ASSET MANAGEMENT SYSTEM (AMS) FOR ROADS

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ABSTRACT

This paper presents a concept of Asset Management System for Roads (ASM), which is determined as an open concept and is grouped in modules to be enable to be implemented it in phases. The paper describes the reason, why it is favourable to use this sort of tools to find out the most efficient way of managing the assets of road's infrastructure.

The concept of AMS makes sense in particular for the object management and the means to their maintenance. Specially those road-agencies, who have the responsibility for different groups of objects could take remarkable advantages of AMS.

By using the same unit indicator, namely the monetary value of the objects, the AMS makes possible to compare different types of objects in a quite pragmatically and simple way. This fact helps also the road-agencies to justify and communicate their decisions, related to the road maintenance, budget issues or priority of the measures, more easier for the politicians and the public.

An essential output of AMS are the optimal maintenance sections of roads, which could include the measures for various groups of objects, like pavements, bridges, technical equipments, etc. These measures are co-ordinated, according to the time and area of realisation, but also other criteria. The optimal maintenance sections represent also the best long-term cost-benefit relation.

The AMS is a system, based on strategic objectives, which are characterised as functional and directional goals. The decisions, which should be prepared by the tools of the system are all related to the criteria, which are deviated from these long-term objectives.

The components of AMS, which are presented in this paper are:

- System of Objectives
- System of Identification
- System of Functional Evaluation
- System of Controlling, Collecting and Evaluation of Condition
- System of Development of the Condition
- System of Global Evaluation of the Objects
- System of Calculating the Monetary Values
- System of Global Costs (Life Cycle Cost)
- System of Global Benefits
- System of Cost-Benefit-Analyse
- System of Planning of Optimal Combined Measures (Maintenance Sections of Roads)
- System of Realisation of the Measures

A very important component of AMS, namely the "System of Development of the Condition" is presented in the paper by an interesting example from the practice, which set relation between certain "standard" conditions of objects and the unit cost of their optimal maintenance measure. The example shows clearly, how much are the financial losses of road-agency, if it would miss the right time to realise the maintenance measures in the road-network.

This "model" of development of condition has been made for the pavements. For other objects, in particular those of engineering structures (bridges, tunnel, galleries, walls) the similar models should be developed soon.

The paper includes also a method how to calculate the monetary values of the objects, by using the "Substance and Using Values". Therefore it presents also the unit costs of different components as well as depreciation models of the objects, as basis of calculations.

The global costs of objects and measures would be compared in AMS with their global benefits to find out the optimal solutions for maintenance issues. The circle of groups, who are affected from the costs and benefits of the measures has been pointed out.

Also the steps of implementation are presented in the paper. They are grouped as organisation and technical treatments, which have to be done once or periodically.

One of these steps is related to clarification of the question of "outsourcing" of some processes or activities of AMS. They could include by example the activities of collecting of condition-data, planning of optimal measures or their realisation, what fore the necessary criteria of quality, performance, costs, etc. must be taken from the system of objectives.

In the chapter "Outlook" there is an appeal to the road-agencies to encourage them to take the first steps to implement the AMS by determining a pilot-project. This step could help to accelerate the development of the system by using the feedbacks from the practice.

1. INTRODUCTION

By beginning of 1970s the road agencies were faced with arising of economic recession and as its consequence, the dramatically lack of financial means. Thus they sought more and more after economic and technical criteria to construct and maintain the assets of road's infrastructure. These efforts have been accelerated by the significant raise of the public attention to the event of traffic congestions, the intensified demand of the traffic users and last but not least the revitalisation of the economy, combined with the policy of globalisation and liberalisation of the markets, which generated a huge volume of new traffic demand (but still lack of financial means). These facts have confronted the road agencies and the road researchers with new challenges to find out reasonable solutions for many complex tasks of maintenance management of the roads.

Up to the middle 1970s the first concepts of pavement management systems have been developed, followed by similar concepts of bridge and tunnel management systems.

Those systems have become at 1980s, because of the progresses of computer aided programs and their performance a greater signification and the obtained results were satisfactory, related to the efficiency of the road agencies. The chronicle continued at

1990s by using of high performance data banks and simultaneously collecting of inventory and condition-data of road's infrastructure network-wide.

The first systems of optimising of integrated road's assets (instead of object-related optimising systems for pavements, bridges, etc.) have been developed at 1990s. These systems, called as Integrated Road Management Systems (IRMS) or Asset Management Systems (AMS) are supposed to find out and accomplish all potentials of rising the efficiencies of the road agencies by improving the quality of their decisions.

In fact such solutions would result advantages not only for the road agencies, but also for the road users and the environment, in particular through higher quality of road's condition, optimising of road-works and consequently reducing of traffic obstacles. The process of optimisation of such integral systems encloses the comparison of different groups of objects in terms of planning of the measures and their prioritisation, which is a quite sophisticated task. To simplify such comparisons it is widespread to use unit criteria, by example the monetary values.

Hence the "Asset Management Systems" are the real tools. They operate and prepare the decisions with methods and criteria, based on monetary values. These systems manage not only the maintenance and renewing of the road's infrastructure, but also of the necessary means as "inventory", which become a certain modus of depreciation (loss of value).

Although the Asset Management Systems (AMS) have been developed as modular systems and they assure to increase the efficiency of the road agencies and reduce their overall costs, they are not yet implemented for the entire road-network of a country. One main reason could be the "historical growth" of the organisation of the road agencies, which does not authorize the staff to operate integral to analyse the problems and find out the solutions. The staff are usually specialised for pavements or bridges or even specialised for periodic maintenance or routine measures. Furthermore it is indispensable to determine the new or additionally competencies of the staff.

Nevertheless there are many countries, where the research and development of such systems have become a remarkable signification and the first pilot-projects have already been started.

This paper is dedicated to general explanation of an AMS with its components and starts with the definition of the AMS.

2. DEFINITION

An AMS for roads is a system based, entire concept to minimise the long-term losses of values of all assets and inventories, maintained by the road agency (including all the necessary human and other resources like know-how, methods, data, materials, equipments) and to maximise the global benefits.

