Identification of Rehabilitation Measures and Savings in the Application of a Pipeline Integrity Management System (PIMS)

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Abstract

Due to steadily aging pipeline grids, it is necessary that rehabilitation measures are identified for aging pipelines in order for the operational safety and integrity to be given at any time. The safety and quality of a pipeline decreases over time and approaches a certain minimum standard. By applying an appropriate proof of integrity it can be determined whether the actual safety and quality of the pipeline still meets a required minimum standard. If this is not the case, appropriate rehabilitation measures have to be identified and applied.

When applying a Pipeline Integrity Management System (PIMS) for the above mentioned proof of integrity, not only the technical integrity but also the process integrity is considered. To prove the technical integrity within a PIMS, the probabilistic approach is applied to assess all significant features influencing the condition of the pipeline. Thus, those pipelines or pipeline sections are identified in which the integrity is no longer given. A rehabilitation program is drawn up only for those pipeline sections. The rehabilitation measures to be implemented will depend on the causes upon which the pipeline section's integrity cannot be assured. Consequently, the total length of pipeline sections to be rehabilitated is limited to a minimum.

The paper and presentation will briefly introduce trascue.PIMS, a pipeline integrity management system jointly developed by Dr.-Ing. Veenker Ingenieurgesellschaft mbH (VEENKER) and Geomagic GmbH for Verbundnetz Gas AG. Following over 25 years of experience in the field of pipeline integrity VEENKER's contribution towards the development of trascue.PIMS is the adaption and integration of VEENKER's long standing and proven methodologies for pipeline integrity assessment as well as corrosion assessment and forecast.

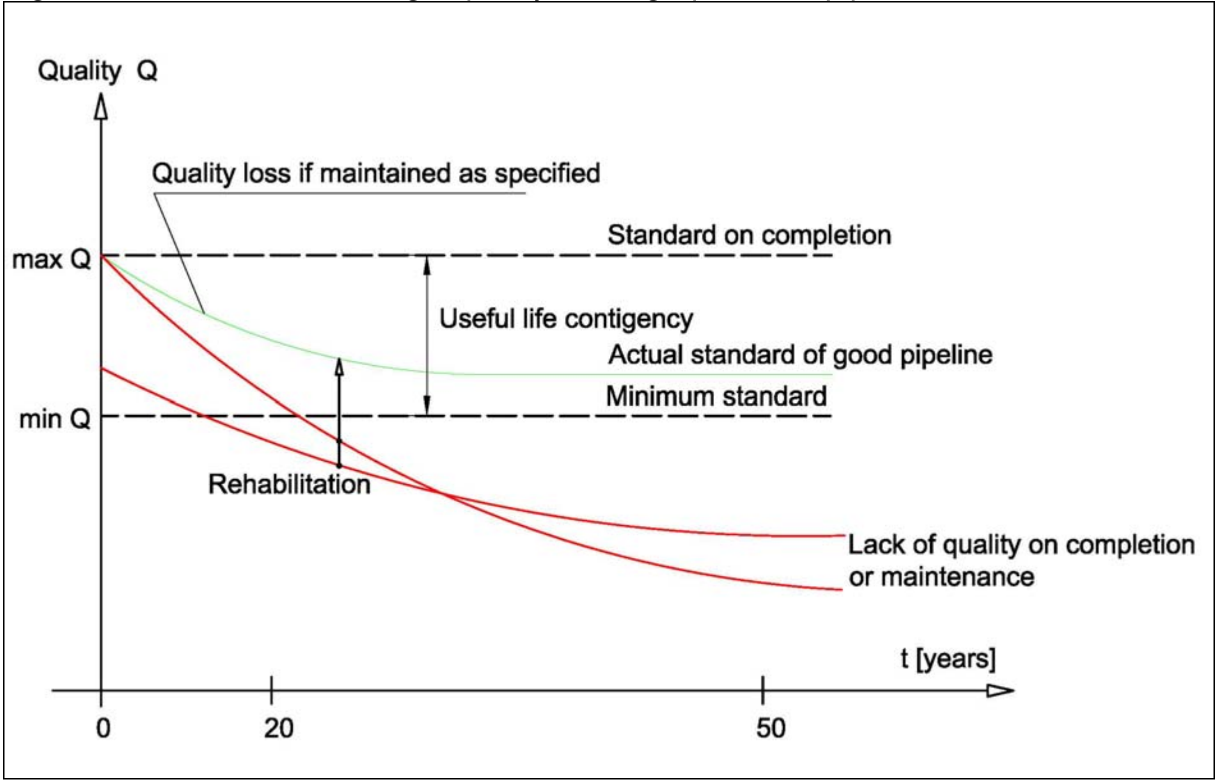
For a specific pipeline section, the rehabilitation need is shown based on results of trascue.PIMS. Savings are determined by comparison with a conventional rehabilitation plan not based on PIMS results. Project experience from numerous projects shows that operators can achieve savings in an order of magnitude of 30 % when rehabilitation is managed with trascue.PIMS.

