Author version, published in: *International Journal of Industrial Ergonomics*, 11, pp. 99-106, 1993.

# Problems in telemaintenance and decision aid criteria for telemaintenance system design

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* Part of this paper was presented at Annual Industrial Ergonomics and Safety Conference, Denver, Colorado, 10-14 June 1992 (Kolski and Millot, 1992).

**ABSTRACT**

*Decision making for the integration of telemaintenance tools into the maintenance of a man-machine system is presented. The Decision aid criteria for telemaintenance can be classified into four main classes: (i) possible, (ii) appropriate, (iii) justified, (iv) acceptable. After introducing the telemaintenance notion, this paper will outline such decision aid criteria.*

**RELEVANCE TO INDUSTRY**

*Telemaintenance notion has not been well applied in industry. Maintaining at a distance industrial installations has particular human and ergonomical problems. This paper provides help to potential designers of telemaintenance tools.*

**KEYWORDS**

*Telemaintenance, human factors, decision aid criteria, telemaintenance tools design*

## INTRODUCTION

The growing level of automation in industrial processes - continuous or not - includes particular telemaintenance problems. It is of paramount importance to insure the best possible productivity of equipment.

According to the AFNOR X60-010 norm, maintenance is defined as "the set of actions allowing to maintain or restore an installation in a specified state or in a state permitting to insure a determined service". Equipment maintainance consists of operations (repairs, lubrification, improvements, visits...) needed to insure the production continuity and quality. Two main forms of operational maintenance exist: corrective and preventive maintenance (figure 1).

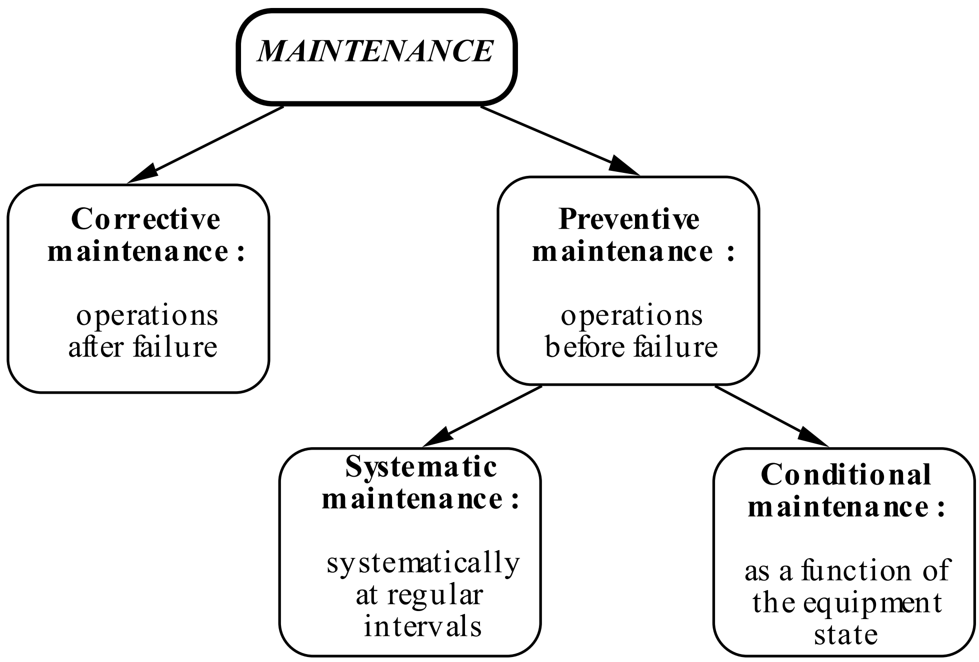


Figure 1: The main forms of maintenance

Many books, proceedings or specialized journals devoted to maintenance can be found in the literature (see for instance the journals: "Maintenance" or "International Journal of Quality and Reliability Management"). Many tools and methods have been developed to optimize maintenance, to insure a better availability of technical means and to decrease costs. Among these methods, the telemaintenance approach appeared in the 80s. It consists of maintaining installations at a distance.

The purpose of this paper is to help in the decision making process to integrate a telemaintenance tool (also called telemaintenance system in the paper) into the maintenance of a man-machine system. The decision criteria can be classified into four main classes: (i) possible, (ii) appropriate, (iii) justified, (iv) acceptable. Considering all four classes together allows the recommendation for the integration of telemaintenance tools (Kolski, 1992). After introducing the the notion of telemaintenance, this paper will outline such decision criteria.

