situation here and now.

This design in terms of support is an alternative to the design in terms of **cognitive prosthesis** which emerged at the beginning of computerization and is still dominant (see Woods & Roth, 1988, for its criticism). A computer system designed as a cognitive prosthesis is supposed to concentrate the intelligence of experts (hence the commercial name "expert systems" for the most sophisticated of these systems). Ideally, the role of the user is that of a cognitive invalid: to provide data for the system in so far as the latter is unable to acquire them in other ways (within technical and economic limitations); to understand the instructions of the system and to act accordingly, in so far as the latter cannot act alone (within technical and economic limitations).

Such systems generally reveal they have not attained the desired ideal by also allocating another role to the user : to manage on his own when the system fails. Hence a contradiction which can entail a heavy price to pay, for both the actors and the quality and quantity of the production: on the one hand, if the user thus accepts to lose, under ordinary circumstances, his decision-making powers and the means to implement them, he plays the role of a cognitive invalid at the high risk to become one; on the other hand, he is called upon to play the role of a super-expert in certain isolated circumstances.

To design support systems for the users in specific situations is not an easy task. It requires a creative and future oriented synthesis of three kinds of analysis:
1) analysis of the global activity of specific users, having a specific culture, in the situations that are concerned, non-computerized or comprising an unsatisfactory computer assistance (for the definition of what must be assisted by computer);
2) analysis of the global activity of assistance supplied to the user by other more competent users in these situations (for the inspiration provided for the design of computer support through the knowledge of human assistance);
3) analysis of the global activity of users in other situations with a more satisfactory computer support (in order to define the computer support using the highest technical possibilities).

Therefore, this research programme has been essentially concerned by the theoretical notions and methods which are needed to make these three kinds of analysis in the current constraints of design processes, with sufficient accuracy and validity for the design of support systems (see Theureau, 1992).

We will be concerned here by the first kind of analysis in the RER A line control room.

## 2. THE RER A LINE CONTROL ROOM

This investigation is part of a wider research[1] which links the analysis of public announcement to the analysis of traffic control in order to guide the modernization of the different technical and organizational components of the complete chain of traffic supervision, starting from the control room and ending up with the passenger.

[1] M. Grosjean and I. Joseph studied other aspects of this work setting. Different theoretical and methodological discussions took place with C. Heath and his colleagues, who were developing a similar research in the London underground (see Heath & Luff, 1991).

It concerned the control room of the RER[2] A line which was, at the time of the study, undergoing important changes. On the one hand, computerization was progressing: it concerned the rolling stock follow up, new functions of signalling and automatic calculation of train delays at each station. On the other hand, the control room was moving to a larger room because of the line's extension towards Euro-Disneyland, which was the occasion to modify it's general layout.

With 70 000 passengers per hour at peak hours, the RER A line has one of the world's heaviest traffic density in urban rail transport. It's operating is relatively complicated because of two forks at both ends of the line and of it's connection with the French railway company (SNCF) and the two different kind of rolling stock incompatible with each other it entails (Figure 1). Every train is identified by a name which indicates its itinerary (such as ZHAN 07 or NAGA 12).

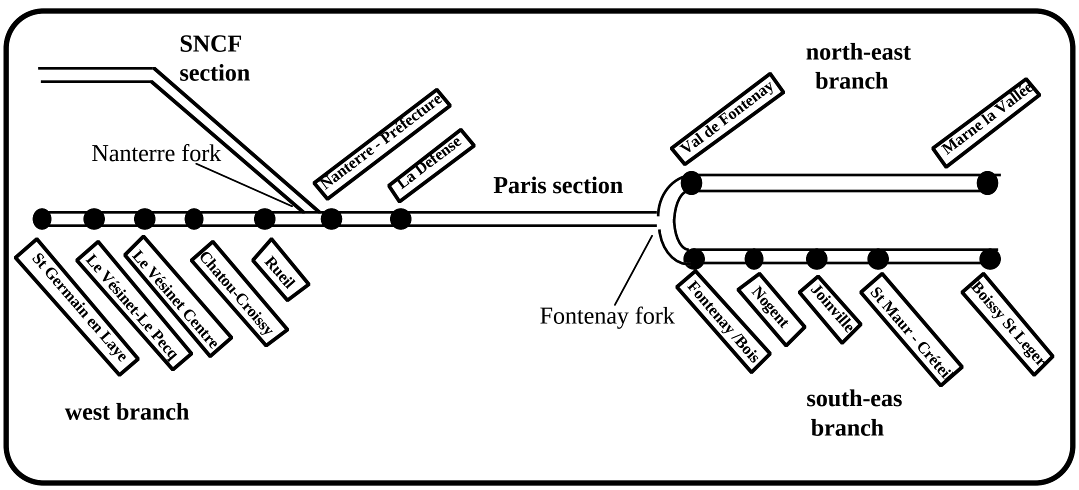


**Figure 1: The RER A Line**

Technical facilities available in the control room have been added gradually with traffic growth and were not designed as a coherent apparatus. This includes means of communication (telephone and radio), a fix-line diagram representing traffic movement in real-time, computer consoles showing the same kind of information but in greater detail, and working documents, including the graph of train movements, the duty roster for drivers, etc.