3. REASONS FOR IMPLEMENTATION

The most important reasons to implement of an Asset Management System by the road agencies are:

- Continuous and natural ageing of the objects of road's infrastructure combined with their abrasion and the consequently loss of their monetary value

- Various modus and speed of losing value of the objects of road's infrastructure
- Saving of financial means for road management
- Increased demand of road users and environment to the traffic and road policy of the road agencies
- Higher attention of public, media and politicians to the events of traffic and roads, specially to the obstacles, caused by the road-works

4. IMPORTANT COMPONENTS OF AMS

An AMS should contain the following components (Figure 1):

- System of Objectives with strategic goals
- System of Identification for the Objects (Inventory)
- System of Functional Evaluation of the Objects, according to the determined criteria
- System of Control, Collect and Analyse of Condition-data of the objects
- Model of development of Condition-data of the objects
- System of Global Evaluation of the objects to follow the development of their "Substance- and Using Values"
- System to quantify the Substance- and Using Values of the objects as monetary values
- System to calculate the Life Cycle Costs of the objects (and the measures)
- System to determine the Global Benefits of the objects (and the measures)
- System to compare the Global Benefits and the Life Cycle Costs of the objects (and the measures)
- System of Optimisation of Planning of the measures at the object-level and to combine the measures of different groups of objects at the project-level
- System of Realisation of optimised measures

Following are some of these components described:

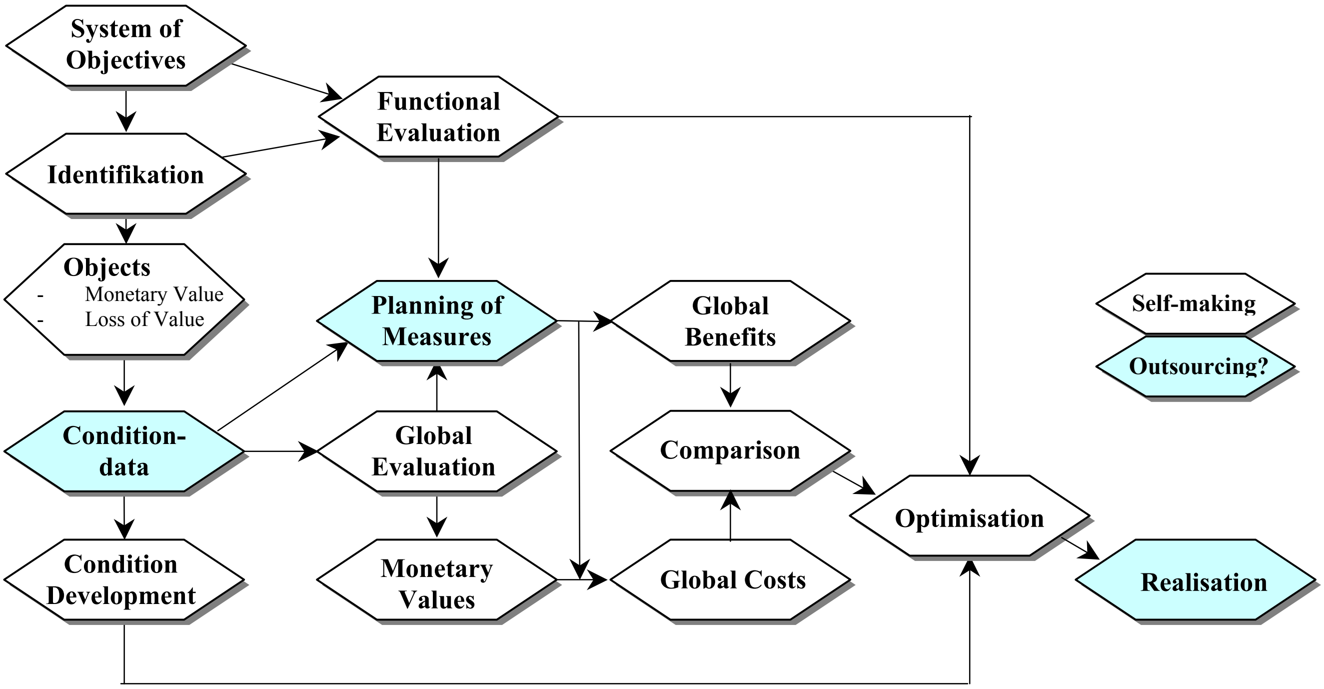

Figure 1: Components and flow-chart of decision-making in Asset Management Systems (AMS) for Roads

4.1 System of Objectives with strategic goals

The long-term goals of AMS are grouped in a System of Objectives, which is formulated as follow:

The principal objective of Asset Management System is to reach the maximal efficiency of tasks of the road agencies to manage the road's infrastructures in terms of:

- Serviceability
- Capacity
- Traffic Safety
- User Comfort
- Substance Maintenance
- Economy (Reducing of Entire Costs)
- Compatibility with the Environment
- Policy of Information
- Keeping a certain level of Know-how by the Staff
- Managing the Means and Resources

The terminology and the definitions of the goals are the content of the Swiss Standard SN 640 900a (Road Maintenance Management System RMMS - Basics).

4.2 System of Identification of the Objects (Inventory)

All objects should be undoubtedly identified and grouped to a group of object in AMS. Therefore the geographic co-ordinates, the space- and time- reference systems should be used (also in combination).

For more detailed information about the reference systems, see the Swiss Standards SN 640 910 (RMMS: Space Basic Reference System) and SN 649 911 (RMMS: Operation Network for Road-Data).

4.3 System of Functional Evaluation of the Objects

A proved and pragmatic instrument to determine the quantified signification of the objects is the method of functional evaluation, which has been published recently as the Swiss Standard SN 640 908: "RMMS-Functional Evaluation of Road-Sections".

