RoSy® PMS - not just a pavement management system……

Part I

1. Grontmij | Carl Bro RoSy® PMS System Description

1.1 Background Introduction

The system supplied is a true Windows program programmed for use under Windows 95/98 and Windows NT/ME/XP.

It is possible to transmit data into RoSy®. This could be data from the visual surveys or other kinds of data collected by e.g. falling weight deflectormeter or bump integrator.

The system is supplied as a true multi-user system and can be used in practically all known networks. Furthermore, access and application of the system can be adapted to be controlled by remote control via e.g. telephone network/satellite or over the Internet.

The system is based on an open structure and applies the relational database format **ACCESS** as a standard. The open standard allows adaptation and direct use of data from practically all types of standard systems available on the market today - e.g. GIS, GPS, spreadsheet, text processing systems, digital images, etc.

RoSy PMS is supplied as integrated software, which prevents data redundancy and allows a very flexible use of the system.

Models for calculation of Vehicle Operation Cost (VOC) must be selected (if any).

The VOC models (equations) are sub-models from HDM III version 4. One of the two models below may be chosen:

1. $VOC = A + B * IRI + C * IRI^2$

where: A, B and C are coefficients

2. $VOC = EXP(A + B * IRI)$

where: A = constant
B = slope

These models have been integrated in RoSy PLAN in a very flexible way allowing the user to adapt the models by changing the future traffic combination only by changing the value of the individual coefficients.

IRI (International Roughness Index) comes from below progression model:

$RI_t = \quad 0.98 * e^{mt} * [RI_0 + 135\ SNCK_4^{-5} * NE_t] + 0.143 * RDS_t$
$+ 0.0068 * CRX_t + 0.056 * PAT_t$

Where $SNCK_4 = 1 + SNC - 0.00004 * HS * CRX_t$
RI_t = roughness at pavement age t, in m/km
RI_0 = initial roughness, m/km
NEt = cumulative equivalent standard axle loads (ESAL) at age t, million ESAL/lane
t = pavement age since rehabilitation or construction, years
m = environmental coefficient
SNC = structural number modified for subgrade strength
HS = thickness of bound layers, mm
CRX_t = area of indexed cracking at time t, %
RDS_t = standard deviation of rut depths, mm
PAT_t = area of patching, %

The World Bank has recommended this model as the best one, especially due to the fact that the model includes distress data and other predictive models for rutting, cracking and patching.

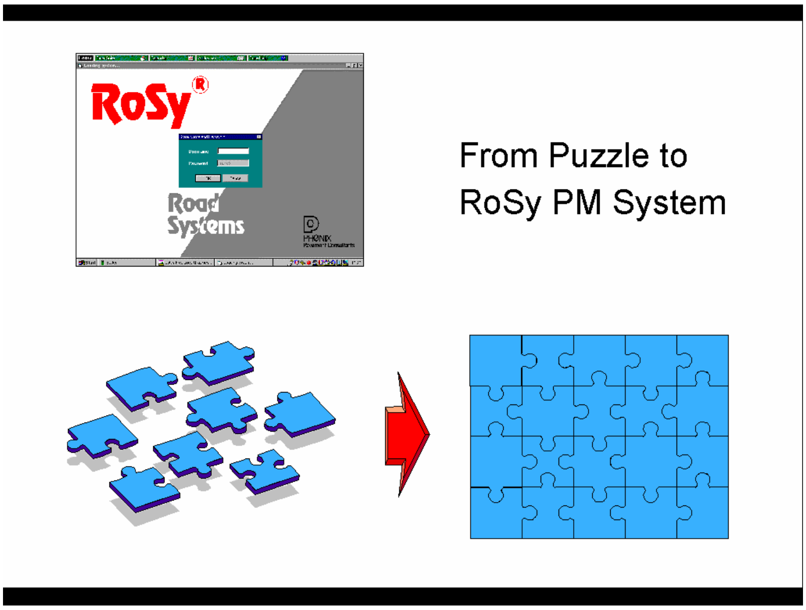
The equation used for determination of IRI has been created on the basis of the World Bank's studies, including studies in cold climate (Sweden) and contains, as appears, also an Environmental Factor.

Recommended value for Environmental Factor:

Dry, non-freeze: m = 0.005 to 0.015 (0.010)
Dry, freeze: m = 0.010 to 0.035 (0.020)
Wet, non-freeze: m = 0.015 to 0.030 (0.023)
Wet, freeze: m = 0.030 to 0.150 (0.070)

Set-up of the Environmental Factor is done in the window where VOC is selected. By changing the Environmental Factor, the user may adapt the change of IRI to the climatic conditions in his area.

2. Introduction



This document gives a general description of the management system – RoSy PMS.

