AUTOMATIC RESPONSES WHEN SOMETHING HAPPENS:
WHAT SHOULD BE IMPLEMENTED IN THE FUTURE

Cand. Scient. Tor Tybring Aralt, Multiconsult AS
Nestunbrekka 98; N-5221 Nestun
(+47) 97688632, tor.tybring.aralt@multiconsult.no

ABSTRACT
Most road traffic centrals are reluctant to the use of automatic response in tunnels. They claim it disturb traffic unnecessarily, give wrong reactions, is dangerous, and many more reasons. But mainly, it is to many false alarms!

The truth is, in many cases it will improve safety, reduce wrong decisions, act faster, but it will cause closed tunnel more often, but only for few minutes.

This paper will consider benefits with automatic response, and demands to system, if you are using automatic response.

Key words: testing of tunnels, demands to consultant, design of ITS systems in tunnels

1. INTRODUCTION
The Road Traffic Center in Bergen is responsible for supervising nearly 250 tunnels, and the number is increasing. To have a cost effective Road Traffic Center, it is necessary to keep the number of people on duty as low as safely possible. One of the conditions to be able to maintain safety with few operators is to increase automatic responses to given safety and traffic-related events. Automatic responses also increase the level of safety for managing various errors, as well. Before the fire in the Seljestad tunnel, in 1999, nothing was managed by automatic responses, except normal ventilation. This fire showed us that we needed more automatic responses. In the same time, the fire in the Gudvangen tunnel showed that automatic response, and predefined actions might cause more people to be exposed to smoke.

2. PHILOSOPHY
In many cases it is critical to close a tunnel fast and the consequences of using 1 or 2 minutes extra cannot be neglected. When an operator receives a fire alarm, he is supposed to check out the alarm to decide if it is real or false.

In the possess industry and oil platforms, we have learned that they cannot safely expect reaction times on less than 90 seconds. They are afraid to shut down production. In the same way, the operators for a tunnel will resist to close the tunnel, in case it was not necessary.

During this time many vehicles may enter the tunnel, and if it is a real fire, the people entering the tunnel during this time are exposed to an unnecessary danger. If the tunnel is closed they are prevented from entering, although a queue may build up for several minutes.

Based on this, the road traffic central in Bergen, has decided that the philosophy should be think and open, not think and close. These are two very different approaches to the same problem. The road traffic central in Oslo use the opposite, think and close.

Fire ventilation in longitudinal ventilated tunnels

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The main philosophy has been to ensure fast access for the fire brigade, to put out the fire as soon as possible. In the considerations, the assumption has been that this will cause more people to be exposed to smoke, but we expect them to survive. The fire in the Gudvangen tunnel showed this. If they had waited, or not changed the direction of the ventilation, far less people would have been caught in the smoke. The road traffic central had no information about how many people it was on either side. The fire was 3.5km in from one side and 8 from the other side. The tunnel do not have any ITV due to that it is a low traffic tunnel. The road traffic central followed instructions. And the result was as planned! No secondary deaths, but 73 people to the hospital for treatment of smoke poisoning.

But the fire has restarted the discussion about what do during a fire!

**If you want to use an automatic response, you MUST have a predefined action.**

In Norway only very few tunnels has installed systems for fire detection. Most of the low traffic tunnels do not have ITV, or any kind of detection exept for traffic caused pollution I the tunnel. According to the EU regulations, these tunnels do not need ITV.

3. **SYSTEMS DEMAND AN AUTOMATIC RESPONSE**

If you implement automatic actions based on what you measure in a tunnel, your tolerance for false alarms is drastically reduced. There is no longer an operator filtering the alarms. When we treat removing a fire extinguisher as confirming a fire, we do not have many false alarms.

We have many long, low traffic tunnels in Norway, where the consequences of starting the fire ventilation system are unnecessarily expensive. But with good systems constructed to avoid false fire alarms, in the last 4-5 years we have allowed fire ventilation systems to start automatically together with an automatic tunnel closing, based on the removal of a fire extinguisher.

Many tunnels used to be closed automatically based on pollution levels in the tunnel, but this was removed due to frequent errors from gas monitors. Today, however, these systems are being installed in some new tunnels again, and will probably be installed in more tunnels.

The main problem here is still zero point drift and the maintenance of the gas sensors.

In the Knappe tunnel in Bergen we originally wanted to close the left lane and specific tunnel section when the video analysis detected a wrong-way driver. The implementation of this was delayed, due to many false alarms. Without automatic response, the time necessary to confirm wrong way driving and, close left lane is too long.

Several “close encounters” forced the road traffic central to implement automatic response to wrong way driving. But now it is based on two successive cameras. This combination does not give false alarms, but the reaction is delayed compared to detection on one camera, with approximately 20 seconds. This is a drastically improvement compared to manual reaction.

