CITYRING PROJECT, SWITZERLAND, AN INNOVATIVE MONITORING SYSTEM FOR SAFE TRAFFIC MANAGEMENT DURING TUNNEL RENOVATION WORKS

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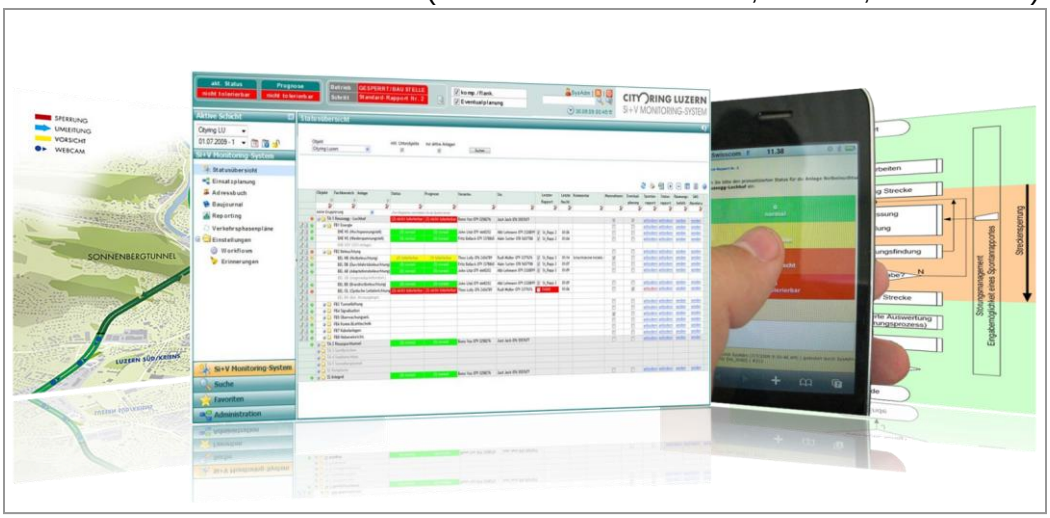


Summary

The Cityring project (www.cityring.ch) at Lucerne, Switzerland, is a renovation project of a 3.5 km A2 motorway section (85,000 cars/ day) including two twin-tube tunnels. 40 different equipment types are replaced through a complicated migration scenario. It is specific to this project that the section is available for traffic during the weekdays. Only during the nights and certain weekends, some sub-sections are closed for the renovation work.

If equipment, which is classified as safety relevant, is not functional in the morning, the entire north-south respective south-north traffic must be rerouted through the city of Lucerne. In order to avoid potential traffic collapse caused by such event a unique control and monitoring system, MonSys, was developed for (1) planning the works and shifts and (2) monitoring and controlling the progress of works at different construction sites.

The objective of the monitoring system is to monitor all renovation and renewal works real time and identify critical situations as early as possible. To our best knowledge, such monitoring system has never been implemented. The development and implementation of such system was in many areas unique pioneer work. The system is well accepted by all parties.

Keywords: Monitoring system, roadwork safety, tunnel renovation, tunnel safety management

1. Introduction

The E35 route is one of the main axes from North to South Europe. It is the fastest route from Benelux countries and western part of Germany through Switzerland to Italy. The Swiss part of the E35 route, A2 motorway, runs from Basel to Chiasso.

Cityring Lucerne (www.cityring.ch) is the renovation project of 3.5 km section of A2 motorway though Lucerne. In average 85,000 cars passes the section daily. The project is to be considered as unique because the tunnels cannot be closed to traffic at daytime, so that all renovation works have to be carried out during the weeknights and circa 25 weekends per year.

A new and innovative database and software system – called MonSys (Monitoring System) – has been developed specifically for this project. Works and shift planning as well as tunnel closing and opening processes are managed safely with the help of MonSys.

