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Optimized traffic control with benchmarked road weather data

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ABSTRACT

Within section control systems on motorways, road weather data are used in order to improve traffic safety during adverse weather conditions. Variable message signs (VMS) are displayed to warn road users of various conditions including slippery road surfaces or fog. However, the quality of acquired road weather data and traffic control measures is not checked on a regular basis, if at all. Within the German Test Site for Road Weather Stations [5], plausibility checks were developed, tested and improved by a German working group. These plausibility checks can be used to detect erroneous measurements and thus improve the quality of traffic control measures. If the speed limits and warnings displayed via VMS correspond to the prevailing traffic and weather situation, the acceptance by the road users will be high. Therefore the input data must be of a high quality. The plausibility checks for road weather data are published within a German Technical Bulletin [4]. In order to maximize benefits from these plausibility checks, operators and traffic engineers must decide how to interpret and react to the results of the checks. Facilitating and improving this decision are the goals of this paper.

Keywords: Road Weather Data, Quality Management, Traffic Control, FMEA

1 INTRODUCTION

Within section control systems on motorways, road weather data are used in order to improve traffic safety during adverse weather conditions. Variable message signs (VMS) are displayed to warn road users of various conditions including slippery road surfaces or fog. The quality of acquired road weather data and traffic control measures is not checked on a regular basis, if at all. This problem is exacerbated by the fact that not all of the tested sensors are able to fulfil the set requirement, as reported by the German Test Site for Road Weather Stations [5].
Validation and quality management of road weather data and corresponding traffic control measures are a major task in data processing. The objectives are to detect malfunctioning sensor systems in order to exclude them from further usage within traffic control systems and to fix malfunctioning equipment as soon as possible or as soon as required. Therefore, plausibility checks for road weather data are published within a German Technical Bulletin [4]. In order to maximize benefits from these plausibility checks, operators and traffic engineers must decide how to interpret and how to react to the results of the checks. In order to facilitate and improve this decision making process, a benchmarking concept is applied to road weather data. This concept will make it possible to optimise traffic control measures. Therefore, benchmarking methods are used to compare the performance of a sensor system with a set best performance standard in the quest for better functionality of traffic control systems.
A benchmarking system was developed that outperforms the plausibility checks used in the sub-centres at present.

2 GERMAN TEST SITE FOR ROAD WEATHER STATIONS AND TECHNICAL BULLETIN

To monitor and enhance the quality of road weather sensor systems, a Test Site was established in 2003 in Germany. This Test Site is situated on the motorway A92 near the Munich-Airport. At this Test Site, different sensor systems from different companies are evaluated in terms of their applicability for use in traffic control. The evaluation of the sensors takes place under real conditions, so that the behaviour of the measurements over a long time period can be analyzed. The applicability of the sensor systems for traffic control is published in an annual report [e.g. 5]. The advantage of the Test Site is that all sensor systems are evaluated under the same conditions.

Figure 1. German Test Site for road weather stations

The plausibility checks were developed using the extensive experience gained at the test site and from the expertise of a German working group. These checks help to identify false detection and generate substitute values. Several types of plausibility checks were developed, tested and optimized, including single measurement checks (e.g. a defined range were the measurement is expected to be), logical-physical coherence checks (e.g. a reduction of visibility is only possible when the air humidity is over a defined value) and long term plausibility checks (comparison of data from neighbouring weather stations) [2]. A data distribution tool was developed and integrated in traffic control centres [6]. It can be used in daily operation for creating substitute values if the input data are not plausible. All detected weather data are analyzed automatically concerning their plausibility.

3 BENCHMARKING CONCEPT FOR USAGE OF ROAD WEATHER DATA

3.1 Objective

In order to maximize the benefits gained from plausibility checks, as documented in a German Technical Bulletin [4], operators and traffic engineers must be supported in interpreting and reacting to the results of the plausibility checks. Facilitating and improving this decision are the goals of the presented benchmarking concept for road weather data within traffic control systems by comparing a given performance with the known best performance.
Possible impacts of failures are to be analyzed, such that the operators and traffic engineers are supported in their day-to-day operations, complementing the help provided only by a technical bulletin. Examples of support offered by benchmarking system are the additional proposal of several standardized reactions to a detected failure as well as assistance for the staff in interpreting the severity of erroneous data.

3.2 Benchmarking Concept

Figure 2 shows the conventional traffic control set-up as described in [4], supplemented by a benchmarking concept that is based on the data processing step “plausibility control”. The severity of errors in road weather data is determined according to a Failure Mode Effects Analysis (FMEA). The procedure for applying FMEA as well as corresponding results are described in section 3.3.
Within the benchmarking concept, FMEA is used to define the severity of erroneous data sets in the context of current road weather and to determine the relevance of the road weather data for the purpose of traffic control. Based on this information and with the help of a knowledge base containing information on pre-defined incident reaction schemes with prior input from traffic engineers, appropriate responses on disturbances are to be displayed to the operator (cf. Section 3.4). Therefore, service levels were defined as agreements on quality so that uniform quality standards can be introduced for different processes, equipment and units, based on the benchmarking system for road traffic data and traffic control [1].