## TELEMAINTENANCE

Telemaintenance consists in carrying out some maintenance operations at a distance.

This particularly interesting technique to optimize "the after-sales service" of an automated installation appeared at the end of the seventies. Gabriel and Pimor (1985) presented one of the first applications in this field: Digital Equipment put a telediagnosis center into service first in the States in 1977, then in France in 1980. Realizing the need for such a maintenance approach for both the installer and the user, the firm integrated a specific micro-computer into every system. This micro-computer served as an intermediary between the end system and the diagnostic center. A specialized console and modem were installed free of charge at the customer's end. Any communication costs were charged to Digital and the maintenance contract amount was reduced by 10 %. This telediagnosis system was first used for corrective maintenance. A 90 % success rate was achieved without the intervention of a nonsite technician. Furthermore, when ever this person did go to the site, most of the time he had the right components. Later preventive maintenance was included. This consisted, on the one hand, of storing technical faults in the telediagnosis center and, on the other hand, in regularly controlling this information regularly with a goal of prevention.

Currently, more and more telemaintenance systems are being developed and progressively installed on industrial sites. They are particularly interesting in the fields constituting some risks for the human beings, those fields where human intervention and/or the production stops are very expensive (off shore, mail order industry, "small" processes without a specific control room like...). Many operational systems are also found in "intelligent" buildings (repairing of lifts, adjustment of steam generator...) and in large computing systems (networks of computers, data processing systems...).

**HUMAN FACTORS CONCERNS**

Before the use of computing tools, the maintenance man-machine system consisted of two elements: the machine and the maintenance expert (figure 2). The corrective and/or preventive maintenance for such a man-machine system was done on the same work site.

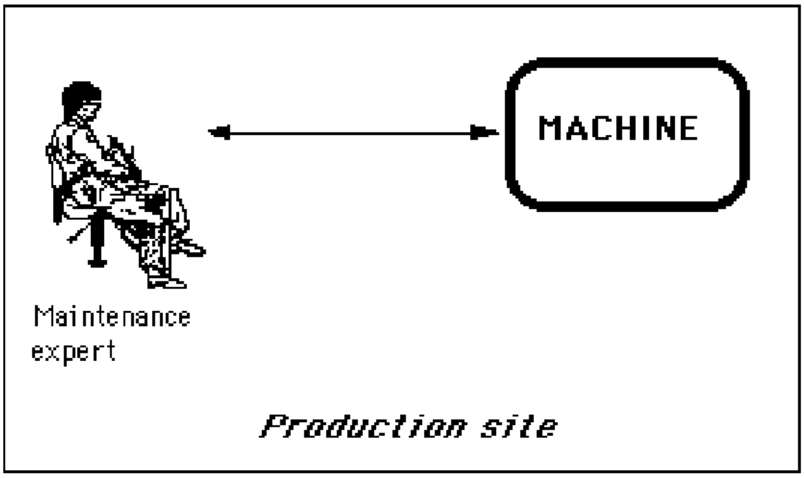


Figure 2: The maintenance expert in direct interaction with the machine

With the appearance of (1) Computer Aided Maintenance, (2) Computer Aided Maintenance Management and (3) conditional preventive maintenance techniques, the maintenance man-machine system includes three elements (figure 3) on the same work site. The computing maintenance system consists of a dialogue software and a console.