Fig.1: E35 motorway

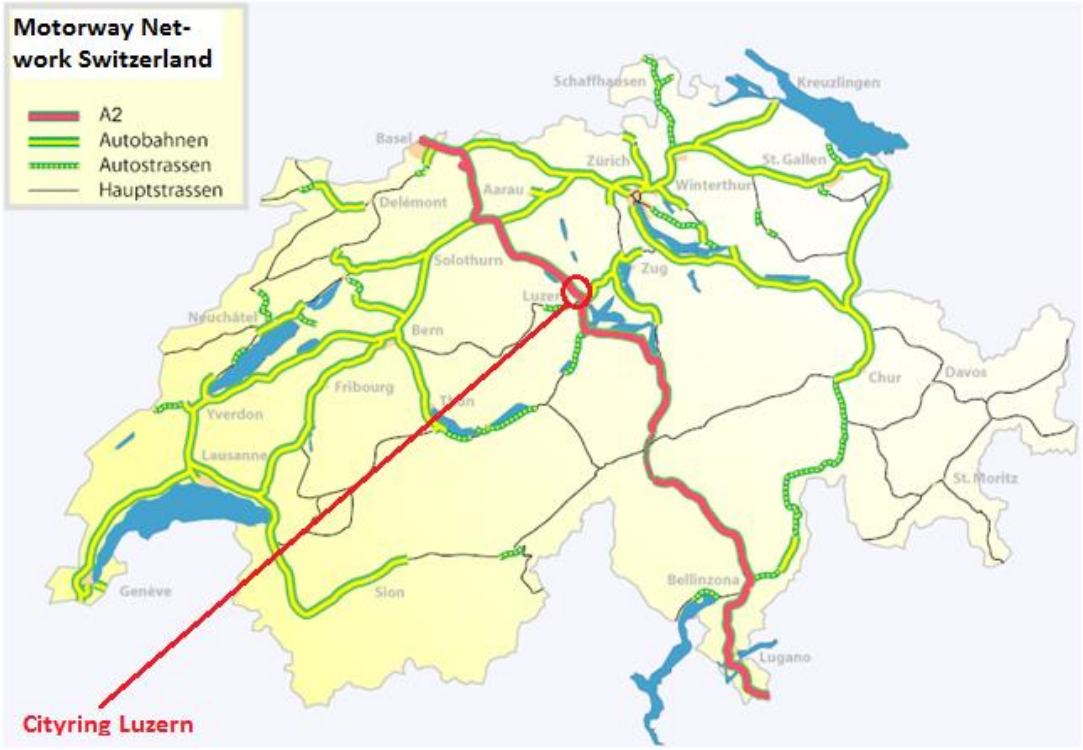


Fig. 2: A2 Motorway

2. Cityring Project

The Federal Roads Office, FEDRO, renovates the A2 motorway section between Reussegg and Grosshof in Lucerne. The works, which are done 2009 - 2013, are divided in five geographical sub-sections:

1) Viaduct
2) Reussport twin-tube tunnel (0.6 km)
3) Five bridges
4) Motorway exit
5) Sonnenberg twin-tube tunnel (1.5 km)

The project with overall cost of around EUR 300 million has the following objectives:

- Upgrading the tunnels to the latest technical and safety requirements
- 20 years without interventions
- Minimizing delays to traffic during the renovation works
- Ensuring safety of commuters as well as the workers during the renovation works

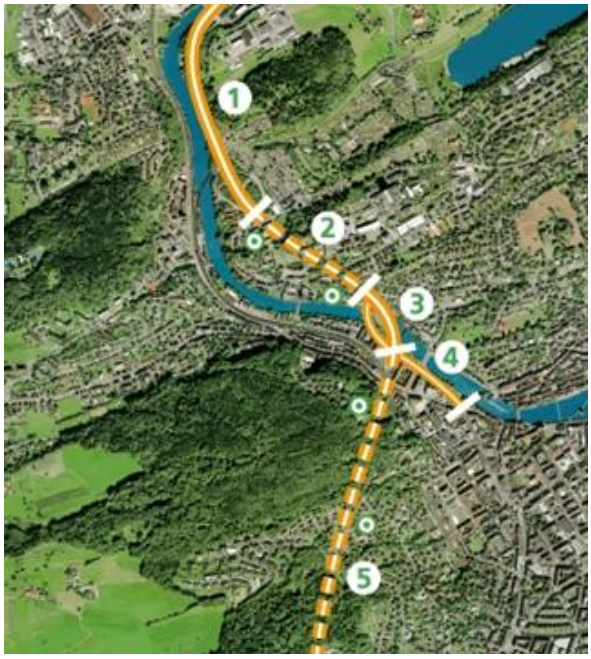


Fig. 3: Five Cityring sub-sections

The Reussport and Sonnenberg tunnels were built in the 70s. Heavy traffic has left its mark, and the tunnels fail to fulfil the modern safety standards. Therefore the five sub-sections will be fully renovated and the operations and safety equipment will be updated with the latest technology.

Construction works include:

- Surface structures
- Street coating
- Waste water drains
- Extension of Reussport tunnel
- Bridge abutment

Operations and safety equipment include:

- Energy supply and lighting
- Ventilation
- Traffic control system and signs
- Fire alarms and video cameras
- Emergency telephones

3. The Challenge

Maintaining the road network is generally an ever increasing challenge for FEDRO.

- There is today more maintenance or renewal work on existing roads than new built.
- Amount of traffic has increased steadily since decades complicating maintenance.
- It is not effective to reroute the traffic to already saturated local roads.

Cityring poses a particularly significant challenge. With 85,000 cars driving through this central motorway section daily A2 is one of the most driven streets in Switzerland, and one of the main routes between north and south Europe. It is virtually not possible to close the tunnels during the daytime without creating a traffic chaos in the greater Lucerne area.

Consequently FEDRO has decided to keep all the motorway sections available for traffic during the weekdays. During the weeknights and about 25 weekends yearly, some sub-sections are

closed for the renovation work, instead. Hence, the construction sites are installed at 20:00 weekday evenings and cleared up in the morning at 06:00.