1 Pipeline Integrity

Every operator of high-pressure pipelines is obliged to keep its pipelines in a correct and sound condition according to safety regulations, to guarantee structural safety and security of supply at any time. These requirements aim at guaranteeing the „integrity“ of the pipeline.

In general, it can be expected, that the pipeline condition has the highest quality level after construction and performance of the pressure test. This quality level is codified in the body of regulations and the quality requirements for the construction of the pipeline. This high quality level can be reduced by internal and external influences during the service life of the pipeline.

Figure 1: Reserves in bearing capacity of a high-pressure pipeline



During the course of the pipeline operation supervision measures are being carried out in order to check the due condition and to identify distinctive features in which the minimum quality might fall short or has already fallen short. The supervision measures are stipulated in the body of regulations and can be supplemented by in-house regulations.

If there is no evidence of distinctive features, then it can be assumed that the integrity of the pipeline is given and that the pipeline is suitable and will remain suitable for its purpose in adherence to the body of regulations.

The integrity of a pipeline is defined as follows:

> Warranty of a comprehensive structural integrity and operational reliability according to specifications while yielding optimal cost effectiveness

If significant features show that the integrity according to specifications is questioned, this has to be pursued. The reaction to this can be as follows:

1. Need for action
Experience of the personnel or the body of regulations necessitates immediate action (e. g. in the case of impact of third parties with significant damage to the pipeline).

2. No need for action
An impairment of the pipeline can be identified, but the experience of the operating personnel can safely assess it (e. g. slight displacement of a pipeline under a surface load).

If at first the situation is unclear and cannot be evaluated according to points 1 or 2, further steps are necessary to identify and assess the condition:

3. Application of assessment procedures
If the distinctive features found cannot be clearly identified as not critical but, at the same time, the taking of immediate measures would imply large economic disadvantages, it is recommended to apply recognised assessment procedures first, which either clearly prove the safety or question it.

In all three cases, the integrity of the pipeline system is given in the end. This is also the case when the result of the assessment implies a need for action at some time in the future and the integrity is to be secured and to be checked at this point in time.

2 Pipeline Integrity Management Systems (PIMS)

A Pipeline Integrity Management System (PIMS) is a safety management system individually established for a company aiming at structural and operational safety of pipelines and security of supply. Large parts of the company are involved in the integrity of the pipeline network. This involves central functions such as, for example, maintenance and also supporting functions such as procurement or training. The organisation and the processes have to guarantee that this aim is achieved in an economic and safe way.

The processes of recognizing and maintaining the actual condition of a pipeline are very important in guaranteeing the integrity of pipelines. Information on the condition of pipelines is required as detailed as possible. All influences which could lead to failure are to be identified. The technical condition assessment within a PIMS like trascue.PIMS is aimed at determining the condition of the pipeline with the aid of existing information and at assessing technical integrity.

When introducing a PIMS, in general, many processes have already been stated in other management systems, handbooks, work instructions etc. After defining the individual extent of the PIMS to be implemented, the relevant processes are to be defined in adherence to the legal regulations and standards and a plan of measures is to be established.

trascue.PIMS is a software solution including the automatable processes of a Pipeline Integrity Management System. It provides tools for the company to document or to achieve the pipeline's integrity.

3 trascue.PIMS

3.1 Overview

trascue.PIMS is a software solution supporting pipeline operators in the management of pipeline integrity and offers an overall system to prove the integrity of high high-pressure pipelines. The consistent modular architecture of the software leads to an open and adaptable design. Due to a flexible interface to data sources, it is possible to work with all common GIS databases as well as any other, logically structured data handling systems.

trascue.PIMS is a joint development of Geomagic GmbH, Leipzig, and Dr.-Ing. Veenker Ingenieurgesellschaft mbH, Hannover initiated by Verbundnetz Gas AG, Leipzig. The different marketing models offer the user the possibility of acquiring licences of one's own and carrying out a condition assessment within the company resp. buying the assessment of single pipeline sections as a service. For the service solution, the operator would merely provide digitally recorded pipeline data. The processing of these data, particularly the adaptation of program interfaces, would be carried out by VEENKER.