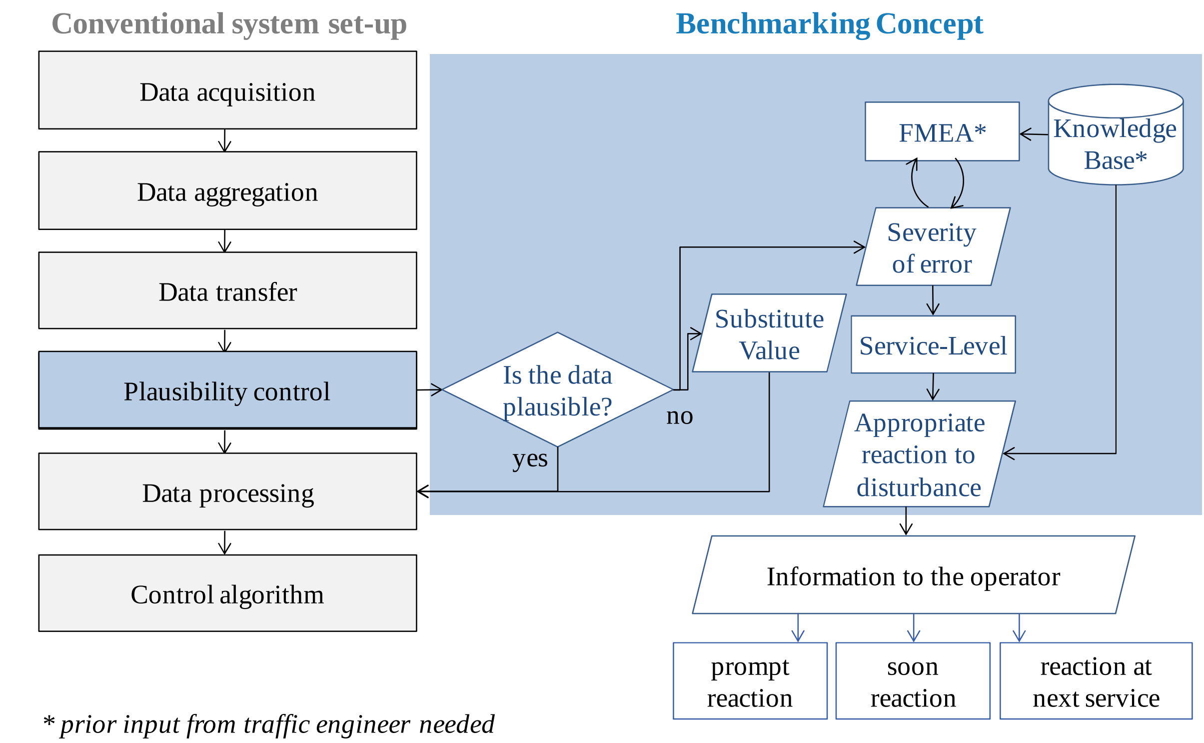

Figure 2. Benchmarking Concept applied to Conventional traffic control system set-up

3.3 FMEA

A Failure Mode and Effects Analysis (FMEA) is a widely used tool to define, identify and eliminate known and potential failures, problems or errors from systems or processes. The fundamental idea is to set the focus on defect prevention instead of on error correction [3]. FMEA is carried out iteratively in several steps. The following Figure 3 shows the proceeded workflow in this project.