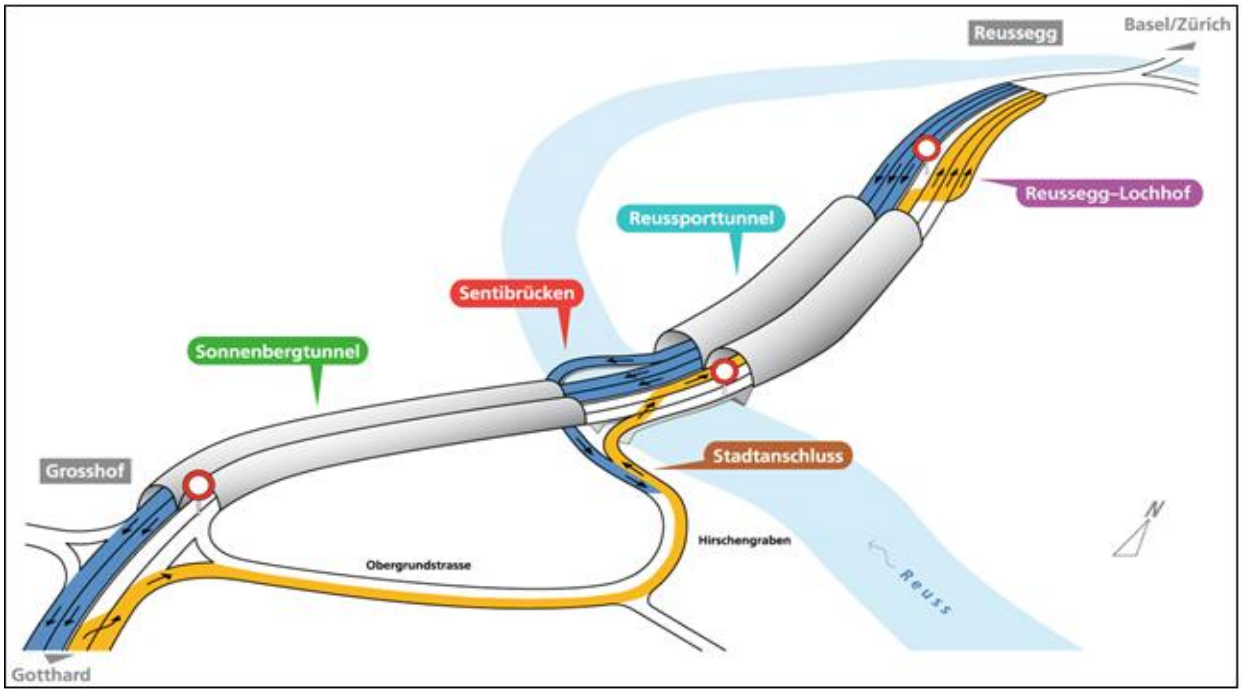


Fig. 4: Nightly traffic routing scheme example, northbound

More than 70 organizations are involved in the project. There are about 200-300 workers at the construction sites working in shifts. This means that during the construction phase not always the same person is responsible and responsive. Planning of works and workers in shifts must be done very precisely. During the renovation works, some equipments are working in a mixed way, i.e. with old, provisional and new devices and components. This fact alone makes security and availability of the equipments extremely complex and error-prone.

It is essential that in the morning all the equipment meet the defined minimum criteria to work properly. If these criteria are not met, the tunnels cannot be opened and the entire north-south or south-north traffic must be rerouted through the city of Lucerne, which would lead to a complete traffic collapse in greater Lucerne area.

The safety of the construction workers as well as the safe opening of the tunnels for the traffic every morning is the most important aspect. Therefore a unique control system, MonSys, was developed for

(1) planning the works and shifts in advance including fine tuning in real time; and
(2) monitoring and controlling the progress of works at different construction sites.

The system collects information concerning both current status and forecast of final status for every main equipment from all construction sites all along the night. This information allows the project management to make the decision whether the tunnels can be safely opened to the traffic in the morning.

To our best knowledge, such monitoring system has never been implemented. The development and implementation of such system was in many areas a unique pioneer work.

4. Project Requirements

FEDRO's classification system assignes the 40 equipment types being renovated/ replaced by Cityring project into nine main categories. Until development of MonSys, no definition existed defining when a tunnel can be driven or not. In other words, it has not been defined which equipment categories are critical for a tunnel to operate safely. The first step in development of MonSys was to define a simple and comprehensible assessment scheme.

The scheme classifies all equipments/facilities into one of the following main levels:

- A – Level: safety critical equipments
- B – Level: important equipments
- C – Level: accessory equipments

The equipment can have one of the following system states:

- Normal state: everything is running normally
- Tolerable state: equipment has small, minor defects
- Undesirable state: equipment has defects, not affecting safety. Corrective actions are needed.
- Non-tolerable state: tunnel/sub-section cannot be opened for traffic because the safety is no longer guaranteed

Now the criticality levels were assigned one or more possible system states as shown in fig. 5.

For example, accessory level equipment (C – Level) cannot have a more severe state than "tolerable" and important equipment (B – Level) cannot have more critical state than "undesirable".