4. **AUTOMATIC RESPONSES**

A main rule for all PLC systems must be: *An automatic response should always be performed as close to the physical process as practically possible.* This is the theorem on which we build all PLC systems. It creates very modular and stable systems where large sections are independent of the levels above them. The discussions arise concerning practical issues, where different designers and system integrators have many different approaches.

When working with instructions for the operators, we decided that some procedures could be replaced with automatic responses in the PLC systems. When a fire extinguisher was removed from its location, the operator was supposed to close the tunnel and start the fire
ventilation system. When this is performed by an operator he will always think and look for confirmation before closing the tunnel. This instruction was replaced with an automatic response. Now, before the operator can react, the tunnel will be closed and the fire ventilation system will be up and running. The instruction for the operator is now reduced to “call the fire brigade”. If the tunnel is equipped with a camera, he will of course have a “pop up camera view” of the actual area. AFTER he has called the fire brigade, he is supposed to start looking for other information that might confirm if there is an actual fire or not. **By doing it this way, we have changed the modus from “think and close” to “think and open”.** In many tunnels with medium traffic, it really doesn’t matter if people have to wait for 5 minutes. In a high traffic tunnel, several vehicles would have entered the tunnel during the decision time, which would represent an unnecessary risk. If it is a high traffic tunnel, it will probably have cameras and thereby quick confirmation of the actual status. In a complex tunnel system with junctions there are also different ways of starting the ventilation system, depending on where the fire is. By definition the fire is assumed to be in the area of the fire extinguisher first removed and the fire ventilation system will then start accordingly. Adjustments can of course be done from the Road Traffic Center. The merging of systems has made it possible to add a command to the “on screen” camera picture for “fire at this location” (see Figure 3). This command will start the fire ventilation system for that area, and stop traffic moving toward the fire at all possible points in the tunnel. “One decision – one button” means fewer operator errors.

The ventilation during normal traffic has of course always been automatic, with the possibility for the operator to override the system.

And of course, if you install modern fire detection systems, and use a combination of smoke and heat for detection of a fire, you will also know where the fire is. The problem are again that few of this systems are stable enough to be used for automatic response, they either give several false alarms, or no alarm.

### 4.1. Automatic response for traffic incidents

Many operators and people working with traffic management, will claim that it is not possible to have automatic response for traffic incidents. Impossible or not possible are word that never should be used.

It is more difficult to predefine action for traffic incidents. Look at stopped vehicle. Is it possible to have automatic response for closing lane, and reducing speed limit due to at stopped vehicle?

Standard ITV detection systems might give you which lane a stopped vehicle is in. The problem arises when it is between lanes.

Most vehicles stop in the right lane or emergency lane. In a highway tunnel with two lanes in each direction it should be possible to categorize a stopped vehicle I three categories.

1-left lane, 2-not sure, 3-right lane

For the number two action, the operator will have to decide what to do, as today. But for the others, automatic closing of lane should be easy to define. In all cases the speed limits and warning signs should come on by automatic response.

Again, the demands for accuracy, and tolerance of false alarms are very low. I do not know of any systems based on video detection with sufficient quality for automatic response. Perhaps radar detection will be good enough for this.
4.2. Construction of automatic systems

4.3. Basic Design

When you choose to use automatic response systems you are vulnerable to false alarms. This forces you to change the construction of certain components in the system.

Let us look at a cabinet for fire extinguishers.

Old systems: The cabinet is mounted on the tunnel wall and is subjected to vibrations caused by high/low pressure from heavy duty vehicles. There are mechanical switches for detecting an open door and the removal of a fire extinguisher. This results in false alarms for fire extinguishers being removed when large trucks pass by. As long as the switch is new the problem does not exist, but as time goes by this becomes a problem, as maintenance is always short of funding! By changing the alarm to “door open” and “fire extinguisher removed” at the same time, the number of false alarms is drastically reduced. This could be done by changes in the software, but this is still not good enough for automatic response systems.

New systems: Mechanical switches have been replaced with inductive sensors, where the steel canister has to be moved 20 mm before an alarm situation is detected. This has been installed in nearly all tunnels in the western region of Norway. Only in one tunnel has I learned of false alarms concerning this. Here it was due to installation, not according to contract. The supplier had used inductive sensors with gap distance 12 mm. This caused false alarms in the cabinet outside the tunnel, when the snow plow passed, at the caused the cabinet to shake.

If the PLC system is constructed the wrong way, you can still have false alarms when you lose power to the station.

Automatic systems require careful construction of the system. What will you do when a fuse is out or you lose power to the cabinet for the fire extinguisher? Close the tunnel? Or just keep an extra eye on the tunnel until it is fixed? It is not popular to close a tunnel just because a few cabinets with fire extinguishers are not being monitored. Closing a tunnel might even have a higher risk of causing secondary accidents. (If you have everything on one fuse, shame on you!)

