A Structure for Requirements

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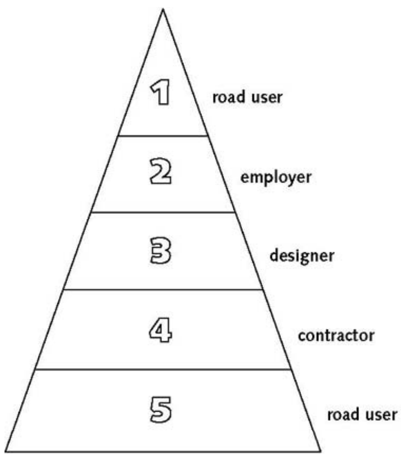
Abstract **A structure for requirements**

Result
It has proven possible to fit the requirements of all the parties in the road design process into a logical structure. In highway construction, a structure of this kind is a vital tool for allocating responsibilities and realizing the requirements for the different parties. Such a structure also makes it possible to show what the effects of maintenance measures will be on safety, accessibility and liveability.

Advantages
This different yet simple structure is described as the pyramid of requirements.

What ?

How ?



In line with the structure what becomes clear is:

- the hierarchy of all requirements;
- the sequence of decisions;
- who is responsible for failures;
- the relationships between costs and benefits;
- the effect of maintenance measures;
- gaps in knowledge.

The structure described is directly available, universal, expandable and software independent.

Follow-up
The present project has mapped out a part of the requirements, which is representative of the system of requirements as a whole. Starting off with the functional requirements (What does the road user want ?) relationships are described with technical requirements (How do you do that?). It would appear wise to establish more information in this way on the basis of costs and benefits. The structure is now available, but there is still a long way to go.
The complete report in English can be found on the internet website at:
http://www.minvenw.nl/rws/dww/uitgaven/structuurdww/structurereq.pdf
The Dutch version can be found at:
http://www.minvenw.nl/rws/dww/uitgaven/structuurdww/index.html

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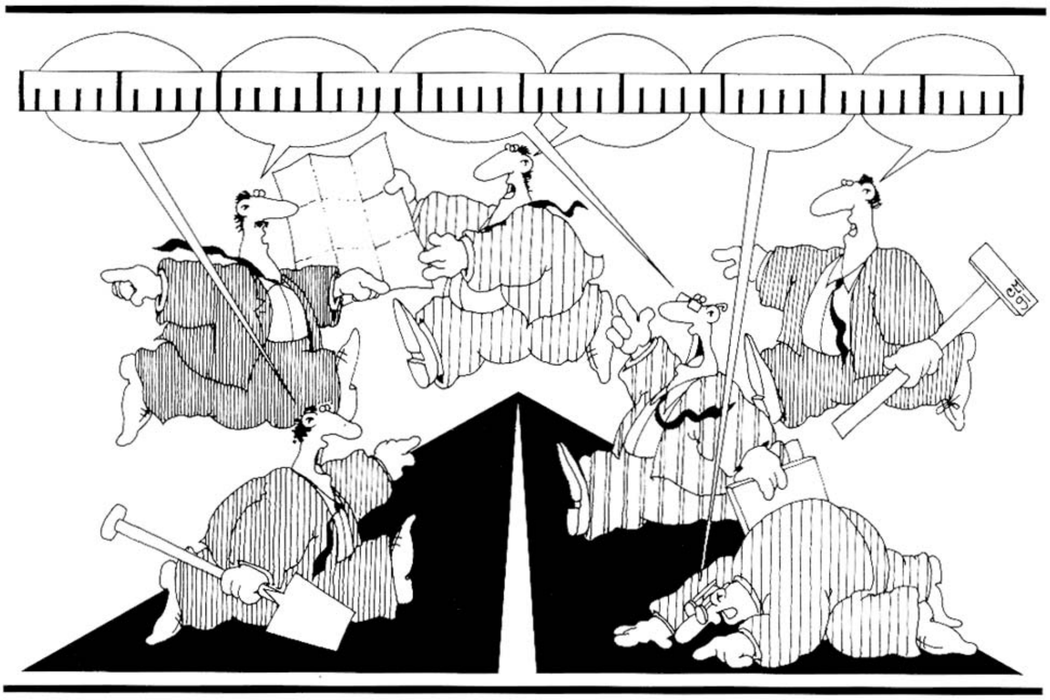

