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► **To cite this version:**

Joachim Wegener, Ute Herold. Requirements and Test Case Tracing. Embedded Real Time Software and Systems (ERTS2012), Feb 2012, Toulouse, France. hal-02263458

**HAL Id: hal-02263458**

**<https://hal.science/hal-02263458>**

Submitted on 4 Aug 2019

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# Requirements and Test Case Tracing

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## Motivation/Introduction

Today's systems in industrial practice - no matter if this is a car or a plant or a software system - are getting more and more complex. Thus a detailed description of functional and non-functional requirements and their tracing throughout the development process are indispensable as they also depend on each other, from design to verification to implementation and test.

This traceability over the whole V cycle is also explicitly required by standards like the ISO 26262 or the ISO 15504. Safety critical systems demand a high quality which must be measured and guaranteed. Each requirement must be implemented and its fulfillment demonstrated by verification and testing. Therefore, it is essential to prove that the system has been tested for each requirement.

Other demands concerning the traceability of requirements result from change management, variant and configuration management and also from project management.

Requirements tracing is thus a basic need in industrial practice. The challenge is to meet these demands by offering a possibility to easily track requirements and test cases. The tool integration of CTE XL Professional for test case design and IBM Rational DOORS for requirements management solves the problem of horizontal requirements tracing in a bi-directional way from requirements to test specification and back.

## Requirements in Industrial Practice

First of all it is important to completely document the life cycle of a requirement. Together with the bi-directional traceability of associated requirements it offers the possibility to identify a requirement and to track its changes throughout the development process. Here, the structural development history of the requirement is most important.

Typical demands for vertical requirements tracing listed in ISO 15504 are bi-directional traceability for

- customer requirements and system requirements
- system requirements and system architecture
- system requirements and software requirements
- system architecture and software requirements
- software requirements and software units

Horizontal requirements tracing should be bi-directional for verification between

- software units and their test specifications
- software requirements and software test specification
- system requirements and system test specification