Solely security critical equipment (A – Level) can be assigned "non-tolerable" state, which would prevent reopening of the sub-section for the traffic.

equipment categories / system state	A	B	C
0 Normal	✓	✓	✓
1 Tolerable	✓	✓	✓
2 Undesirable	✓	✓	
3 Non-tolerable	✓		

Fig. 5: Assessment scheme

This simple schema introduces a generic rating for every system state for any of the 40 systems in nine categories. It generates two clear outputs from any possible combination:

- Can the section be reopened for the traffic safely?
- Are corrective actions needed?

This schema was a central part in MonSys development project. Once the schema was defined, FEDRO can use the same schema in other projects relying on same equipment categories.

Furthermore, the usability of the monitoring system is improved by filtering out not-used categories from particular sub-section or contract. Hence, only parts of the system categories are visible for the different geographical sub-sections of the project.

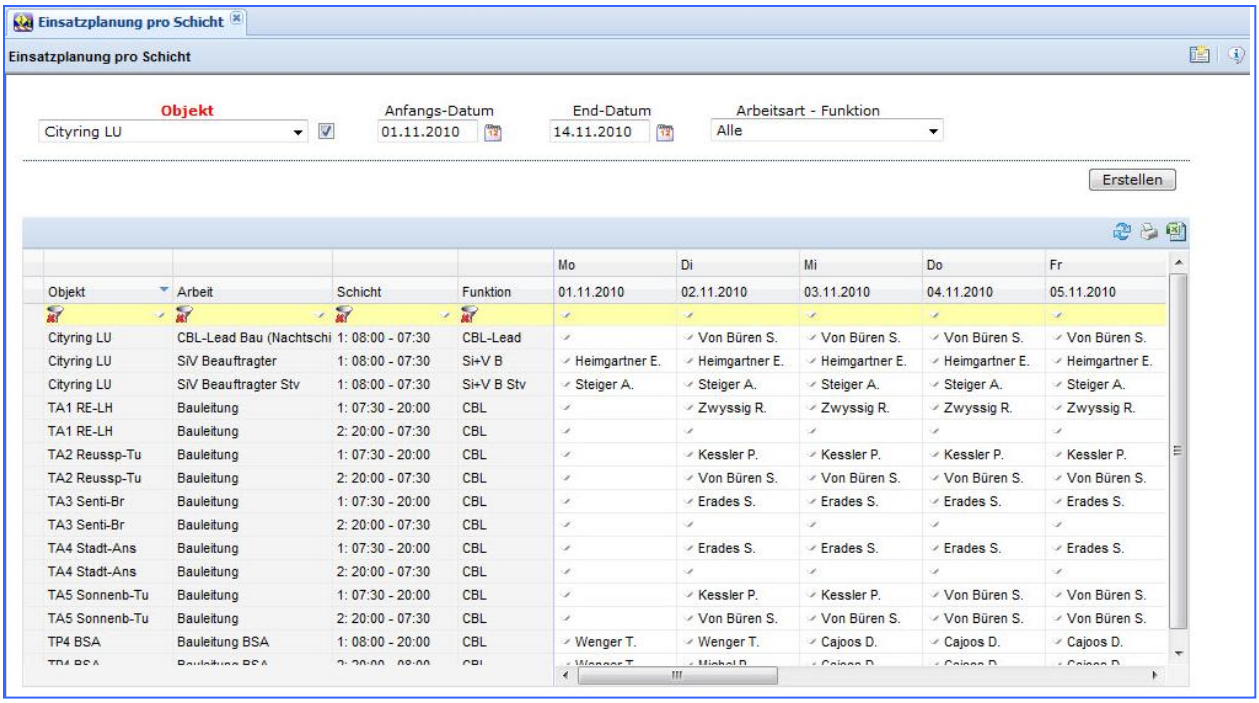
5. Project Organisation

In addition to the usual organizations in a construction project – such as the Client, overall project management, external project management, designers and site supervisors – new organizations were created for ensuring the so called Safety and Availability (S+A) topics.

First of all a safety and availability group was established to design the S+A processes. Then a group of S+A officers was given a mandate to implement these processes in praxis. All the S+A organizations report directly to FEDRO and its representatives.

Furthermore, a new unity, the Alarm Center operated by Securitas, was created to support S+A organization during the construction phase. They act as an information hub answering calls around the clock, keeping event logs up to date, making sure all standard reports are submitted in time and when needed calling responsible people according to the predefined responsibility matrix. MonSys is their main tool of work as for everyone involved in the S+A organization. MonSys helps governing the S+A processes and providing an event log visible to the project team.

In addition to the above mentioned organizations also other parties involved in the project use data from MonSys, such as the police and the street maintenance department "zentras".