Controlling the RER traffic is a collective activity which involves about a dozen operators in the room: a team of three Controllers in charge of the different geographic sectors of the line: West, South-east and North-east., each having two signal assistants under their responsibility,

[2] The Reseau Express Regional is a high speed suburban branch of the Paris metro.

an Information assistant and, in the event of disruptions, the managerial staff of the line. (Figure 2). The controllers are responsible for ensuring the smooth running of the trains in case of disruptions (small and moderate disruptions are usual during peak hours), implementing actions to control traffic by taking into account the supervision of drivers, following the rolling stock and handling their entry into the depots (maintenance and repair). The signal assistants establish the itineraries, check the times the trains passing through their sectors and inform the controllers of any delays, they control the movement of the rolling stock by carrying out the instructions for the trains to be shunted in or out of the sheds and by keeping an accurate account of the shunting positions. They also check the time-tables posted in the stations and make amendments when necessary.

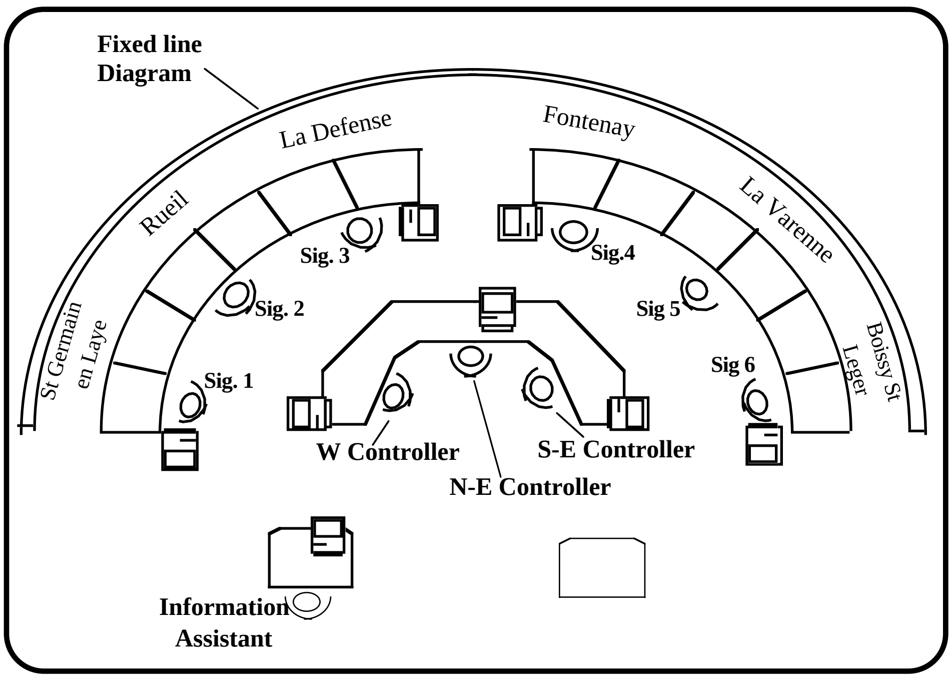


**Figure 2: The RER A Line Control Room**

We therefore have a work environment with teamwork considered as fundamental, which is immediately reflected by the importance, on the one hand, of the verbal communication between the various control room officials, and on the other hand, of the radio and telephone links with persons external to the control room, such as train drivers, station masters, depot managers and other operators.

## 3. THE COLLECTIVE ORGANIZATION OF MULTIPLE COURSES OF ACTION

Let's consider the system constituted by the control room and it's actors. It is fairly **complex**: it involves many different components, which are linked in many different ways.

Besides, many of these components can't be observed directly. Most of the physiological processes can be observed only in the laboratory, and can be analyzed only with very simple tasks and environments. But this complexity is not the main difficulty. It can be overcome by defining a level of the system which can be analyzed in the natural situation.

The main difficulty is that it involves **autonomous** systems. The system formed by each actor with his environment (including the other actors) is autonomous. This autonomy is, for a current of research initiated by Maturana and Varela, a fundamental characteristic of human actors, and more generally of living systems. It is the capacity of such an actor or living system to exist as a unit and to make a relevant and significant, while not pre-defined in advance, world to emerge (Bourgine & Varela, 1992). The important consequence of this autonomy is that, at a given moment, an actor interacts with a situation in the emergence of which he has himself contributed, with his physiological constitution, his history and his interactions with the immediately preceding situation. Therefore, this situation has neither spatial or temporal boundaries nor content, which can be determined a priori. The content and the boundaries of the situation depend on the actor and on his history , and vary with his interactions with the immediately preceding situation. In the case of the control room, where many actors are involved, the content and the spatial and temporal boundaries of what is relevant in the environment depend on the different actors and on their different histories, and vary with their different interactions with the immediately preceding situations.

A correlated difficulty is that the system formed by each actor with his environment (including the other actors) is **open**. It changes from day to day, not only because of the interactions which occur on the inside, but also because of the interactions of the actor with other situations: other work situations, the characteristics of which can be very different from those of the first one, and the situations of his different practices of leisure, household, etc... The control room, with its multiple actors, is a multiply open system.

These characteristics of the control room don't make the analysis of its dynamics impossible. They only oblige to define theoretical objects, which (1) take in account the presence of autonomous and open systems, and (2) the study of which can tell how and when this autonomy and this openness can be considered as limited.

Also, these theoretical objects must allow to make the best use of the resources of the situation to get the richest data as possible. If we consider an actor's environment (apart the other actors whose processes are accessible by the same way as the ones of this actor), most of the hidden physical processes are accessible by the intermediary of the knowledge of the physical laws and of the functioning of the machines, and by their observable effects, but also, in the case of a human built environment like the control room, by the intermediary of observable symbolic representations of the traffic, of the signals and of the electric power supply, displayed by different tools, which can be symbolic-iconic (like fix-line diagram), symbolic-indexical (like the color indicating the presence of a train on the fix-line diagram) or full fledge symbolic (like the mission numbers of the trains). If we consider the actor himself, if most of his internal processes are non-accessible in natural situations, his behaviour is accessible, but also his reflexivity about his behaviour and other elements of his activity. It gives a third criteria for a theoretical object, concerning the data it allows to consider: on the one hand, the data about the environment must include the most of which is observable, and not only the symbolic representations, and on the other hand, the data about actors must include reflexive data, and not only behavioural data.