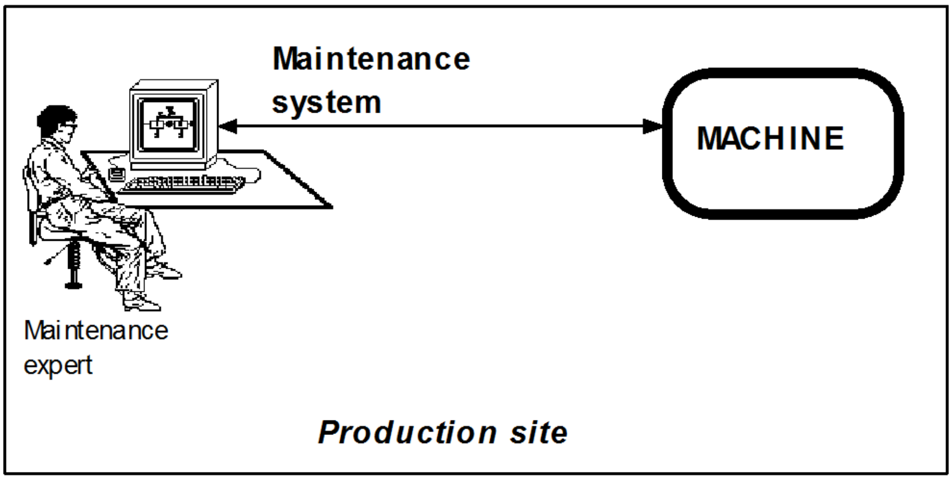


Figure 3: The Computer Aided Maintenance principle

Telemaintenance can lead to particularly interesting human factors problems. Indeed, the telemaintenance expert uses a computing system from a site different from production (figure 4). So, the computing system always consists of a dialogue software and a console. It also integrates communication.

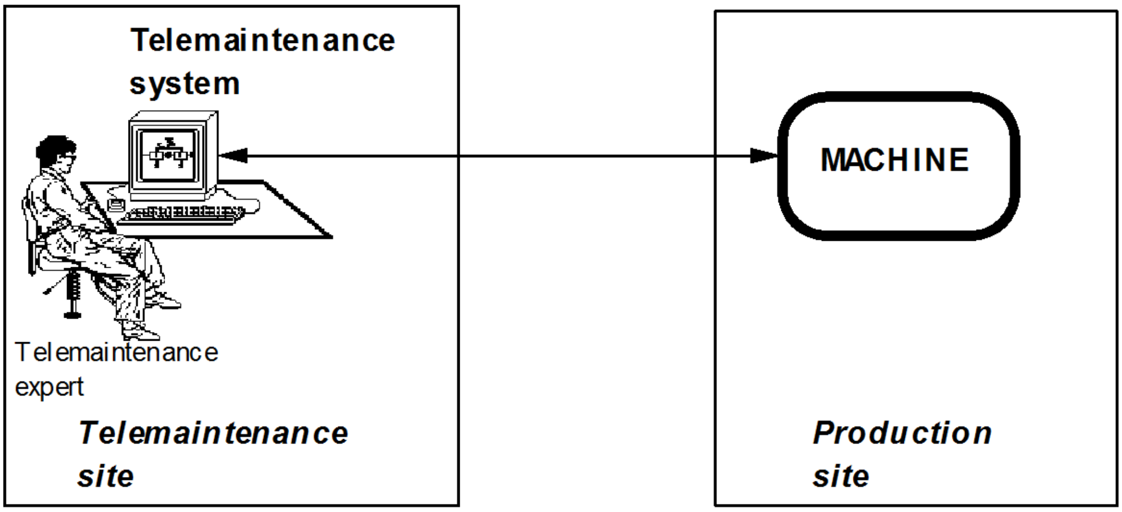


Figure 4: The basic telemaintenance principle

Of course, an operator or a maintenance technician can be present on the production site. But the maintenance technician has less knowledge than the expert. In this case, a connection must be maintained between them. In most cases this connection is a telephone (figure 5). This is not a general case, but is the most typical for telemaintenance systems.