Table 1 presents this method for a selected example (main road of a Canton) with the relevant criteria and the notes:

Table 1: Functional Evaluation (Example for global evaluation of main roads of Cantons)

No.	Criteria	W (%)	Domains				
1	**Traffic Character**	25	International	Over-Regional	Regional	Local	
	Note		10	8	6	4	
2	**Function in Network (Type of Construction)**	19	Freeway	Highway	Main Road	Secondary Road	Access Road
	Note		10	8	6	4	2
3	**∅ Average Daily Traffic (ADT)**	12	>= 15’000	< 15'000, >= 6’000	< 6'000, >= 3’000	< 3'000	
	Note		10	9	8	1-8	
4	**∅ Average Daily Truck Traffic (ADTT)**	8	>= 1’500	< 1'500, >= 1’000	< 1’0000, >= 500	< 500, >= 250	< 250
	Note		10	9	8	7	1-7
5	**Planning Speed (V_A)**	4	>= 120	< 120, >= 90	< 90, >= 60	< 60, >= 30	< 30
	Note		10	8	6	4	2
6	**Maximum Admissible Speed (Vz)**	8	>= 100	< 100, >= 80	< 80, >= 60	< 60, >= 40	< 40
	Note		10	8	6	4	2
7	**Alternative Road Connections**	4	Nothing	> 40% Length	>20%, < 40% Length	< 20% Length	
	Note		10	8	6	4	
8	**Using By Public Traffic**	4	Yes		No		
	Note		10		5		
9	**Existence of Engineering Structures**	10	Tunnel + Bridge	Tunnel	Bridge	Nothing	
	Note		10	8	7	4	
10	**Signification for Tourists**	6	High during the whole year	High seasonal	Medium	Low	
	Note		10	8	5	2	

S = Σ (W x Note)	817 < **S** ≤ 1000	635 < **S** ≤ 817	452 < **S** ≤ 635	270 ≤ **S** ≤ 452
Category	**I**	**II**	**III**	**IV**

The functional evaluation of an object is considered as the main factor to determine the priority of a measure, as well as the global maintenance strategy of road-network, depending on the road's category, which is a result of the functional evaluation. The functional evaluation determines also the signification of the objects by achieving the goals of AMS, which represent the interests of road agency, road users and environment.

4.4 System of Control, Collect and Analyse of Condition-data of the objects

The controlling, collecting and analysing of condition-data (named as condition-data in the Figure 1) is a central component of AMS and has to collect these data for different assets in the determined cycles of time. These data contain for the objects of road's infrastructures information about their substance and using condition, and information about the actuality of the know-how of the staff. The collecting of the data should be prepared carefully and it is necessary to have "neutral value" units to compare the data from different sources.

Table 2 shows as an example the system of data collecting for the auxiliary installations of roads.

Table 2: System of visual collecting of condition-data of road's auxiliary installations

AMS (Auxiliary Installations of Roads)															No.:
Street:			Site:					Section:			Object:				
From:			To:					Chief of Project:							
Reference Point:								Position: on level Bridge Tunnel Dam Cut						Datum:	
Length of Section (m):								Exposition: sunny partial shadow shadows							
No.	Object	Characteristic	A*	S**	G= Weight	G x A x S	Remarks	No.	Object	Characteristic	A*	S**	G = Weight	G x A x S	Remarks
1	**Resting**	Traffic space						1	**Plants/**	Buildings					
2	**Area**	Communication means						2	**Support**	Parking hall					
3		Sanitary installations						3	**Stations**	Factory					
4		Signalisation + Marking						4		Salt and sand hall					
5		Restaurants						5		Store					
6								6		Apartments					
K1 = Σ G x A x S								7		Communication means					
1	**Parking**	Traffic space						8		Sanitary installations					
2	**Places**	Communication means						9		Open air stores					
3		Sanitary installations						10		Open air parking					
4		Signalisation + Marking						11		Washing place					
K2 = Σ G x A x S								12		Gas station					
1	**Stops of**	Traffic space						13		Green space					
2	**Public**	Communication means						14		Traffic space					
3	**Traffic**	Sanitary installations						15		Fences					
4		Signalisation + Marking						16		Entrance and exit					
5								17		Signalisation + Marking					
K3 = Σ G x A x S								K6 = Σ G x A x S							
1	**Green**	Inventory						K = Σ (K1 till K6)							
2	**areas**	Condition						Remarks:							
3		Range of sight													
4															
K4 = Σ G x A x S															
1	**Gas**	Traffic space													
2	**stations**	Safety installations													
3		Communication means													
4		Sanitary installations													
5		Signalisation + Marking						***: A**= Frequency of degradation							
6		Restaurants						1 = < 10%, 1.5 = 10 - 50%, 2 = > 50%							
7		Traffic space						****: S**= Density of degradation							
K5 = Σ G x A x S								1 = few, 1.5 = medium, 2 = large							
Additional Tests:															

4.5 Model of development of Condition-data of the objects

The development of condition-data is an element of AMS to forecast the condition of the assets and the loss of their value. It is based on heuristically presumptions and assessment of empirical results of data collecting. The models of development would be controlled and improved periodically on the base of the feedbacks from the practice, see

Figure 2. This figure presents the development of the costs of maintenance measure, depending on the condition of the road for the example of the main roads of a Canton in Switzerland. Therefore was first necessary to determine some "standard" conditions, which are characterised by special features. The optimal maintenance measure is also established for each of the standard condition depending on the type (or category) of the road and the standard conditions of the features. The unit costs (per m or m^2) of each measure has been calculated and connected with the standard conditions of the features of the road. So was possible to determine the basis for decisions, related to wait or not with the realisation of the measures.