As a theoretical object, matching these three criteria, we will study the **collective organization of multiple courses of action** in the control room. We define the **course of action** as:

*The activity of one specific actor, actively engaged in a specific situation, belonging to a specific culture, which is significant for the latter, in other words, that can be related or commented by him at any moment to an observer-interlocutor.*

The aim of the study on the course of action is to understand its **intrinsic organization** and its e**xtrinsic constraints and effects** in the **state of the actors**, their **situation** and **culture**.

This significant activity for the actors, constituted by the course of action, includes action and communication, but also other elements: interpretations, feelings, changes in focus, perceptive, proprioceptive and mnemonic judgements, their commitment to the situation and their use of past experience in the present course of action. It can be described from two complementary points of view: from the point of view of its **global dynamics**, characterizing the units of the course of action and the relations between these units; from the point of view of its **local dynamics**, characterizing the underlying structure of the elementary units.

The data necessary to study the course of action must therefore include **continuous observations** of the behaviour of action and communication in a work situation as well as different kinds of **instigated verbalizations** from the actors which would provide access to other elements.

The analysis of these data is carried out according to the principle of the **primacy of the intrinsic description** of the course of action over the extrinsic description of the state of the actor, the situation and the culture. As in fact demonstrated by various ergonomic studies (Montmollin 1972), the definition of the "aptitudes" of the actors outside their work activity is limited, and leads to scientific errors with disastrous practical consequences. Likewise, to reduce the work activity to a component of the situation, the "task", even if it is only to demonstrate the divergences from it, is of limited explanatory interest. For example, it makes it possible to distinguish the errors but says little on their origin (Pinsky & Theureau, 1982). Finally, the pertinent characteristics of culture are difficult to define outside the work activity. The actors put into practice all or part of their acquired experience in other practical activities (ibidem).

The study of the course of action concerns individual actors. In the case of cooperative work, it deals with the collective aspect of the activity of these actors, but only in terms of the social character of its elements: communications, actions directed toward other actors, interpretations, feelings, changes in focus, perceptive and mnemonic judgements concerning the behavior of other actors. To deal more thoroughly with this collective aspect, we have to study the **collective organization of multiple courses of action**:

*The synchronic and diachronic relations between the intrinsic organizations of the courses of action of the different actors of the control room, and their constraints and effects in the state of the actors, their situation and culture.*

## 4. THE DATA ON THE COURSES OF ACTION IN THE CONTROL ROOM

The information collected must permit a thorough analysis of the cooperation between the staff in the control room. But in order to understand the group as a whole, we believe that one must first focus on individuals in the situation.

We don't mean that the individual is prior to the collective. First, we say that we must know the individual activities to know the collective activity, and also to be able to improve the design of both the individual situations and the collective situation. Secondly, we say that it is easier for the observer to begin with the individual courses of action, and also that it facilitates the cooperation of the operators, by showing them that the research is aimed, not only at improving the performance - which is evidently collective - , but also at supporting the activity of each individual.

Thus, as a first stage, we carried out an **analysis of the individual courses of action** of the various staff members in the control room: controllers, signal assistants, information assistants. The purpose was to clearly follow the course of action of each person concerning the traffic control, while seeking to understand what the actions of the other colleagues mean to this person.

One can then consider collective action as such, as several individual courses of action which take place synchronically, so as to see how they are linked to each other to constitute a coordinated collective activity whose characteristics would then have to be defined. It is this **analysis of the collective organization of multiple courses of action**, which we realized as a second stage. This analysis is to compare with Hutchins's studies in cognitive anthropology, in which this author puts forward the notion of "distributed social cognition", use the group as a unit of analysis, that is to say, a functional cultural unit. This last theoretical approach makes it possible to describe cognitive processes by tracing the movement of information through the "joint cognitive system" (Woods & Roth, 1988) composed of men and technical artefacts. In the analysis of the collective organization of multiple courses of action, we aim at trying a synthesis between the analysis in terms of social courses of action and of the analysis in terms of distributed cognition, in order to articulate the individual-environmental coherences (which make, for example, that an individual notices a problem, before collectivizing it) and the social-environmental coherences.

The choice of data to be collected is induced by this interest in the cooperation between officials in the course of their traffic control activity. But it is also induced by the possibilities offered by the work situation. It is in consideration of these possibilities that we decided to observe **moderately disrupted situations**, that is to say, all the usual incidents that occur nearly every day at peak hours (emergency breaks, late trains, etc.), rather than to focus on major incidents which, on the one hand, are too complex to understand in detail and, on the other, imply very heavy individual responsibilities which the persons involved must account for to their superiors. This choice therefore depends just as much on methodological criteria as on criteria linked to the social organization of work.

The data collected covered:
- **continuous observations** of the behaviour of action and communication of diverse chief controllers and signal assistants in the control room which consisted of recordings (by tape recorder and video camera), completed by notes on the events taken into account by each actor and the actions of the others when related to his course of action;
- different kinds of instigated verbalizations from the actors, in particular those arising in **self-confrontation** interviews: the operator is shown a video recording of his activity and he is asked to comment on very specific aspects of his behaviour. The purpose of such an exchange is not only to obtain a description of the operator's activity from his own point of view, thereby eliminating the risk of the observer making erroneous interpretations, but also to probe more deeply into the problems encountered by the actor.