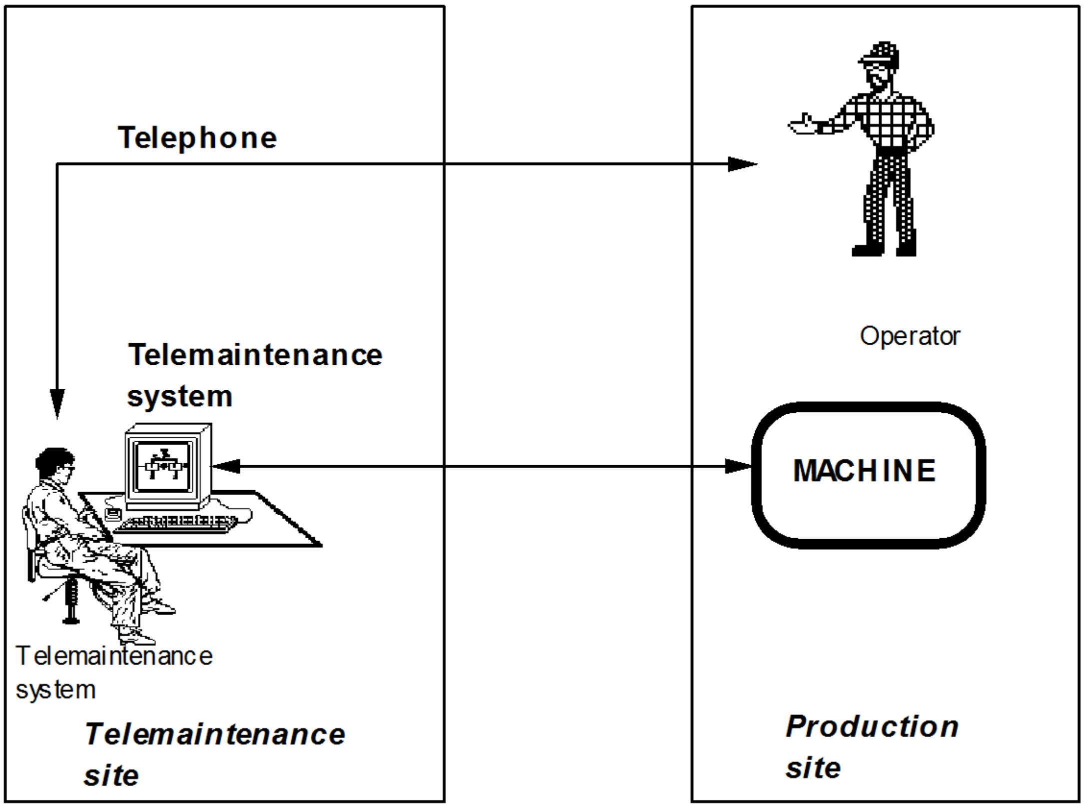


Figure 5: Collaboration by telephone between the telemaintenance expert and an operator