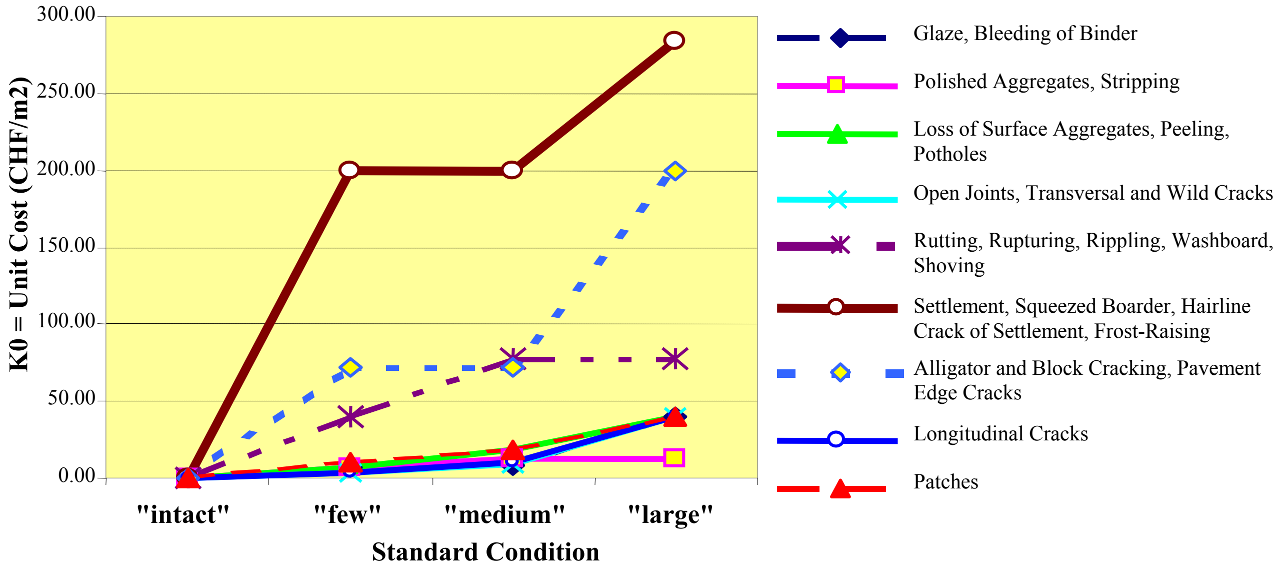

Figure 2: Development of unit costs of maintenance measures depending on road's condition (model for flexible pavements of Main Roads)

Similar models have also been developed for Freeways and Secondary Roads.

4.6 System of Global Evaluation of the objects to follow the development of their Substance- and Using Value"

To control and follow the development of the general road-condition in AMS, two special values, named as Substance and Using Values, are determined. They are build as a combination of different visual and measured aggregated condition indicators. For example for the pavements there are the visual collected indicators „General Surface Condition“, “Cracking”, “Surface Drainage” and “Joints” or measured collected indicators "Evenness longitudinal", Roughness" and "Bearing Capacity".

These indicators are the components of the Substance and Using Values and their signification for the values must be considered by adequate weights.

Table 3 shows four typical roads to build these values for the flexible pavements. These roads are characterised by their importance (Free- and Highways or Main and Secondary Roads) and area of their layout (Inter-Urban and Urban Roads).

In the Model "A" is the indicator "evenness transversal" as a component of Using Value. Because this model represents an inter-urban freeway, where the highest admissible speed is 120 km/h, therefore the problems of rutting and surface drainage become a matter of traffic safety rather than sustainability of their substance. This example shows that setting relation between the indicators and the goals must be carefully analysed before.

The Substance and Using Values could also be quantified in monetary way, as following.

4.7 System to quantify the Substance- and Using Values of the objects as monetary values

The following forms are used in AMS for monetary quantifying of the Substance and Using Values.

Substance Value = [Re-installation- + Demolition Cost] –[Cost of Totally Maintenance]
Using Vale = [Time Cost, caused by totally blockage] – [Real Time Cost]

The adequate unit time costs are given in the following chapters.

Table 3: Models to build the Substance and Using Value

A (Free- and Highways)		**B** (Main and Secondary Roads)		**C** (Free- and Highways)		**D** (Main and Secondary Roads)	
Inter-Urban Roads				**Urban Roads**			
Indicator	Weight [%]	Indicator	Weight [%]	Indicator	Weight [%]	Indicator	Weight [%]
Bearing Capacity	50	Bearing Capacity	40	Bearing Capacity	45	Bearing Capacity	35
Cracking	30	Cracking	25	Cracking	25	Cracking	20
Joints	10	Joints	10	Joints	10	Joints	10
Evenness longitudinal	10	Evenness longitudinal	10	Evenness longitudinal	10	Evenness longitudinal	10
Evenness transversal	30	Evenness transversal	15	Surface Drainage	10	Evenness transversal	15
Surface Drainage	20	Surface Drainage	30	Evenness transversal	30	Surface Drainage	10
Roughness	40	Roughness	50	Roughness	50	Roughness	70
General Surface Condition*	10	General Surface Condition*	20	General Surface Condition*	20	General Surface Condition*	30

*: Glaze, Bleeding of Binder, Polished Aggregates, Striping, Loss of Surface Aggregates, Peeling, Potholes

(yellow)	Component of Substance Value
(white)	Component of Using Value

4.8 System to calculate the Life Cycle Costs of the objects (and the measures)

To calculate the Life Cycle Costing (LCC) in AMS following unit costs (according to the Swiss Standard SN 640 907: RMMS-Global Costs of Maintenance Measures) will be used (Tables 4 - 9). These unit costs are related to the year 2001 and should now be actualised (depending on the term, by a rate of 2-3%).

4.8.1 Unit cost for pavements (PMS for flexible pavement)

Table 4: Unit cost of maintenance measures for flexible pavements (2001)

Type of Measure (flexible pavement)	Ø Unit Cost (CHF/m^2)	
	Free- and Highways	**Main Roads**
Repairs	10.00	10.00
Restoration of Overlays	70.00	45.00
Strengthening of pavement	145.00	70.00
Partial Renewing of Pavement	210.00	120.00
Totally Renewing of Pavement	290.00	190.00

4.8.2 Unit cost for Engineering Structures

Due to the multiple sorts of the maintenance measures of the engineering structures, there are only the costs of their totally renewing, which are presented at the Table 5.

Table 5: Unit costs of totally renewing of engineering structures (2001)

Engineering Structures (BMS-Objects)	Ø Unit Cost
Bridges	2'200 CHF/m^2
Galleries	1'500 CHF/m^2
Underpasses	2'500 CHF/m^2
Overpasses	1'000 CHF/m^2
Protection Walls	2'200 CHF/m
Passages (Water)	3'080 CHF/m

4.8.3 Road Users Unit Costs

These costs are grouped as time costs, vehicle operation costs and costs of accidents. The unit time costs are for different categories of users as follow:

Table 6: Unit Time Costs (2001)

Categories of Vehicle	Ø Unit Cost [CHF/h]
Private Cars: - Business Traffic (incl. Shuttle) - Free time / Shopping	 35.00 10.00
Trucks (incl. Wan Cars)	70.00
Trailers	90.00

The calculated unit vehicle operation costs are:

Table 7: Vehicle Operation Costs (2001)

Categories of Vehicle	**Ø Vehicle Operation Cost [CHF/ 100 Vehicle-km]**
Private Cars	40.00
Wan Cars	50.00
Trucks	65.00
Trailers	90.00
Busses	90.00

The costs of accidents could be considered in the LCC in two ways, either depending on the length of drive (as vehicle km) or as the absolute cost of the accident.