Key modules of trascue.PIMS regarding the assessment of pipeline integrity are the modules for technical condition analysis (TCA) and for corrosion assessment. These modules were contributed by VEENKER. The methodologies implemented in these modules were developed and applied in more than 20 years of experience in the field of pipeline integrity and were now implemented within trascue.PIMS.

trascue.PIMS is applied in several issues involving the integrity of high-pressure pipelines:

- Assessment and documentation of pipeline integrity for existing assets
- Design and construction
- Regulatory approval
- Rehabilitation planning
- Maintenance
- Corrosion assessment and forecast

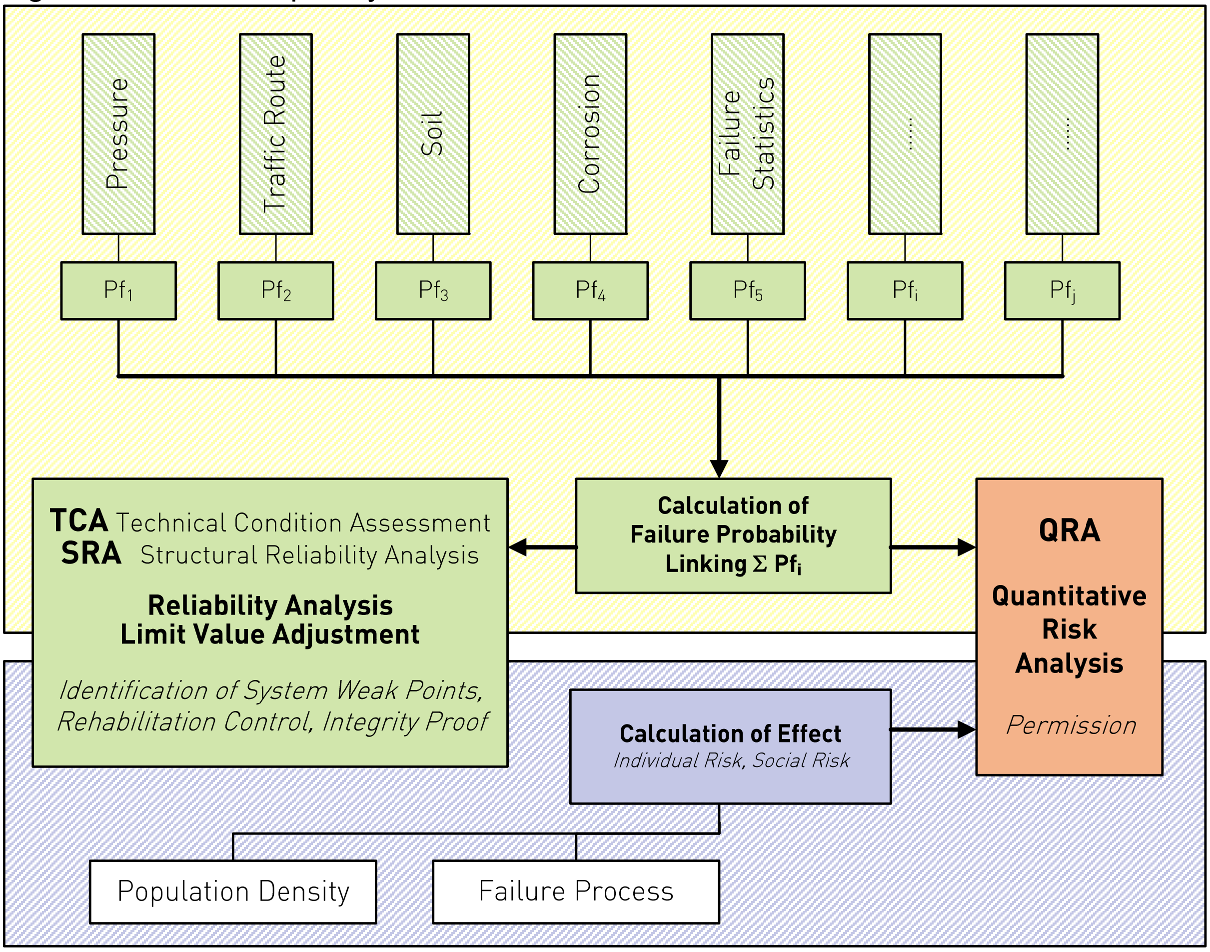
3.2 Technical Condition Analysis (TCA)

The TCA application is a component of trascue.PIMS and can be performed independently from a PIMS or as a key process in a PIMS.