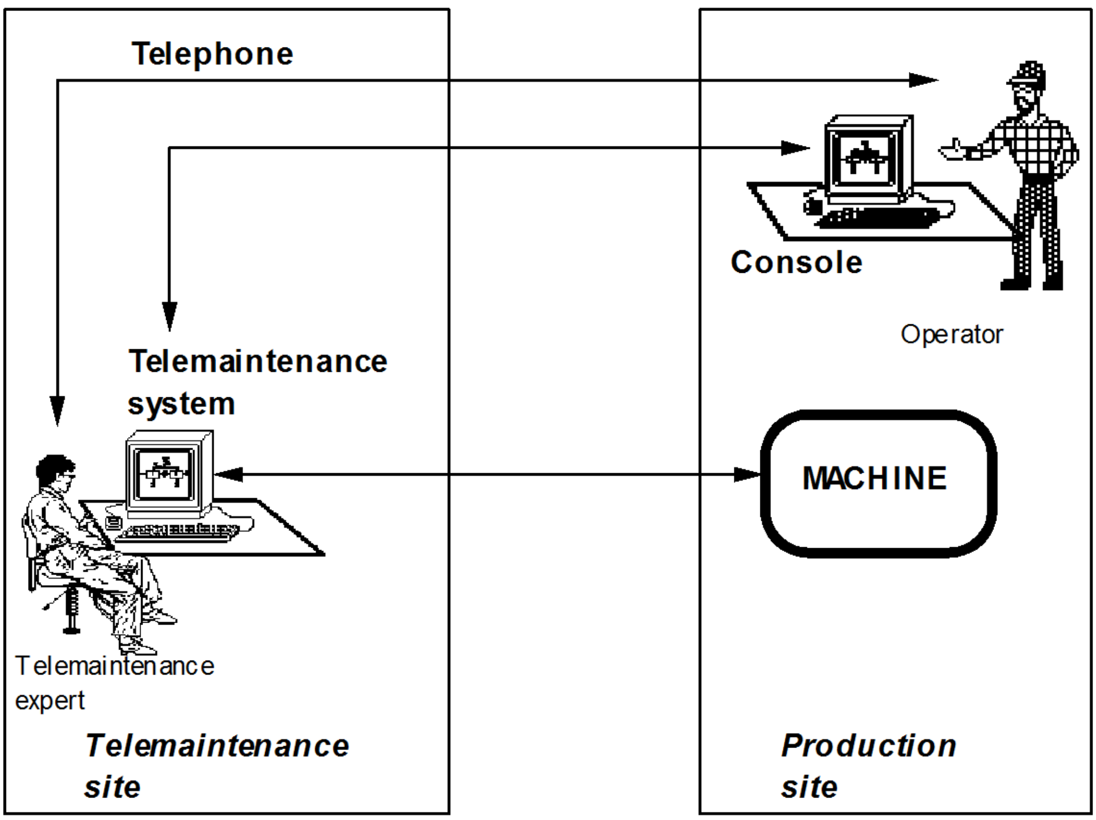


Figure 6: Collaboration by telephone and computing system between the telemaintenance expert and an operator

According to the competence and/or to the function of the operator at the production site, he may also have access to certain functions of the telemaintenance computing system, and may collaborate with the expert by telephone and a console (figure 6). This last case is very rare, but is the subject of current research.

The operator who is on the production site is likely to perform some maintenance actions on the machine following expert instructions. Nevertheless, for certain repairs, the expert will probably need to go to the production site, or to send a specialist.

"Intelligent", graphic and/or algorithmic computerized fonctions generally include the following (Kolski, 1992): (1) alarms, (2) preventive failure detection, (3) shallow and/or deep diagnosis, (4) automatic action advices, (5) access to information about appropriate actions or task to perform, (6) graphic guidance and advice to the operator present on the production site, (7) preparing for visit on the production site, (8) calculations and statistics, (9) recording information related to failures, repairs, and so on, in database, (10) visits and/or actions planning, (11) continuous supervision of specific variables, (12) access to the life cycle of components, (13) analysis of numeric or symbolic data, and so on.

## CRITERIA FOR INTEGRATION OF TELEMAINTENANCE FACTORS

There are four criteria for the integration of telemaintenance factor: (i) possible, (ii) appropriate, (iii) justified, (iv) acceptable. Considering all four classes together provide the final recommendation for integration of telemaintenance tool (Kolski, 1992; Kolski and Millot, 1992). Of course, this list of criteria is not exhaustive, since each company has its own proper constraints and objectives. Nevertheless, these criteria will provide potential designers with a decision base.

Each of these criteria is briefly examined below and explained in a synthesis diagram (see the figure 7).

### For possible integration of telemaintenance factors

In this class, we include all the criteria which are essential for setting up of a telemaintenance system. It considers four sub-classes which correspond to the four entities (figure 7): (i) the telemaintenance operator (also called telemaintenance expert), (ii) the required operator expertise, (iii) the operator on the site, (iv) the information the telemaintenance operator needs to manipulate at a distance.

<u>About the telemaintenance operator:</u> First at all, he must be able to intervene at the right time at distant maintenance operations. Then he must be able to answer his informational needs, either by the way of the computer (by tele-measures) or by asking the onsite operator complementary information. Finally, if the telemaintenance operator concludes that it is necessary to intervene physically on the site, he may be able to guide the operator in the necessary actions.

<u>About the telemaintenance expertise:</u> The expert's reasoning process must be possible at a distance. For this reason, his reasoning must be essentially cognitive and can not require too many manipulations. To design a telemaintenance system, the knowledge used must be previously validated, and perfectly mastered. This knowledge may not be retained -consciously or not- by the telemaintenance expert and has to be accessible by the designer.

<u>About the onsite operator:</u> This operator may be contacted in case of need by the telemaintenance operator. The fact that he is free must be sufficient. In other words, an operator present on the site must be able to answer the informational needs of the telemaintenance operator. For efficient co-

operation, the operator must be able to formulate his observations. His competence and/or training levels must be sufficient. So, in each case, the operator must be able to understand the telemaintenance operator and to answer his informational and action needs.

About the telemaintenance information: All the measures useful to the telemaintenance operator must be instrumented, and therefore accessible at a distance: indeed the telemaintenance operator must quickly access the information without worrying about its reliability. Thus the information must be essentially of two following types: objective "signs" (taking the form of measures) and "symbols" (interpreting the information: too high, too low...) (for this notion, see Rasmussen, 1986). The information must not be of the subjective "signs" type such as smoke, smell, and so on: but, in this case, they have to correspond to well-known and explainable at a distance (for instance by using a telephone) by the operator present on the site.