Figure 1. Collaboration between different parties

The design, construction and maintenance of a road involves many parties, who must agree clearly on certain factors if road-users are to be provided with a good and preferably uniform product. (See figure 1)

1.1 Reasons for adjustment

It is doubtful whether the present system of agreements is sufficient:

- There is a lack of a distinct hierarchy in the body of regulations.
- Functional requirements are a condition for innovation
- Technical regulations have become increasingly complex.
- Other forms of tender require suitable regulations.

1.2 The first step

This publication is the result of a pilot project; a new basic structure for requirements has been established and some of the requirements have been developed in detail. The structure must clarify the following aspects:

- relationships between quality requirements;
- methods for quantification;
- decision-making sequence;
- classification according to importance

Currently this model is being expanded into a complete set of requirements for road-building.

2. The study

A road can be seen as the result of the efforts of people from various areas of expertise: policy-makers, planners, civil engineers, traffic engineers, materials scientists, and others. Each has its own methods and imposes its own requirements. We have endeavoured to identify the relationships between all the requirements by means of interviews with experts in the various disciplines.

2.1 How does a requirement come into being?

At the start of the project we took a pyramid model giving a general impression of possible relationships between requirements at various levels. (see figure 2).

At each transition:

Above:
What do you want ?
(Functional requirements)

Underneath:
How do you do that ?
(New technical requirements)

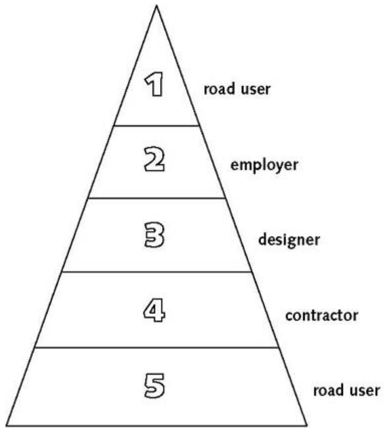

Figure. 2 Pyramid of requirements

This model roughly describes the translation from the public's functional requirement (the public wants to be able to go somewhere) to the technical requirements (how can this best be realized).

In the transition from one stage to another, the higher stage sets requirements (what) on the lower step. In the following stage technical requirements (how) will be formulated as an answer to the functional requirement of the higher step. In elaborating the set requirements new functional requirements come into being at the same time for the following lower step, and so on.
By questioning from the bottom-up as well as from the top-down a transparent system is developed that can also be used in both directions.

In order to work out who is responsible for the end result, relevant data from all the steps must be recorded.

2.2 Design of a data model

The "cognitive mapping" technique was used in developing the data model [Literature 5]. For this experts in the Netherlands and abroad from all stages of the entire process were asked which questions they were asked and what requirements they set for the following stage. [Literature 1] "Cognitive maps" were produced for all the interviews. These are simple descriptions of relationships between concepts. These separate “maps” were then combined into one single data model, in which all relationships are recorded together. This data model was used as a basis for creating the structure.

All the cognitive maps are included in the complete report (in Dutch). The method of collecting, checking, establishing and distributing areas of information which were never previously described, appears to be very effective.