With aid of the TCA, an analysis of the condition and the technical integrity of a pipeline is carried out, which analytically assesses the relevant influences for every pipeline section with the criterion of failure frequency and compares it to a limit value for reliability.

This probabilistic method has worldwide recognition and has, meanwhile, also been stipulated in standards (e. g. ISO 16708). Figure 2 shows that for every impact the individual failure frequency Pf is identified and that this individual failure frequency is then combined to give a total failure frequency for every individual pipe section. Limit values for the technical failure of a high-pressure pipeline lie in the order of magnitude of max. $Pf \leq 10^{-6}$ (failure with significant effect per kilometre and year).

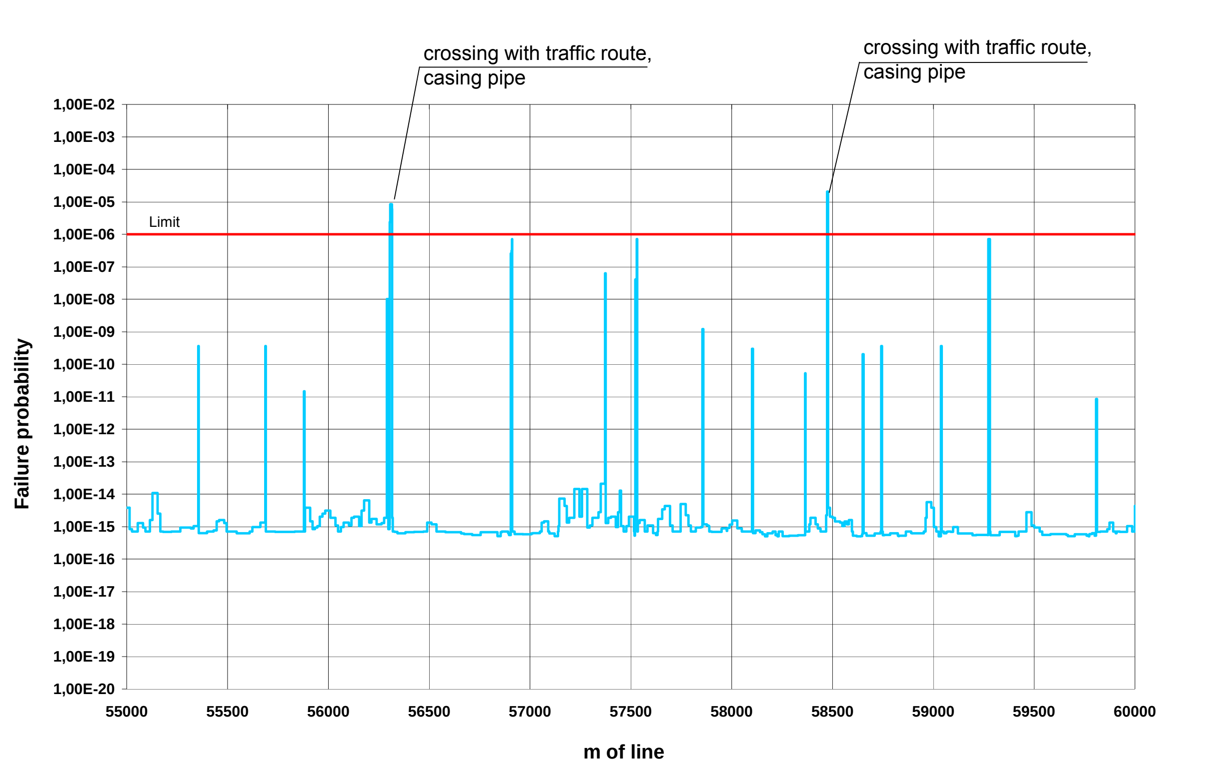
Figure 2: Failure frequency, QRA and SRA



With this instrument, pipeline rehabilitation can be specifically planned for those areas in which the limit values have been violated. On the other hand, technical integrity is given, as long as the limit values are not violated. This is especially advantageous when the requirements of the body of regulations (e. g. by metal loss) have been violated and proof of the pipeline safety becomes necessary.