The Table 8 contains the unit costs of accident for the length of drive and the event.

Table 8: Unit Costs of Accident per 100 Vehicle km for different categories of vehicles and per accident in CHF (2001)

Unit Costs of Accident per 100 Vehicle km for different Categories of Vehicles [CHF]								
Attributes		Traffic sort		Category of Vehicle				
Type of Road	Ø Road Traffic	Persons Traffic	Goods Traffic	Private Cars	Trucks	Busses	Motorcycles	Bicycles
Urban	24.4	23.6	33.3	21.1	33.3	27.8	62.1	34.3
Inter-Urban	13.9	13.8	14.8	11.4	14.8	25.4	42.6	48.3
Freeways/ Highways	1.4	1.4	1.2	1.3	1.2	3.7	4.7	-
All Roads	13.6	13.5	14.2	11.4	14.2	22.3	36.9	37.5
Ø Costs of Accident of Road Traffic per Event [CHF]								
Social Costs per Accident	16’700	15’900	28’300	16’400	28’300	28’300	35’200	10’300

4.8.4 Unit Costs of Noise

The costs of noise (for residential areas) are presented in Table 9.

Table 9: Costs of noise, caused by road traffic in CHF per 100 vehicle-km (2001)

		Traffic sort		Category of Vehicle				
Attribute	Ø Road Traffic	Persons Traffic	Persons Traffic	Private Cars	Trucks	Busses	Motorcycles	Bicycles
Noise*	2.0	1.5	5.9	1.2	5.9	11.2	11.2	1.2

*: Costs of noise include the loss of value of real states, caused by the road traffic und also the costs of protection measures

4.9 System to determine the Global Benefits of the objects (and the measures)

To calculate the global benefits in AMS it is necessary to determine the components of the benefit with their weight, as well as their unit monetary values. Therefore the AMS determine also the range of time to be considered by the calculation.

It means that any investment in road's assets would result some short- and long-term costs and benefits, which have to be comprehensively considered in the analysis.

The short-term benefits include the reduction of costs, resulted by planning and realisation of the optimised measures. These are the profits of the road agency but also of the public (tax payers).

The long-term benefits result by the impacts, coming out from the optimised measure during its life cycle. Examples of these benefits for the road agency are the increasing degree of achieving the objectives of the system in terms of serviceability and capacity as well as sustainability of substance of the roads, traffic safety, life cycle costs and so on. For the road users there are also improvements in terms like general user comfort, drive time, traffic safety, which are the resulted by AMS. Even for the residents and environment there are benefits in issues of compatibility with environment, including the reducing of the pollution (in particular the noise) and the contribution to the regional and national economic boom. Following is the list of the affected groups of maintenance measure's benefits.

Affected Groups	
Directly affected (Direct)	Road agency
	Road-Users
	Residents / Environment
Not directly affected (Indirect)	Regional Economy
	National Economy
	Road Research
	Society / Politics

It is obvious, that not the whole quantity of the potential benefits of the maintenance measures could be quantified in monetary values. Therefore it is inevitable to present them in monetary values, as well as in qualitative indicators (by example the maintenance of fences to protect the fauna could not only be justified in monetary values, especially then, if it refers to rare sorts of animals, who must be protected). The Figure 3 presents the process of determining the global benefits of the measures to compare them with their life cycle costs (cost-benefit-analysis).