The following is an example (causes of rutting) of a “cognitive map” as part of this data model (figure 3):

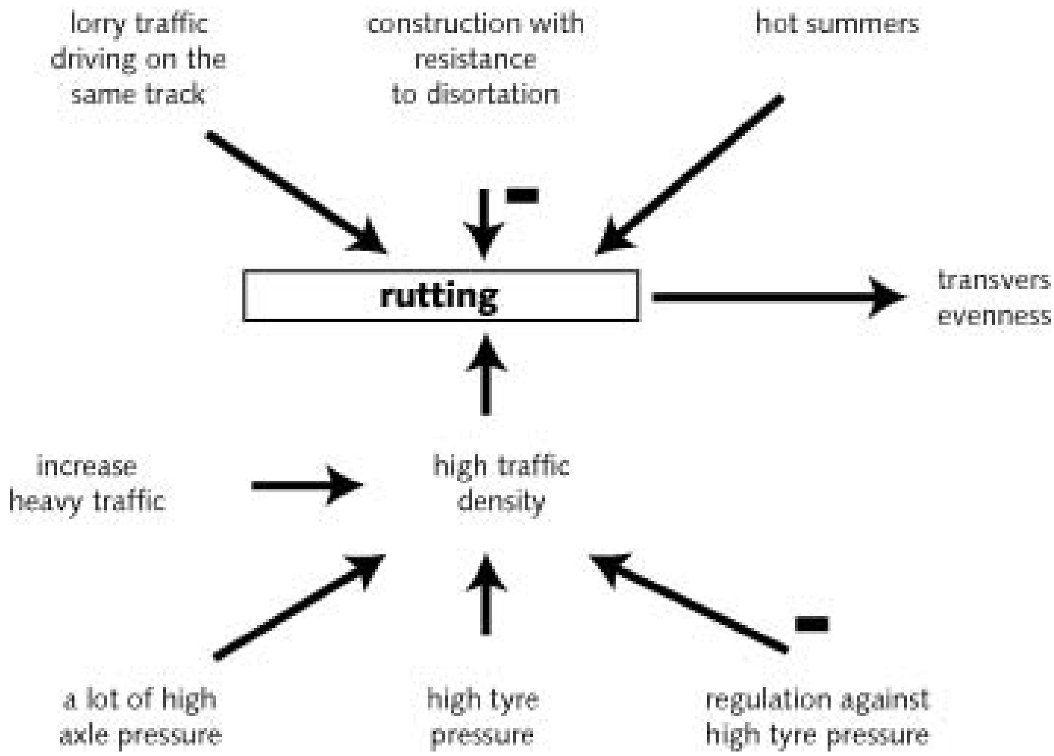

Figure 3 Relationships of rutting as part of the data model.

3 Obstacles to a good structure

There is persistent confusion standing in the way of developing a well-structured system of requirements. Several are clarified here.