4.4. Where to use automatic responses

4.4.1. Start-of-Fire Procedure

Today only the removal of a fire extinguisher will trigger an automatic start-of-fire procedure. We regard the removal of a fire extinguisher as a “confirmed” fire until a “no fire exists” is confirmed. This means that the theft of a fire extinguisher will close the tunnel, and start the ventilation as if the fire is in the area of the removed fire extinguisher. This procedure may only be stopped by a manual command, either from an emergency control panel or from the Road Traffic Center. The Road Traffic Center has many different ways of changing fire procedures or stopping them.

4.4.2. Wrong-Way Driver

If we have a trusted system for the detection of a wrong-way driver, we will be able to have the left lane closed in less than 20 seconds. This reduces the risk of accidents during these situations. Camera detection does have some limits, and other systems are preferable.
When using image analysis we had one situation where we had an alarm due to a fly crawling across the camera lens in wrong direction. Don’t expect that it is possible to eliminate all false alarms!

4.4.3. **Pollution – High Gas Concentration**

No one should intentionally construct a system where they would have to read pollution levels and manually set the levels for ventilation. But, unfortunately, we have built many tunnels where the closing of the tunnel due to high levels of pollution must be done manually based on an alarm from the tunnel. The main problem is a lack of accuracy and neglected maintenance. To close a tunnel based on 0.75 ppm NO2 ±0.4 ppm is not something we feel comfortable about. And this is the warranted accuracy for the best electrochemical sensors. To use NO, and close with a level of 6.75±1.5 ppm is far better. But since the NO2 levels as compared to NO levels are not constant, you still need to measure NO2, especially in long tunnels.

4.4.3.1. **Other Situations for Automatic Responses**

All tunnels longer than 500m are supposed to have a radio system for FM radio as well as the channels used by emergency personnel. The possibility for speaking to people in cars via FM radio is nearly never used. No one has been able to provide regulations on what to say when. Different people in fire brigades, police, and health care services are unable to agree on standard messages during different kinds of accidents.

If we were able to define what to say when, it would be possible to have predefined messages in the tunnel, which could by triggered by automatic or manual response systems.

4.4.3.2. **Automatic Reduction of Speed Limits During Queue Situations**

Many tunnels will have a queue situation during rush hour or during accidents. A queue stretching halfway through the inside of a highway tunnel is a situation no one likes, but it is unavoidable unless you close the tunnel during rush hour.

It is easy to reduce the risk by automatically reducing speed limits based on speed measurements in the tunnel. Here a few too many speed reductions, do not pose a major problem.

5. **SPECIFICATIONS FOR NEW TUNNELS**

When you write the specification for an automatic system, you have to consider, and specify with great detail how the system should work. DO NOT EXPECT the system integrator to know how it should work.

It is now very important that the demands for the software are strict, and well planned. Any combination of input, where the output is not specified might cause a dangerous situation in real life.

All demands must be possible to identify and verify. Any demand that cannot be verified is worthless.

This detailed specification of how the software must work is time consuming, and difficult. Most consultants will be afraid of being sued, and thereby try to avoid giving specific instructions. This in combination with few consultants who know software and traffic makes them even more reluctant.
Byers will also try to say, it must work, and stop there. Their problem is when the system integrator asks, where do contract say it must work that way? The road administration must then order a changer. Even when the supplier accept, it as his responsibility, it will often be time consuming to change the software, and the opening of the tunnel will be delayed.

Remember, if you cannot tell the software engineer how it should work, how can you then expect him to understand how it should work? He is good at writing software, not traffic safety!

6. TESTING

Since what you build in a tunnel is a safety system, you should write the entire specification in a way, which makes it easy to test.

The Norwegian public road administration has specified several levels for testing, but they are still, in my opinion, taking to light on Factory Acceptance Test, and parts testing before systems are finished. But they have specified System integrators performance test, which has do be done as a complete test for sensor to automatic response to road traffic central. This test consists of testing all objects in the tunnel. For every object the system integrator must sign that it works from end to end.

After this is delivered, then the road administration starts their test, the Site Acceptance Test. If it shows that the previous test is false, they can demand that the system integrator test everything again. And when SAT is accepted, User Acceptance test start, and now it is the road traffic central testing the system. They are looking closely to stability. To test this they test all kinds of combination of commands.

Many a tunnel has worked fine, when you go from a normal situation – to situation 1 or x and back to normal. Trouble often arises, when you change from situation 1 to situation 2 and so on. Now the lack of specifications becomes visible. Combinations of commands not thought of, might give very dangerous situations in a highway system with traffic.

These results, when discovered at the end of the project will normally cause delayed opening of the tunnel.

7. CONCLUSION

If you want to reduce the risk of delayed opening, and extra bills at the end of the project, you must use more time for specifications, and make it easy for yourself when you are going to test the systems. A detailed specification like this will always contain some errors. The benefit is that you often discover them early in the project, so the consequence is reduced, compared to when you just say, “It should work”. In the last case you will discover the errors during SAT.