Objekt	Arbeit	Schicht	Funktion	Mo 01.11.2010	Di 02.11.2010	Mi 03.11.2010	Do 04.11.2010	Fr 05.11.2010
Cityring LU	CBL-Lead Bau (Nachtschi	1: 08:00 - 07:30	CBL-Lead		Von Büren S.	Von Büren S.	Von Büren S.	Von Büren S.
Cityring LU	SiV Beauftragter	1: 08:00 - 07:30	Si+V B	Heimgartner E.	Heimgartner E.	Heimgartner E.	Heimgartner E.	Heimgartner E.
Cityring LU	SiV Beauftragter Stv	1: 08:00 - 07:30	Si+V B Stv	Steiger A.	Steiger A.	Steiger A.	Steiger A.	Steiger A.
TA1 RE-LH	Bauleitung	1: 07:30 - 20:00	CBL		Zwyssig R.	Zwyssig R.	Zwyssig R.	Zwyssig R.
TA1 RE-LH	Bauleitung	2: 20:00 - 07:30	CBL					
TA2 Reussp-Tu	Bauleitung	1: 07:30 - 20:00	CBL		Kessler P.	Kessler P.	Kessler P.	Kessler P.
TA2 Reussp-Tu	Bauleitung	2: 20:00 - 07:30	CBL		Von Büren S.	Von Büren S.	Von Büren S.	Von Büren S.
TA3 Senti-Br	Bauleitung	1: 07:30 - 20:00	CBL		Erades S.	Erades S.	Erades S.	Erades S.
TA3 Senti-Br	Bauleitung	2: 20:00 - 07:30	CBL					
TA4 Stadt-Ans	Bauleitung	1: 07:30 - 20:00	CBL		Erades S.	Erades S.	Erades S.	Erades S.
TA4 Stadt-Ans	Bauleitung	2: 20:00 - 07:30	CBL					
TA5 Sonnenb-Tu	Bauleitung	1: 07:30 - 20:00	CBL		Kessler P.	Kessler P.	Von Büren S.	Von Büren S.
TA5 Sonnenb-Tu	Bauleitung	2: 20:00 - 07:30	CBL		Von Büren S.	Von Büren S.	Von Büren S.	Von Büren S.
TP4 BSA	Bauleitung BSA	1: 08:00 - 20:00	CBL	Wenger T.	Wenger T.	Cajoos D.	Cajoos D.	Cajoos D.

Fig. 6: Accurate planning of key persons in MonSys

6. Monitoring Process

The monitoring process is cyclic and is pointed out in the following flow chart.