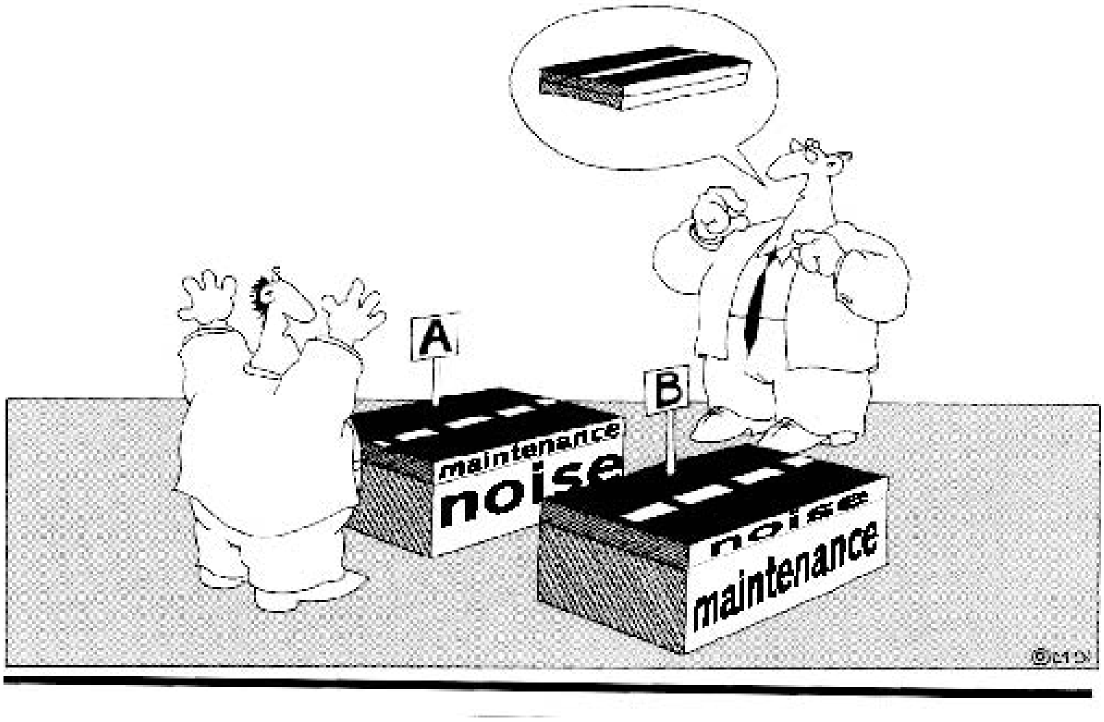

Figure 4. Difference between requirements and solutions

3.1 Difference between requirements and solutions

There is often some confusion between requirements on the one hand and the solutions which satisfy those requirements on the other. One must realize that the requirements are not in conflict, but a conflict may arise if asphalt is selected as the material (solution) and is expected to meet both requirements (rutting and cracking). However, it is essential to be aware that it is not the requirements but the known solutions that create conflict (see figure 4).

3.2 Performance requirements versus technical requirements

Another source of misunderstanding is provided by the concepts of performance requirements and technical requirements. One might say that performance requirements indicate what
the desired properties are, while technical requirements specify how the solution is to be realized. This implies that one functional requirement only says something about one fixed function. The first question is: Which function?
Note that the arrangement generally used in most Pavement Management Systems for functional and technical requirements can deviate from the description given here.

In the P.M.S. it is mainly surface properties only which are called functional. In the description given above functional requirements appear at each level.

3.3 Economic and technical feasibility of requirements

An important question which arises in the specification of requirements relates to technical and economic feasibility. It will be clear that cost will be a characteristic of the solution, not of the requirement itself. The level of the 1norm is mostly a compromise between the ideal and the technically feasible.

3.4 The time factor: failure mechanisms

Complying with requirements in the road-building world means long-term compliance. In order to be able to predict long-term behaviour, we need to know something about the causes, resulting in functional requirements being no longer being met: the failure mechanisms.
Failure mechanisms describe the causes of the insufficient functional requirements in the form of a model.

It may be noted that a failure mechanism is the source of new requirements, i.e. resistance to a failure mechanism.