RoSy PMS consists of the modules RoSy BASE, RoSy PLAN and a number of supplementary modules such as RoSy DIG, RoSy MAP, RoSy MEMO, RoSy SERVICE, RoSy ACCIDENT.

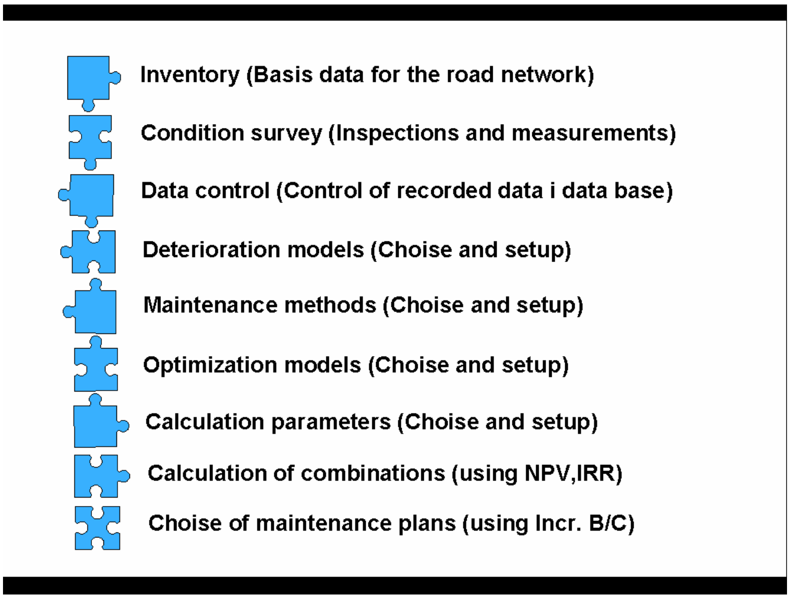
- RoSyBASE is the Road Database
- RoSyPLAN is the optimisation part for calculation of optimum maintenance solutions as well as consequence analyses.

The systems supplied by Grontmij | Carl Bro, Pavement Consultants (GMCB) are adjusted and set up for application by the individual user. This holds for the application possibilities of the systems as well as for the system calculation models.

Apart from the basic user interface, the system has an administration part, which can only be accessed with a code. If the administration part is accessed with the code, practically all basic conditions in the systems may be altered as well as the way they process data, make calculations etc. It is also possible to change and/or add new calculation models and methods to the system. The present introduction to the system provides that access authorisation to the administration part has been granted. This allows the user to have a more detailed description of several ways of setup. Part of this description may therefore seem rather comprehensive but has been included with the purpose of describing the flexibility of the system. Only in very rare cases, the individual user has entered the heart of the system once it has been supplied and set up by GMCB.

Finally, the supplied systems may be extended with supplementary windows for entering of other data on a road network e.g. digital traffic signs, equipment, road marking, lightning, road furniture, etc., administrative data.

3. Overview



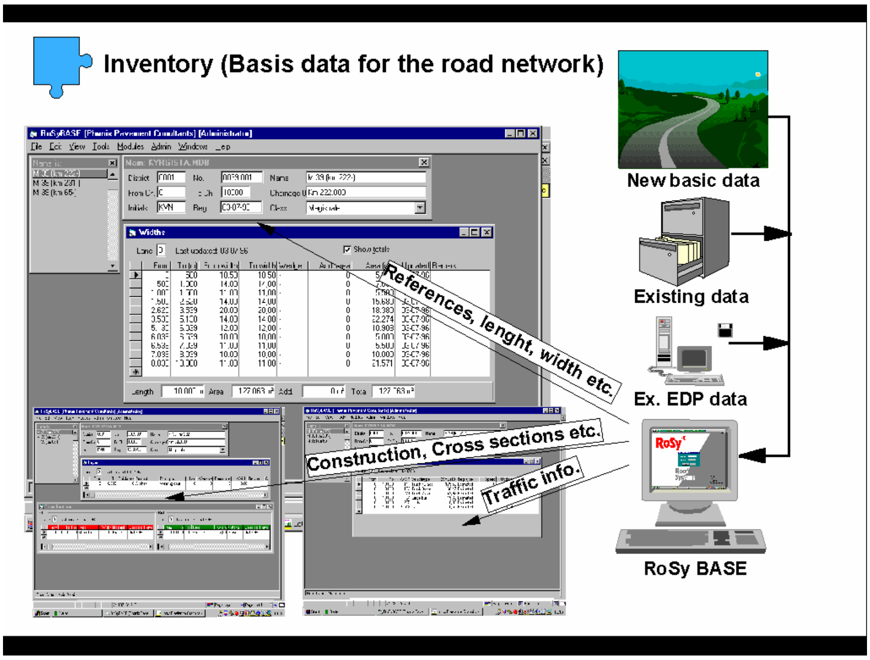
The setup and application of RoSy PMS may be done in many ways.