During the first stage, with a view to analyzing the courses of action of each individual, we made several observations, with a camera focussed on a controller and a microphone in the middle of the team of controllers.

Likewise, during the second stage, in order to perceive the synchronic linkage between individual activities, we collected systematic data on **"subsets of cooperation"**:
- three controllers belonging to the same team who are constantly coordinating their actions in order to control the line's total traffic;
- a traffic controller and the signal assistants of his geographical sector, who have to work together concerning their part of the line.

These observations were made with two video cameras and two tape recorders.

The duration of the observations was about three or four hours, corresponding to the peak hours and their preparation, that is to say, roughly from 6. 30 a.m. to 10. 00 a.m. and 3. 30 p.m. to 7. 00 p.m. The choice of these observation periods corresponds to the times during which the common incidents which we wished to study were likely to occur.

## 5. THE ANALYSIS INTO SIGNIFICANTS UNITS OF THE COURSES OF ACTION IN THE CONTROL ROOM

Now that we have rich enough data on the courses of action of RER traffic control, it is a question of analyzing them. The theoretical framework, which we have described as **semio-logical**, makes it possible to describe the courses of action in general structural terms, expressing underlying regularities. It allows on the one hand, such a description of the **global dynamics** of the courses of action, and on the other hand, such a description of their **local dynamics**. It also links these two descriptions.

We will limit our analysis of the collective organization of the courses of action to the analysis of it's global dynamics. Then, of this semio-logical framework, we will present here only the hypotheses which were considered in this particular study, the ones which concern the global dynamics of the courses of action of the different actors and the relations between these global dynamics:

1) **global dynamics of a course of action**: the units of courses of action are **significant units** for the actor (or actors) which are classified by more abstract structures, **significant structures** of different **ranks**; a significant unit, and also the significant structure which classifies it, expresses a coherence through time between the ranges of the possibles open for the actor at every moment of the time span of this unit. Along this first hypothesis, the course of action is composed of a stratified set of significant units and this composition gives depth to the range of possibles for the actor at every moment.

2) **relations between the global dynamics of multiple courses of action**: the actors of a team share significant units, at certain ranks. In other words, they share parts of the ranges of the possibles open for each one at every moment. This sharing is the key to their coordination.

The analysis of data in significant units for a controller (or signal assistant) provides a particular description of the incidental situations observed. It is a matter of dividing the continuous development of the course of action of this controller (or signal assistant) into significant units by replying to the question: "What is this about, from the point of view of the controller (or signal assistant)?" By naming each of these units, an account is built up which gives meaning to the rough data. This analysis clarifies the temporal organization of the actions and events and provides elements on their sequencing. Thus, the intricacy of significants units, that is the interruption of significant units by other significant units, reflects work carried out in divided time during which several preoccupations are handled simultaneously by the controller (or signal assistant).

This analysis can be made in parallel for the different actors of a "subset of cooperation". The significant units at a given moment can be **separate** for these actors. But they can also **overlap** on all ranks or on certain of these ranks. Along with the second hypothesis above, such overlapings witness that these actors share parts of their ranges of possibles. This sharing is more or less developed depending of the ranks where the overlapings take place.

After showing, through the example of an incident, the principle of the analysis in significant units for two controllers, and also the characteristics of the synchronic collective organization of the courses actions in this "subset of cooperation" this analysis permits to discover, we will precise, through the example of an other incident following the first one, the diachronic collective organization of the courses actions and its relations with the synchronic one, in the same "subset of cooperation". We will finally present one of the directions for the design of a support system for coordination which this analysis allows to formulate.

## 6. THE SIGNIFICANT UNITS AND THE SYNCHRONIC COLLECTIVE ORGANIZATION OF THE COURSES OF ACTION IN THE CONTROL ROOM

In order to show the principle of the analysis into significants units for a "subset of cooperation", let us, for example, present the following extract from the transcription of the handling of an incident, which has been observed during the second stage of the study[3]:

[3] NAGA 12 is the name of the mission of a train. A mission can be changed. Evidently, it changes when the train arrives at on or the other end of the line. CR W, CR E and CR NE are the three chief controllers, respectively in charge of the West branch, of the East branch and of the North East branch of the line. Sig is a signal assistant. Man is the manager of the control room.