3.5 From public requirement to technical requirement

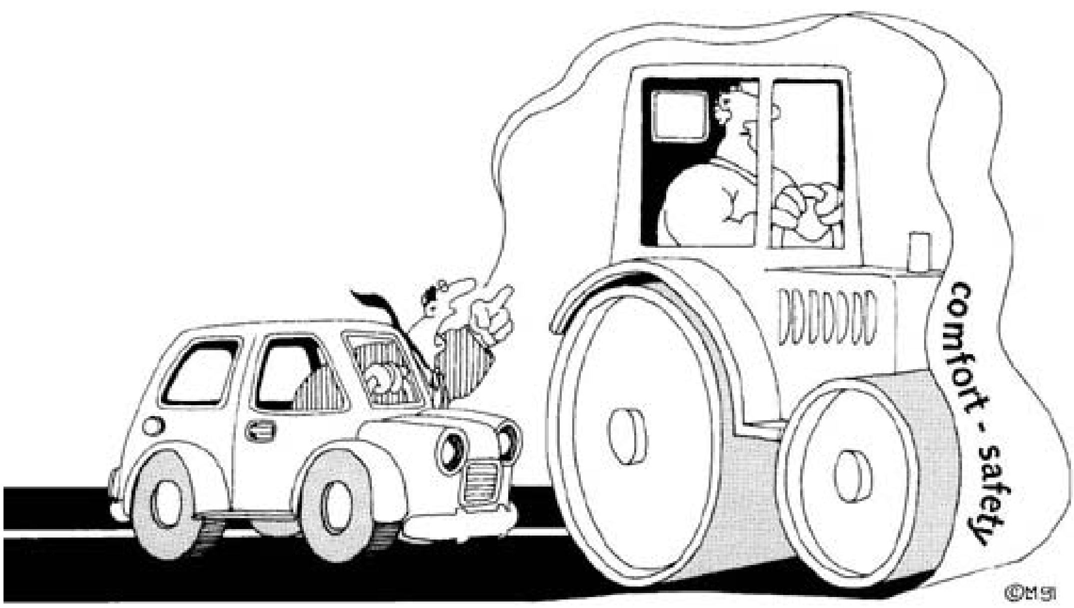

Figure 5. Translation of public wishes

A road-user's requirements for a road are relatively basic and relate mainly to environment, accessibility and comfort. In developing the decision-supporting systems and quantitative measuring methods, many of these simply formulated requirements are complex and subjective in nature and must therefore be translated into more manageable technical requirements. Discrepancies may arise in translating these. Discrepancies between requirements and the "social reality" may arise in a variety of ways:

- Through translation errors: the value of the technical standard has not been selected correctly; road users continue to have complaints;
- Through the omission of important aspects: non-existent standards;
- Through obsolescence of standards: the standard is no longer in line with the state of the art;
- Through policy decisions: it may be decided that a high percentage of complaints is acceptable.

3.6 Transfer of information in the transition to other stages.

Figure 6. Loss of information

Information is passed on in the transition from one stage to another (see figure 6). By using the same integral information system for all stages, this loss becomes minimal and the predictability of the end result is optimal.

4. The result: a structure for requirements

The most important result of the project is the knowledge that it is possible to specify requirements within one structure which can be used at all levels, as much functional (what) and technical (how) requirements, from public requirements to material specifications. The structure is the specification which includes relevant qualities for the whole process, including relationships between requirements from different stages.

Measuring results can therefore support decisions for the whole process, not only within one stage. The described structure is a complete specification of all relevant qualities, the pyramid is a clear but incomplete communication aid.

The structure has three purposes:

1. It must indicate an interrelationship between requirements;
2. Relevant information is given with each requirement enabling testing of the requirement.
3. Using the information on failure mechanisms for each requirement it is possible to regulate individual liabilities

In 4.1 the types of requirement are discussed. In 4.2 the relevant qualities of simple, objective verifiable requirements are raised.

4.1 Type of requirements, classified according to ability to be verified

In realizing requirements it is very important to know to what extent it is possible to check whether a product meets the requirements set. The general method of approach is:

- determine the function: what must the product, service or process do;
- determine the functional requirements: what sort of qualities must the product, service or process have in order to carry out the established function;
- test whether the product, service or process satisfies the specified requirements.

In the case of aspects such as safety and comfort testing creates problems because a variety of factors influence the result. Requirements can be classified according to the verification method. For that reason the classification which is reflected in table 1 has been chosen.

Table 1. Requirements divided up according to verifiability.

Type of requirement, classified according to verifiability	What to do?	result	example	elaborated example
Use-dependent	Analysing in simple influence factors	data for road designer	safety	1 roughness 2 transverse evenness
subjective	agree measuring procedure	verifiable size	aesthetic	Survey among users
combined	Analysing in sections	simple units	evenness	1 longitudinal evenness 2 transverse evenness
Objective verifiable	formulating and employing test regulation	size review	layer density drill cores	minimum layer density

Unravelling use-dependent, complex and subjective requirements into objective verifiable requirements, creates a large number of new requirements.