In our experience, a systematic implementation, which follows the above order, will lead to the target in the most rational way. The below introduction to the structure of RoSy PMS will follow this order.

However, in the present description the emphasis is on RoSy's treatment of information and which data to enter to the system and not on how the data was collected.

An example could be the information on a given road section's present IRI (measured by means of e.g. a bump meter). The present introduction will solely describe, how RoSy® applies the IRI values after they have been entered to the system and not how the IRI values were calculated on the basis of the Bump Integrator data before they were entered to RoSy®.

4. Inventory



Inventory data or the basic geometric data is entered to RoSy BASE in e.g. below files (windows). The registration may be done manually and/or digitally from other recording systems or already existing databases. The data entered to RoSy can of course also be applied by other systems.

Basically the below data is entered:

- **Main Details:**

  District, road number, road name, Start chainage (From ch.), end chainage (To ch.), Chainage 0, initials, data and road class.

  Co-ordinates for e.g. **GIS** may be entered as well.

  The data may be used for superior recognition of the road network and may form the basis of a later priority and selection of the maintenance efforts.

- **Width Details:**

  Road widths with chainages and any wedges, traffic islands, additional areas etc.

  Later the data forms the basis of calculation of the exact areas for each individual maintenance section.

- **Roadside area element details:**

  Widths and types of roadside area elements, chainages for all elements - e.g. shoulders, ditches, kerbs, etc.

  Later the data forms the basis of the calculation of any additional costs or limitations - e.g. kerb heights in connection with the calculation of maintenance combinations.

  Data may be presented graphically in cross as well as longitudinal sections of the road network in any point selected. Data from the files (windows) Width, Roadside area elements and Layer are applied for this presentation.

- **Pavement structure details:**

  In this window, information on the individual layers of a road structure is entered to the extent known. This is information such as thickness, type of material, chainage, year, E-moduli, recipe/ mix designs, supplier, guarantees, prices etc.

  Later, the data forms the basis of the determination of bearing capacity, roughness (IRI), deterioration process, choice of maintenance method, etc.

- **Traffic Details:**

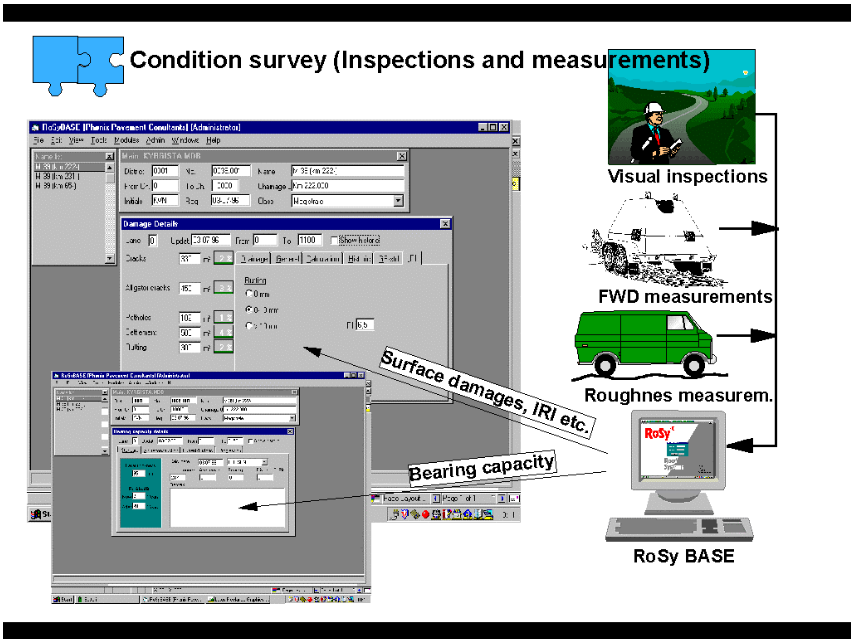
  Data on the expected traffic is entered (as a minimum for the maintenance optimisation period). The traffic may be grouped into vehicle types, and/or AADT and ESAL. Furthermore, traffic forecasts may be entered and thus any changes in traffic load during the plan period.

  Later, the data forms the basis of the determination of e.g. IRI, VOC, deterioration of bearing capacity, and choice of maintenance methods applicable with the expected traffic load.

- **Other files (windows):**

  Apart from the mentioned windows, a number of windows are available for administrative purposes, e.g. for storage of scanned documents, maps, digital images, etc.

5. Condition Survey



When the basic geometric data has been entered into RoSy BASE, the files/windows containing the structural and the functional condition data of the individual road sections are ready to receive data.

RoSy PMS is a flexible system capable of working with many kinds of condition data. Standard parameters to be worked with should therefore be selected when setting up the system.

Furthermore, distress data can be entered in accordance with pre-set maintenance laps with uniform lengths or in accordance with dynamic section lengths where the length of the individual maintenance section depends on a change in the condition of the road network.