The TCA leads to results showing a constant failure frequency for pipe sections with constant data. The failure frequency changes at the end of each pipeline section. These sections can be very short (e. g. the case of corrosion) or show great lengths, in the case of the standard cross-section with no particularities documented. A typical result is shown in figure 3. It is typical in that the standard cross-section of a high-pressure pipeline has a failure frequency in the order of magnitude of 10^{-15}. Many distinctive features lead to peaks, which, however, do not exceed the limit value for the SRA of 10^{-6} and thus, are not subject to further consideration. Only a few distinctive features require immediate measures which, in general, cannot be delayed.

Figure 3: Results of the technical condition assessment (TCA)



By parameter studies – in particular simulating the ageing of the pipeline – the influences are identified which can become critical in future.

3.3 Corrosion assessment within the TCA

3.3.1 Overview

Corrosion is, in general, the most important influence on the condition of a pressurized pipeline. For the consideration of corrosion as far as the condition assessment by trascue.PIMS is concerned, two methods are available. The selection of the applicable method depends on the possibility of pigging the pipeline.

If the pipeline is not piggable, trascue.PIMS offers a corrosion model to be calibrated based on a limited set of pipeline parameters. This model can be applied without knowledge of the actual pipeline condition as far as corrosion is concerned (cf. chapter 3.3.2).

If the pipeline is piggable, and the pigging data is available, the system „KaRo“ can be applied (cf. chapter 3.3.3) which can determine the strain very exactly from a few parameters regarding the geometry of metal loss and the pipe.

3.3.2 Corrosion assessment without pigging data

The condition assessment contains a corrosion model calculating the potential metal loss based on data regarding the age of the pipeline, the coating, the soil aggressiveness, and the condition of the CP. This model is applied for the assessment of pipelines that are not piggable or have not been pigged so far.

Such a corrosion model can be adjusted to the local particularities of the pipeline site. In the simplest case it works with linear rates of metal loss according to the above mentioned influencing parameters. The punctual verification of the results, e. g. by uncovering, is recommendable.

3.3.3 Corrosion assessment based on pigging data (KaRo)

KaRo is the programme module making the results of a pigging available as input for the further assessment of the pipeline condition.

The corrosion assessment „KaRo" is applicable to pressure steel pipes. Internal and external metal loss can be assessed. A corrosion forecast can be carried out either based on the knowledge of further parameters of the pipeline site or based on assumptions.

KaRo can be applied for metal losses meeting the following boundary conditions:

- Pipe parameters
  - Materials with yield strengths of Re = 190 N/mm² to 485 N/mm²
  - Outside diameters of 100 mm to 1440 mm
  - Nominal wall thicknesses between 3 mm and 40 mm
  - Ratio wall thickness to outside diameter up to 0.05

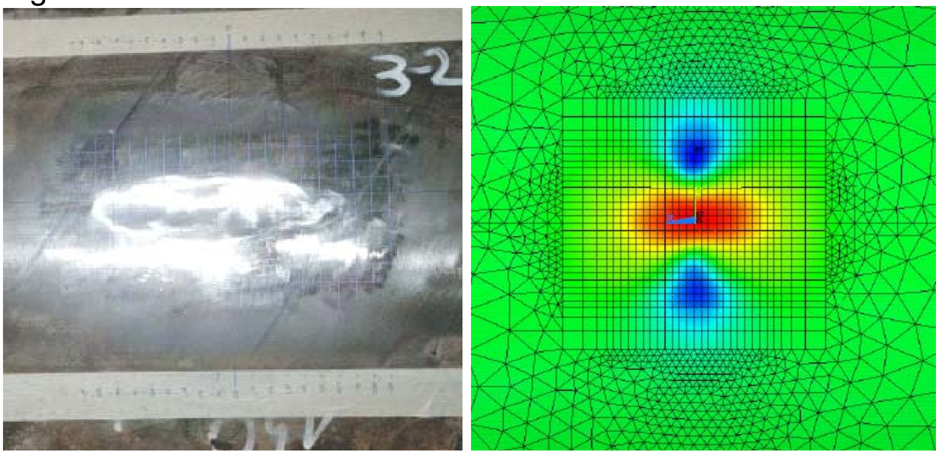
- Metal loss parameters
  - Corrosion depths up to 90 %
  - Minimum remaining wall thicknesses up to 1.0 mm
  - Circumferential expansions up to ½ pipe circumference
  - Ratio longitudinal expansion to circumferential expansion up to 8.0
  - Ratio longitudinal expansion to square root of the product of pipe radius and nominal wall thickness up to 20.0

$$\left(\frac{Lx}{\sqrt{Da/2 \cdot t}} \leq 20{,}0 \right)$$

As a rule, these limits cover all cases of corrosion defects appearing in practice.