## V Model

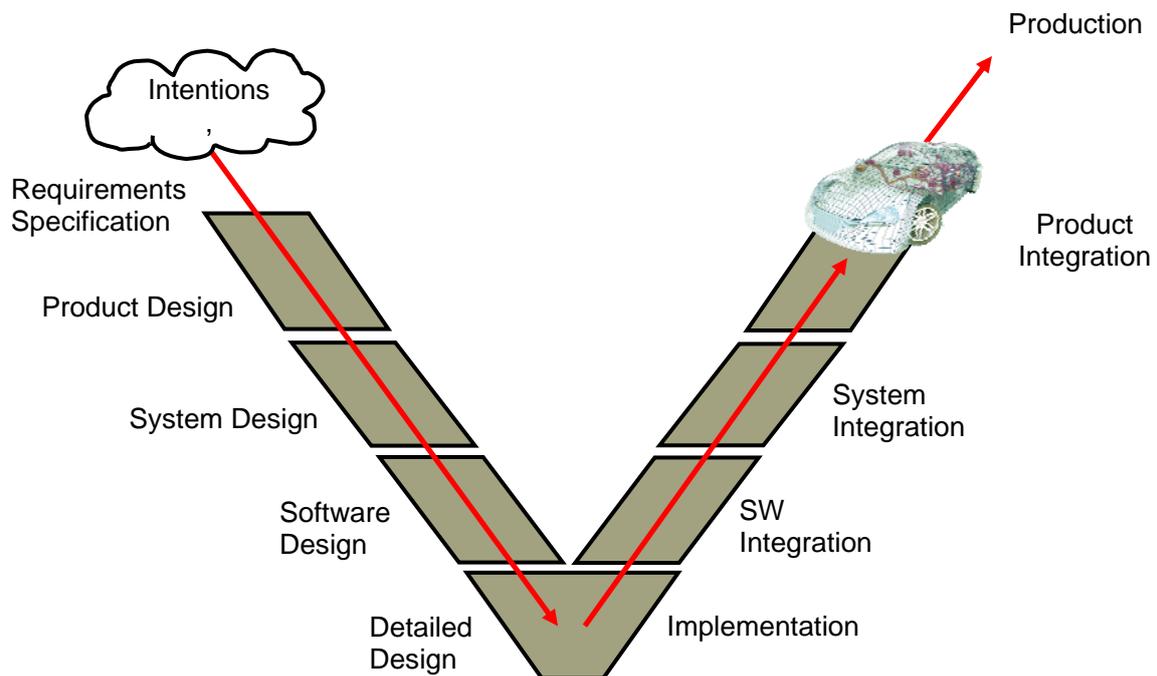


Figure 1: V Model with different phases of the software development process // Reference [2]

If one looks at the functional safety requirements for road vehicles, the ISO 26262 defines special demands. This includes the following subset of typical demands.

It is required to evaluate the completeness of test cases and to demonstrate that there is no unintended functionality. The coverage of requirements at the software unit level shall be determined for a better evaluation.

Another demand is to evaluate the completeness of tests and to obtain the confidence that there is no unintended functionality. Also, the coverage of requirements at the software architectural level by test cases shall be determined.

Each functional and technical safety requirement shall be verified at least once in the complete integration subphase.

## **Methods and tools for requirements and test case tracing**

### Introduction to IBM Rational DOORS

IBM Rational DOORS is one industry standard for requirements management. It is used in many domains which makes it so wide spread throughout the industries – from aerospace to defence and automotive to transportation systems.

Managing successfully requirements means that it is essential to document them so that they are easy to interpret and to work with. “Rational DOORS software allows you to capture, trace, analyze and manage changes to information and demonstrate compliance to regulations and standards.” [1]

In many projects, Rational DOORS helped to meet the high quality standards, time schedule and budget by providing a standard industry solution.

With its individual views of requirements and the possibility to assign additional and individual information, Rational DOORS is after all flexible tool for its users.

## Introduction to the Classification Tree Method (CTM)

Functional testing of a system is essential to find errors and discrepancies with the desired behaviour which is fixed in the specification. But how to get a test design that covers the needs and is easily comprehensible for revisers. This traceability is a basic need in all industries.

There are many approaches of designing tests and to get a good set of test cases to verify the system. One is the Classification Tree Method (CTM) which has been developed in the early 90ties and is now well-established all around the world.

The classification tree method is an all-purpose test method for specification-based test case design. It is independent from the test phase and also from the application domain. So whether there is a unit test of a technical system or a system test for an IT system, the CTM is applicable.

Approaching the test case design systematically, the classification tree method helps to keep a clear view despite of complexity and scope of test cases.

As shown in the example in figure 2, the different aspects of the camera-based distance control system which monitors the distance to the preceding vehicle are neatly arranged and grouped. The test design becomes a systematic and structured approach and thus a better set of tests.

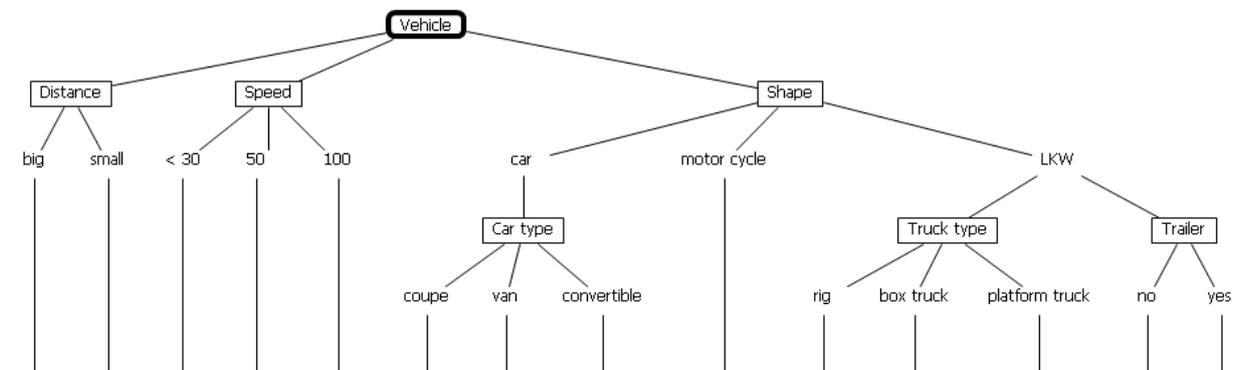


Figure 2: Classification Tree showing the systematic approach for test case design