**For appropriate integration of telemaintenance factors**

The criteria which are put together in this class must estimate if a telemaintenance system is better than a classic maintenance approach. These criteria are divided in two sub-classes corresponding to the two maintenance steps: (i) tele-supervision and tele-diagnosis, and (ii) actions of maintenance deduced from reasoning at a distance.

About tele-supervision and tele-diagnosis: These two operations (the most classical in the field of telemaintenance) have to be faster than if they were performed by a maintenance expert which must move on site. The telemaintenance time has then to be inferior than the displacement time plus the maintenance time on the site. The reliability level of the system has to be as close as possible to the level which is reached when the maintenance operations are performed on the site.

About the resulting actions: The actions resulting from the telemaintenance, and which cannot be directly performed by the telemaintenance operator using his computing system, have to be workable in most of the cases by an operator present on the site. Indeed, if it is not possible, the telemaintenance operator (or a maintenance expert) must systematically move on site to make the maintenance actions. In this case, the profit-earning capacity of the maintenance approach decreases. Another telemaintenance criterion is to be able to optimize the displacement of the maintenance expert on the site: the expert has to move only if it is necessary and in this case he has to know the type of operation he will have to perform. For instance: a maintenance expert went on site only to press an "on/off" button to start a machine. The inexperienced onsite operator did not understand the situation at all !

**Justified integration of telemaintenance factors**

In this class, economical and strategic criteria are considered.

About the availability of the telemaintenance operator: If the operator in charge of the maintenance of a machine is not available, then telemaintenance is a possible solution. For instance, maintenance companies can insure the maintenance of machines for which a travel to the site may last two or three days because of geographical reasons whereas an intervention at a distance would have lasted just a few minutes.

About temporal constraints of maintenance interventions: For some industrial sites, one day of machine unavailability can be disastrous. A telemaintenance system can then optimize the intervention time relating to the maintenance.

About the profit-earning capacity: A telemaintenance system corresponds above all to a service, or even to a product. If this system is sold in sufficient quantities, the profit-earning capacity is ensured.

About the training: If it is envisaged to attribute to the telemaintenance system a double function, the second one may concern the training. For example, operators can learn diagnosis at a distance on the telemaintenance center. Furthermore, training of onsite operators is possible, for instance when they must exploit a new machine.

About the impossibility to send a maintenance expert on the site: It can be impossible to send an expert on the site, for instance when the system is closed or difficult of access (off-shore, nuclear or chemical processes, space...). In such conditions it is necessary to choose a telemaintenance approach.

About the volatility of the expertise: With a more strategic point of view, maintenance expertise could disappear. This situation may influence the design of a telemaintenance system.

**Acceptability of integration of telemaintenance factors**

The level of acceptability for choosing a telemaintenance approach is centered on the human factors linked to this new technique.

About the evolution of the work: It must be possible to insure the interest of the tasks of the onsite operators. This is true if we try to exploit as often as possible the dialogue between the two operators. Of course, this dialogue has to be possible and must not come down to actions asked by the telemaintenance operator to the onsite operator. Furthermore, the onsite operator has to find an interest due to the pedagogical aspects of the operations in which he is involved.

About the motivation of the operators present on the site: The telemaintenance system must not be integrated from the opposite direction in the company's culture and of course it must not involve problems relating to the confidential aspect of certain information which are accessible on the site by the telemaintenance operator. Moreover, the operators present on the site may perceive the necessity of such a maintenance approach. More and more, the integration of such a system implies a participation of the end users to the design process (Gould, 1988). If the operators present on the site wish to take part in this process, it is a sign of the "human" success of the integration. Nevertheless, a telemaintenance approach involves changes in the work methods, the different operators must be conscious of this situation. Specific sessions organized to prepare the telemaintenance integration will here find their usefulness.