The mentioned conditions and their mutually independent section lengths are entered into RoSy BASE in two independent files (windows) in the following way:

- **Distress Details:**

  The functional data (cracks, alligator cracks, potholes, settlements, rutting, etc.) is entered along with IRI data. The same road section may have more maintenance sections as the division is done according to the principle "from chainage to chainage", should a considerable change in the homogeneity of the condition parameters occur. The distress data is entered in m^2 or m in accordance with a pre-set methodology.

  It is possible in connection with later condition surveys to store old condition data as historical data. The historical data and the latest entered data automatically influences the development of the individual deterioration models, as these will become dynamic models. In other words, the more historical data entered into the system, the more the deterioration models will adapt themselves to the actual individual development of the condition and the more accurate the future maintenance calculations will be. In this way the system is self-adapting.

All entered conditions entered into this file are used later for calculation of the optimum maintenance solution for each condition section.

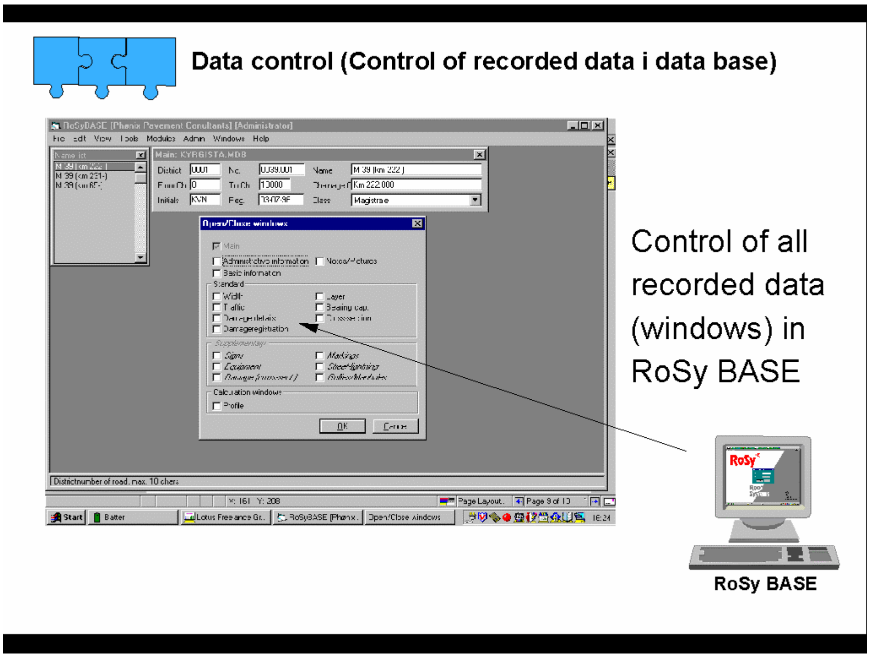
- **Bearing Capacity Details:**

  Data on the bearing capacity of the road network is entered according to bearing capacity homogeneous sections. These divisions (*from/to chainages*) often differ from the divisions made in the above-mentioned distress file. This is often due to the small coincidence between chainages for changes in bearing capacity and chainages for changes of functional conditions found on the road surface.

  In the bearing capacity file, a large amount of data may be entered. In this project only data from the bearing capacity measurements carried out with Falling Weight Deflectometer (FWD) is entered. This information contains data on residual life and required reinforcement and is applied for calculations considering reinforcement for a given design period for the individual maintenance sections.

  Later the data in this file is applied with the data in the distress file and the traffic file for division of the road network into homogeneous maintenance sections. Furthermore, the data is applied in connection with calculation of the optimum time for the maintenance efforts and which method/product would be the optimum at a given time.