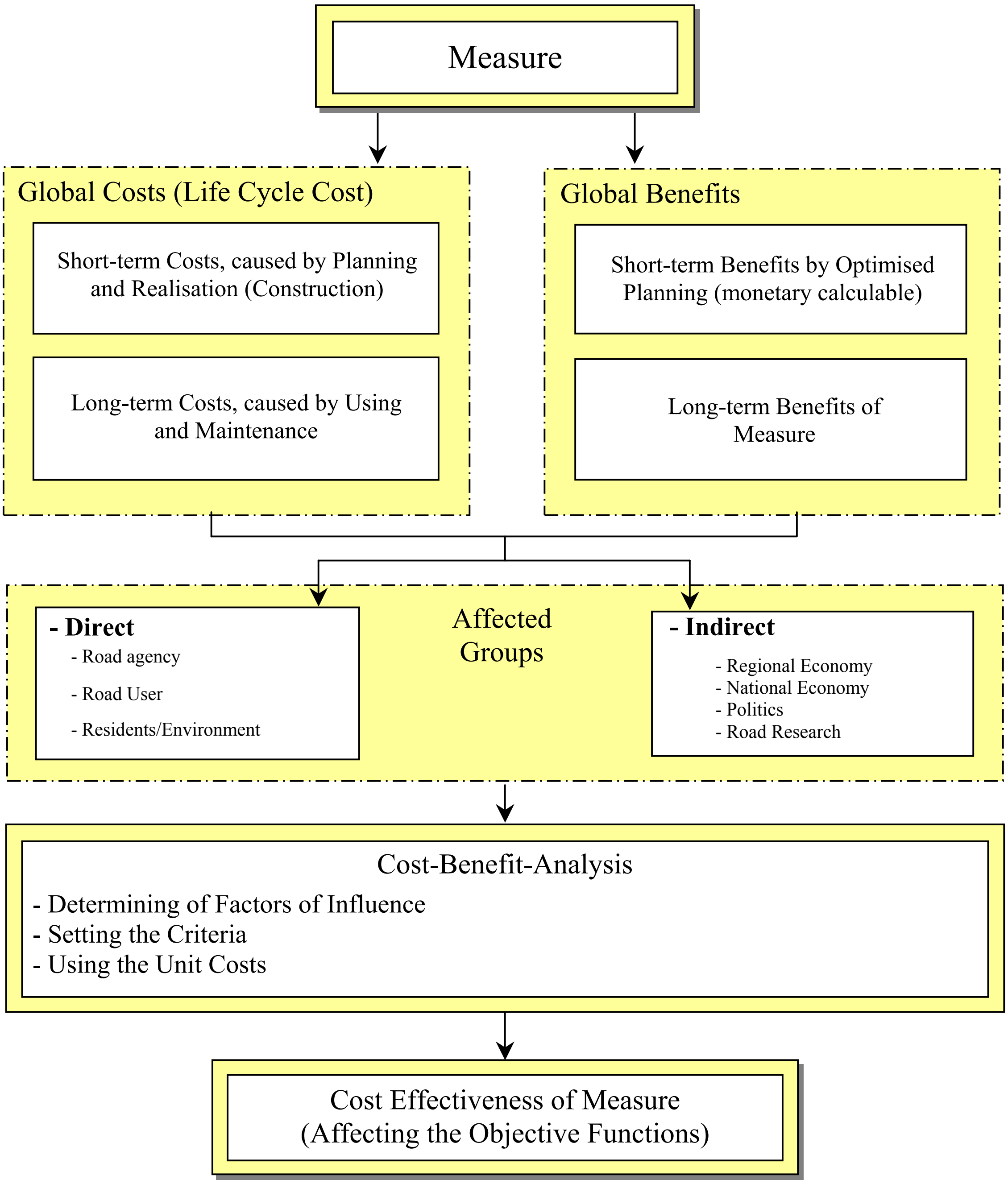

Figure 3: General process of Cost-Benefit-Analysis in AMS

4.10 Planning of the Optimal Measure

The process of planning the optimal measure is supported in AMS by two auxiliary models. The both are presented in the Table 10 and 11 and called “Measure-Model”, respectively “Optimisation-Model”. In these models each measure is characterised at least by specific information about its behaviour to achieve the objectives of the system, its expected duration of effectiveness (life cycle) and its unit costs. These information permit to determine particular values, which are representative for suitability of the measure to maintain the deteriorated road, according to the evaluation of its condition-data.

Table 10: Example of a version of „Measure- Model“ of PMS to plan the optimal measure for flexible pavements, Canton GR, Switzerland (without data)

Characteristics of the Maintenance Measures (I)

Maintenance Measures for Flexible Pavements			Key-Nr. 1)	1 (Achieving of Functional Objectives) Weighted Functional Objectives **[%]** Max. Potential Degree of Achieving **(G)** 2)							**L** = Life Cycle Period (Year)	Technical Suitability	
Type of Measure	No. 1)	Sort of Measure (Example)		SA 20	CA 5	TS 25	UC 10	SM 30	EC 10	**Σ G**		Layers	Condition Indicators
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Repairs	1.0	Crack filling	1.01										
		------------------	1.04										
Overlay and Cold micro pave **3)**	2.0	Local overlay (=<20%)	2.01										
		------------------	2.06										
Restoration	3.0	Scraping	3.01										
		--------------------	3.12										
Strengthening	4.0	Incl. Support Layers	4.01										
		------------------	4.04										
Partial Renewing	5.0	Scraping, Excavation, 20 cm Foundation Layer, 1 Support Layer + Overlay	5.01										
		------------------	5.04										
Totally Renewing	6.0	Scraping, Excavation, Foundation Layer, Surface Drainage, 1 Support Layer + Overlay	6.01										
		------------------	6.04										

1) Number of Identification of the measures
2) SA = Serviceability, **CA** = Capacity, **TS** = Traffic Safety, **UC** = User Comfort, **SM** = Substance Maintenance, **EC** = Environment Compatibility
3) K1 = Life Cycle Period / Cost, K2 = [G] x Life Cycle Period / Cost

Characteristics of the Maintenance Measures (II)

2 (Economic Efficiency)				3 (Environment Compatibility)				4 (Additional Criteria)			Remarks
C = Costs / m2 (CHF)	**K1 = L / C** 3)	**K2 = G x L / C** 3)	Rank **(K2)**	Duration of Works (Week)*	Use of Resources	Need of Depot	Noise	Special Condition for Realisation.	Additional Thickness of Pavement (cm)	Following Measures	
15	16	17	18	19	20	21	22	23	24	25	26

*: For a determined unit of surface (100 m Length and 1 drive lane width)

Table 11: Optimisation-Model for PMS (Example for surface smoothness of flexible pavements, Canton GR, Switzerland)

Group of Indicators	Indicator	Standard Condition (Grade of Deterioration)*	Pragmatically Selected Optimal Measure for Roads			Remarks
			Secondary Roads of Cantons	Highways of Canton	National Freeways	
Surface Smoothness	Glaze, Bleeding of Binder	Few	Local Overlay	Local Overlay	Local Overlay	Immediate measure, if the smoothness is not enough
		Middle	Partial Overlay	Partial Overlay or Cold micro pavement	Partial Restoration	
		Large	Partial Restoration	Restoration	Restoration	

*: "Few", if [A] x [S] <= 1.5 (respectively <= 2.0 according to the SN 640925a); "Middle", if [A] x [S] > 1.5 (respectively 2.0 according to the SN 640925a) and <=2.25; (respectively 4.0 according to the SN 640925a); "Gross", if [A] x [S] > 2.25 (respectively > 4.0 according to the SN 640925a)

A = Frequency of deterioration, S = Density of deterioration (according to the SN 640 925a)

4.11 System of Optimisation of Planning of the measures at the object-level and to combine the measures of different groups of objects at the project-level