| | Action of CR W | Communications of CR W | | Communications of CR E | | Actions of CR E | |
|---|---|---|---|---|---|---|---|
| | | | | CR E->train | "OK, your colleague who is trying to solve the partial blocking, if you see him on the platform, ask him to call before going on" | Hangs up the radio telephone | 1 |
| | Turned toward TC (East branch) | | CR E->others<br>CR W<br>CR N-E<br>CR E<br>CR N->CR E<br>CR E<br>CR W<br><br>CR N->CR W<br>CR E<br>CR N-E | "And, I will try to make him drive back a little...."<br>"...with rear gear"<br>"No, with rear gear, you..."<br>"And, where can I get through?"<br>"But, yes, a transit action"<br>"It's a TGS!"/<br>"But, no, he is right, it doesn't get through, even w<br>transit<br>action"<br>"Why does it not get through"<br>"Because, I don't know... how much he is on the point"<br>"Oh,.. he isn't on the other point zone." | | | | 2. |
| | Circular glance tow TCO and, finally, the TCO (East bra | | | Sig -> CR E<br><br>CR E> train<br><br>CRE->train<br><br>train<br><br>CRE->train<br><br>train<br><br>CR E->train | "I think that he is speaking now."<br><br>"Yes, the train which is in Joinville, platform 1, it's you ..who calls me?"<br><br>"Yes, the train who just called, I listen<br><br>"who is on platform 2 at Joinville . I to tell you that there one carriage and half out of the platform, and that he is nquiring. You will not easily contact<br><br>"OK, I than you. We will try to cont him anyway, because if he drives bac little toward the platform , we will be able to make the other trains get throu<br><br>"OK, listen, he is on the platform, th colleague who is on the platform,xx tell him, but he is gone.... "<br><br>"OK, , thank you" | Picks up the radio-telephone<br><br>Hangs up | 1' |
| | | Sig ->CR SE<br>CR W | "You can't...it is diverted up there<br>"xxx in case of partial blocking o brakes, we have it in the ass" | Man->CRE<br>CRE<br>Man<br>CRE | "Did you contact La Varenne ?"<br>"There is nobody there"<br>"There is nobody there"<br>"There is nobody there" | | 3 |

**Figure 3: Extract of the transcription of data about the courses of action of CR W and CR SE during the handling of the "breack down of NAGA 12 in Joinville"**

NAGA 12 a train running in the direction of Boissy St Leger, breaks down at the exit of Joinville's station stopping all trains eastbound. As soon as the S-E Controller, in charge of the Joinville sector, understands there is a beakdown concerning platform 1, he directs the next train, RUDY 12, onto platform A, letting it wait in the station. The solution viewed by S-E Controller is to ask NAGA 12 to back a hundred meters in order to free the station's exit point (see figure 4). This solution allows trains following behind to pass NAGA 12 by platform A. But its implementation is rather risky because the Controller cannot communicate directly with NAGA 12 driver, who is busy trying to repair his train and is therefore not in the front cabin: the S-E Controller has to pass on his message to RUDY 12 driver.

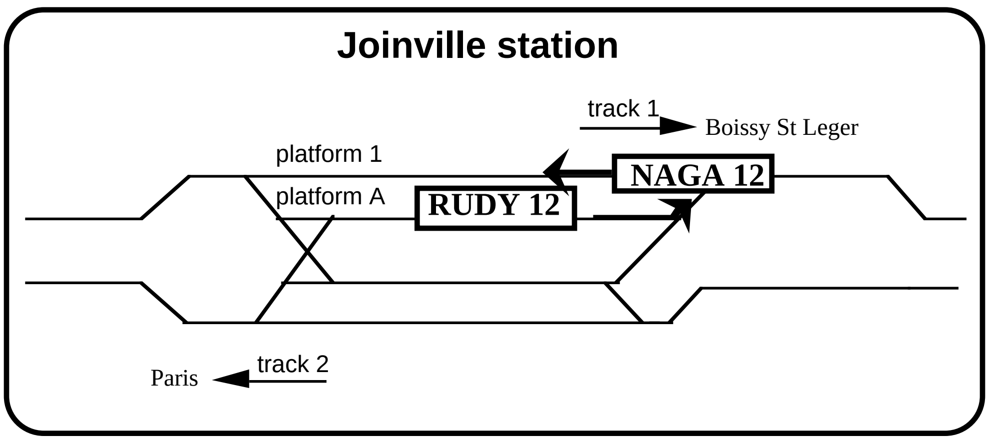


**Figure 4: NAGA 12 blocking Joinville station**

Considering the uncertainty of a rapid outcome of this solution, the controller launches another solution which is more costly to put up insofar as it implies to run trains on the opposite track. But, eventually, NAGA 12 driver succeeds in reversing his train and the controller is able to cancel the second solution.

Once the core of the problem (i.e. NAGA 12 blocking the Joinville station) is solved, the controller has to deal with the other problems resulting from this disruption such as using RUDY 12 to ensure the rest of NAGA 12's journey up to Boissy St Leger, and also finding replacement trains and standby drivers for the return journey of these two trains.

The implementation of a decision is gradual and shifted in time, that is to say that the handling of the incident is dependent upon the time needed to manoeuvre the trains as well as the possibility of communicating with the drivers. In the meantime many other problems have cropped up and some have already been solved.

The relatively long time - about twenty minutes - needed to sort out the breakdown makes it very difficult to turn back once a decision is launched. Consequences of the decision must, therefore, be evaluated in advance. Furthermore, this type of relatively long process time leads to solve overlapping problems: other incidents are tied with that of the NAGA 12 breakdown and must be handled simultaneously.

The analysis of the handling of incident also reflect the importance of colleagues for each controller's activity. A high number of persons involved in an incident (drivers, station masters, signal assistants, other controllers) are to be informed. This creates an additional difficulty for planning the actions of the controller, for he must ensure that everyone has completely understood what it is about and what has to be done.