6. Data Control

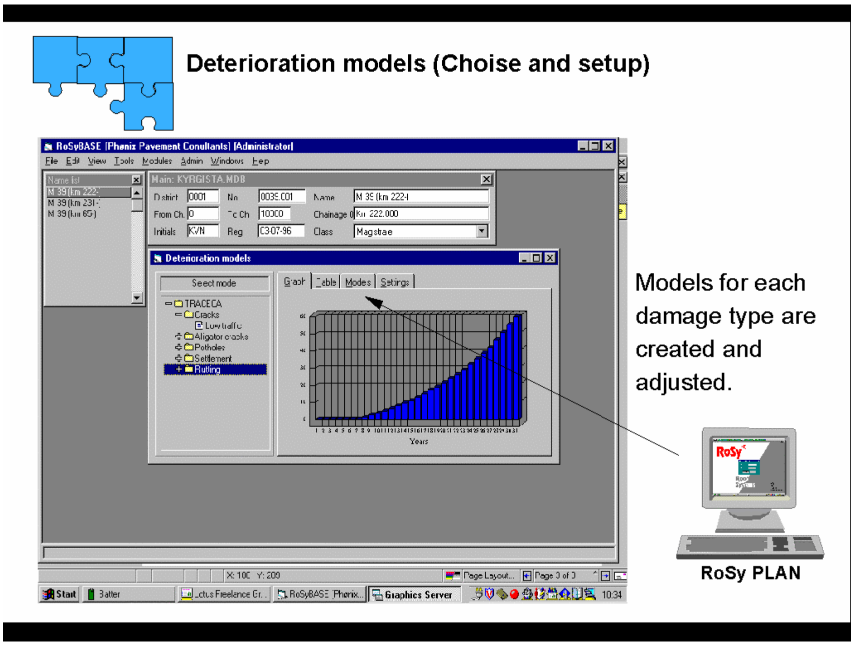


When all inventories and condition data have been entered to RoSy®BASE, a control of the contents of the database is made. The system performs a data control in order to check, whether data for all required roads has been entered to the system and whether all other data necessary for the maintenance optimisation is present.

It should be considered, which other data should be entered to the parts of the database that do not have a direct impact on the maintenance calculations but only concern administrative purposes.

Now the necessary data has been stored in the database RoSy BASE and the data necessary for the maintenance calculations has to be entered to RoSy PLAN.

7. Deterioration Models



Deterioration models must be created in order to allow RoSy PLAN to make long-term calculations of the road maintenance for each individual maintenance section. The deterioration models must be capable of simulating the expected condition development of each individual condition parameter under various circumstances.

If required, RoSy PLAN will be capable of making simulations for up to approx. 100 years. Simulations with such a long horizon are not recommendable as this makes very heavy demands on the computer capability. Thus, it will typically be relevant to make calculations with a time horizon of 20 years.

The deterioration models require the creation of models for each individual condition parameter describing the entire life cycle of the given condition. This means that the models must often seek to describe a lapse of time of approx. 30 years.

The creation, adjustment and adaptation of deterioration models in RoSy PLAN to local conditions is rather flexible, as the user (the administrator) can decide, how many and how detailed the individual models should be. Compulsory for this process is, however, that minimum one model should be created for each condition parameter. At the same time this means, that in cases where three road classes are applied, (e.g. motorways, primary roads, and secondary roads), three individual models for the same condition parameter can be created. Furthermore, the models may, if required, be subdivided so that they become traffic load dependent.

The individual models will ensure that the result of e.g. the crack development simulation will give different results from road class to road class and from traffic group to traffic group. In this way, the reality will be reflected to a larger extent than if only one fixed model per condition parameter was applied.

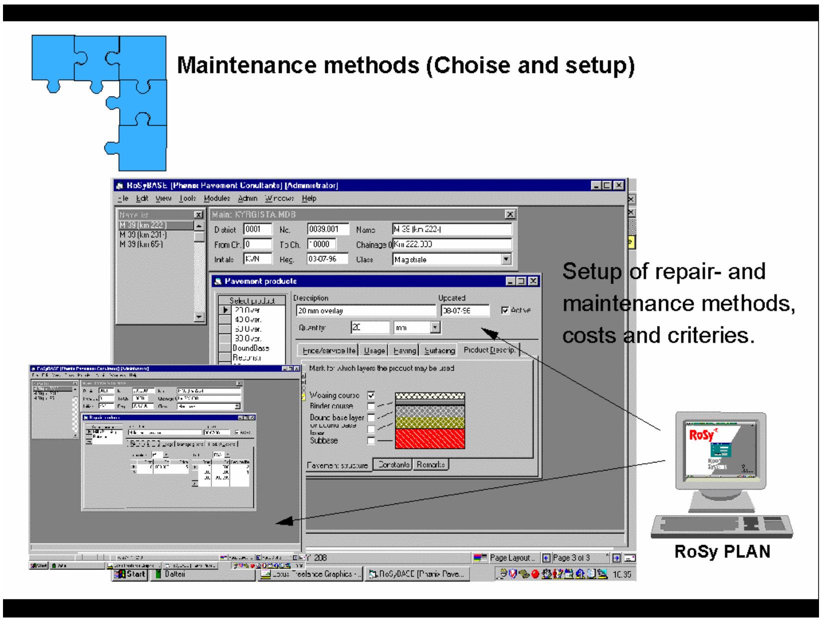
The creation of this large amount of models requires, however, that knowledge of the individual condition development as a function of road class and/or traffic load is available and/or a study is carried out on the subject.

At the same time, we would like to stress that any negative effects (due to lack of studies) from not having created a large number of sub-models will diminish along with the use of the system and along with a systematic condition survey becoming a current process e.g. every second or every third year.

This is due to the fact that for each individual maintenance section, the initially created "global" deterioration models will react automatically to the historical data and create "local" dynamic models reflecting the actual local development on each individual maintenance section.