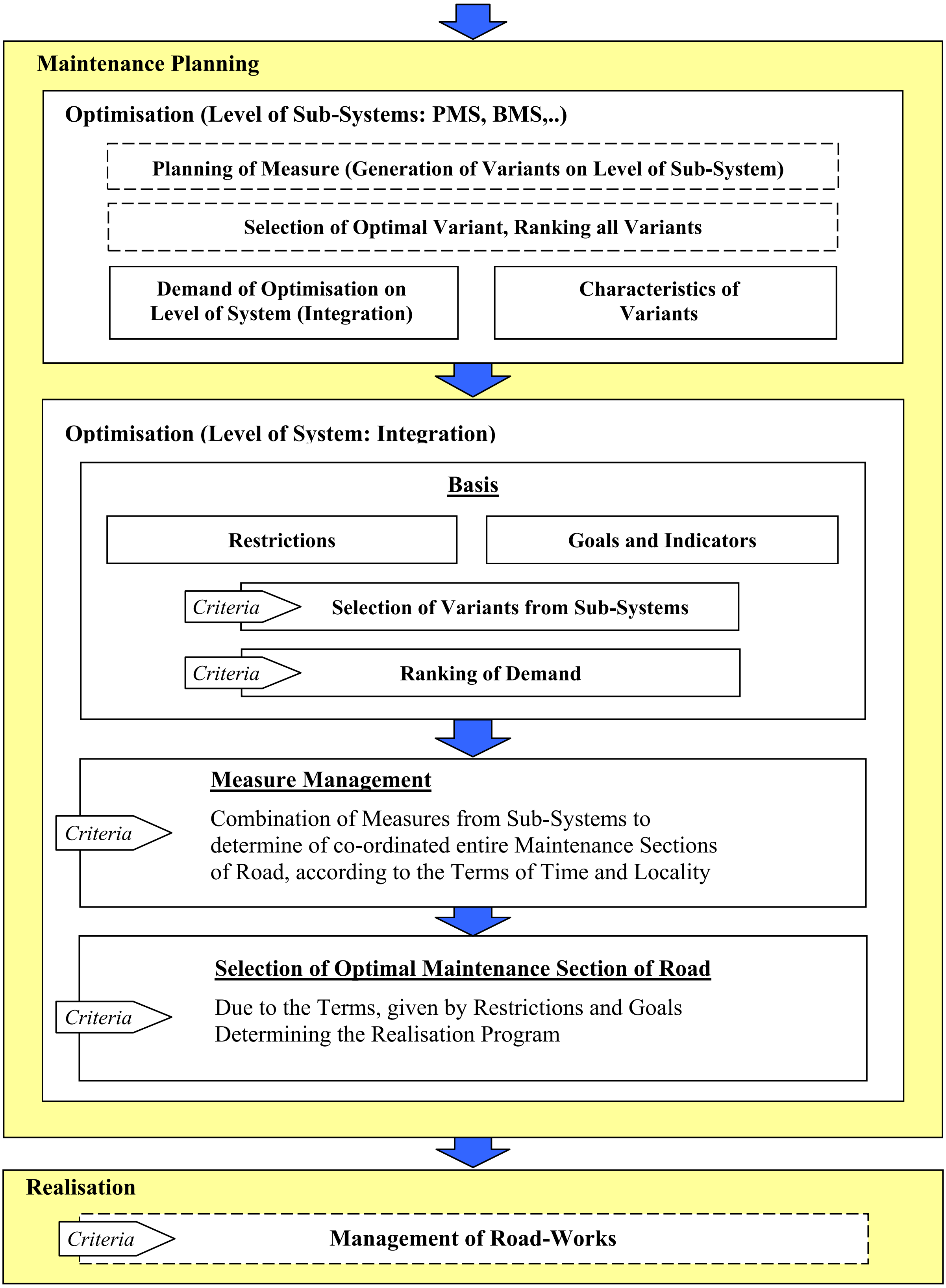

Figure 4: General flow-chart of optimisation process in AMS

The Figure 4 contains the general process of optimising in AMS, by using the results from the sub-systems to determine the optimal maintenance road sections. The outcomes of this process are presented in the Figures 5 and 6.

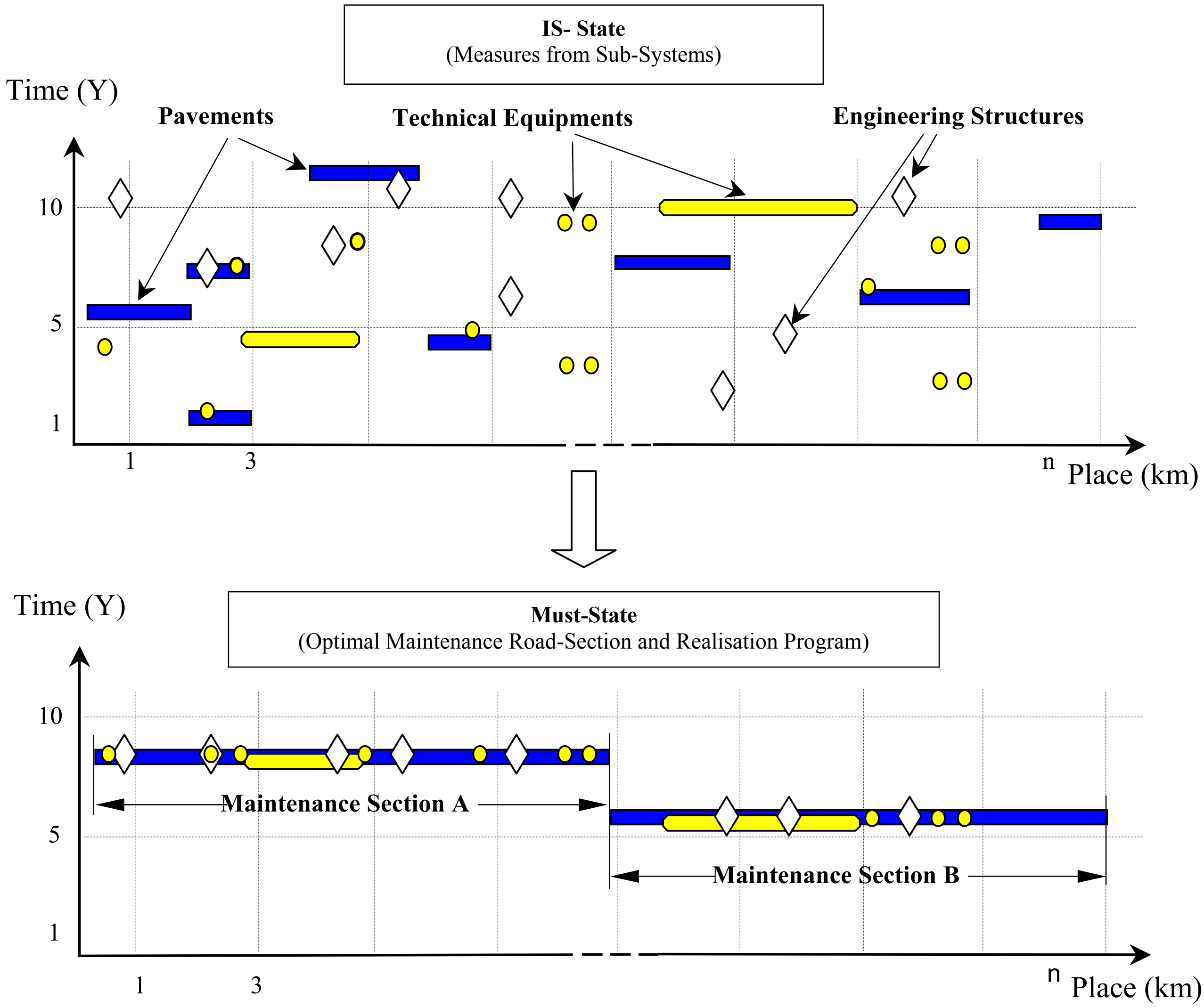

Figure 5: Example of geographically (place) and timely optimised maintenance sections (creation of combined measures)