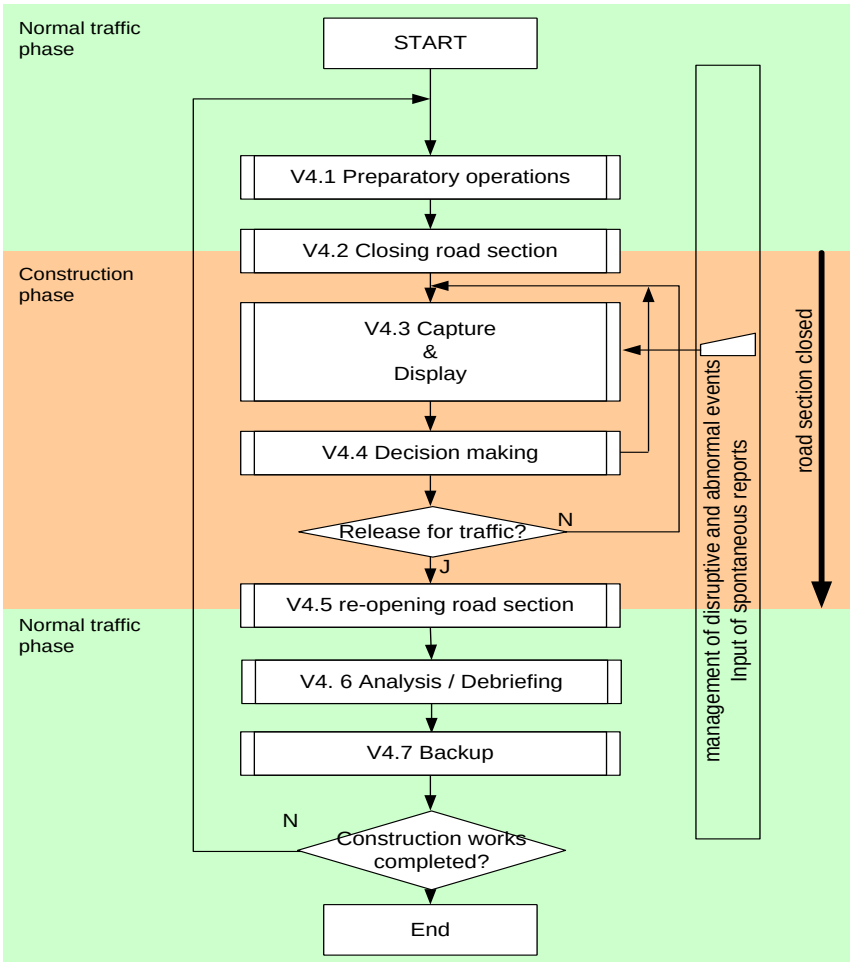


Fig 7: Monitoring process flow chart

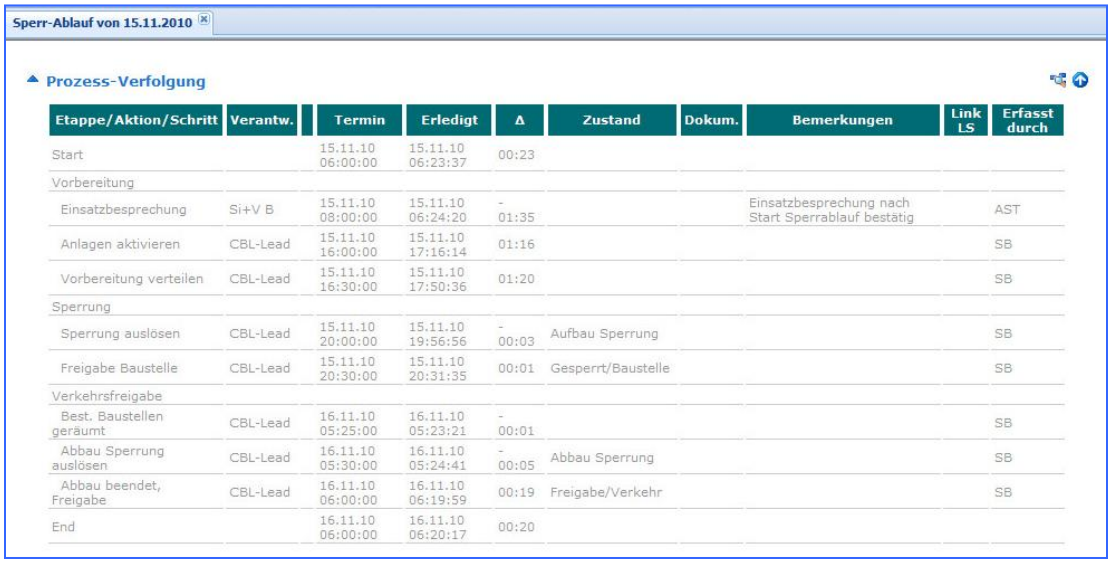
First step of the process is the work planning (preparatory operations), which extends from an overall scheduling of activities and participants until precise tuning, to be completed latest one week before the particular work starts. The data to be planned includes traffic routing schemes, closing times and durations, on-duty site supervisors, S+A officers, etc.

All these data are stored into MonSys and are thus available 24/7 for managing the entire S+A monitoring process. Specific reports, such as weekly plans and road traffic routing schemes, are printed out for the police and the street maintenance team, to be available in tunnel operation rooms and assembly points as a backup.

Before the works start, all equipments to be monitored are activated in MonSys.

During every work closure (night or weekend), the following process is repeated:

- at 20:00: rerouting of traffic and closing
  Workers and site supervisors start to work at predefined time by barricading the road section being renovated.
- at 22:00, at 01:00 and at 04:00: standard reports
  Site supervisors are reminded via SMS to enter into MonSys their "standard reports" concerning work progress and forecasts for every of their equipment. A specific user-friendly iPhone application was developed for this purpose. The standard report includes both the current status of the equipment as well as a forecast of final status for the road reopening.
- at 05:20: end of works
  Works are finished and all construction sites are cleaning up from material and machines.
- at 06:00: reopening to traffic
  If no abnormal situation are stated in MonSys and every workflow step has been successfully completed, the section can be released to traffic at 6:00.


Sperr-Ablauf von 15.11.2010

Prozess-Verfolgung

Etappe/Aktion/Schritt	Verantw.	Termin	Erledigt	Δ	Zustand	Dokum.	Bemerkungen	Link LS	Erfasst durch
Start		15.11.10 06:00:00	15.11.10 06:23:37	00:23					
Vorbereitung									
Einsatzbesprechung	Si+V B	15.11.10 08:00:00	15.11.10 06:24:20	- 01:35			Einsatzbesprechung nach Start Sperrablauf bestätig		AST
Anlagen aktivieren	CBL-Lead	15.11.10 16:00:00	15.11.10 17:16:14	01:16					SB
Vorbereitung verteilen	CBL-Lead	15.11.10 16:30:00	15.11.10 17:50:36	01:20					SB
Sperrung									
Sperrung auslösen	CBL-Lead	15.11.10 20:00:00	15.11.10 19:56:56	- 00:03	Aufbau Sperrung				SB
Freigabe Baustelle	CBL-Lead	15.11.10 20:30:00	15.11.10 20:31:35	00:01	Gesperrt/Baustelle				SB
Verkehrsfreigabe									
Best. Baustellen geräumt	CBL-Lead	16.11.10 05:25:00	16.11.10 05:23:21	- 00:01					SB
Abbau Sperrung auslösen	CBL-Lead	16.11.10 05:30:00	16.11.10 05:24:41	- 00:05	Abbau Sperrung				SB
Abbau beendet, Freigabe	CBL-Lead	16.11.10 06:00:00	16.11.10 06:19:59	00:19	Freigabe/Verkehr				SB
End		16.11.10 06:00:00	16.11.10 06:20:17	00:20					

Fig. 8: Workflow log during closing (incl. due/real times, delays and comments)

In case of an abnormal situation, the S+A officers escalates the situation according to a predefined scheme. If opening of the road is at risk, a special “Task Force” is called together. The “Task Force” embodies FEDRO's representatives, external project management, S+A officers and also representatives from the City and the State of Lucerne.