## Introduction to the Classification Tree Editor (CTE XL Professional)

The CTE XL Professional is the syntax-oriented graphical editor which supports the CTM. As it has over 10,000 installations worldwide, the CTE XL and thus the CTM has proven their use in many industries like finance, automotive, insurance or defence.

Various process and testing standards, e.g. ISTQB Certified Tester, recommend test case design techniques, such as equivalence partitioning and boundary-value analysis, techniques that could be directly applied using the CTM and the CTE XL Professional.

Key features are the weighting for classes, automatic test case generation rules based on combinatorial operators, such as minimal, pairwise, threewise, or complete combinations, or prioritized test case generation operators, logical dependency rules and the modelling of test sequences with timing information.

The CTE XL Professional offers an automatic verification of test cases against dependency rules and to support requirements traceability an interface to the requirements management tool IBM Rational DOORS.

In addition to the IBM Rational DOORS linking, it offers also interfaces to HP QualityCenter, a test management software, or MESSINA, Berner & Mattners test platform for virtual validation of AUTOSAR software components and HiL testing.

With the comprehensive tag concept, The CTE XL Professional enables the annotation of information which can also be used for automated test case execution.

## Horizontal Requirements Tracing using CTE XL Professional and Rational DOORS

As described before, Rational DOORS is used for requirements management and CTE XL Professional is based on the established CTM which offers a systematic approach for test case design.

The following example shows how this tool coupling enables the user to trace requirements in the v cycle.