The more RoSy PMS is applied, the more precise the future maintenance calculations will become, as the progression of the future condition will be done on the basis of the actual local development instead of the "global", which would, obviously, only reflect the average condition development.

8. Maintenance Developments



In order to allow RoSy PLAN to perform maintenance calculations, necessary information on possible methods and products must be created that can be used for routine maintenance, repair and the final maintenance and in this connection also reconstruction, etc.

- **Repair Products:**

  In this window the products (methods) to be used for repair and routine maintenance are entered.

  Product names, properties, limitations, and conditions for applications, price (cost), and grouping according to quantity. Finally if required, information on recipes, suppliers etc.

  The user can select number of methods freely. However, it should be remembered that the more models chosen to work with, the more maintenance combinations will be calculated and the more combinations, the more RoSy PLAN will calculate - resulting in a rapidly increasing complexity and use of calculation time.

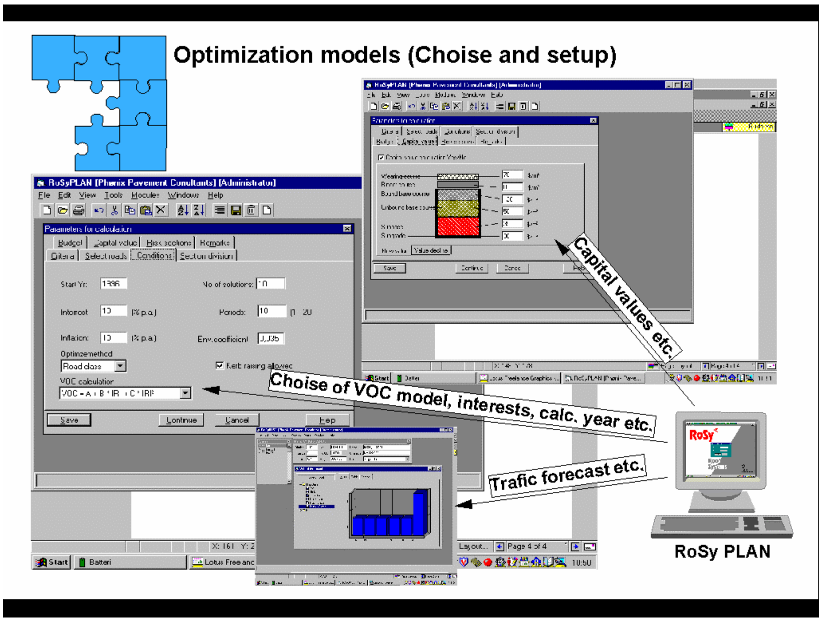
- **Pavement Products:**

  In this window the products (methods) to be used for the actual maintenance - and reconstruction - are entered.

  All the kinds of applicable sealing, wearing courses, recycling, reconstructions etc. are entered. The individual product's name (method's), function, properties, thickness, reinforcement capability, stability, limitations, conditions for prior measures (e.g. repair of alligator cracks), price (costs), which may be divided according to area and expected service life resulting from e.g. traffic loads. Furthermore, information on recipes/ mix designs, supplier, etc. may be entered.

The user can freely select the number of products/methods. However, it should be remembered that the more methods chosen, the more maintenance combinations must be calculated and the more combinations, the more RoSy® PLAN will calculate - resulting in an increased use of calculation time but also a more precise choice of optimum maintenance solution and combination.

9. Optimisation Models



When administration and condition data has been entered to Rosy BASE and the deterioration models and the available methods for road maintenance have been created in RoSy PLAN, RoSy PLAN has a basis for performance of optimisation calculations.

Before starting the calculations, the user (and partly the administrator) should make a set-up of the optimisation conditions, in order to apply and select the calculation models to form the basis of the calculations.

The starting year for the calculations is one of the first conditions to decide on. If the starting year is not identical with the year in which the road conditions were entered, the conditions will on the basis of the deterioration models be progressed automatically to the starting year before the calculations are started.

Subsequently, the levels for interest rate and inflation should be applied for the calculations.

Also the number of calculation combinations to be stored for the later optimisation calculation should be indicated here. With a 20-year calculation horizon, the number of combinations per section will often be 500-2000. Storage of this large amount of solutions will make heavy demands on the disk capacity of the computer. If, 20 solutions/strategies are indicated, then the 20 most optimum solutions/strategies per maintenance section will be stored for later use.

Finally, a model for calculation of Vehicle Operation Costs (VOC) should be selected. The models appear from the menu in the system.