In addition to the standard reports a so called "spontaneous report" can be sent at any time through the iPhone application. The spontaneous report is used to change a system status or a forecast, or to generally share information, e.g. when the works have finished earlier as planned. Incidents and information can also be registered into the MonSys event log by calling the Alarm center at any time. MonSys automatically forwards the gathered information via SMS to the project management and S+A officers. Others can access the information everytime online and in real time.

Rigourous checks and alerts are moreover provided by the MonSys, in order to avoid human errors and machine failures and hence to ensure a faultless and successful workflow.

7. Monitoring System

The "Monitoring System" (MonSys) project was developed and realized in a classical manner. In the beginning no one knew how the graphical user interface (GUI) could look like. A conference room prototyping (CRP) was done simultaneously with two software companies resulting basics for the calling for tenders. A bid from SISO Ltd. won the tender, mainly due to its references in the management of large construction projects.

As soon as requirement specifications were approved, the MonSys development and implementation started parallel in the following four sub-areas:

- Application software
- Central database, server hosting and redundancy
- Client hardware
- System network

MonSys communicates through internet using secure traffic encryption and electronic certificates (https). As standard web technologies are used, MonSys can be accessed from anywhere as soon as the security certificate is installed on the client device.

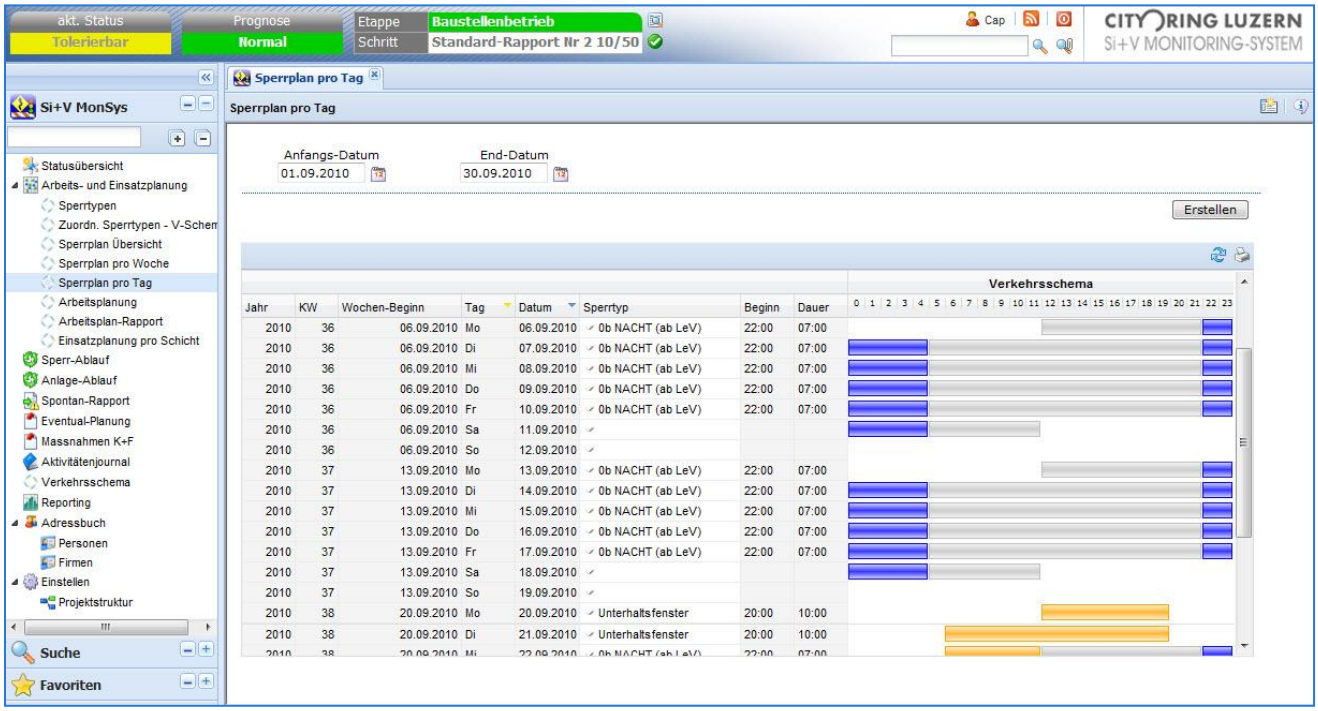


Fig. 9: MonSys graphical user interface (GUI)

MonSys can be used by multiple users and on several different client devices.

Standard local area network (LAN) computers with large displays are used in offices. Forms and diagrams (e.g. traffic routing schemes) can be printed on network enabled A4/A3 color printers. S+A representatives and project managers use laptop and netbook computers with fast mobile connection (UMTS).

Site supervisors have been delivered iPhones with special user-friendly MonSys application, in order to simplify entering and submitting of their standard and spontaneous reports.