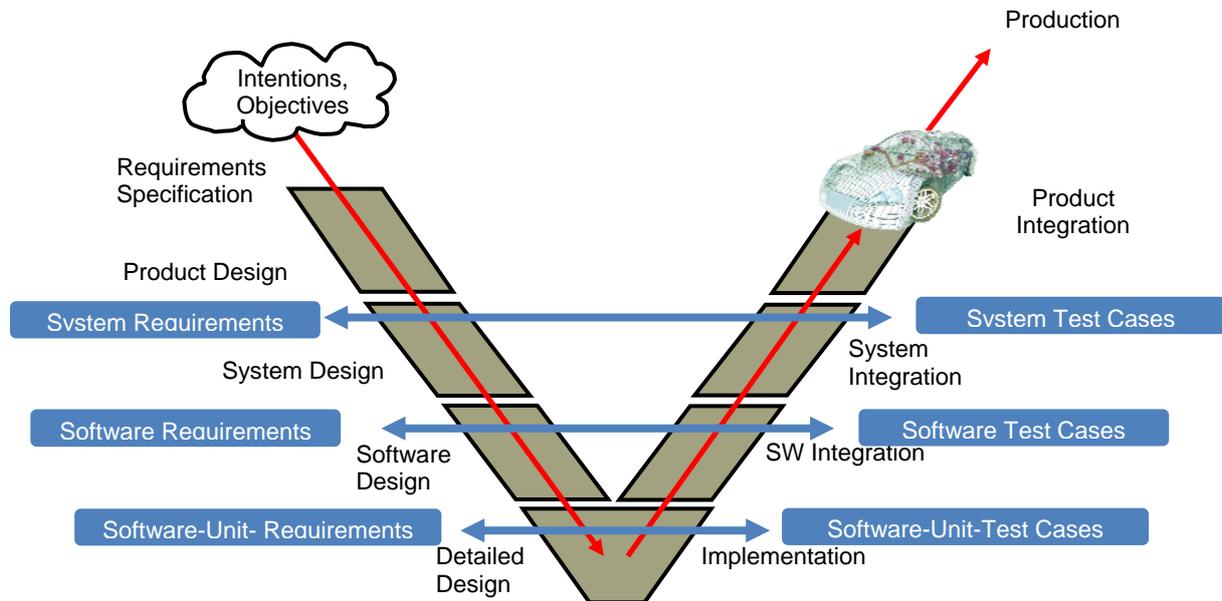


Figure 3: Showing horizontal requirements tracing in the v cycle // Reference [2]

In general, the desired result of requirements tracing is to facilitate the whole understanding of the product, to increase the quality of the product and to easily manage changes of requirements without losing traceability.

So what are target elements for requirements tracing?

This should be the elements of the classification tree, generation rules and elements of the combination table.

Taking a practical example with a camera-based distance control system which monitors the distance to the preceding vehicle as shown in the example tree in figure 2, the tree elements are

- Classifications, i.e. the distance to the preceding vehicle must be monitored continuously  
→ Linking with distance
- Classes, i.e. prompt a warning when the distance is less than speed/2.5 meters for more than one second  
→ Linking with small and large
- Dependency Rules, i.e. the system must be inactive for speeds smaller than 30 km/h  
→ speed: < 30 → state: inactive

Generation rules are used to generate a special subset of test cases. This is very useful to do entrance tests or to combine only the desired classifications. Back to the example, this means that if you would need to detect, i.e. all preceding vehicles independent from the speed. This results in the combination of speed with vehicle kind → speed \* vehicle kind.

The elements of the combination table are also of importance for requirements tracing. Here, test cases like speed is 50 km/h; distance is small; vehicle is a truck; etc. are listed. It is also possible to have test sequences with the corresponding test steps modelled, i.e. if the speed is less than 30 km/h for more than one second, the system has to be deactivated and an information must be shown. This means that Step1: speed is 50 km/h; Step2: speed is < 30 km/h

By linking the CTE XL Professional with Rational DOORS, it is possible to monitor requirements changes and to prove the actual test coverage and thus quality of the system.

In detail, this includes a Rational DOORS views in the classification-tree editor and a drag and drop support to establish the linking between requirements and the related test cases and classification tree elements as shown in figure 4.