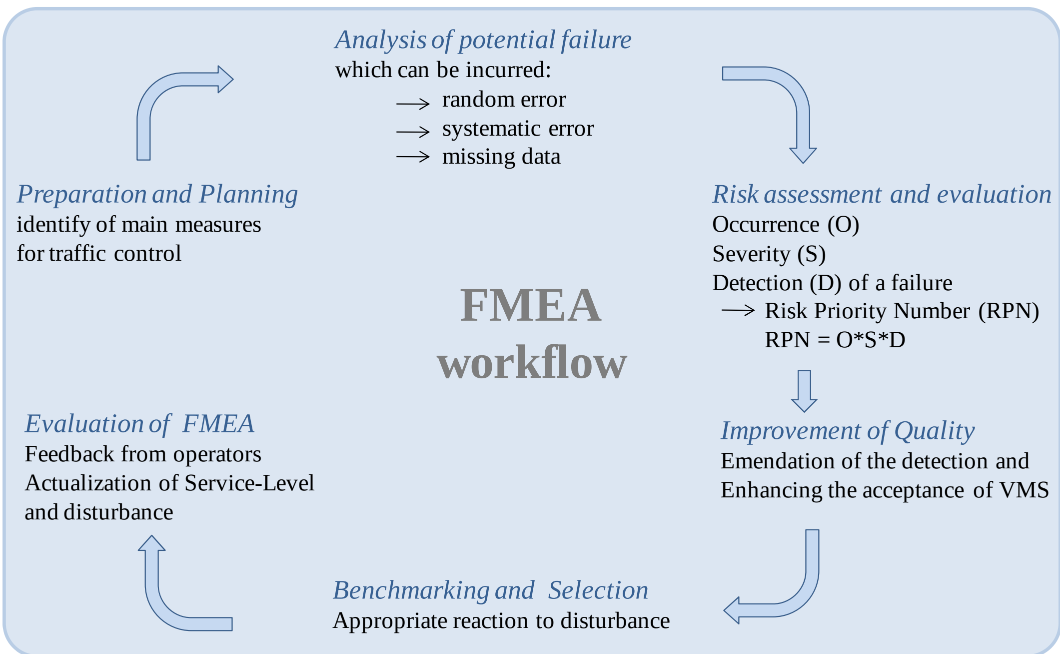

Figure 3. FMEA Workflow

A working group, which also works on the Test Site for Road Weather Systems, identified potential errors within road weather data. After the first step of planning and preparation of the FMEA, the potential failures were analysed.
Three categories of failures are possible:
- random error (error that is unpredictable)
- systematic error (error that occurs with a specific scheme, e.g. a calibration error) or
- missing data (no measurement is available).

Furthermore, these errors can be categorised into time periods or measuring ranges regarding their relevance on traffic control. For every meteorological measurement, the risk priorities of failure modes were defined. The risk priority number (RPN), which is the product of the occurrence (O), severity (S) and detection (D) of failure, gives information about the importance of a failure on this traffic control task. The three risk factors are defined in Table 1. Every risk factor is clustered in a 10-point scale.

Rating	***Occurrence (O)***	***Severity (S)***	***Detection (D)***
10 9	Very high: Frequent failure	Very critical: Direct influence on traffic control	Unlikely: No plausibility check available
8 7	High: Repeated failure	Critical: Indirect influence on traffic control	Incidental detection at service work
6 5 4	Moderate: Occasional failure	Moderate: Influence on plausibility check of a primary measurement	Plausibility check or Information from road users/police
3 2	Low: Relatively few failures	Influence on plausibility check of a secondary measurement	Few plausibility checks available
1	Unusual failure	No influence on traffic control	Evident failure

Table 1. Definition of rates for every risk factor

A failure mode with a high RPN is more important and has a higher priority for correction than a failure mode with a low rating. But it is also important to check every single risk factor O, S and D. If one of them is ranked with a high number, the relevance of the error within the measurement is high. Different values for RPN must be analyzed carefully, because different combinations of the three risk factors may produce the same value of RPN. In this step of FMEA, the experiences and knowledge of the working group members is very important.
The following figure shows the specified rate for O, S, and D and also the RPN for all road weather data that were used in traffic control.

road weather measurment	O	S	D	RPN
ground temperature	3	1	3	**9**
dew-point temperature	3	3	3	**27**
wind speed (maximum)	2	5	3	**30**
wind speed (medium)	2	5	3	**30**
wind directon	1	5	7	**35**
air temperature	3	6	3	**54**
relative air humidity	3	6	3	**54**
temperature of the road surface	3	7	3	**63**
precipitation type	4	9	2	**72**
precipitation intensity	4	10	2	**80**
waterfilm thickness	4	10	2	**80**
freezing temperature	3	7	4	**84**
status of road surface	4	9	3	**108**
visibility	4	10	3	**120**

Figure 4. Risk Priority Number (RPN) for failures in road weather measurements in the context of traffic control

The measurements with the highest number are most important for traffic control. If there is a failure in this data, the road user acceptance of the traffic management system will be reduced or the safety aspect will not be considered efficiently.
For the purpose of traffic control, the main parameters visibility (RPN = 120), precipitation intensity / type and water film thickness (RPN about 80) are used. Measurements including the status of the road surface and the freezing temperature, which are mainly used for semi-automatic traffic control in winter time, are also ranked with a high RPN.
Measurements that are used for plausibility checks of the main parameters are ranked with a second priority – RPN about 50 to 80 (E.g. air humidity, air temperature). The other collected data have the lowest priority within this FMEA classification.
Based on the first classification of the RPN, every measurement unit is analysed more detailed concerning the possible failure types, as shown in Figure 4. The road weather measurement with the highest RPN – visibility – will be shown with more detail. For every possible failure category the RPN is shown in Figure 5.