4.2 Relevant qualities of objective verifiable requirements

The following relevant qualities must be described for every simple objective verifiable requirement from the previous analysis process:

- name
- purpose
- measuring method; for each measuring method:
    - relationship with practice
    - accuracy
    - ability to be reproduced
    - construction standard
    - maintenance standard
- failure mechanisms; for each failure mechanism:
    - importance
    - causes
    - precautionary measures
- models; for each model:
    - necessary data
    - preconditions
    - accuracy

With **subjective** and **use-dependent requirements** the following are added:

influence factors	factors which can influence the assessment of a requirement.
importance of influence factors	extent to which each factor contributes to the final assessment for the specified purpose

With **combined requirements** the following are added:

components	parts which make up the combined requirement
influence of components	relative contribution of the components to the requirement (weighing factors in decision processes)

With some requirements the following are added to the specification:

design aspects	design stipulations to adapt to a specific solution, such as the maximum permissible weight of asphalting on a steel bridge.
realization aspects	aspects which concern the technical completion of a requirement, for example, weather conditions during construction.

Degree of detail

The structure can be expanded easily, if greater detail is required.

- For instance, under determination methods one could also include something about the measuring principle and the type of test (e.g. in situ/ laboratory, destructive/non-destructive).
- In order to be able to test by standards the accuracy of the measuring method must be known in terms of its ability to reproduce standard abnormalities.
- Information can be established about the practical feasibility and costs of the measuring methods.
- Using the same system experiences can be established with certain types of construction work and reference can be made directly to sources on the internet.

The degree of detail is chosen on the basis of the application purpose and the costs. One system can be shared worldwide via the internet. Local and specific parts can easily be added to this (for example, legal aspects, financial responsibility or project-linked properties).

4.3 Interrelationship between requirements

Interrelationships between performance requirements may come about in a variety of ways:

- A subjective, combined or use-dependent requirement has a number of influence factors or components, or parts.
- The design aspects which determine the result are known for a given requirement.. (e.g.: the rigidity of a layer depends on the rigidity of the material and the thickness).
- A property (e.g. transverse evenness) has a known failure mechanism (e.g. rutting), against which preventive measures must be taken.

The relationships between functional and technical requirements are described as "Technical realization aspects". For instance, it is stated that plastic material rigidity in mastic mixes is connected with bitumen content, void content, condensation, etc.

What is important is that the present structure can be used at any level of detail.

4.4 Conclusion

If we want to establish clearly who should be responsible for what and how, a clear, complete and consistent body of requirements is necessary: a structure for requirements.
The directly available and software independent system described satisfies this.

5. The advantages of a requirements structure

It has been demonstrated that it is possible to fit requirements into one structure. This has important advantages:

- it guarantees a logical interrelationship between requirements;
- using the structure the client can determine up to which level specifications are necessary in order to ensure a good end-product;
- on the basis of the background to a requirement an indication can be given of the possible consequences of deferred maintenance for aspects such as safety (or conversely what is the effect of tightening up a standard).
- the system is universal. It can be used for every process except for road-building.
- no special software is necessary except a word processor and a browser.
- communications between the different parties becomes unambiguous and orderly.

6. Follow-up

6.1 Completion of the structure

In [Literature 1] the present project has mapped out a part of the requirements, which is
representative of the system of requirements as a whole. This means that the structure as such can remain in place as the missing requirements are added. On the basis of costs and benefits it is advisable to complete the set of requirements, in other words to develop such aspects as safety and environment in greater detail.

6.2 Complete report on internet with effective example.

The complete report of the study is published in Dutch at http://www.minvenw.nl/rws/dww/uitgaven/structuurdww/index.html. Here along with the description of the structure in Appendix E, a detailed example is given of a requirement in the described structure. This example shows that the structure can be used in a practical way.
We refer to the full study on the internet for more detailed information.

The English version “A structure for requirements” can be downloaded as a .pdf-file from the Internet at:
http://www.minvenw.nl/rws/dww/uitgaven/structuurdww/structurereq.pdf
The English report is less complete than the Dutch internet site.

Literature

1 Complete report in Dutch in HTML:
http://www.minvenw.nl/rws/dww/uitgaven/structuurdww/index.html
2 Shorter English report as .pdf-document.
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