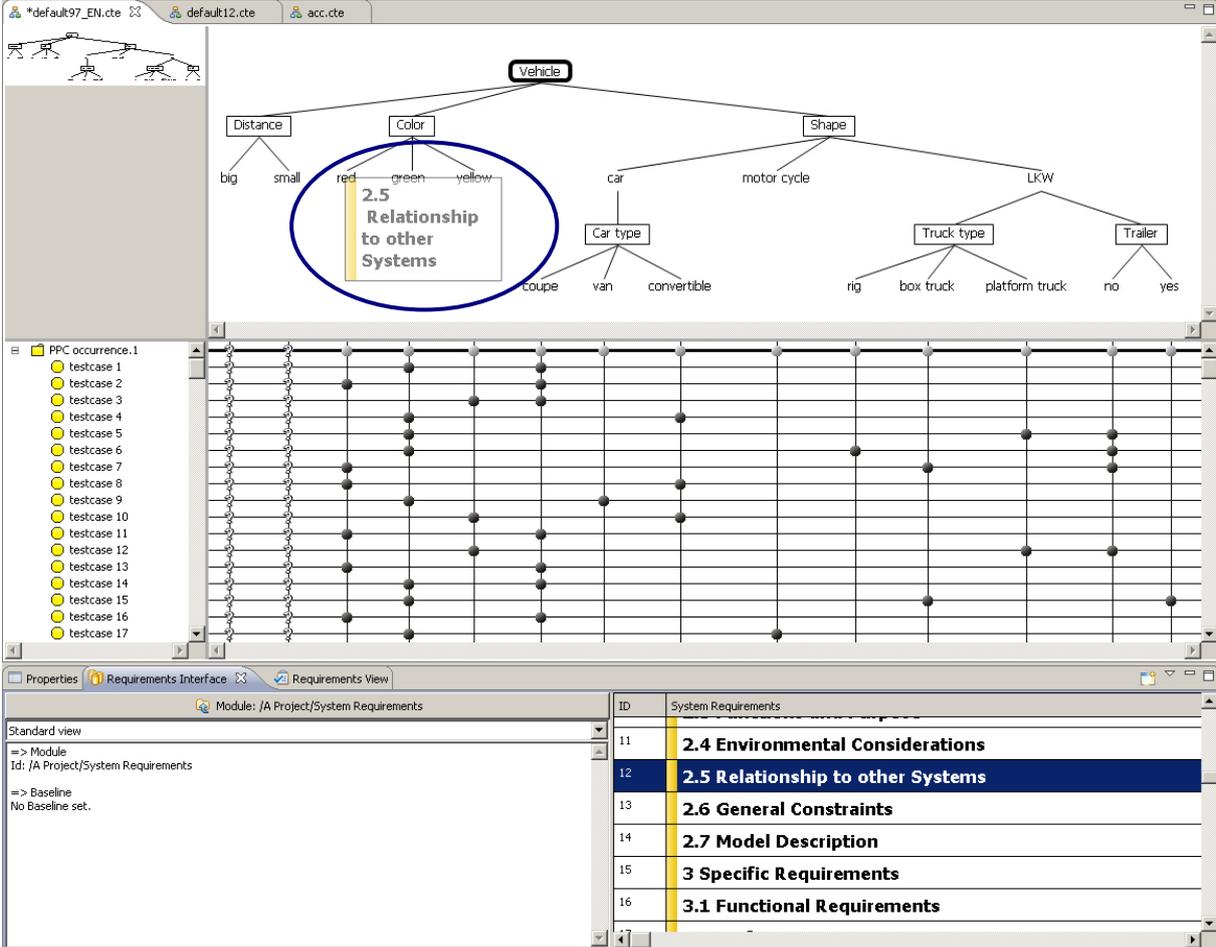


Figure 4: Requirements Interface and Linking per Drag&Drop with the CTE XL Professional

In case requirements change during the development process, the CTE XL Professional synchronizes the new module version which includes the new, changed or deleted requirements. All classification tree elements, test cases or sequences that are affected by the new version are highlighted (Figure 5). A tool-supported work flow is offered to testers and requirements engineers to browse through the changes and to document its processing. This enables testers to keep track of the changes made to requirements and adjust test case design easily by accepting or declining the changed items.

Object ID	Value	Connection	Linked CTE Objects
	3.12 Reliability Requirements		
C 28	<b>3.12 Maintainability Requirements</b> 3.13 Maintainability Requirements	Interface: NBK130;36677 Module: /A Project/System Requirements	
C 29	<b>3.13 Safety Requirements</b> 3.14 Safety Requirements	Interface: NBK130;36677 Module: /A Project/System Requirements	
D 18	3.3 Interface Requirements	Interface: NBK130;36677 Module: /A Project/System Requirements	
C 19	<b>3.3 Operational</b> 3.4 Operational Requirements	Interface: NBK130;36677 Module: /A Project/System Requirements	

Figure 5: Changed and deleted requirements after synchronization in the CTE XL Professional

All requirements are shown in a table view with their unique object id, the value itself, the connection of the Rational DOORS database and of course the linked CTE XL Professional objects, if applicable. With this feature, the test designer can easily check, whether all necessary requirements are modelled in the tree or if the requirements are covered by one or more test cases (see figure 6). It is possible to link several modules to one classification tree.