measurement unit: **visibility**	**O**	**S**	**D***	**RPN**
random error / systematic error				
relevant time period				
measurement value is too high	4	6	8	**192**
measurement value is too low	2	4	5	**40**
relevant measuring range for traffic control				
measurement value is too high	4	7	8	**224**
measurement value is too low	2	5	5	**50**
not relevant time period				
measurement value is too high	4	4	8	**128**
measurement value is too low	2	2	5	**20**
not relevant measuring range for traffic control				
measurement value is too high	4	5	8	**160**
measurement value is too low	2	3	5	**30**
missing data				
relevant time period	10	1	3	**30**
not relevant time period	9	1	3	**27**
*dynamic adaptation; here the range of most of the failure is shown				

Figure 5. Risk priority number (RPN) for every failure type (example: visibility)

The check of the measurements and classification of RPN is carried out for every single measurement value which is collected each minute. The rate of the risk factor detection D is set every minute and depends on the number of activated plausibility-checks. The most relevant time period for visibility is in autumn and in the morning. With overestimated visibilities, a reduction of visibility may not be detected. The relevant measuring range for visibility is between 500 m and 0 m. If the detected measurement is always higher, than the VMS, a (reduced) speed limit will never be shown, or will be displayed later than expected. Acceptance of traffic control measures by road users as well as traffic safety aspects have to be balanced when displaying appropriate warnings and restrictions via VMS. In context of proceeding FMEA this was kept in mind while analyzing and categorizing different types of failures according to their severity. The analyses of single measurements as well as the long-term behaviour of a failure can give information about the failure type.
The RPN shown in Figure 4 are used for a first classification of the measurement units. In a second step, each measurement unit of the possible failure types are defined and ranged with the help of FMEA. Both classifications are described and ranked in a database. This information is used to classify service levels.
The classification of the risk of failure is based on the experiences from the Test Site for Road Weather Stations. The FMEA notification for every measurement unit must be carried out for every road weather station separately because the topography and other factors influences the risk number, so other risk numbers should be given.

3.4 Appropriate reaction to disturbances

Based on the quality monitoring taking place within the scope of the benchmarking process, disturbances were identified promptly during operation of the traffic control system. Using service levels, failure of equipment and low data quality were detected.
Service levels are uniform agreements on the desired quality of data and equipment. Such levels are needed in order to interpret the severity of errors and have a direct impact on the efforts for services and for support. The use of these levels within traffic control systems is described in detail in [1]. Service levels for several aspects, such as state of equipment, completeness of data and quality of data are to be defined.
When displaying service levels graphically for several aspects, colours are to be chosen a consistent way, e.g.:

- ok: green
- change: yellow
- warning: red
- neutral: grey

As an example, the service levels describing the quality of road weather data are shown in Table 2.

Service-Level	***Description***
OK	Data are completely plausible
Change	Data are largely plausible
Warning	Data are not plausible
Neutral	No information on quality of data available

Table 2. Service-Level on the quality of data

In addition, the benchmarking system will be able to evaluate formerly calculated service levels in order to obtain information regarding the duration and continuity of certain conditions. This helps to maintain a traffic control systems properly over time.
Regarding the results of the FMEA and thus the results of the quality assurance process itself, appropriate reactions to the errors may be carried out.
A basic idea when determining suitable reactions to disturbances is that one of the people responsible should be informed for each disturbance. Therefore responsibilities must be pre-defined.
This person then has to decide how to react to the reported disturbance. For this purpose, the person responsible should be supported by the system as far as possible. This means for example, that a number of possible appropriate reactions are to be displayed to the user. Appropriate reactions to disturbances are classified into

- prompt reaction
- soon reaction and
- reaction at next service.

The system tracks the "history" of a reported error until the successful removal of the error of the cause of the error. Additionally, the system shall be informed after the removal of a disturbance, so that an assessment of the removal is possible.

4 CONCLUSION AND OUTLOOK

A benchmarking system was developed that exceeds the functionality of the plausibility checks used currently in sub-centres.
Using plausibility checks for road weather data that are published within a German Technical Bulletin [4], a schematic procedure was created to categorize the severity of several error types. This helps to maximize benefits from these plausibility checks because operators and traffic engineers have to decide how to interpret and react to the results of the checks. By providing further information and proposing appropriate reactions on individual errors and disturbances, these decisions were facilitated and improved.
The benchmarking system has not yet been applied. Expert knowledge from practitioners as well as expertise in operating a Test Site for Road Weather Data was used to define the benchmarking system and to interpret possible failures ex-ante. Using the infrastructure of the Test Site, the next steps are to define appropriate failure reactions in details as well as to convert the schematic procedure into software.
In addition to the overall goal to reach a stable and well-functioning traffic control system, it may be used to evaluate sensor systems within the Test Site in a more gradual way.
It is expected that by implementing the benchmarking concept into the practice of traffic control, the acceptance of the traffic control system will be enhanced. This will lead to further increased traffic safety on motorways during adverse weather situations.

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