The way we have presented the extract of Figure 3 already shows part of the collective synchronic organization of the courses of action in the "subset of cooperation" formed by the chief controllers West (CR W) and East (CR E). The left part of the figure concerns the chief controller West (CR W) and the right part his East colleague (CR E). A central column is created when they are involved in the same, usually collective, communications.

| **Course of action of CR W** | | | **Course of action of CR E** | | |
|---|---|---|---|---|---|
| **Story** | **Theme** | **Sequence** | **Story** | **Theme** | **Sequence** |
| BREACK-DOWN OF NAGA 12 | | | I. BREACK-DOWN OF NAGA 12 | NAGA12 blockingJoinvil-le: undertakes a first solution (to back NAGA 1 a hundred meters | 1. Tries to give the mes-sage to NAGA12 throug RUDY 12 |
| | CR E' problem: NAGA 12 stoppe in Joinville | 1. Discussion with colleagues to find a solution to prevent NAGA 12 to block the traffic | | | 2. Discussion with collea gues concerning the po-sition of NAGA12 at th station's exit point to determine the feasability of the solution |
| | | | | | 1'. Asks RUDY12 to tel NAGA12 to try to drive back out of the station's exit point |
| | | | | Prevision of extra-drivers | 3. Man asks if La Varenne'statio master knows about NAGA12 |

The analysis of the extract precises this collective synchronic organization of the courses of action. The significant units resulting of this analysis belong to three ranks, namely **Story**, **Theme** and **Sequence**. The analysis shows that the shared sequences, though named identically at the lower rank, are named differently on the higher ranks. For example, the sequence 1 of CR W and the sequence 2 of CR E correspond to a discussion with CR N-E: CR E informs the two other chief controllers about his intention to ask the driver of NAGA 12 to drive back a hundred meters, in order to free the end point of the station this train blocks, and they collectively evaluate the idea. For CR E, this discussion makes him immediately prepare his action, which will consist in beginning to undertake this first solution by asking the driver to try to drive back. For CR W, the question is to follow his colleague's actions on one hand, to be ready to act if the incident has repercussions for his sector, and on the other hand, to participate in a playful way to the problem solving, because the handling of a new kind of incident constitutes an experience which can be useful in the future.

This analysis into significant units for the different "subsets of cooperation" constitutes a frame for different findings concerning the collective organization of courses of action. Various forms of cooperation emerge during such disrupted situations. Relatively to a story like the "breack down of NAGA 12", the different significant units for a given actor can be classified in four categories: he is **responsible**; he is **co-responsible**; he follows up **in the background**; he is busy with other stories and **ignores it**.

While a controller solves the core of an important incident, the other controllers and signal assistants often carry out secondary jobs to help their colleague, such as holding back, in a station, the trains following behind a defective train to avoid jamming them under a tunnel; or informing station masters of a breakdown; or searching for a line manager to ask him to the train's driver.

They also participate in the background to the solving of an incident by giving advice to their colleague in charge of it and by showing him aspects of the problem he may have overlooked. In this sense, they play a role of guardians of the smooth handling of an incident. When the controller's attention is focused on a specific problem, the intervention of others makes it possible to "de-focus" on the general context when this is necessary. Or else, when a breakdown occurs at peak hours, the urgent nature of the situation immediately generates an implicit sharing of the work: the controller concerned by the core of the incident tries to solve it with the driver, while the other controllers handle the upstream and downstream traffic.

However, when the general situation in the control room is too disturbed because of the accumulation of incidents, every body tends to focus on his own problem solving, and nobody can play the role of collective guard anymore. The result is often a lack of coordination in the passing on of information towards colleagues outside the control room.

## 7. THE SIGNIFICANT UNITS AND THE DIACHRONIC COLLECTIVE ORGANIZATION OF THE COURSES OF ACTION IN THE CONTROL ROOM

To characterize also the diachronic collective organization and its relation to the synchronic one, we will take an other example, an incident which is a repercussion of the "breack down of NAGA 12 in Joinville". Let's summarize it.

> About an hour after the stopping of NAGA 12 in Joinville station, i.e. quite a long time after this incident had been settled by the south east controller, a problem appears concerning track 2 at the other end of the line: the west controller notices that three ZHANs (return journey of the RUDY) and three XILOs (return journey of the NAGAs)

are following each other without their usual spacing. The consequences are important for passengers because the XILOs stop in all stations up to Le Pecq whereas the ZHANs are semi-direct to St Germain en Laye.

The origin of this erroneous sequence of trains is an error of the signal assistant in charge of the Joinville sector. The many manipulations of trains made by the south east controller to make up lost time after the breack down of NAGA 12, and in particular the change of decision concerning ZHAN 23 (the return journey of RUDY 12) which had first been cancelled and eventually had been reintroduced, misled the signal assistant.

The west controller is immediately able to connect together this sequence of three ZHAN and three XILO with the breack down of NAGA 12 which happened an hour earlier. It is a consequence of the synchronic articulation of his course of action with the course of action of the south east controller. In particular, he had kept up with its management by the south east controller, in particular when the latter had found a replacement train for ZHAN 23, which consequently was running behind schedule. Thus, the synchronic organization of the courses of action during the core of the handling of the breack down of NAGA 12 and its repercussions contributes to the diagnosis of the incidents which follow.

But, this synchronic organization hasn't enabled the chief controllers and the signal assistants to manage all the repercussions.

Two reasons for that: on one hand, there is a co-existence of two logics in the sharing of the handling of an incident, which, in certain cases, can be contradictory, and on the other hand, the handling of the breack down of NAGA 12 and of its repercussions has taken place in a multi-disrupted situation.

The first logic, which corresponds to the prescribed allocation of roles, is **geographic**: each controller manages the disruptions occurring in his own sector, even though the sectors' borders are loose and giving a hand is a tacit rule. The second logic, which follows the dynamics of train movement, can be called **historic**: it postulates tacitly that the person who starts handling a disruption is responsible for it during its entire course, because he knows all the surrounding circumstances and the consequences of his own decisions.

The co-existence of theses two logics is implicit to the coordination of the controller's action, the choice of one or another depends of how each person is involved in the situation: a controller may make way for his colleagues depending on their receptiveness at the moment and on the fact that they have participated in the background to the beginning of the incident's solving.