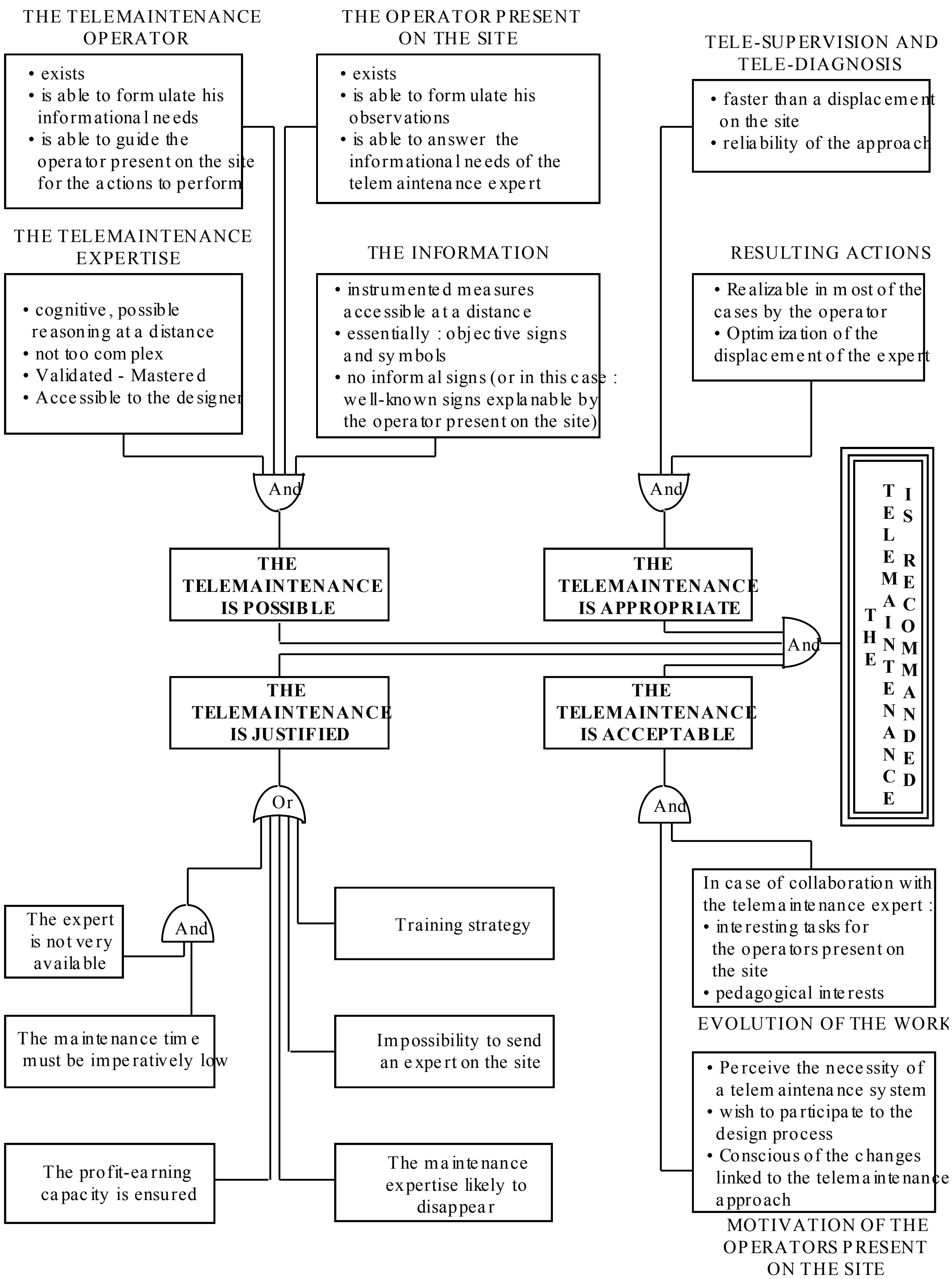


Figure 7: Criteria for helping the integration of telemaintenance factor

## CONCLUSION

This paper has first dealt with telemaintenance and its human factors problems. It is evident that the telemaintenance system is integrated into man-machine system in which the characteristics and the tasks of the telemaintenance expert will have a direct influence on the successful result of the project concerning the telemaintenance system design.

The designer of such telemaintenance systems will need to consider such notions. Our paper has provided criteria for deciding the integration of telemaintenance factors.

The classification proposed in this paper is part of a project supported by the French Ministry of Research and Technology. This work has led to a report entitled (in english) "Ergonomical guidelines for telemaintenance system design: application to automated machines" (Kolski, 1992).

## ACKNOWLEDGEMENT

The authors would like to thank Dr. Andris Freivalds for his improvement of the manuscript.

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