Despite the initial skepticism, the feeling about the use of iPhones at a construction site has rapidly converted into enthusiasm as soon as the following advantages were discovered:

- The input device is small, compact and thus always present
- Input can be done while standing; table is not required
- No loss of time with booting of a computer
- iPhone is multifunctional; in addition to sending standard and spontaneous reports it can also be used for phone calls, SMS messaging or for browsing project address list. Hence, reducing the amount of devices site supervisors have to carry around.

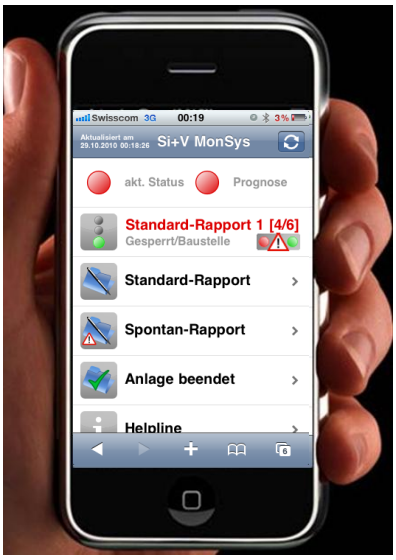


Fig. 10: iPhone application

Besides to the main tunnels, also access tunnels and tunnel operating rooms were equipped with UMTS network. Wired network computers were placed in every tunnel operating room for redundancy.

Another new feature is an automatic control of traffic signalization to the construction sites. During normal traffic in daytime, the MonSys Cockpit as well as the physical traffic lights are set to red. During traffic rerouting process they are both set to yellow. During the construction and maintenance work they are both set to green, which indicates that the constructions sites can be accessed safely.

Fig. 11: MonSys cockpit during daytime (red color)

8. Conclusion

After an intensive trial period and despite initial skepticism, the various user groups are now, during the actual deployment, very happy with the MonSys. The monitoring workflow and the software system have fully met the expectations. Although entering the reports is an additional small effort for the site supervisors, the benefits outweigh clearly the initial outlay.

Here are some important points:

- ✓ Design quality: MonSys forces designers to more accurate, consistent.
- ✓ Documentation: the designing and planning steps are all well documented.
- ✓ Automatic creation of different reports such as weekly plans, shift reports, etc.
- ✓ Information hub: all messages are recorded in an event log and sent to the affected people.
- ✓ Contacting currently responsible people: based on the shift planning input MonSys knows at any given time which person is responsible for different functions at different sub-sections.
- ✓ Problems are detected early and corrective actions can start at the earliest possible time.
- ✓ The implementation of the alarm center produced a significant relief for S+A officers. However, alarm center could not work without MonSys.
- ✓ MonSys is hosted by third party and, thus, used as a Software As A Service (SAAS). This relieves the project team from complicated IT tasks such as backups and updates, and allows them to focus on their core competence.
- ✓ The usage of web technologies allows users to access the system securely from anywhere.

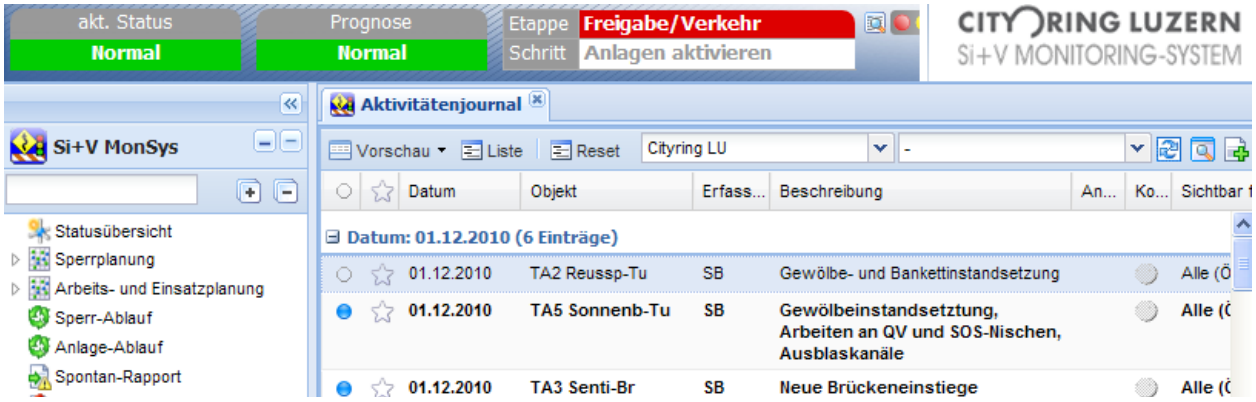


Fig. 12: MonSys event log

The monitoring system project has become much more complex than it was assumed in the beginning. Since the MonSys is "just" a tool for communication between organizations within the project team, the detailed definition of the organizational processes is an essential success factor, probably as important as the technological solutions.

Another success factor was the very positive attitude of the users, who intensively worked with MonSys during the prototyping and the production phases, and gave constructive feedbacks. The users were almost involuntarily faced with all possible and impossible system states during the software testing. This allowed the identification of weaknesses and improvements to them.

MonSys demonstrated that such a monitoring system is very helpful and may represent a new way of conceiving safe traffic management during renovation work.