In the case of the repercussion of the breack down of NAGA 12, the signal assistant who mixed up the trains is in charge of the junction, which is at the border of the north east sector and the south east sector. Following the geographical logic, both controllers were liable to supervise what was happening at the junction. But, at that time, the north east controller happened to be dealing with another incident on the north east branch and had not paid attention to the details of the arrangement made by his colleague in relation to NAGA 12's return journey. The south east controller was busy evacuating the defective NAGA 12 out of Joinville station and he didn't consider there could be a problem for the signal assistants to follow through the return journey of the trains.

In fact, the handling of the "breack down of NAGA 12" has taken place in a multi-disrupted situation:

> Three important incidents have kept the officials bust: the breack down of NAGA 12, handled principally by CR E but which has been followed more or less by everybody, the breack down of OLAF 12 which has been handled by the cooperation between CR W and CR N-E, and also the ZHAN 27 stuck in Auber station, handled principally by CR N-E. To these important incidents, we must add many small or medium incidents, such as an alarm concerning the electric power supply of the tracks, the non-display of the ZHANs in Rueil station, the presence of passengers on the tracks in the direction of Joinville station, and finally the bad succession of ZHAN and XILO we have already described.

From this evidence, it is clear that multi-disrupted situations, when controllers and signal assistants are busy with several incidents at the same time, affect functioning of the group because neither of the two logics may be efficiently followed.

## 8. THE DEFINITION OF A SUPPORT SYSTEM FOR COORDINATION

Such an analysis of the courses of actions of the different officials and of their collective organization orients the reflection concerning the modernization of the traffic regulation apparatus toward the design of a support system for the coordination of actions (see Winograd & Flores, 1986).

The proposals for the design of tools supporting coordination we have put forward after this analysis are along three complementary directions: developing the current **computer support**; improving the **fix-line diagram** and the **spatial design** of the control room; improving the **tools for communication**. In this paper, we will briefly present these directions and stress one of the proposals along the first direction, which stems directly from the example we presented above (7), while the others stem from the analysis of other disrupted situations.

### 8.1. Three directions for design

The first direction is developing the current computer support. Different proposals have been made, with a decreasing order of importance.

One of the proposals along this first direction concerns the **synchronical/diachronical and chronological aspects of the traffic** which we will present further with more details.

A second proposal concerns the **display of the reordering of the trains**. Now, when an agent update the computer, his actions are not enough visible for the other agents. A simple solution is to display the number of a reordered train with a different color, in order that an agent who has not followed up the actions during the handling of an incident is immediately informed about the resultant modifications.

A third proposal concerns computer support concerning the **supervision of drivers**. One of the imperative criteria when handling an incident is to respect the schedule of the drivers. To enforce this criterion when the mission of a train is changed, the chief controllers aim at restoring as rapidly as possible the coupling between drivers and missions. They use standby drivers and replace the drivers as soon as they attain the station where their mission begins. Therefore, the chief controllers must know the coupling drivers' teams-missions. Now, they write down the drivers' teams numbers on the graph of train movements, but it is difficult to find on this graph the different missions of a given driver, because the coupling driver-train is unstable. Then, when there is a change concerning the drivers' teams, the chief controllers are obliged to consult the drivers' duty roster. In order to harmonize the multiple sources of information used when handling an incident, we proposed to make the drivers appear on the computer display, in two different modes: for each mission, the drivers' team which is really assigned; for each drivers' team, the succession of it's missions.

The final proposal is a computer support concerning the **estimation of the number of passengers**. When handling an incident, the chief controllers try to transport the maximum of passengers, at the risk of penalizing the passengers, less important in number, who are at the end of the line, or are in the opposite direction to the main flow. But they work blindly. An apparatus detecting the approximate number of passengers in certain key stations would allow them to refine their decisions.

The second direction is improving the fixed line diagram and the spatial design of the control room. The analysis of the collective organization of the courses of action in the control room shows that there is a necessity of a mutual visibility, of a mutual listening and of a common referent. The proposals along this direction concern the **interior design** of the control room. They concern also the improving of the f**ix-line diagram**. Against the present international tendency to suppress the fix line diagrams and to rest on computer consoles, the fix line diagram must be kept and improved. All the agents can see in a glance the state of the traffic, which is scattered in different images on the computer consoles. When positioning their body in the direction they are looking at, they make visible for every body the focus of their attention.

The third complementary direction is improving the communicative tools. Many proposals stem from the analysis. The first one is improving the **quality** of the present system, which is responsible for many communicative failures, some with dramatic consequences. To facilitate the communication by the radio-telephone and prevent confusions, the agents need also an **automatic display of the number of the train** whose driver is calling. To facilitate the multiple communications which occur between the driver, the station master of the station where the driver is assigned and the chief controller, a **multi-communication device** would be useful.

{C40} THEUREAU J, G. FILIPPI (1993) Metropolitan traffic control activities and design of a support system for the coordination of actions in future control rooms, communication in 4th European Meeting on Cognitive Science Approaches To Process Control: Designing for Simplicity, August 25-27, Copenhagen, Denmark.

## 8.2. A computer support concerning the synchronical/diachronical and chronological aspects

The proposal we will present with more details is a device which enhances the present computer system. It is liable to support the individual handling of an incident, but also, the collaborative supervision of train movements.

We have first to consider more precisely the present means of handling an incident. Three main devices are of permanent use: the fix line diagram, the consoles' images and the graph of train movements. They are different maps representing the same territory, the RER A Line.