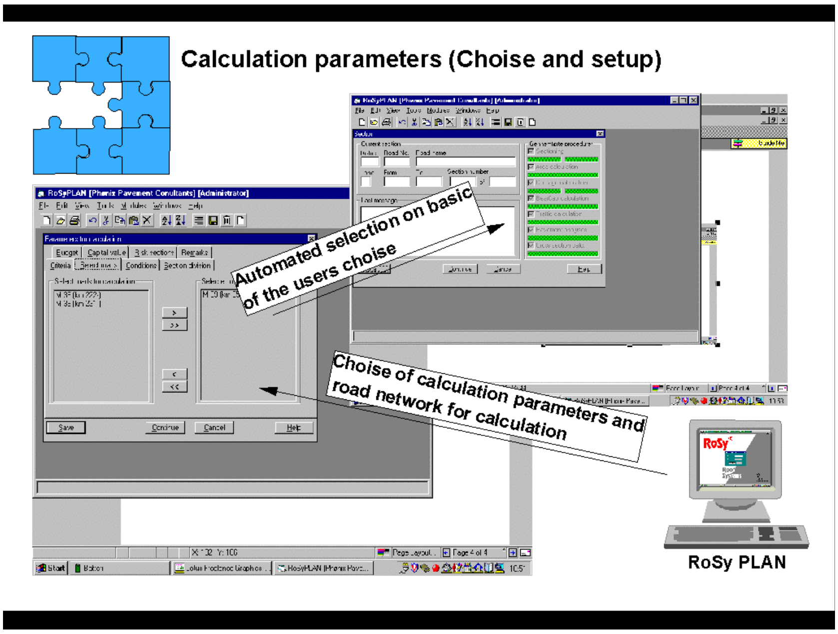
Apart from the VOC models, a model for the traffic forecast must be selected. The traffic forecast models may work with increasing as well as decreasing traffic loads - also "jumps" in loads from year to year.

The calculation of the optimum maintenance combinations in RoSy PLAN is done by comparison of e.g. Net Present Value (NPV) and Internal Rate of Return (IRR). A known problem is that if the NPV compared strategies do not leave a road network of uniform quality at the expiry of a calculation period (normally 20 years), a minor error is incorporated in the comparisons, which is often ignored.

In RoSy PMS this problem has been solved by currently calculating the value of the invested road capital. This means that the difference (expressed in loss or gain of road capital) between the individual strategies may be included in NPV at the end of the calculation period and thus ensures that the comparison between the strategies happens on an absolutely optimum basis.

Application of this principle requires that information on initial pavement values and development of value loss as regards calculation must be entered to the set-up menu.

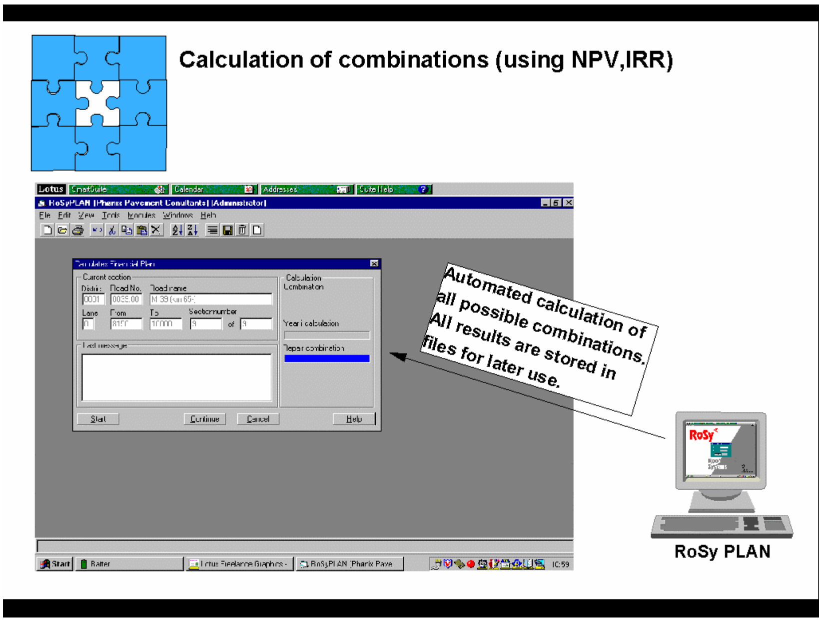
10. Calculation Parameters



When all necessary models have been selected, the conditions should be defined so the calculation can be performed.

- First of all, the road sections to be calculated should be selected. In the menu all accessible road sections are listed and the sections to work with can easily be selected.
- Now the criteria for automatic division of the network into homogeneous maintenance sections should be selected. The division made in the distress windows will basically be used for maintenance sections.
- If the division according to e.g. bearing capacity and traffic appear to differ from the basic division, the system must be told which criteria should be used for a sub-division. This holds for mutual differences in bearing capacity as well as for differences in the individual chainages.

11. Calculation



The calculations may now be initiated by pressing START. The calculations now run automatically until all possible combinations for all selected road sections (road networks) have been processed.