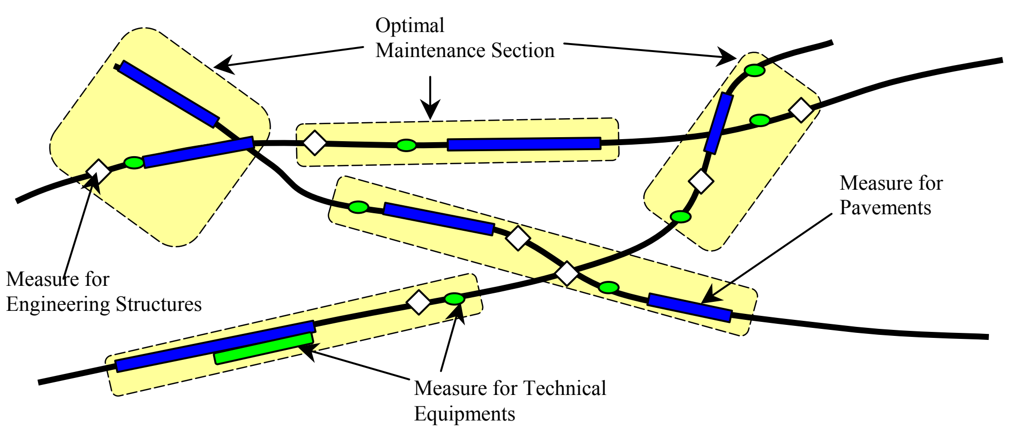

Figure 6: Generation of maintenance sections of roads (result of optimisation)

5. MEASURES OF IMPLEMENTATION

To implement the AMS the following steps should be taken by the road agencies:

- Determining the involved organisation units

  All the organisation units of the road agency, who are involved in the processes of decision-making must by identified and integrated in the concept of ASM. All the competencies must be clearly determined, according to the decision-making processes of AMS, which are based on the objectives of the system.

- Install of a system of identification for all objects and means

  The identification of each object is the basis of object management in the framework of AMS. Therefore it is necessary to use an adequate system (geographic co-ordinates, code, references,..) and to register the complete inventory of roads' infrastructures and the necessary means of their maintenance.

- Inventory of all integrated objects and means

  Registering of complete inventory of objects, which are supposed to be integrated in the system (one for ever) and their periodically refreshing (at least once per year). The objects must be characterised by their identification, age, expected life cycle, stress situation, condition and other relevant technical significations.

- Calculation of monetary value of all objects and means

  The AMS requires that all objects and means should be represented by their monetary value. Therefore it is necessary to use special unit values, which have to be refreshed periodically.

- Determination of depreciation's modus for all objects and means

  The loss of value (depreciation) of objects and means should be observed by (in the first step pragmatically selected) modus of depreciation.

- Definition of processes of decision-making in AMS, including their input and output

  The processes of decision-making in AMS should be co-ordinated and tuned, consisting with the long-term objectives of the system. They must be identified clearly by their input and output (data and information). The expenditures to prepare and generate the necessary input-data must also be analysed and optimised.

- Testing the process of decision-making by using the criteria of quantity and performance to clarify the advantages of their outsourcing

  The decision of outsourcing of processes of AMS should be made by criteria, related to the quantity, quality and sort of the performance, according to the long-term objectives of the system. The processes of decision-making are to be evaluated for the case of outsourcing, in relation to their ability to achieve the objectives.

- Analysing and ranking the private organisations (enterprises), who could be a potential candidate to take over the responsibilities of certain processes of AMS

  An „enterprise- analyse“ (strength/weakness- as well as risk-/ chances-analyse) must clarify this issue.

- Planning the flow of the feedbacks of the processes of decision-making by all units

  The processes of decision-making of AMS must be planned dynamically and transparent. The feedbacks from all involved units of road agency and private enterprises must be able to affect the processes and even the goals and criteria of the system. This is a continuously process to improve the system and to assure the minimising of loss of values of all assets.
- Evaluation of staff to clarify their ability to take the responsibilities of tasks of AMS

  According to the criteria of leading competency, performance and expert knowledge the staff must be periodically evaluated to optimise the distribution of the strategic and operational tasks and responsibilities of AMS. This step is depending on some administrative restrictions, which should be determined before (a member of staff could usually not be displaced back in the organisation), therefore it is necessary to use some "motivation-factors" to encourage them to take greater responsibilities in the agency.
- Planning the necessary measures of sustainable formation of the staff

  Finally the success and failure of AMS depends on the staff, specially their motivation and level of formation. In the case of AMS the formation of staff is an essential factor, because AMS is a new field of activity, which needs to consider the integral quantity of assets, their relations and the comprehensive consequences of decisions for the road-network. Further more the staff must always be able to compare the long-term costs and benefits of the measures, not only for the road agency, but also for the road users and environment.

6 OUTLOOK

The AMS for roads is an entire concept consisting a number of modules, among them a majority have already been developed and tested.

The AMS is based on knowledge of civil engineering, object management and business administration. The road agencies could operate and make their decisions by using the AMS as "entrepreneur", by considering the criteria of "value sustainability" as a central aspect.

The implementation of AMS must be accompanied by treatments of formation of staff and (if necessary) particular modifications of the organisation. An essential advantage of this system is its ability to co-ordinate and to optimise the measures of different sub-systems on a higher level to determine the optimised maintenance road-sections. It is also an "open" system, so that the road agencies could decide which groups of the objects should be integrated in the system in which phase of its implementation.

To run the system of AMS, the road agencies could first determine a "pilot-project" and after analysing the results and using the feedbacks, extend it to their entire road-network.

Simultaneous to the road agencies, the road research must be continued to clarify the still existing lacks of know-how (in particular the models of depreciation of the objects) by evaluation of empirically obtained data and to continuously improve the system.