The bearing capacity of damaged pipes with metal losses was investigated in the course of burst-tests with accompanying strain measurements and calculations according to the finite-element-method (FEM)

Figure 4: Metal loss and FEM result



The FEM is a numerical calculation method in widespread use in engineering which is based on principles of continuum mechanics and permits a sufficiently exact representation of any structure in an engineering model. This procedure makes it possible to consider exact defect geometry and allows the simulation of the interaction of several damage and load conditions (internal pressure and additional loads). By means of parameter studies and the use of neuronal networks the method was extended in order to be able to process both individual occurrences of metal loss and large quantities of data quickly. This design procedure is implemented in the KaRo programme system.

KaRo has the advantage that an assessment is possible on the basis of few parameters, which indicate the metal loss geometry and the pipe parameters. This applies both to individual metal loss and to complete pigging results.

4 Example for the application of trascue.PIMS

The presentation to this paper includes an example for the application of trascue.PIMS from recent project experience. The results presented are based on the assessment of pipeline integrity for a section of a high-pressure gas pipeline operated by one of the major operators in Germany. The rehabilitation plan for the specific pipeline based on results of trascue.PIMS is compared to a conventional rehabilitation plan based on experience mainly of the operational personnel.

The pipeline section in the example shows various singularities like intersections with traffic routes with and without casing pipes, reduced soil cover, etc. that need to be assessed in order to decide whether rehabilitation measures are necessary.

The assessment of pipeline integrity applying trascue.PIMS gives very accurate results for every single section of the pipeline. The failure frequency is calculated for each section and is compared to limit values. Rehabilitation measures are required for pipeline sections with a failure frequency exceeding the limit value of 10^{-6}. As not all rehabilitation measures can be implemented immediately due to time and financial constraints, the measures are prioritized. This is achieved by introducing additional limit values. This allows for the critical pipeline sections to be recognized immediately from the graph plotting failure frequency against pipeline length.

For this example a conventional rehabilitation plan was drafted at the same time in order to be compared to the rehabilitation plan based on results of trascue.PIMS. This conventional rehabilitation plan is based largely on individual knowledge and experience of the operational personnel. The conventional rehabilitation plan also identifies singularities with need for rehabilitation and prioritizes the measures included in the rehabilitation plan.

A comparison of rehabilitation plans shows that on the one hand pipeline sections are scheduled for rehabilitation in the conventional rehabilitation plan that do not need any rehabilitation at all according to the rehabilitation plan based on results of trascue.PIMS. On the other hand priorities of rehabilitation measures in the conventional rehabilitation plan differ from those in the rehabilitation plan based on results of trascue.PIMS.

This shows that the conventional rehabilitation plan in this example tends to address more sections for rehabilitation than necessary tying up limited financial resources. At the same time those pipeline sections requiring rehabilitation most are not addressed first due to priorities of the conventional rehabilitation plan being not in line with the actual technical condition of the pipeline.

Pricing the rehabilitation measures and thus evaluating the rehabilitation plans in terms of total investment leads to significant savings when following the rehabilitation plan based on results of trascue.PIMS. This remains true even when the cost for an external engineering consultancy assessing pipeline integrity is taken into consideration.

Exact data from projects recently completed for pipeline operators cannot be stated here due to reasons of confidentiality. However, when pipelines in need of rehabilitation are assessed with regard to pipeline integrity and rehabilitation plans are based on PIMS results, savings are in order of magnitude of 30 % compared to conventional rehabilitation plans.

5 Conclusions

The application of trascue.PIMS will yield an optimized rehabilitation plan leading to reduced total cost and downtime. A major advantage of applying trascue.PIMS is the consistent, transparent and comprehensible approach to assessment and rehabilitation of pipelines. A disadvantage of a conventional rehabilitation plan is that it is based on individual knowledge and experience of single persons that might not be available when needed or when work is continued or reviewed at some time in the future.

The methodologies for the assessment of pipeline integrity including the assessment of corrosion defects implemented within trascue.PIMS have been developed and proven over a period of twenty years of professional experience. They have been tested and certified by authorities and applied to more than 10.000 km of high-pressure pipelines that have been assessed for major pipeline operators.