Object ID	Value	Connection	Linked CTE Objects
9	2.2 Relationship to Predecessor and Successor Projects	Interface: NBK130;36677 Module: /A Project/System Requirements	- van
12	2.5 Relationship to other Systems	Interface: NBK130;36677 Module: /A Project/System Requirements	- Color
16	3.1 Functional Requirements	Interface: NBK130;36677 Module: /A Project/System Requirements	- testcase 1
3	1.2 Scope of the Software TEST	Interface: NBK130;36677 Module: /A Project/System Requirements	- Shape
4	1.3 Definitions Acronyms	Interface: NBK130;36677 Module: /A Project/System Requirements	- testcase 2
7	2 General Description	Interface: NBK130;36677 Module: /A Project/System Requirements	- Truck type

Figure 6: Used requirements with their linked CTE XL Professional object

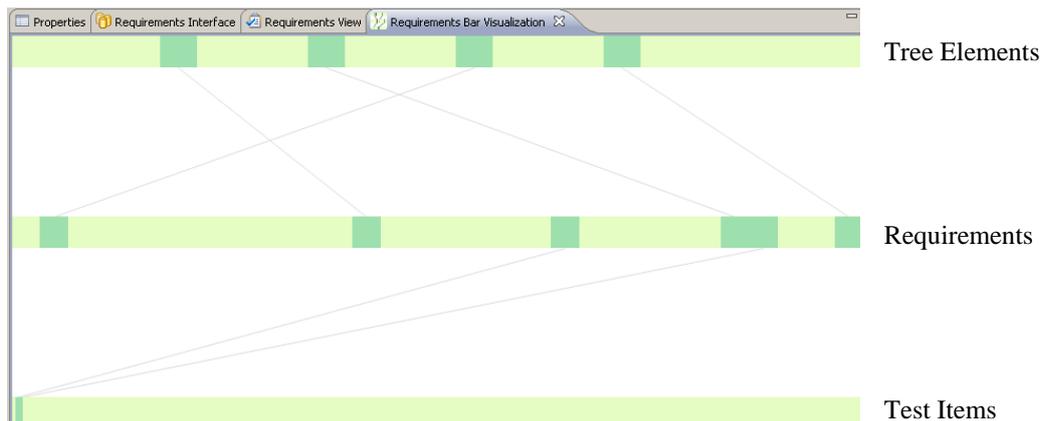


Figure 7: Linked requirements with tree and test items

The requirements visualization as shown in figure 7 offers a high level view for the progress of requirements linking. All tree items are listed in the upper bar, all requirements are listed in the bar in the middle and all linked and unlinked test items are shown in the lower bar.

Sometimes requirements are linked to tree elements. When creating test cases, the user has the option to use the existing links and hand them on to the test cases. This saves time and ensures quality.

## **Conclusion**

IBM Rational DOORS is one standard tool for requirements management and set in the market. CTE XL Professional provides tool support for the well-known and applied classification tree method. This systematic approach for test design is state of the art and has a really good tool support with the CTE XL Professional.

Coupling those two tools, enables the user to easily link requirements to test specification and test cases. Now, a qualitative overview shows the coverage for test cases to requirements and also shows where are still gaps to close. The comfort of requirements tracing is thus increased significantly.

The whole process of requirements tracing benefits from the syntax-oriented graphical editor CTE XL Professional which will be further developed upon market needs and research topics. One of them is, i.e. that several classification trees are used for the test of a specification module. For this it would be good to have a visualization of the complete coverage of requirements.

A topic that is also demanding is the usage of natural language processing to divert content changes from typing errors.

In the field of requirements management, variant management is also a challenge. With Berner & Mattner's tool MERAN, which complements Rational DOORS with a powerful tool to master variants, a coupling would be of help to have a consistent variant management from specification to test and to support model-based testing.

The tool coupling of Rational DOORS and CTE XL Professional gives now a way for horizontal requirements tracing throughout the v cycle and many possible ways for the future.

## **References**

- [1] <http://public.dhe.ibm.com/common/ssi/ecm/en/rad14037usen/RAD14037USEN.PDF>  
(2011-12-10)
- [2] Revvert presentation slides Dr. Joachim Wegener at ICST 2011