The graph of train movements is a reference document indicating the journeys of every train. Its graphic presentation makes it possible to follow a given train (where does he come from? what was his previous journey? where does he go? what will be his future journey?). It also allows a comparison between several trains.

Contrary to the fix-line diagram, or to the computer consoles, the graph of train movements, is not a representation of what is going on "here and now", but is the basis to which controllers permanently refer, as a tool to evaluate the present situation. In this sense, it is a map of a "normal" situation, from which modifications are defined (for example: the amendment made on a train's itinerary). When perturbations occur, information given by the computer system is meaningful only in reference to its discrepancies with the normal situation seen on the graph of train movements.

However, it is not easy to draw a correlation between these two information sources, because they are not related to the same level of information.

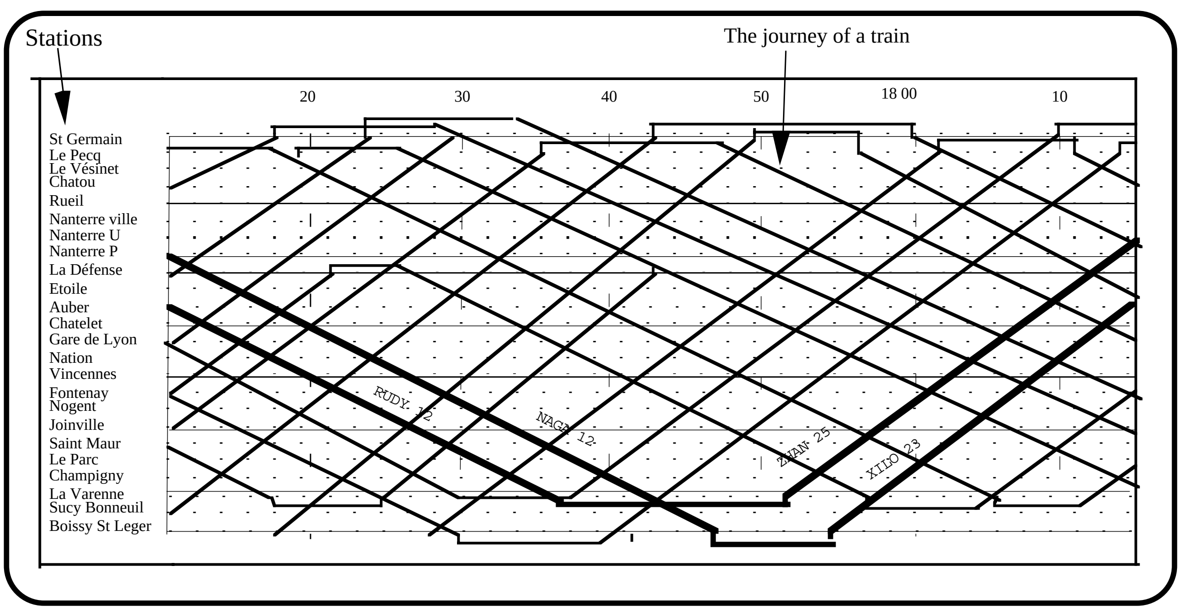

**Figure 5: The synchronical/diachronical aspect of the graph of train movements**

On one hand, the graphic is about the dynamics of the normal traffic, as a whole. It is a very rich tool, which shows several aspects of the traffic:
- diachronical aspect: each train has it's past and future route;
- synchronical aspect: at a given time, the location of all the trains is defined. What the Controllers are actually interested in is a combination of the synchronical/diachronical aspects: on a given portion of the line, there is a set of trains going in the same direction but having different itinerary. By comparing this set of trains, it is possible to replace a defective train by another train with a similar journey;
- chronological aspect: at a given location, one has all the trains passing from the beginning of the day.

On the other hand, the computer consoles give in real time, a precise view of all trains at a given moment, in other words, the synchronical aspect: it operates like a succession of snapshots.

This design proposal is optimizing the current computer system for the follow-up of train movements which should give the historical background of all the trains by providing equivalent information to those of the graph of train movements, but applied to the real running of trains. Hence, this dynamic tool would hold concurrently the synchronical/diachronical and the chronological aspect of train movements which is now lacking.

When the computer system is updated, this tool would also support the coordination of actions between the staff by rendering the amendments made on trains more visible than it currently is. For instance, a changed itinerary should be displayed one way or the other on the consoles so that any member of the staff knows immediately of modifications of the traffic even if he is unaware of the details of the handling of the incident.

## CONCLUSION

We would like to make, in conclusion, two remarks.

First, we are just beginning to develop the analysis of the collective organization of multiple courses of action, in order to **develop the insights of both the course of action analysis and the distributed cognition analysis** (Hutchins, 1988). The present study proves it necessary to give empirical funding to the design of support systems for the coordination of actions which don't forget the role of individuals. It is one of the main directions of our future research.

Secondly, as we said above (see 5.), in this analysis of the collective organization of multiple courses of action, we have only considered thus far the global dynamics. To tell the truth, in order to give more precision to our different design proposals, we also used the theoretical tools we have developed for analyzing the **local dynamics** of the course of action, in particular the notion of triadic sign (see Theureau, 1992), but only in a comprehensive way, not in a systematic modelling way. As, in our idea, the notion of triadic sign is the basis of an "experiential semiotics" necessary to replace usual "product semantics" which has shown its incapacity to guide the design in terms of support system for the users (see Adler & Winograd, 1992), in our future research, we will aim at extending it from the analysis of the course of action to the analysis of the collective organization of multiple courses of action.

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