In brief, the calculations are running as shown below. In principle, the calculations run 3-dimensionally according to the following (X= sequence of years, Y= Strategy, Z= number of possible combinations with the actual strategy):

As a basis for the determination of the value of each individual combination, NPV is applied for the determination of the effect of all investments and costs during the calculation period.

The combination with the lowest NPV of the Total Transport Costs (TTC) with a given strategy corresponds to the most optimum maintenance solution for exactly this strategy, as TTC also contains Agency Costs (AC).

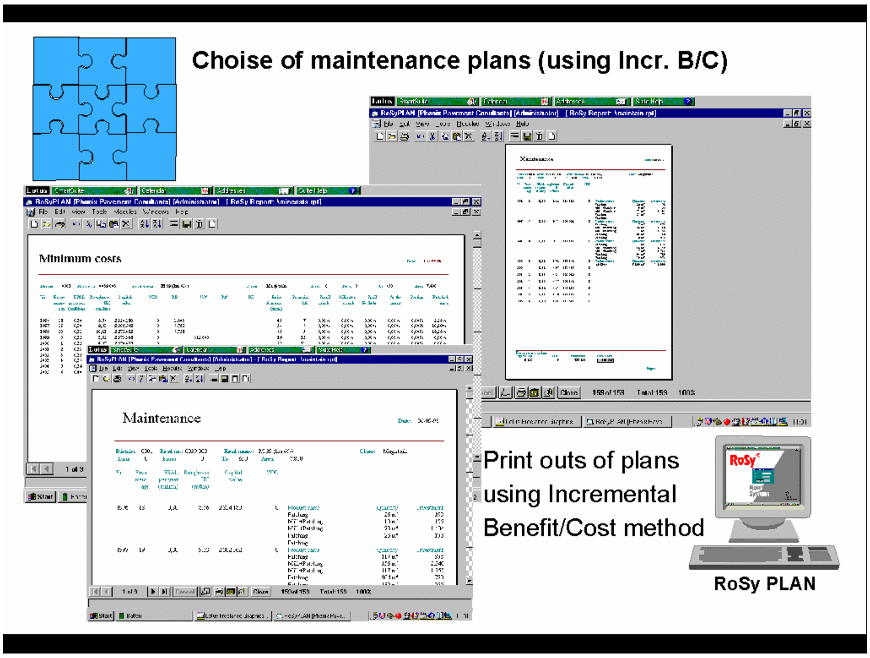
Thus, for each strategy ONE optimum combination will be displayed.

For a given maintenance section, the optimum maintenance solution and thus the optimum strategy is the maintenance combination with thelowest NPV in all performed calculations. At the same time, this solution often gives the best IRR when all solutions are compared to the **DO NOTHING strategy**.

The calculated solutions are stored pr section (the pre-set maximum number) and can be printed out when all sections have been calculated. That is both the optimum solution for each individual selection but also a number of alternative solutions and obviously the solution **DO NOTHING**.

Practically all the necessary data have been stored together with every single solution for a later calculation of the economic consequence analyses with limited budget funds as well as with unlimited funds. Furthermore, information was stored for the processing of detailed maintenance plans (when, where) when the final strategy for the individual section has been found.

12. Choice of Maintenance Plans



When all calculations have been performed, the selected calculations have been stored on the hard disk ready for further analysis and final selection.

If a printout of the economically optimum strategy with optimum solution is wished, all the maintenance combinations for each individual section giving the lowest NPV are retrieved.

In case of a limited budget, only those solutions will be retrieved, which ensures the lowest possible NPV for the entire road network and do not exceed the available budget amount.

The Incremental Benefit/Cost method (IBC= delta TTC/ delta AC) will be applied for the selection of the optimum strategies when only limited funds are available. During the automatic iteration routines to adapt the budget limitations, the combinations giving the lowest rise in the total Transport Costs (TTC) and at the same time the largest reduction in Agency Costs (AC) are stored.

13. Printouts

A number of printout examples generated by the system are enclosed. The amount of printouts and the design of these may be varied in innumerable ways as well as "printout" does not only mean printout on paper but also saving data to be applied by other databases, spreadsheets, GIS programs, etc.

Appendix A: List of abbreviations

ESAL: *Equivalent Standard Axle Load.* Standard axle loads per day indicate the total traffic load converted into one standard axle. E.g. 5 busses = 1 ESAL.

AADT: *Annual Average Daily Traffic.* This factor indicates the average number vehicles passing by each day (24 hours).

IRI: *International Roughness Index*. The IRI-value (m/km) is a way of expressing the roughness of a road measured by means of e.g. a bump meter.

VOC: *Vehicle Operation Cost.* The total costs for the vehicles applying the road. The costs include e.g.: consumption of fuel, tyre wearing, repairs, etc. VOC is a function of IRI.